Handbook on Construction Techniques


The report highlights a broad spectrum of environmental impacts triggered due to construction, operation, and maintenance and their mitigation for four sectors: (i) power transmission, (ii) distribution, (iii) run-of-river hydropower, and (iv) solar photovoltaic generation projects for dissemination among Asian Development Bank specialists working in the energy sector and environment fields.

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Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.
HANDBOOK ON CONSTRUCTION TECHNIQUES
A PRACTICAL FIELD REVIEW OF ENVIRONMENTAL IMPACTS IN POWER TRANSMISSION/DISTRIBUTION, RUN-OF-RIVER HYDROPOWER AND SOLAR PHOTOVOLTAIC POWER GENERATION PROJECTS

Rajat Jain and Shotaro Sasaki

September 2015
Handbook on construction techniques—A practical field review of environmental impacts in power transmission/distribution, run-of-river hydropower and solar photovoltaic power generation projects.


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Abstract

The report highlights a broad spectrum of environmental impacts triggered due to construction, operations and maintenance and their mitigation for four sectors - power transmission/distribution, run-of-river hydropower and solar photovoltaic generation projects (hereby known as “designated sectors” in the report). These include impacts on physical resources, environmental resources, ecological resources and the human environment in the project area.

This report discusses construction related project aspects and presents an inventory of methodologies used, their environmental impacts, mitigation and management issues for dissemination among Asian Development Bank's (ADB) specialists who are working in the energy sector and environment fields, are involved in appraisal, day-to-day due-diligence for project approvals, progress monitoring and impact evaluation.

Section I introduces the relationships between the designated sectors while Section II discusses the type of construction techniques used for designated power projects vs. the alternative methods available and the reasons for using them. Section III-VI brings forth several instances of technical design, construction, commissioning including discussions on the impacts noted at each stage and mitigation actions proposed for each of the impacts noticed for each designated power sector. Section VII reviews the triggers for environmental due-diligence and general cumulative impacts for designated power projects at their various stages of construction as well as discusses the monitoring needs for each type of designated power project. Section VIII highlights few experiences of project implementation in the designated power sector whereas Section IX concludes the report by summarizing the key findings.

The glossary of terms used along with common explanations, and the references section containing lists of sources of information obtained from project documents and other secondary sources. The pictures attached in the report are cross referenced with the activity, its impact and/or mitigation measure. The site photographs have been taken by the author at various project sites.
Authors

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Abbreviations

ADB – Asian Development Bank
CSP – Concentrated Solar Power
CSR – Corporate Social Responsibility
DC or D/C – Double Circuit
DPR – Detailed Project Report
EHV – Extra High Voltage
EIA – Environmental Impact Assessment
EMoP – Environmental Monitoring Plan
EMP – Environmental Management Plan
EPC – Engineering Procurement and Construction
GHG – Green House Gas
GRM – Grievance Redress Mechanism
HT – High Tension
HVAC – Heating Ventilation and Air conditioning
HVDS – High Voltage Distribution System
IEE – Initial Environmental Examination
LT – Low Tension
MSL – Mean Sea Level
PCB – Poly Chlorinated Biphenyl
PIC – Project Implementation Consultant
PP – Project Proponent
O&M – Operations and Maintenance
ROW – Right of Way
ROR – Run-of-River
RTS – Roof Top Solar
SPV – Solar Photovoltaic
SF₆ – Sulphur Hexafluoride

Weights and Measures

Ha. (hectare) – 10,000 sq m = 2.47105 Acres
km (kilometer) – 1,000 meters
kV – kilovolt (1,000 volts)
kW – kilowatt (1,000 watts)
MW – Mega Watt
Introduction

1. A power engineer’s view on the role of an environmental expert in power sector development has not always been unanimous. For instance, questions are often raised over the environmental concerns that may lead to adverse impact on nature vis-a-vis the consequential additional costs to the project or delay in the construction of projects.

2. The environmentalists have debated that it is necessary to do so as the energy demand will never plateau with the vast needs of man-kind for energy. Looking at recent trends on global energy scenario—be it solar, wind, water or coal based energy generation, the appetite for each has risen in the past and is expected to increase in future. However adverse be impacts of energy generation, the development of power sector projects using sound environmental management practices will be needed in future to bring direct benefits to the people.

3. The audience for the paper includes ADB energy specialists and the environment/safeguards specialists. This report shall work as a practical handbook to ADB specialists to improve their understanding of construction techniques and their linkages to the requisite environmental due diligence at each stage of project implementation as specified under ADB’s Safeguard Policy Statement (SPS) 2009. The paper discusses all technical aspects that normally an engineer may be aware but the specialists who are from nonengineering background and environmental experts may be confounded when these are mentioned in the project preparation document and monitoring reports from the Project Proponent.

4. In the power sector, ADB is funding many of the following type of projects frequently in its member countries:

**ADB’s Transmission/Distribution Projects**

**Power Transmission**

- Overhead long distance power transmission lines (between grid/pooling substations to consumption centers) - 220 kV, 400 kV, 765 kV and 800 HVDC (high voltage direct current).
- Grid and pooling substations (See Glossary 79) (66 kV, 110 kV, 132 kV, 220 kV, 400 kV, 765 kV and 800 HVDC).
- Overhead power lines for Line-In-Line-Out (LILO) connectivity from the switchyard (See Glossary 120) of power generation plant for power evacuation to grid/pooling substations (66 kV, 110 kV, 132 kV, 220 kV, 400 kV)
- Underground power cable for network reliability (mostly 66 kV, 132 kV, 220 kV) within substations, crowded urban centres or areas that experience frequent outages and damages due to severe cyclone, snow, avalanches etc.

**Power Flow Management**

- Smart Grid network including Supervisory control and data acquisition (SCADA) systems.
Power distribution

- High voltage distribution system (HVDS) (See Glossary 53).
- Urban/Semi-urban network improvements.
  - Distribution Transformers (DTR) (See Glossary 35).
  - Billing and metering.
  - Automation.
- Rural feeders.
- Rural feeder separation for villages/pump-sets.

ADB’s Clean Energy Generation Projects

Hydropower Generation

- Mostly Run-of-River projects (See Glossary 98).
  - Large/Medium hydropower projects.
  - Small hydropower.
  - Micro hydro projects.
  - Pump storage projects (See Glossary 89).
- Dam projects (rarely)

Solar Power Generation

- Solar Photo-voltaic (SPV).
- Concentrated solar thermal.
- Rooftop SPV installations.
- Distributed SPV generation.

Relationships between Proposed Designated Sectors

5. The study deals with the following sectors - power transmission/distribution, run-of-river hydropower and solar photovoltaic generation projects (known as “designated sectors” in this report). The causal relationship between the above-designated sectors i.e. availability of reliable power in consumer areas fed by power evacuation lines constructed from remotely located generation plants is shown in Figure 1.

6. Secondly, most project sector specialists or environmental specialists do not get to witness each aspect of construction, and operation and maintenance (O&M) for the project they are assessing. Without knowing the local technical and engineering aspects of each type of physical construction work at site during the construction and operation, most of them may not know the kind of environmental impacts that may be generated as a consequence.
7. The paper focusses extensively on discussion of various construction process related aspects:

- design criteria and environmental due diligence used,
- environmental impacts at each stage of construction - activities causing impacts and their locational aspects, construction impacts, mitigation, reason and work processes. The above vary significantly for different types of terrains and project site-specific locations,
- environmental due diligence triggers and cumulative impacts due to the project,
- site monitoring requirements and review of completed activities, and
- assessment and modification of approaches for ADB funded projects based on key experiences learnt during project implementation.

8. This paper reviews the practical applicability of environmental safeguards and the SPS 2009 to the construction methodology adopted by the project proponent with a view to enhance good practices in project management. This paper hopes to provide insights to the project specialists to understand the gaps that may not be visible ordinarily in the initial environment examination (IEE) or an environment impact assessment (EIA) for these designated power sector projects.

9. The paper, however relevant to the topic, does not cover technological issues related to reduction of greenhouse gases and overall climate change as it is not the focus for this study.
10. This section focuses on providing a view of construction techniques for various designated sector power projects which show the human labor-mechanized construction interface in regions where construction costs and availability of these state-of-the-art machines in remote areas are a primary concern for the project proponent.

Normal Construction Related Perceptions About Proposed Projects

11. In the construction manual or technical specifications prepared by the Project Proponents (PP) handed to ADB officers, there are going to be references such as “when the transmission lines are built, the tower materials will be brought in manually head-loaded to remote areas without machines; the erection of towers is done manually, and similarly the power cables are pulled manually between two mountain tops by physically carrying the lead wire and then using pulleys to string the wire”. Similarly, in run-of-river hydropower projects, instead of using tunnel-boring machines, project proponents prefer to use drilling and blasting for all underground tunneling work instead.

12. Following are some illustrative queries that are generally raised while reviewing the project plan proposed by the proponent. There is neither a “right” or a “wrong” way of using a particular construction technique – rather it depends on the costs, the size of equipment, the accessibility of the project sites and/or the technology used for construction.

LOGISTICAL

- Will the helicopters be used to erect transmission line towers in high hills, riverine bed or even plain areas?
- Are drones being used to string the power transmission lines in high valleys?
- Are heavy lift helicopters used to airlift the heavy equipment such as transformer, reactor, hydropower turbines, pen-stock for delivery at site?
- Are high boom cranes, diesel/gas based machines normally used to lift accessories to various locations including the top of tower?
- All manpower must be locally employed to avoid impacting local community and also reduce costs and environmental impacts?

continues on next page
Construction Techniques and Methodology used by Project Proponents

Uniqueness of Construction Practices

13. This section discusses the construction practices that are unique to the region and is derived from the following sections that contain a detailed list of all project activities that are required to completely design, construct and commission any power transmission, distribution, or run-of-river (ROR) hydropower or solar photovoltaic (SPV) power generation projects.

14. Table below 1 briefly gives a sample snapshot description of construction techniques normally used versus the alternative methods of construction available and the reasons for using them. For example, a typical hydropower project could involve several such illustrations, but only a few are listed here. A detailed step-by-step process of construction followed is discussed in later sections for each of the designated sector projects.

<table>
<thead>
<tr>
<th>No.</th>
<th>Project Type</th>
<th>Construction Technique normally used</th>
<th>Alternative Methods of construction available</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Transmission/Distribution Line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tower material</td>
<td>Manual labour used to carry material to site of erection from the last accessible point on access road</td>
<td>Tower material reached to erection site by high boom cranes in hilly areas</td>
<td>Cost issues and status of access roads.</td>
</tr>
<tr>
<td>2</td>
<td>Tower foundation</td>
<td>Digging, reinforcement cement concrete (RCC) (See Glossary 92) and casting using manual methods</td>
<td>Digging, casting using mechanical tools and prefabricated casts</td>
<td>Terrain issues and cost of erection</td>
</tr>
<tr>
<td>3</td>
<td>Tower erection</td>
<td>It is erected member by member using chain pulleys manually</td>
<td>Tower structure is completely erected lying on ground and then mechanically/aerially erected.</td>
<td>Terrain issues and cost of erection</td>
</tr>
</tbody>
</table>

Box continued

**TECHNICAL/COST**

- Will tunnel boring machines will be used for all hydropower tunneling work instead of drilling and blasting?
- No cutting and welding of tower parts, hydropower steel components (penstock, liner) required at site as material must be made to order as per bill of quantities?
- All foundations for towers, poles, transformers, buildings, tunnel lining etc. must be prefabricated or precision casted using metals casts?

**TECHNOLOGICAL**

- Are all gas insulated switchgear (GIS) (See Glossary 47) substations proposed only in hilly areas?
- The high-tension low sag (HTLS) (See Glossary 52) type conductor is only used to reduce excessive sag due to temperature difference?
- Is remote operated switchgear in substation useful only in high altitude conditions?

Table 1: Illustrative Differences in Construction Practices followed

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<th>No.</th>
<th>Project Type</th>
<th>Construction Technique normally used</th>
<th>Alternative Methods of construction available</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Installation of tower suspension accessories</td>
<td>They are erected manually by hauling the accessory using chain pulley.</td>
<td>Tower material reached to top of erection site by high boom cranes.</td>
<td>Terrain issues and cost of erection</td>
</tr>
<tr>
<td>5</td>
<td>Paying out (See Glossary 69) of earth wire and conductor</td>
<td>Manually controlled conductor drums used.</td>
<td>Mechanically (diesel/gas) operated conductor drums.</td>
<td>Cost issues and lack of equipment</td>
</tr>
<tr>
<td>6</td>
<td>Stringing of pulling line over each stinging block for the conductor</td>
<td>The pilot wire is manually strung over valley in mountainous area which is attached to power cable.</td>
<td>The pilot wire is sometimes shot using a winch or through drones.</td>
<td>Cost issues and lack of equipment</td>
</tr>
<tr>
<td>7</td>
<td>Tensioning and sagging of conductor. (See Glossary 101)</td>
<td>Tension and sag corrected using manual winch, chain pulleys, bull wheel type pullers and other associated equipment</td>
<td>Mechanically operated (diesel/gas) powered pullers (See Glossary 88) and tensioners to correct the tension and complete sagging operation.</td>
<td>Cost issues and lack of equipment</td>
</tr>
</tbody>
</table>

B. Transmission/Distribution substation and distribution transformers

<table>
<thead>
<tr>
<th>No.</th>
<th>Project Type</th>
<th>Construction Technique normally used</th>
<th>Alternative Methods of construction available</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transformer erection</td>
<td>Manually using wooden logs and hydraulic jacks</td>
<td>Using high capacity cranes that can lift above 100 tonnes or more.</td>
<td>Non-availability at site, road access, cost issues.</td>
</tr>
<tr>
<td>2</td>
<td>Foundations</td>
<td>Digging, reinforcement cement concrete (RCC) and casting using manual methods</td>
<td>Digging, casting using mechanical tools and prefabricated casts</td>
<td>Cost of erection</td>
</tr>
<tr>
<td>3</td>
<td>Erection of structures at substation site</td>
<td>It is erected member by member using chain pulleys manually</td>
<td>Structures are completely erected lying on ground and then mechanically/airially erect.</td>
<td>Cost of erection</td>
</tr>
<tr>
<td>4</td>
<td>Erection of equipment</td>
<td>Erected manually using chain pulleys (upto 132 kV substation size) beyond which it is done using cranes</td>
<td>Erected using mechanised cranes entirely</td>
<td>Cost issues.</td>
</tr>
</tbody>
</table>

C. Run-of-River Hydropower Generation

<table>
<thead>
<tr>
<th>No.</th>
<th>Project Type</th>
<th>Construction Technique normally used</th>
<th>Alternative Methods of construction available</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tunnel Boring for underground</td>
<td>Blasting and tunneling</td>
<td>Tunnel boring Machines</td>
<td>Terrain, road access, cost issues</td>
</tr>
<tr>
<td>2</td>
<td>Steel liners -underground penstock</td>
<td>Metal sheets which are welded and used</td>
<td>Precast penstock components</td>
<td>Road access, cost issues</td>
</tr>
<tr>
<td>3</td>
<td>Workshop –Bending, cutting of underground steel lining</td>
<td>Metal girders are used which shall be bent and used</td>
<td>Precast material or tunnel lining</td>
<td>Cost issues</td>
</tr>
<tr>
<td>4</td>
<td>Muck loading and dumping</td>
<td>Mostly using shovels, dump trucks</td>
<td>Using continuous loaders and conveyor belts to dumping sites</td>
<td>Cost issues</td>
</tr>
</tbody>
</table>

D. Solar Photovoltaic (SPV) Power Generation

<table>
<thead>
<tr>
<th>No.</th>
<th>Project Type</th>
<th>Construction Technique normally used</th>
<th>Alternative Methods of construction available</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water used for solar plant construction and operation</td>
<td>Mostly using underground or water from nearby canal or pond. Water used for panel cleaning after installation is normally untreated.</td>
<td>Panels used have self-cleaning property and water used for panel cleaning after installation and testing is ultrapure that has no impurities</td>
<td>Cost issues and viability</td>
</tr>
</tbody>
</table>

TDS: Total Dissolved Solids
15. The table above shows that the best construction practices or technological innovative approaches may not be followed by the project proponent due to limitations of physical location, high cost, or financial unviability due to high technology and innovation. Although vast supply of cost-efficient labour presumably is preferred due to logistical issues; although, under certain circumstances, a more manual approach could be environmentally beneficial even if it becomes a cost neutral option.

16. The project proponent may evaluate the environment and cost-benefit of each technique prevalent in most on-going turnkey contracts. The Engineering Procurement and Construction (EPC) contractors may shift toward less labour intensive construction techniques wherever topographic conditions permit using better technology and innovation if they are cost efficient, safe and effective.

17. The following sections discuss project proponents plan for construction with ADB intervention, and what they assess as the potential impacts, measures and human intervention. Given that most projects have their unique characteristics for construction depending on the above, the type of environment impacts that occur due to these physical works and disturbances at project sites are discussed in the following sections along with suitable flow charts depicting various stages of construction and practices being followed in the designated sectors. This information is supplemented by several photographs from project sites taken by author presented in the order of their occurrence during the construction process and the write up provides details about their environmental impacts and consequent mitigation measures. Each designated sector has a separate pull-out section for easy reading.
3 Stages of Power Transmission and Distribution Lines Project Design, Construction and Related Environmental Impacts and Mitigation

18. This section discusses various project design aspects and lists various stages of construction process along with the environmental impacts, type, impact and impact mitigation measures for power transmission and distribution line projects.

**Different Type of Power Lines**

- Power Transmission lines – Voltages above 33 kV i.e. 66 kV, 110 kV, 132 kV, 220 kV, 400 kV, 765 kV, 800 HVDC (High Voltage Direct Current) (See Glossary 54).
- Power Distribution lines – 33 kV including High Voltage Distribution System (HVDS), 22 kV, 15 kV, 11 kV, 0.4 kV and rural feeders.

19. Pictures of Illustrative Power Transmission Lines:
20. Pictures of some illustrative Power Distribution Lines:

220 kV and 66 kV lines

220 kV, 132 kV, and 33 kV lines

21. Following pictures show overhead power lines for Line-In-Line-Out (LILO) connectivity from switchyard of power generation plant for power evacuation to grid/pooling substations (66 kV, 110 kV, 132 kV, 220 kV, 400 kV). When a transmission line is passing nearby generation station switchyard; to add power, the line is tapped by creating an interconnecting bays and/or installing tower. This system of connectivity is called LILO. The incoming line is connected to “incomer” bay while the outgoing is connected to “outgoing” bay. If a new EHV power evacuation/receiving substation is to be connected into an existing power line running between substations, the connecting transmission line for new inserted substation creates a Loop In Loop Out and is also called a LILO.
Distribution Transformer (DTR), 11 kV and 0.4 kV lines

LILO for line

LILO near substation
A. Transmission Lines

22. Figure 2 provides a schematic for the entire power transmission and distribution process from generation end to the consumer end.

Design Criteria

23. Transmission line is linear project (See Glossary 64) and one of the key factors that govern the design of transmission projects is the possible infringement of populated/forest/cultivated area and scarce land. For selection of optimum route, the following design criteria are usually taken into consideration by project proponents:

(i) Normally, the route of the transmission lines does not involve any human habitation. As a principle, alignments are generally cited at-least 500 m away from major towns, whenever possible, to account for future urban expansion and electromagnetic field for at-least 50 m away from any houses or structures.

(ii) Any monument of cultural or historical importance is not affected by the route of the transmission line.

(iii) The proposed route of transmission line does not create any threat to the survival of any community or indigenous peoples.

(iv) The proposed route of transmission line does not affect any public utility services, playgrounds, schools, community places, temples and other establishments etc.

(v) The line route does not pass through any sanctuaries, protected park etc. Similarly, plantations/forests are avoided to the maximum extent possible. Whenever it is not possible, a route is selected in consultation with the forest department that causes minimum damage to existing plantation/forest resources.

(vi) The line route does not infringe with area of natural resources. Alignments selected to avoid wetlands and unstable areas for both financial and environmental reasons.

Construction Practice, their Environmental Impacts, Mitigation and Work Process

24. The Flow Chart in Figure 3 displays activities undertaken while constructing a transmission line. On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, and Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1-12 (as shown by arrows). Some “Tasks” are grouped together in a particular “Step” in the order of their occurrence in a project cycle. Their placement (i.e. 1&3, 2&4) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 5-12. These “Tasks” are usually performed by the Engineering Procurement and Construction (EPC) contractor.
Figure 2: Schematic Diagram of the Transmission/Distribution System

HYDROPOWER GENERATION → HYDROPOWER SWITCHYARD FOR POWER EVACUATION → POWER EVACUATION LINE

POWER TRANSMISSION AND DISTRIBUTION SYSTEM

RECEIVING TRANSMISSION SUBSTATION → POWER TRANSMISSION LINE → POOLING SUBSTATION

DISTRIBUTION LINES → FEEDER SEPARATION → DTRs AT CONSUMER END

Transmitting Techniques in Construction
25. Table 2 provides information about each of the steps involved in transmission line design, construction, testing and commissioning, the environment impacts and the proposed mitigation, and work process involved. In Table 2, layout of the each box is represented as follows:

- The colored box on top left of the Table represents the “Steps” matching the color of boxes in the Figure 3.
- “Tasks” lists work undertaken to accomplish the “Steps” shown in Figure 3. This followed by explanation of the task conducted.
- “Activity causing Impact and Location” lists the activity undertaken to accomplish each “Task” that impacts the environment and also gives the location of the environmental impact in brackets.
- “Impact of activity and its type” describes the impact on environment of each activity and lists it type – temporary, permanent, planning etc. in brackets.
- “Mitigation Measure for the Impact” lists environmental mitigation measures taken to mitigate the impact.
- “Work process” provides a write up on the work done by EPC contractor for each “Task” and the human aspect involved during task completion.
- The right side of the Table 2 contains pictures from actual working sites that are mapped to each relevant “Activity”.
Figure 3: Process Flow Chart for Construction of Transmission Lines

CONSTRUCTION OF POWER TRANSMISSION LINES

PRECONSTRUCTION

1. Surveys
2. Forest case Preparation and Preliminary Survey
3. Detailed Surveys
4. Soil Investigations, other environmental baseline information

FACILITIES SETUP

5. Temporary worker Camps
6. Unloading site storage and workshop

CONSTRUCTION

7. Pits Marking, Digging of Foundations
8. Construction of Foundation, Revetment

ERECITION

9. Pre-erection Checks
10. Erecting Towers and Accessories
11. Earthing, Clipping, Fixing of Accessories

COMMISSIONING

12. Stringing, Final Sagging, Testing, and Commissioning
### Table 2: Transmission Lines- Stepwise Project Activities, Construction Impacts, Mitigation, and Work Process Involved

<table>
<thead>
<tr>
<th>PRECONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity causing Impact and Location</strong></td>
</tr>
<tr>
<td>Enumeration of trees for cutting, identification of locations for digging of soil for tower base, development of quarrying sites, stacking area for construction material etc. (Location: Tower Base)</td>
</tr>
<tr>
<td><strong>Impact Mitigation</strong></td>
</tr>
<tr>
<td>Better choice of route alignment and tower bases to avoid adverse impact to common property resources, biodiversity, public utilities, etc.</td>
</tr>
</tbody>
</table>

**Notes:**
- **Surveys:** Several surveys are carried out prior to design of transmission system to ensure technical, financial, environmental viability.
- 1. **Initial Survey:** Conducted along shortest distance between the sending (generating end) and the receiving end (substation) of the transmission line (known as a Bee line) (See Glossary 12).
- 2. **Reconnaissance Survey:** Information on field data required for transmission line design. Major power line crossing details (66 kV and above), railway crossing details, major river crossing details, distance from community resources - worship places, village common grounds, community centers', schools, hospitals etc. Picture a. depicts a typical ongoing survey. Picture b. shows a potential tower location.
- 3. **Alternative analysis survey:** All alternative routes proposed and collection of details about features observed and facilities marked on topographical map (1:50,000). See Picture c.
c. Alternative analysis of lines with tower locations (three alternatives – red, blue and black line)
### 2. Forest Case Preparation and Preliminary Survey

1. **Forest case preparation (See Glossary 45):** Enumeration of trees to be cut, lopped/trimmed in the Right of Way (ROW) (See Glossary 95) clearance according to girth, height, type of tree. (See Pictures a and b.)

2. **Preliminary survey:** A schedule of angle points (See Glossary 4) (a point where the line makes a deviation from a straight line) along with the brief description of terrain and physical features that lie between each angle point section is done. The alignment is plotted on Government survey maps. Details of places of worship/electricity/forest/telecommunications/roads/railways tracks, bank, police station, hospital, schools, restricted plantations etc. to be recorded. (See Pictures c-f).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marking of trees/vegetation for cutting at the tower base and for trimming inside the right of way, access roads etc. (Location: Tower)</td>
<td>Potential impact on physical resources, topography during construction and loss of tree cover which would lead to erosion, landslips and landslides in hilly areas causing topographical impacts creating gullies, ridges etc.) (Type: Planning stage)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper clearance from appropriate agencies such as railways, roads, airports etc. Planning for compensation afforestation details in consultation with Forest Department in consonance with watershed development plans of the area.</td>
<td>Requires about 3-4 months of trees survey along the ROW - enumeration, age, girth, etc. along selected alternative. Forest department prepares and processes details for trees, wild life corridors, or plantations (if any) etc. for compensatory afforestation (See Glossary 22). Also, record coordinates for railway tracks, places of worship and the like.</td>
</tr>
</tbody>
</table>

- **a. Trees marked for cutting or lopping along the alignment**
- **b. Right of Way clearance.**
c. Place of worship near right of way

d. Medicinal plantation (restricted plantation)

e. Wildlife corridor

f. Crossing marked on railway tracks
### 3. Detailed Surveys

All details along the line up to 200 m on either side to be recorded and depicted on the plan and details - villages, temples, physical cultural resources, etc.

Leveling, Plan and Profile, Tower spotting and plotting sag of wire

Normally, a final alignment and pegging (location marking of towers) to be carried out (See Picture a). After spotting of towers, the ground clearance curves for conductor drawn, a list of tower positions, type of tower, angle of tower (known as tower schedule (See Glossary 124)) is prepared using a workstation (See Picture b.). GPS coordinates (See Glossary 49) are also recorded. (See pictures c).

The profile sheet that is drawn for the complete line using contours of the area details the type of towers, standard extensions and leg extension, normal wind and weight span, conductor sagging and maximum single spans for complete line as shown in Picture d.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towers located in agricultural fields, forest areas, portions of houses/buildings falling in tower foundations. (Location: Tower Bases)</td>
<td>Potential impact on physical resources, topography. Possible loss of biodiversity, soil erosion, land slips/landslides in the area. (Type: Planning stage)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential tower locations deviated by at least 5-10 m sideways to avoid transmission line directly over the houses, or any existing asset which would negatively impact the land owner.</td>
<td>Manual checking of location of center peg, plotting of position of various landmarks on to the profile sheet. Derive specifications for tower alignment, tower type, angle of conductor, sag, and direction and controlling elevations, sag of wire, area topography and plot them on the profile sheet.</td>
</tr>
</tbody>
</table>

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* a. Pegging of the line
* b. Workstation to assess tower location
c. GPS coordinates

d. Profile sheet for transmission line
## PRECONSTRUCTION

### 4. Soil Investigation, other environmental baseline information

Air, water, soil and noise samples are also collected for testing to develop an environmental baseline for the area. Besides, the soil investigation (soil/rock formation, clay, gravel, rock etc.) is important to determine the transmission tower placement in any area – hilly, plain level area, or marshy areas. General characteristics of the soil mentioned above, wind, weather, rainfall etc. that occur in the area has a direct influence on the design of type of foundations and towers.

Picture a. shows pit level manual soil collection and Picture b. shows dust samplers in operation.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection of soil samples by digging manually/using machines as well as collection of water from wells/water sources nearby ROW. (Location: Tower Base)</td>
<td>Minor impact of collection of soil samples on topography or pollution of water source during sample collection. (Type: Planning Stage)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Avoid marshy areas, low-lying areas, riverbeds, earth slip zones that would involve risk to stability of the foundations.

Baseline development will help in monitoring environmental parameters on a regular basis during construction period. Reduces potential impact on environmental resources in the area—air quality, noise quality, ground water quality and surface water quality during construction.

**Work process**

Soil samples taken manually by digging holes or using an augur tool (See Glossary 7) or digging machine.
b. Air dust samplers
**5. Temporary Worker Camps**

Temporary worker camps are set up en-route the transmission line.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scatter of kitchen waste, toilet waste, scrap, unusable/nonrecyclable waste in the area.</td>
<td>Oils, untreated wastewater, sewage etc. flowing into water body, river, drainage areas from the camps causing impact to surface water, ground water, any aquatic life downstream.</td>
</tr>
<tr>
<td>Solid waste disposal, liquid waste disposal in camps spillage into river, streams.</td>
<td>The downstream water in river can be polluted making it unfit for bathing or potable water.</td>
</tr>
<tr>
<td>Poaching of animal life, fishing, harvesting of wood by workers. (Location: Worker Camp)</td>
<td>The camps can also adversely impact on ecological resources through poaching of wildlife and using wood from trees as firewood causing ecological damage in the area. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Contract provisions specifying minimum setback requirements for construction camps from water bodies, reserved areas etc. Engineering Procurement and Construction (EPC) contractor can provide liquefied petroleum gas cylinders for cooking etc. to workers.

Provision of adequate washing and toilet facilities by the contractor to the workers should be made obligatory.

**Work process**

The worker camps mainly migratory in nature and away from local populations. Given the strength of man-power to be between 10-20 and the duration of work in one place might be for 2-3 weeks before moving on to next place; the impact will not be permanent.
c. Use of firewood for cooking

d. Water tanker for all purposes—drinking water (unsafe), bathing, washing etc.
6. Unloading of material at site, storage and workshop

The tower erection sites are normally very remote where mechanized equipment is not readily available or are not accessible (e.g. in hilly regions). Storage and workshop areas are established in an area accessible easily by trucks, motorized equipment, has power availability and storage area.

Mostly a small mechanized boom crane (see Picture a.) is available, otherwise it is manually unloaded using chain and pulleys blocks (see Picture b.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levelling of soil for creation of storage place.</td>
<td>Levelling of soil, vehicular emissions impacts air quality/noise levels in the area. Cutting of trees, soil erosion will impact terrestrial ecology of the area. (Type: Temporary)</td>
</tr>
<tr>
<td>Transportation of equipment to sites using heavy cranes to unload/load equipment (See Picture c.) (Storage areas, Tower Bases)</td>
<td>Workshop wastes impacts ecological resources due to unplanned solid waste, unsafe wastewater, other liquid waste disposal flowing into water bodies, drainage etc. affecting the ground water, aquatic ecology of water bodies in the area. (Type: Temporary)</td>
</tr>
<tr>
<td>Toilet waste, scrap, unusable/nonrecyclable waste, oils, sewage, slurry from machines, dripping oils from trucks etc.</td>
<td></td>
</tr>
<tr>
<td>Welding, cutting and fabrication of raw material etc. (See Picture d.) (Location: Workshops, stores, machine shops)</td>
<td></td>
</tr>
</tbody>
</table>

**Impact Mitigation**  
Select locations for material storage yards and Workshops established away from any environmental sensitive areas. The vehicles used at the site must be compliant with pollution standards of the country. Protective equipment (PPE) (See Glossary 86) for handling of material and in the workshop is required.

**Work process**  
Cutting of trees and levelling ground to create a storage facility; arrange transportation and unloading of equipment and raw material using cranes.
d. Welding, cutting of raw material.

c. Camp, store and work place
7. Pit Marking, digging of foundation

After the location marking (see step 3) has been done, the marking of the pits for excavation for the foundation is done. Each pit and foundation is specific to the type of tower to be erected at that location. Angle of deviation (See Glossary 5) for each tower must be compared with the profile sheet. Pits must be free from excess soil after excavation. Clearing of any trees etc. near the foundations is required.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing of land for tower in agricultural fields or hilly areas (See Pictures a. &amp; c.)</td>
<td>Improper soil type encountered making the tower footing very huge and contour specific.</td>
</tr>
<tr>
<td>Pile foundation (See Glossary 75) in case of marshy lands, hilly and river basins may be required (see Pictures b.&amp;c.)</td>
<td>Ground and surface water quality, aquatic ecology may be affected due to surface soil run-off, dripping of oils from engines of digging machines. Impact on environmental resources- air quality/noise levels due to use of machinery for digging or stacking of loose soil. (Type: Temporary)</td>
</tr>
<tr>
<td>Stacking of dug up soil, usage of digging machines for foundations. (Location: Tower Foundation)</td>
<td>Impact on physical resources, topography during construction - loss of trees would lead to erosion, landslips and landslides in hilly areas creating gullies, ridges etc.)</td>
</tr>
</tbody>
</table>

Impact Mitigation

Ensure proper drainage, proper soil type to ensure minimum tower base footing due to contour, tower alignment, distance from trees, sensitive areas.

Ensure minimum/noise pollution at digging points.

Work process

Manual labor or a backhoe loader (See Picture d.) used to dig the foundations and for removing excess mud from tower foundation sites.

a. Constructed foundations in agricultural land
b. Tower line using pile foundation in river

c. Hilltop-to-hilltop transmission line in hills

d. Backhoe loader
8. Construction of Foundation, Revetment (See Glossary 94)

Bending steel rods, tying with steel wires and mixing concrete for the foundation is done manually. This is followed by pouring in concrete prepared using a manual mixing machine (See Picture a.). This steel-concrete structure is known as Reinforced Cement Concrete (RCC).

The concrete is casted manually into the foundations and footing prepared manually using ply-boards and/or wood casts made as per design. (See Picture b.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface run-off of prestacked soil, oil leakages from engine and vehicles.</td>
<td>Ground and surface water quality, aquatic ecology may be affected due to surface soil run-off, dripping of oils from engines of digging machines.</td>
</tr>
<tr>
<td>Steep contour, improper soil type encountered. (Location: Tower base)</td>
<td>Steep contour, improper soil type encountered making the tower footing very huge and contour specific requiring revetment. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Restore the loose soil from foundations through ramming (See Picture c.). Excess soil is laid out in areas that do not interfere with local drainage pattern.

- For any revetment structure, the weep holes are placed (Picture e.) to ensure water/moisture shall pass through easily without damaging the structure.

**Work process**

- Erection takes from 2-3 weeks for construction of RCC structure.

- The construction work for all foundations including concreting is done manually at all remote tower locations where no access roads exist (such as those shown in Picture d.).

---

![Image a. Manual concrete mixer](image-a)

![Image b. RCC tower foundations](image-b)
c. Loose topsoil left untreated after leg erection

d. Revetment at tower bases

e. Weep holes in revetment to allow water/moisture to pass through
### 9. Pre-Erection Checks

Checking of all tower locations with respect to design type, the wind load, the conductor weight, the type of accessories, the angle of wire and determine the tower erection methodology for sag and tensioning (see Picture a.). Cutting of trees and vegetation for the right of way. (See Picture b.).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifting of distribution lines, water supplies, cutting trees etc. under the planned right of way. (Location: Tower base and Right of Way)</td>
<td>Disturbances to local population due to temporary outages of power as distribution lines are disconnected</td>
</tr>
<tr>
<td></td>
<td>Utilities such as water supply etc. may be disturbed because of the above. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Re-routing of public utilities affected by the transmission line – distribution lines, power lines, telecom lines etc.

**Work process**

Engineering design team reviews potential tower loads, method of erection and stringing to wire to balance loading at each location of the tower (either situated on steep hill or any plain area).

![a. Revetment, Tower sag, accessories](image)

![b. Right of way of tower line (under-construction)](image)
## ELECTION

### 10. Erecting towers, arms, Erection, Tightening and Punching

The Lattice structure (See Glossary 62) tower parts are moved/loaded manually up to the erection point and then lifted manually/using chain pulleys to the top. There is no high boom crane available in remote areas to help lift the towers parts to the top.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Protective Equipment (PPE's) not used by workers and not available to nearby residents. Adequate distances not maintained from neighboring properties and structures. Loose soil left unattended after completion of erection of tower. (Location: Tower)</td>
<td>Unsafe erection of tower can result in injuries to the workers and residents in the area. Untrained workers can lead to more accidents and fatalities. Weather conditions in hilly areas could result in tower failure or topple partially or fully during erection and stringing due to uneven stringing loads, severe wind conditions. Soil erosion as discussed in “Activity 2 and 3” earlier. (Type: Temporary)</td>
</tr>
</tbody>
</table>

### Impact Mitigation

<table>
<thead>
<tr>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of proper PPE (See Glossary 72) for workers, safety protocols during erection process must be observed. Proper on-site training to staff and residents must be provided by EPC contractor. The EPC contractor will ensure proper design of tower structure to avoid accidents due to toppling (partially or fully) takes place during erection and stringing due to uneven stringing loads, severe wind conditions. Soil erosion to be contained as mentioned in activities 2 &amp;3.</td>
</tr>
<tr>
<td>Single tower erection takes at least a team of 5–8 workers for a week. Manual hauling of the tower parts using chain pulleys to the top of the structure and erecting each of them individually. See Picture a. After completion of erection EPC contractor must compact and remove extra soil from tower base (See Picture b.)</td>
</tr>
</tbody>
</table>

---

*a. Erection of lattice structure tower  
b. Loose topsoil left untreated after erection of tower and earthing of tower*
11. Earthing, clipping and fixing of accessories ([See Glossary 20], installation of OPGW (Optical Ground Wire)) ([See Glossary 68])

Double earthing of each tower is done using manual labor to ensure proper protection of the entire system from faults and accidents. All accessories are erected manually using small pulley and tensioner (See Picture a.) followed by erection of disk insulators (See Glossary 34). Earth wire or OPGW is usually strung first on the top arms of the tower followed by accessories on the lower arms. (See Picture b.) followed by stringing of power conductor.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
</table>
| Installation of Earth wire and Accessories.  
Earthing the tower and the conductor. (Location: Tower) | Accident at tower site due to falling of accessory, snapping of earth-wire of incorrect tensioning etc. Impact on safety of workers due to lack of PPEs.  
Improper refilling of soil at earthing location may cause soil run-off. (Type: Temporary) |

**Impact Mitigation**

EPC contractor must ensure proper PPEs are worn by work staff and safety protocols for earthing, accessories and installation of OPGW are followed.

Ensure proper earthing and maintaining specified distances from the under erection earth wire in case the tower line is passing over another live transmission or distribution line.

**Work process**

A tower earthing needs digging for 3.6 m depth using a manual auger tool. The installation of tower earthing takes about 2-3 days.

Manual hauling of the accessories using chain pulleys to the top of the structure and erecting each of them individually.

The OPGW erection process is undertaken one segment at time depending on the location and altitude of power line.

![Erection of accessories](image1.png)

![Stringing of Ground wire](image2.png)
12. Stringing and final sagging and tensioning of earth-wire and power conductor, Testing and Commissioning

The paying out/stringing (See Glossary 110) of power conductor (See Glossary 82) is done manually using aerial rollers (See Glossary 112)/pullers (See Glossary 88), tensioners (See Glossary 123) winches etc. to provide the correct sag (See Glossary 101) prescribed for the wire.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringing of cable onto the erected towers, accessories manually or using equipment. (See Pictures a.-c.). Addition lopping of trees required within the ROW. (Location: Tower line)</td>
<td>Snapping of stringing blocks (See Glossary 111), unbalance load during stringing on tower leading to collapse, falling cables injuring workers, others etc. Stringing the wire loosely may result in cable touching the ground and other obstructions that could cause damage. Extensive lopping of branches etc. in hilly terrain may be required to maintain ROW as compared to lines running over level ground. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Proper tension maintained between the tensioner and the puller keeps the conductor clear of the ground and other obstructions that could cause damage (See Pictures d.-f.). Scaffolding shall be used where roads, rivers, channels, telecom lines, overhead power lines, railway lines, fences or walls have to be crossed during stringing operations. No. of trees to be lopped needs to be ascertained.

**Work process**

Towers are provided with stays/anchors to balance one sided load on them when stringing is done initially on one side only.

One end of pulling line (See Glossary 87) (Picture c.) attached to the conductor end, is strung through each stringing block between the puller and tensioner. The conductor is then pulled through the stringing rollers until the end reaches the puller. Length of conductor segments is equal to length of cable in the drum (See Glossary 39).
c. Cross-section of ACSR conductor (See Glossary 3)

d. Stringing of power conductor in hilly terrain

e. Stringing in plain terrain

f. Final tensioning and sagging
B. Distribution Lines

26. Power lines having voltage carrying capacities above 33 kV are termed as transmission lines; those carrying 33 kV are termed subtransmission (See Glossary 116) lines whereas 33 and 22, kV and 11 kV lines as medium voltage (MV) (See Glossary 128) and 0.4 kV low voltage (LV) distribution lines. The distribution line projects being funded usually consists of erection of subtransmission, MV and LV lines.

27. Overhead distribution lines would involve the following:

(i) Distribution network is constructed on using either of the three types of poles – concrete, steel poles and steel rail. Besides, some select subtransmission 33 kV lines for long distance also use lattice towers.

(ii) The distribution lines emanating from power substations connect to step down voltage distribution transformers (DTRs) of various sizes ranging from 3 kVA to 100 kVA depending on power required at the load centers – industrial, commercial, residential urban areas, rural as well as agricultural feeders. Following is all illustrative sizing of DTRs as per their tentative applications at consumer end:

- Rural feeders, residential (rural/urban) - 0-3 kVA
- Residential, small commercial - 3-10 kVA
- Residential, Commercial - 10-25 kVA
- Commercial, Group Housing - 25-50 kVA
- Large Housing, Commercial, Industrial - 50-100 kVA
- Industrial - 100-200 kVA

The above transformers are rated for voltages upto 33 kV and is illustrative in nature.

**Design Criteria**

28. For selection of optimum route, the following design criteria are usually taken into consideration by project proponents:

(i) The route of the proposed 33/11/0.4 kV lines does not involve any uprooting of habitation. As a principle, distribution alignments generally pass through all towns and villages, but the minimum right of way (RoW) distance shall be kept safe distance away from any houses or structures.

(ii) Ensure that Polychlorinated Biphenyls (PCBs) are not used in the transformers installed in the project-funded facilities.

(iii) Any monument of cultural or historical importance is not affected by the route of the distribution line.

(iv) The proposed route of distribution line does not create any threat to the survival of any community with special reference to tribal community.

(v) The proposed route of distribution line does not affect any public utility services, playgrounds, schools, other establishments etc.

(vi) The line route does not pass through any sanctuaries, protected park etc. Similarly, plantations/forests are avoided to the maximum extent possible. When it is not possible, a route is selected that causes minimum damage to existing plantation/forest resources.

(vii) The line route does not infringe with area of natural resources. Alignments are selected to avoid wetlands and unstable areas for both financial and environmental reasons.
Construction Practice, their environmental impacts, mitigation and Work process

29. The Flow Chart in Figure 4 displays activities as they progress while constructing a distribution line. On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, and Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1–10 (as shown by arrows). Some “Tasks” are grouped together in a particular “Step” in the order of their occurrence in a project cycle. Their placement (i.e. 1&3, 2&4) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 5–10. These “Steps” are usually performed by the Engineering Procurement and Construction (EPC) contractor.

30. Table 3 provides information about each of the step involved in transmission line design, construction, testing and commissioning, the environment impacts and the proposed mitigation, and work process involved. The “Steps” involved in the erection of distribution lines are nearly common up to point 6 in Table 2 (for transmission lines).

31. In Table 3, layout of the each box is represented as follows:

- The colored box on top left of the Table represents the “Steps” matching the color of boxes in the Figure 4.
- “Tasks” lists work undertaken to accomplish the “Steps” shown in Figure 4. This followed by explanation of the task conducted.
- “Activity causing Impact and Location” lists the activity undertaken to accomplish each “Task” that impacts the environment and also gives the location of the environmental impact in brackets.
- “Impact of activity and its type” describes the impact on environment of each activity and lists its type – temporary, permanent, planning etc. in brackets.
- “Mitigation Measure for the Impact” lists environmental mitigation measures taken to mitigate the impact.
- “Work process” provides a write up on the work done by EPC contractor for each “Task” and the human aspect involved during task completion.
- The right side of the Table 3 contains pictures from actual working sites that are mapped to each relevant “Activity”.

Figure 4: Process Flow Chart for Construction of Distribution Line

CONSTRUCTION OF POWER DISTRIBUTION LINES

1. Surveys
2. Forest case Preparation and Preliminary Survey
3. Detailed Surveys
4. Soil Investigations, other environmental baseline information
5. Temporary Labor Camps
6. Unloading of material at site, storage and workshop
7. Digging Pits for Poles, Erection of Poles/Lattice structures and concrete pouring into pole foundations
8. Mounting pin insulators, Stringing with jointing sagging and tensioning of conductors
9. Fixing of Distribution Transformers (DTRs)/accessories
10. Sectionalising and protection of line using automatic circuit reclosures, Testing and Commissioning
### Table 3: Distribution Lines - Stepwise Project Activities, Construction Impacts, Mitigation and Work Process Involved

#### CONSTRUCTION

**7. Digging Pits of poles, Erection of Poles/lattice structures and concrete pouring in pole foundations**

Distribution networks – both urban and rural areas normally use poles/lattice structures (see Pictures a.–c.) at erection sites are normally located away from the road (both in level or hilly regions).

Foundation pits for these poles are very small and they are dug manually in both level and the hilly areas. Concrete mixture for the foundation prepared using a manual mixing machine and casted manually using ply-boards and/or wood casts.

The poles are unloaded manually at the erection point using chain and pulleys blocks. Mostly a small mechanized truck such as the one in Picture d. is available at the loading/unloading point.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging of pole foundations using manual auguring tool along the roads and agricultural/barren land. Using concrete to erect the pole. (Location: Pole base locations)</td>
<td>Surface soil run-off of soil not compacted at the pole base. Agricultural/barren land (small area of max. 1 sq. m.) affected. Excess concreting raw material left strewn in the area after work complete. (Type: Permanent)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Restore the excess soil through ramming and ensuring the loose soil is removed and construction material from pole base so that it does not interfere with drainage of the area.
- Ensure lines do not cross the agricultural fields in manner that adversely affects the famers.

**Work process**

- The poles are prefabricated whereas the lattice structure is erected at site.
- The concrete mixture is prepared and poured manually at most pole line locations.

---

a. Urban distribution 33/11/0.4 kV
b. Rural feeder 11 kV

c. Under construction Lattice type 33 kV line

d. Concrete poles and transportation by truck
### ERECTION

#### 8. Mounting pin insulators (See Glossary 76), Stringing with jointing, sagging and tensioning of conductors

The stringing of wires is done manually using pulleys, ropes to provide the correct sag prescribed for the wire. (Pole line)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringing of cable onto the erected poles, accessories manually or using equipment. (Location: Pole line)</td>
<td>Improper distance from houses, trees, and other building effected due to distribution line. Stringing the wire loosely may result in cable touching the buildings, trees and other obstructions that could cause damage and accidents during operations. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Distances from public receptors maintained as per the mandatory requirements of the country. Proper sag and tension maintained between conductors installed to keep it clear of the buildings, trees and other obstructions that could cause accidents/short circuits during operation. (See Pictures a.-b.).

**Work process**

Poles are provided with permanent stays/anchors to balance them during stringing as well as operational stages.

The conductor is laid on the ground between each pole and is pulled up through a chain pulley and attached to the accessories on the pole.

Checking of final sagging is done manually.

#### a. Metered rural connections

![Metered rural connections](image)

#### b. Metered semi-urban connections

![Metered semi-urban connections](image)
### 9. Fixing of Distribution Transformers (DTRs)/accessories

DTR transformers have rating ranging from 3 KVA–100 KVA, which depends upon the power requirements at the consumer end are installed on single pole, double pole or four pole structures based on their sizes. (See Pictures a.–c.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTRs on poles and ground are installed close to consumer end i.e. close to industrial, commercial, residential buildings as well as agricultural fields. The poles will be erected along the roads or along agricultural and/or barren lands. (Location: Poles and Right of way)</td>
<td>Pole structures for mounting DTRs are normally not secured by protective fencing and can become a hazard if someone climbs over. Physical cultural resources (PCR) (See Glossary 74) can be affected. Dripping of transformer oil may cause soil pollution Loss of agricultural land, and interference with other utilities and traffic may happen during erection process. (Type: Temporary)</td>
</tr>
</tbody>
</table>

### Impact Mitigation

Ensure DTR is installed at safe distance from human reach, does not spill oil, and has secure connections to the 33/22/11 kV line.

Line through agricultural lands must be carefully routed to ensure no loss of land, or disruption of water utilities occur during construction.

Care to ensure Physical Cultural Resources are not affected by the DTR placement.

### Work process

Installation of each DTR is done manually using chain pulley method to lift and place it on to the pole by a 3-4 persons.
c. Cluster of 11/0.4 kV transformers on two pole structure, four pole structures
### COMMISSIONING

#### 10. Sectionalizing & protection of line using automatic circuit reclosers (See Glossary 8), Testing and Commissioning

Installation of fault-break devices to detect and isolate sections to ensure supply to consumers using automatic circuit recloser and other associated equipment.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecting DTR’s and newly strung distribution lines using reclosers, switches/other accessories. (Location: Pole line)</td>
<td>Improper sag and distance from nearby structures causing breakage of lines and falling on people etc. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of shielded Ariel bunched conductor (ABC) to avoid short circuits and shocks to nearby residents.</td>
<td>Installation of reclosers/switches group the network into sections thereby reducing the number of customers disconnected due to permanent faults.</td>
</tr>
</tbody>
</table>

- a. Tapping of 0.4 kV line
- b. Connection of lines
- c. 11 kV lines emanating from 33/11 kV substation
Stages of Power Substation project design, Construction and Related Environmental Impacts and Mitigation

32. This section discusses various project design aspects and lists various stages of construction process along with the environmental impacts, type, impact and impact mitigation measures for power transmission and distribution substation projects.

**Different types of Power Substations**

- Transmission Substations – Voltages above 33 kV ie. 66 kV, 110 kV, 132 kV, 220 kV, 400 kV, 765 kV, 800 HVDC. There are two types - step-up transmission substation (See Glossary 114) and step-down transmission substation. (See Glossary 115).
- Distribution Substations – 33/11 kV, 33/22 kV, 33/0.4 kV, 22/11 kV
- Distribution Transformers – 22/0.4 kV, 15/0.4 kV 11/0.4 kV etc.

33. The above differentiation is made on the basis of the voltages of transmission/distribution lines (described in Section III) that feed to these substations and the type of end-load on each substation.

**A. Transmission/Distribution Substations**

34. Figure 5 provides a schematic for the power flow from the incoming subtransmission lines to outgoing distribution lines.

**Design Criteria**

35. At the planning stage itself, land availability is one of the main factors that govern the establishment of a substation project. This involves a contiguous piece of land that can infringe upon scarce populated/forest/cultivated land.

36. While identifying the power substation as part of the system for a generation project or as a part of distribution grid, preliminary site selection is done by the utility based on the shortest length of the incoming (incomer) and outgoing lines which are normally surveyed/marked on the 1:50,000 maps/topographical maps of the area with details about proximity to sensitive receptors in the area.

37. For selection of appropriate site for substation, the following design criteria are usually taken into consideration by project proponents:

(i) Site selection should consider seismicity and geography of the local area; the area should not be prone to landslide or located in unstable marshy or flood prone areas.
(ii) Construction activities do not adversely affect the population living near the proposed substations and does not create any threat to the survival of any community with special reference to tribal community etc.

(iii) The location of substation does not affect any monument of cultural or historical importance.

(iv) No resettlement of households by the substation site, no loss of livelihoods, siting of transformers away from schools, hospitals and other sensitive receptors, with due consultation with the community and local government units concerned.

(v) Transformers and other equipment specifications compliant with government rules/regulations & International Electro-technical Commission (IEC) standards shall be followed.

(vi) Construction techniques and machinery selection to be made with a view to minimize ground disturbance.

(vii) While planning for substations, drainage plan shall be prepared to avoid seepage/leakages and pollution of water sources and natural springs etc.

(viii) Substation location/design to ensure that noise will not be a nuisance to neighboring properties. Provision of noise barriers near substation sites to be made. Security fences will be erected around substations. Warning signs to be displayed.

(ix) Though the standard limits for electromagnetic interference are not prescribed, substation design will incorporate best suited technology and technique to minimize the electromagnetic interference within floor area.
(x) Utility shall adopt good practices and shall always strive for a high standard of housekeeping for its substations and ancillary facilities.

(xi) Utility shall incorporate the best technical practices to deal with environmental issues in its working.

(xii) Design of substations to include modern fire control systems/firewalls. Oil storage systems, provision of fire-fighting equipment would be located close to transformers, switchgears etc.

(xiii) For distribution substations, the above items remain the same however, the intensity of impacts get limited due to small size and lower voltages.

Construction Practice, their Environmental Impacts, Mitigation and Work Process

Types of Transmission substations

38. There are two types of electrical substation design that are used depending on the availability of land and its location—Air Insulated Switchgear (AIS) (See Glossary 2) substation design where all equipment is erected outdoors where the land is available; while the Gas Insulated Switchgear (GIS) (See Glossary 47) substation where all equipment besides transformer are erected both indoors and outdoors as shown in Table 4. The GIS technology is used where the land is scarce such as highly populated urban areas, high hilly terrains or security reasons.

Table 4: Type of Power Substations

<table>
<thead>
<tr>
<th>Table 4: Type of Power Substations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. GIS based substation equipment Indoorrom 33/11 kV substation</strong></td>
</tr>
</tbody>
</table>
b. GIS substation control room layout

c. AIS based substation switchyard equipment
39. The AIS substation requires all its components to be situated in the switchyard and air serves as the insulating dielectric medium (See Glossary 32) between different switchgear. Whereas the GIS substations are normally very compact and all equipment are enclosed in Sulphur Hexafluoride (SF6) (See Glossary 117) envelope, a nontoxic greenhouse gas (GHG) used as a dielectric in circuit breakers, switchgear, and other electrical equipment. GIS station uses very small size of land and building unlike the AIS. The equipment is designed to ensure prevention of even 0.5% leakage of the gas into the environment.

40. The Flow Chart in Figure 6 displays activities as they progress while constructing a transmission substation. On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, and Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1-17 (as shown by arrows). Some “Tasks” are grouped together in a particular “Step” in the order of their occurrence in a project cycle. Their placement (i.e. 1&3, 2&4) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 5-17. These “Tasks” are usually performed by the Engineering Procurement and Construction (EPC) contractor.

41. Table 5 provides information about each of the step involved in transmission line design, construction, testing and commissioning, the environment impacts and the proposed mitigation, and work process involved. In Table 5, layout of the each box is represented as follows:

- The colored box on top left of the Table represents the “Steps” matching the color of boxes in the Figure 6.
- “Tasks” lists work undertaken to accomplish the “Steps” shown in Figure 6. This followed by explanation of the task conducted.
- “Activity causing Impact and Location” lists the activity undertaken to accomplish each “Task” that impacts the environment and also gives the location of the environmental impact in brackets.
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- “Work process” provides a write up on the work done by EPC contractor for each “Task” and the human aspect involved during task completion.
- The right side of the Table 5 contains pictures from actual working sites that are mapped to each relevant “Activity”.

Stages of Power Substation project design, Construction and Related Environmental Impacts and Mitigation
Figure 6: Process Flow Chart for Construction of Transmission Substations

CONSTRUCTION OF POWER TRANSMISSION SUBSTATIONS

PRECONSTRUCTION

1. Surveys, Alternate analysis
2. Development of Environmental baseline
3. Substation layout
4. Sizing of equipment, type and capacity

FACILITIES SETUP

5. Temporary Worker Camps
6. Unloading, site storage and workshop

CONSTRUCTION

7. Digging Pits, bending steel wires, reinforced cement concrete (RCC)
8. Constructing foundation, Control Room building, pathways, cable trays
9. Switchyard earthing, civil works for foundations of equipment, switchyard structures, earthing of structures

ERECTION

10. Unloading and erecting power transformer
11. Erection of substation bus bars bus coupler, all bus items
12. Erecting transformer bay, line bays, incoming and outgoing lines, terminal gantry
13. Transformer Oil filling
14. Control Room Accessories and switchyard

COMMISSIONING

15. Charging Power transformer, Auxiliary power supply
16. Communication, Power Line Carrier Communication
17. Connecting terminating lines into substation equipment, Restoration of soil, slope stabilization, green belt development, etc., Testing and Commissioning
Table 5: Transmission/Distribution Substation—Stepwise Project Activities, Construction Impacts, Mitigation and Work Process Involved

<table>
<thead>
<tr>
<th>PRECONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Survey, Alternate analysis</strong></td>
</tr>
<tr>
<td>Reconnaissance Survey: Information on field data required for substation design, distance from community resources – worship place, village common grounds, community center’s schools, hospitals etc. Location of substation as compared to the direction of incomers and outgoing lines is an important factor in determining the site.</td>
</tr>
<tr>
<td>Alternative analysis survey: All alternative locations for the substations are proposed and collection of features observed and facilities marked on topographical map (1:50,000). See Picture a. GPS coordinates are noted for each location finalized for surveys (See Picture b.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumeration of trees for cutting, identification of locations for digging of soil for foundations for equipment, buildings etc., stacking area for construction material etc. (Location: Substation land)</td>
<td>Potential impact on physical resources - Topography, possible loss of biodiversity in the area, interference with common property resources, public utilities such as roads, water, sewage facilities etc. (Type: Planning stage)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid biodiversity areas such as location near water body etc. Consider better choice of location to avoid issues regarding common resources with community and public utilities.</td>
<td>This activity takes the first initial 3-4 months to ascertain the alternative location, the alignment of power lines. Local public resistance to give free tower land may cause delays in preparing alternate analysis case.</td>
</tr>
</tbody>
</table>

a. Alternative locations for substations  
b. GPS locations
## 2. Development of Environmental Baseline

Air, water, noise, soil investigation is the important aspect of the substation land in any area – hilly, plain level area, or sandy areas. (See Picture a. for noise sampling and Picture b. for air and dust sampling). General characteristics of the soil formation to be included in the plan, giving details of weather, clay, gravel, rock etc. that exist in the area as this information has a direct influence on the type of foundation types.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection of soil samples by using digging machines as well as collection of water from wells/water sources. (Location: Substation Land)</td>
<td>Minor impact of collection of soil samples using digging machines on topography or pollution of water source during sample collection. Marshy areas, low-lying areas, riverbeds, earth slip zones that would involve risk to stability of the foundations. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of baseline with no project situation a must for monitoring impact of project construction activities. Marshy areas are avoided. Care taken to ensure proper profiling of the ground rock formation and ground water.</td>
<td>Soil samples taken manually by digging machines and sink new tube well(s) in the planned premises for the substation.</td>
</tr>
</tbody>
</table>
### PRECONSTRUCTION

#### 3. Substation Layout

Electrical layout of the site is finalized. (See Picture a.) Facilities layout, selection of benches for substation (various levels in hilly areas), Cutting and filling for levelling land (See Picture c.). Development of drainage, road and other facilities (See Picture b.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of benches by cutting and filling inside the substation sites to ensure proper placement of all equipment. - See Picture d.</td>
<td>Planned cutting and filling will lead to soil erosion, runoff of soil, potential water logging, suitable places to dispose excess soil, cutting of trees on the site. (Type: Planning)</td>
</tr>
<tr>
<td>Benching allows voltage level separation by physically colocating similar equipment in one bench. (See Picture d.) (Location: Substation site)</td>
<td></td>
</tr>
</tbody>
</table>

#### Impact Mitigation

- Water logged/steep sloped/degraded sites must be avoided while selecting the location of substation.
- The layout of the site must be such that cutting of trees, soil must be minimized.
- Extreme slopes need to stabilized for avoiding soil runoff (See Picture e.)

#### Work process

Preparation of site level contour mapping, coordinates, enumerating number of trees to be cut, plotting location of building, position of various equipment, control rooms, access roads etc. on to the profile sheets.

---

![a. Electrical drawing for substation](image1)

![b. Substation layout (blue gives drainage plan; rectangles give the benching placement locations of control room, transformers, other equipment, roads etc.](image2)
c. Cut and fill of soil for substation land. Source: HPPTCL documents (blue is current hill profile. Three benches are designed for placement of equipment, transformer, road etc.

d. Benching inside substation land
e. Proposed sloping substation land
4. Sizing of Equipment, Type and Capacity

Sizing of all substation equipment - The numbers are required in substation according to no. of load centers to be connected and the corresponding incoming power from power generation sources (either type of generation – renewable and nonrenewable sources).

Substation has several equipment: Circuit Breakers (vacuum/oil) (CB) (See Glossary 19), SF6 Circuit Breaker (See Glossary 100), Isolators with and without earth Switch (See Glossary 61), Current Transformers (See Glossary 30) (CT), Capacitor Voltage Transformers (CVT)/Voltage Transformers (VT) (See Glossary 15), Surge Arrestors (See Glossary 118), Bus Post Insulators (See Glossary 13) and Bus bars, Potential Transformers (PT) (See Glossary 81), Lightning Arrestors (LA) (See Glossary 63) etc. that are included in design (See pictures a.-d.).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of equipment installations/foundations planned as per electrical layout plan (shown in Picture a of Task 3 above.) (Location: Substation land)</td>
<td>Potential digging for foundations and surface runoff of soils and any leaching of oils to ground water. (Type: Planning)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan for proper location analysis to ensure appropriate distances, installations of equipment, proper access roads etc.</td>
<td>The equipment will be outdoor for AIS substation and indoor for GIS substation. Such equipment are normally handled using mechanized boom cranes.</td>
</tr>
</tbody>
</table>

a. Isolators for incoming (Incomer) lines
b. Other equipment – AIS equipment

c. Line isolators

d. GIS based substation equipment Indoor
### FACILITIES SET UP

#### 5. Temporary Worker Camps

The worker camps are temporary in nature and will be used until facilities are fully constructed. These camps are normally made at the substation site and the strength of man-power is between 10-20 workers for a maximum of 6-12 months until construction is complete.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scatter of kitchen waste, toilet waste, wastewater, scrap, unusable/nonrecyclable waste in camps. Poaching of animal life, fishing, harvesting of wood by workers. (Location: Worker Camp)</td>
<td>Oils, untreated wastewater, sewage etc. flowing into water body, river, drainage areas from the camps causing impact to surface water, ground water, any aquatic life downstream in the area. The downstream water in river can be polluted making it unfit for bathing or potable water. The camps can also adversely impact on ecological resources through poaching of wildlife and using wood from trees as firewood in the area (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract provisions must specify minimum setback requirements for construction camps from water bodies, reserved areas etc. EPC contractor to provide liquefied petroleum gas cylinders for cooking, safe drinking water, washing and toilet facilities and sanitary soak-pits (See Picture a.), medical facilities (See Picture b.) at the construction site for the workers.</td>
<td>EPC contractor establishes a camp that has proper facilities – camp, drinking water, sanitation, electricity, toilets, medical facility before the start of construction at substation.</td>
</tr>
</tbody>
</table>

**Picture a.** Proper toilet facilities  
**Picture b.** Medical Facility and display of Personal Protective Equipment (PPE)
### FACILITIES SET UP

#### 6. Unloading of material at site, storage and workshop

Substation sites are accessible by roads to mechanized equipment for unloading, while some are manually unloaded using chain and pulleys blocks.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levelling of storage place and cutting of trees to establish workshop, stores (See Picture a. and b.) and designated maintenance areas (See Picture c.). Stores have storage of oils, and chemicals; the workshop for steel cutting welding etc. Toilets for workers will be constructed. Transportation of equipment to sites using heavy cranes to unload equipment. (Location: Stores, machine shops)</td>
<td>Impact on terrestrial ecology – tree cutting, disposal of scrap, unusable/nonrecyclable waste. Impact on air quality/noise levels due vehicle emissions and water quality - toilet waste, oils, sewage, slurry from workshops flow into the ground or into surface water polluting the land and water body affecting aquatic life. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of approved locations for material storage yards and workshops away from the environmental sensitive areas. The vehicles used for unloading, transportation of equipment to site must comply with national pollution control standards. Drainage into water bodies to be avoided. Soak-pits for waste to be provided for toilets by the contractor</td>
<td>Creating storage facility, transportation, unloading, storage and usage normally would take between 6-8 months for any substation project.</td>
</tr>
</tbody>
</table>

![](image)

*a. Cable storage for underground wiring*
b. Storage of Equipment

c. Designated Maintenance Area
7. **Digging Pits, Bending steel wires, reinforced cement concrete (RCC)**

Bending steel rods, tying with steel wires and mixing concrete for the foundation is done manually. This is followed by pouring concrete prepared using a manual mixing machine. This steel-concrete structure is known as Reinforced Cement Concrete (RCC).

The concrete is casted manually into the foundations and footing prepared manually using ply-boards and/or wood casts made as per design. (See Picture a.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Activity causing Impact and Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface run-off of prestacked soil, oil leakages from engine and vehicles.</td>
<td>Ground and surface water quality, aquatic ecology may be affected due to surface soil run-off, dripping of oils from engines of digging machines.</td>
</tr>
<tr>
<td>Steep contour, improper soil type encountered. (Location: Substation land)</td>
<td>Steep contour, improper soil type encountered making the foundations very huge and contour specific requiring revetment (See Picture b). (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Restore the loose soil from foundations through ramming. Dispose of excess soil spread out in areas that do not interfere with local drainage pattern.

**Work process**

- Foundation construction takes between 6-12 months depending upon the size of substation. Any major RCC foundation/structure would need about 1-2 weeks for construction.

---

a. Steel and concrete foundations
b. Concrete walls to stabilise the land area which is in various levels.
### CONSTRUCTION

**8. Constructing foundations, Control Room (CR) building, pathways, cable trays**

The foundations casted manually using prefabricated ply boards and/or wood casts made as per design and concrete is poured manually. Control rooms (CR) (See Glossary 28) include control wires (See Glossary 29), housing cable trays, bays for panels, battery room etc. Other structures include transformer foundation, cable trays (See Glossary 14), plinths (See Glossary 78) for auxiliary transformer (See Glossary 9) etc. Erection of Earth-mat (See Glossary 40) inside the entire substation boundary.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging and concrete casting of foundations for structures, transformers (See Pictures a.&amp; b.), pillars/columns for buildings, trenches, cable trays (See Picture c.), road, drainage etc. (Location: Substation Control Room, and switch yard area)</td>
<td>Solid waste generation at the substation site will include metal scraps, wooden packing material etc. Excess soil from foundations/ muck will be laid out in areas that may interfere with drainage of the area. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Concrete waste, wooden waste and metal scrap will be collected and disposed to offsite in compliance with applicable regulations and rules.

Contractor to manage waste generated from the construction sites without contamination to natural environment and it will reduce risk to public who stay close to sites. Ensure proper drainage system is constructed.

**Work process**

Civil Construction works normally take up to 3-12 months depending on size of the substation. The construction workers may live at the site or may be local residents of the area.

---

*a. Construction of Transformer bay*
TRANSMISSION SUBSTATION

b. Manual construction of room

c. Cable Trays within substation
### 9. Switchyard earthing, Civil work for foundations of equipment, Switchyard structures, Earthing of structures

Installation of switchyard lighting, communication and firefighting system. The foundations for structures (See Picture a. & b.) and equipment are also casted manually using prefabricated ply boards and/or wood casts made as per design and concrete is poured manually. Earthing of each structure is done within the yard.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging and concrete casting of foundations for structures, earthing of equipment (Location: Substation Control Room, and switch yard area)</td>
<td>Solid waste generation at the substation site will include metal scraps, wooden packing material etc. Wastewater may also be generated at site. Excess soil from digging of structure foundations if laid out in areas may interfere with drainage of the area. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Concrete waste, wooden waste and metal scrap will be collected and disposed to offsite in compliance with applicable regulations and rules.

Contractor to ensure no waste/wastewater is collected at site that will contaminate the natural environment. Ensure proper drainage system is constructed.

**Work process**

The foundations require digging and erection of foundations for structures in the outdoor switch yard.

Pipe earthing (See Glossary 77) (as shown in Picture c.) is usually used in all substations to ensure double earthing (See Glossary 36) for each equipment and structures.

---

![Switchyard structures](image1)

**a. Switchyard structures**

![Pipe earthing in switch yard](image2)

**c. Pipe earthing in switch yard**

![Switchyard structures](image3)

**b. Switchyard structures**
10. Unloading and erecting Power Transformer (See Glossary 84)

Power transformer is usually brought to the site using specialized flatbed trailer and high capacity truck to remote areas in the hilly terrains as well as the level areas.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation of transformer to the site on flatbed trailer (See Picture a.), unloading and erection of the power transformer on the Transformer bay (See Picture a. in Task 8 above) (Location: Road access).</td>
<td>Improper road access and road bridges that can withstand the weight of the transformer to the site causing delay in transportation and unloading. (Type: Temporary).</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure bridges are tested for weight capacity and road widened enough in hilly areas so that the transformer could reach the site.</td>
<td>Unloading of the transfer is usually done manually using sleeper and jacks because of unavailability of high capacity cranes to unload them. (See Picture b.)</td>
</tr>
</tbody>
</table>

Transportation of transformer has many issues: It is wide bodied and its movement on the road has be regulated, load capacity of bridges determined and some of them need to be supported by installing iron girders, plates depending on the span. In a freak case, the transformer may have to be taken off the truck trailer mid-way of transportation and stored temporarily until road/bridge which is broken/unsafe due to avalanches, landslides is repaired or the weather condition such as heavy monsoon, snow, blizzards etc. clears out.

---

*a. Transportation of power transformer*
b. Unloading of transformer using wooden sleeper jack system (manually)
11. Erection of substation bus bars, Bus Coupler all Bus items

The substation bus bar structure along with all CTs, PTs, Isolators, surge arrestors (See Picture a.) are erected manually/using chain pulleys. As per transmission towers, manual pulleys are used to lift the towers parts and fittings to the lattice type horizontal/vertical beam structure (See Picture b.) as well as to the bus bar connectivity (See Picture c.).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Protective Equipment (PPE’s) not used by workers. (Location: Substation site)</td>
<td>Unsafe erection of tower can result in injuries to the workers. Untrained workers can lead to more accidents and fatalities (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction manpower to use PPE at site at all times.</td>
<td>A typical horizontal/vertical beam structure erection takes at least a team of 5-8 workers for a month.</td>
</tr>
</tbody>
</table>

a. Erection of substation equipment
Stages of Power Substation project design, Construction and Related Environmental Impacts and Mitigation

TRANSMISSION SUBSTATION

b. Lattice box type beam structure

c. Bus Bar connections through line isolators
### ERECTION

#### 12. Erecting transformer bays, line bays, incoming and outgoing lines, terminal gantries

At any substation a minimum of one incoming transmission line (See Picture a.) and 2-3 outgoing transmission/distribution lines are erected (See Picture b.).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of terminating towers outside the substation (e.g. See single tower outside substation land in Picture a.) and similarly for outgoing lines (See lattice structures in Picture b.) and terminal gantry (See in Picture c.). Erection of adjoin Bus bars and transformer bays (See in Picture d.) (Location: Tower bases)</td>
<td>There will be numerous terminating gantries for incoming and outgoing lines near the switchyard boundary causing problems to local community and making their agricultural fields useless. In case of electric short/blowout, the adjoining bay transformer and equipment may get affected. (Type: Permanent)</td>
</tr>
<tr>
<td><strong>Impact Mitigation</strong></td>
<td><strong>Work process</strong></td>
</tr>
<tr>
<td>Proper survey of incoming and outgoing lines to a substation to ensure the adjoining agricultural land required is minimized and the owner is compensated. Erection of firewall (See Glossary 43) between two transformer bays to ensure protection from fire accidents.</td>
<td>The incoming and outgoing gantry cannot be deviated as it is normally aligned with the incomer and outgoing bays of the substation, hence the project proponent must ensure proper alignment as the time of design to avoid buildings etc. The area under the tower is not usually paid as compensation to the landowner. If there are two-three lines passing in his yard, his land becomes basically useless for mechanized agriculture.</td>
</tr>
</tbody>
</table>

---

a. Transformer bay and bus bar
b. Outgoing feeder bays and lines

c. Terminal gantry
d. Bus bar, transformer bays separated by firewall
13. Transformer Oil Filling, Storage of Battery water, battery bank etc.

Transformer oil and battery banks are essential part of storage facilities at substation control room and storage yard.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage of equipment, transformers, oils (See Picture a. and b.), fuels, battery water, other chemicals (See Picture c.) battery bank (see Picture d.) and at the project site for erection and filling. (Location: Transformer bay and battery room)</td>
<td>Contamination of land and or nearby water bodies by transformer oil, fuels, chemicals, battery water etc. can occur during erection and operation due to leakage or accident. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Proper drainage facilities will be constructed to avoid overflow or contamination of water bodies, streams, river etc. especially during the rainy season.
- Storage of bulk fuel should be on covered concrete pads away from the public and worker camp.
- Fuel storage areas and tanks must be clearly marked, protected and lighted.
- Maintain account of the usage of oil through oil monitoring mechanism, and have mitigation plan for any oil spillage.

- Substation transformers are normally located within secure and impervious areas with a storage capacity of 110% spare oil.

---

a. Improper Transformer oil storage  
b. Transformer oil filling and circulation machine  
c. Storage of chemicals and battery water  
d. Battery bank
14. Control Room, Accessories and switchyard

The control room buildings have both alternating (AC) (See Glossary 3) and direct current (DC) (See Glossary 3) distribution room facilities such as battery & charger room, Power line carrier communication (PLCC), substation automation (SA) system, Control Room (CR) Panels, Circuit Switchers (See Glossary 18), HV AC (heating, ventilation, and air conditioning) and normal & emergency AC & DC lighting, firefighting equipment etc.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity and internal wiring in Control room panels for bays (See Picture a.)</td>
<td>Short circuits, fire due to improper connectivity, overload or accident.</td>
</tr>
<tr>
<td>Storage of SF6 gas cylinders. (Location: Substation switchyard)</td>
<td>Inapt storage of SF6 gas cylinders, untracked leakage of SF6 from equipment. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Ensure correct connectivity of wiring, availability of firefighting equipment (See Picture b.) maintained in working order at construction site.

Ensure fully trained personnel handle interconnections, wiring, chemicals, tracking of leakage of SF6 from circuit breakers etc.

**Work process**

Internal wiring is done by highly specialist technicians well versed in the manufacturer equipment installation. Depending on the numbers, each module of the panel would take between 1-2 weeks to complete. (See Picture c.).

---

*a. Control Room Panels for Incomer and outgoing bay controls*
b. Firefighting equipment

c. Indoor CB, Bus coupler, Control room panels for indoor SF6 based switching cubicles.
15. Charging Power Transformer, Auxiliary power supply

Connection of control room equipment, power transformer (Pictures a. & b.), substation auxiliary transformer (Picture c.) and back-up power source (usually outdoor silent type diesel generator (DG) set) (See Glossary 33).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erection, filling of oil and charging the power transformer. (Location: Switchyard)</td>
<td>Leakage of transformer oil and sparking due to loose connections from standby power set. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Concrete lined pits are erected to contain the oil. Firefighting equipment maintained in working order at site.
- Transformer connectivity is done mostly trained personnel from the manufacturer who are adept at interconnections, wiring and testing.

---

a. Power transformers

b. Power transformers

c. Substation auxiliary transformer
16. Communication, Power Line Carrier Communication (PLCC)

PLCC equipment for speech transmission, line protections, and data channels provides communications over power transmission lines. SCADA (Supervisory control and data acquisition) (See Glossary 102) is a system operating with coded signals over communication channels.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity and internal wiring in Control room panels for bays (See Picture a.) Wave trap and other installations in the bus bar/bay are shown in Picture b. SCADA system is shown in Picture c. (Location: Control Room, Switch yard)</td>
<td>Remote operation of substation and line jeopardized due to faulty installation. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper safety protocols implemented while installation of communication equipment</td>
<td>PLCC uses time–tested technology of communication via modulation of voice frequency over the power cable. SCADA is used to provide control system for remote operation.</td>
</tr>
</tbody>
</table>

a. SCADA panels at substation
b. PLCC equipment - Wave trap

c. SCADA System
### COMMISSIONING

**17. Connecting terminating lines into substation equipment Restoration of soil, slope stabilization, green belt development, Testing and Commissioning**

The connecting of incomer and outgoing lines is done manually using pulleys, ropes and winches to provide the correct distance within substation connections prescribed as per international IEC (International Electro-technical Commission) (See Glossary 56) standards.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecting jumpers between the suspension clamps on incomer lines to the bus bar, and drop down to power transformer via isolators, CT, PT, CB etc.</td>
<td>Improper connections, improper spacing and distance from nearby structures causing faults. Increase in soil runoff, soil erosion due to improper slopes, blockages in drains and slopes. terrestrial ecology, migratory birds (Type: Temporary).</td>
</tr>
<tr>
<td>Connecting of cable spacers and other accessories on the power cable. (Location: Substation)</td>
<td></td>
</tr>
</tbody>
</table>

#### Impact Mitigation

- Proper connectivity of jumpers and clamps to avoid short circuit faults.
- Ensure impact on human environment, health and safety norms are followed during erection and testing and commissioning.
- Restoration of soils, removal of blockages from drains, slope and gulley’s, cleaning of all construction material leftovers and proper green belt development.

#### Work process

- A system of ropes and pulleys is used to manually provide specified spacers, clamps, vibration dampers etc. on the power cable.
- Testing and commissioning takes 2-3 days and involves modular tests on each aspect of transformer operation, operation of each switchgear, and running of normal operations using auxiliary power supply.

---

![Termination of incoming lines into bus bar](image-url)
b. Clamps, CC rings (See Glossary 26), etc.
B. Distribution Transformers (below 33 kV)

42. Using 11 kV or 33 kV lines over longer distances increases the technical and commercial losses compared to 66 kV, or 132 kV lines. This factor limits the threshold usage of 33 kV or less voltage lines to shorter distances (say upto 30 kilometers) for distribution system. Therefore, as a normal practice, all distribution transformers are connected to lines which are charged at 33 kV lines or below to the consumer end applications.

43. Distribution Transformer (DTR) for generally connected to distribution feeders (33 kV, 11 kV and 0.4 kV lines) to supply power to consumers. The poles are three type normally – concrete, steel poles and steel rail. The erection sites are normally have motorable access (both in level areas or hilly regions) and located close to population centers. Mostly a small mechanized boom crane, otherwise it is manually unloaded and installed using chain and pulleys blocks.

Construction Practice, their Environmental Impacts, Mitigation and Work Process

44. The Flow Chart in Figure 7 displays activities as they progress while constructing a distribution transformer (DTR). On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, and Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1-7 (as shown by arrows), however some “Tasks” are grouped together in a particular “Steps” in the order of their occurrence in a project cycle. Their placement (i.e. 2&3) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 2-7. These “Tasks” are usually performed by the Engineering Procurement and Construction (EPC) contractor.

45. The following steps are usually performed by the EPC contractor:

(i) Surveys, Alternate Analysis
(ii) Temporary Worker Camp
(iii) Unloading of material at site
(iv) Digging Pits of Poles: Foundation pits, which are very small in this case are dug manually in both level and the hilly areas.
(v) Pole erection and concrete pouring in pole foundations: The poles are unloaded manually at the erection point. Foundation concrete mixture is usually made using a manual mixing machine and casted manually using ply-boards and/or wood casts.
(vi) Erecting Distribution Transformer (DTR): DTR is usually brought to the site in trucks and can be normally lifted using Morris cable pulley.
(vii) Connecting of terminating lines into DTR, Testing and Commissioning: The stringing of wires is done manually using pulleys, ropes and a manual winch to provide the correct sag prescribed for the wire and ambient conditions.

46. Table 6 shows three different types of distribution arrangements –

(i) Distribution switching substations where there is no transformers and a system of switches is used for isolating or sectionalizing the feeders;
(ii) A fenced DTR facility atop bi-pole or four pole structure; and
(iii) the ground 33/11 kV transformer to split the 11 kV feeder lines and also supply on-the-ground facility.

47. The impacts normally related to distribution transformers and the lines as described earlier in “Tasks” 7 and 9 of Table 3 in section III.
Figure 7: Process Flow Chart for Construction of Distribution Transformer (DTR)

CONSTRUCTION OF POWER DISTRIBUTION TRANSFORMERS (DTR) FOR FEEDERS

PRECONSTRUCTION
1. Surveys, Alternate analysis

FACILITIES SETUP
2. Temporary Worker Camps
3. Unloading of material at site

CONSTRUCTION
4. Digging Pits for Poles
5. Pole erection and concrete pouring in pole foundations

ERECTION
6. Erecting distribution transformer (DTR)

COMMISSIONING
7. Connecting of terminating lines into DTRs, Testing and Commissioning
Table 6: Distribution transformer construction activity

a. Distribution switching substation (gantry structure)
b. Distribution Transformer on concrete poles

c. 11 kV lines emanating from on-ground 33/11 kV transformer
48. This section discusses project design aspects and lists various stages of construction process along with the environmental impacts, type, impact and impact mitigation measures for run-of-river hydropower generation projects.

49. Hydropower generation projects that are funded by ADB are mostly Run-of-River (ROR) hydropower projects. These are mainly -

- Large/Medium hydropower projects (See Glossary 55)
- Small hydropower (See Glossary 55)
- Micro hydro projects (See Glossary 55)

50. The other two type of projects – Pump storage Projects and Dam projects (rarely funded by ADB) are not covered in the following sections.

51. Figure 8 provides a schematic for a typical run-of-river hydropower generation project.
Figure 8: Schematic diagram of the Hydropower generation system

RUN-OF-RIVER HYDROPOWER GENERATION SYSTEM

Hydropower Barrage → Reservoir for peaking load

Headrace Tunnel-Pressure Duct → Hydropower spillway

Turbine Generator Hall → Hydropower Tailrace

Switch Yard For Power Evacuation
A. Run-of-River (ROR) Hydropower Project

Design Criteria:

52. Run-of-river hydropower projects provide peaking loads due to storage potential and hence optimize generation, result in fossil fuel savings and minimize greenhouse gases. This also results in sources of revenue to change from traditional forest and other similar resource exploitation to an increased dependence on power from hydropower projects. The following factors are usually considered while selecting the project site for the hydropower project by project proponents:

- Forests are usually avoided. If not possible, proper mitigation to minimize damage to existing forest resources within regulatory requirements
- Avoidance of ecologically significant or environmentally sensitive areas, such as national parks, nature reserves, or wetlands.
- Minimization of potential environmental impacts (including land taken, and cultural or religious sites) associated with initial alignments and locations by selection of alternative sites.
- Minimization of involuntary resettlement. Consultation with community and adequate compensation of affected people as appropriate.
- Alignments usually selected to avoid riverbeds and unstable areas.
- Avoidance of monuments of cultural or historical importance.
- No threatening of indigenous peoples, including tribal communities.
- No direct impact on community based infrastructure such as playgrounds or schools, religious places, marriage halls etc.
- Access road alignments and dumping sites are generally sited away from towns, villages and whenever possible, to account for future population expansion.

Construction Practice, their Environmental Impacts, Mitigation and Work Process

53. The following studies are preceded before the commencement of construction work on the ROR hydropower project. Following is an illustrative list:

- Geological mapping.
- Aerial photo interpretation along the tunnel alignment.
- Field tests on rocks, point load index tests, laboratory tests.
- River discharge and levels, suspended load sampling.
- Flow for power generation - river discharge and level.
- Water profile along river upstream and downstream of tunnel outlet.
- Reservoir area capacity curves and flood studies.
- Environmental characteristics of the project area.
- Environmental impacts and Impact evaluation.
- Environmental management plan.
- Environmental monitoring program.
- Power studies.
54. During the hydropower project construction, excavations that are done manually as well as using mechanized equipment, whereas all other cutting of rock is done using blasting and cutting instead of using tunnel boring machines. The practice of not using tunnel-boring machines (TBM) may be limited due to its operating expense, or its transportation to remote locations or even its availability.

55. **Preconstruction - Geo-technical Exploration:** The following explorations are made using manual labor:

- Exploratory drifts
- Borehole/Test pit/trench excavation
- Geophysical Investigation at dam area

56. **Underground Project Activities:** To construct a diversion barrage it is necessary to divert the river from its natural bed to give access to the river bottom in a dewatered condition during the nonmonsoon period. Cofferdams are normally built above and below the diversion tunnel. All the following project components are constructed using mechanized equipment for concrete mixing and pouring, steel liners for adits (See Glossary 1), portals (See Glossary 80), shafts and tunnels, roof bolting (See Glossary 96), cutting and blasting.

- Diversion Tunnel
- Intake Tunnels
- Sedimentation Chamber (See Glossary 104)
- Silt flushing tunnel (See Glossary 105)
- Link Tunnels
- Headrace Tunnel
- Adits/drifts
- Main Access Tunnel (See Glossary 65)
- Surge Shaft/Surge Tank (See Glossary 119)
- Orifice (See Glossary 67)
- Pressure Tunnels (See Glossary 85)
- Power House (See Glossary 83)
- Transformer Hall
- Tailrace Tunnel (See Glossary 121)
- Outlet Structure for Tail water (See Glossary 122)

57. Following is a schematic diagram of the underground project components for the powerhouse for a typical ROR hydropower project.
58. Surface Project Activities

- Barrage and/or trench weir (in place of barrage in medium size projects)
- Other civil works (on-ground) in the project area includes:
  - Dumping areas.
  - Resettlement areas.
  - Development of portals for working, equipment.
  - Camps, offices, workshops etc.
  - Access roads, highway.
  - Temporary bridges.
  - Buildings.
  - Development of quarry for construction material.

59. Electro Mechanical Works: The hydropower project contains several electrical mechanical equipment such as the generator (See Glossary 48), the stator (See Glossary 113) and the turbines (See Glossary 127). Besides there, there are several mechanical equipment used in the hydropower projects such as gates of various types: diversion tunnel gates, barrage and sluice gates, barrage bay and sluice bay stop logs, trash racks (See Glossary 126) and trash cleaning machine, intake gates, sedimentation chamber gates, flushing conduit gates, emergency valves, main inlet valves, draft tube gates, outlet gates, and access doors.
60. The ROR hydropower projects usually generate electricity at 11/33 kV voltages and then step up to 132 kV or 220 kV in the switchyard substation using a step up transformer. The power evacuation lines emanate from the switchyard’s terminating gantry and then travel to a pooling substation where the power generation from other generators is pooled to interstate power evacuation lines after another step-up to 400 or 765 kV.

61. The Flow Chart in Figure 10 displays activities as they progress while constructing a hydropower generation project. On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, and Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1-17 (as shown by arrows). Some “Tasks” are grouped together in a particular “Step” in the order of their occurrence in a project cycle. Their placement (i.e. 1&3, 2&4) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 2-17. These “Tasks” are usually performed by the Engineering Procurement and Construction (EPC) contractor.

62. Table 7 provides information about each of the step involved in hydropower generation project design, construction, testing and commissioning, about the environment impacts and their proposed mitigation, and work process involved. In the Table, layout of the each box is represented as follows:

- The colored box on top left of the Table represents the “Steps” matching the color of boxes in the Figure 10.
- “Tasks” lists work undertaken to accomplish the “Steps” shown in Figure 10. This followed by explanation of the task conducted.
- “Activity causing Impact and Location” lists the activity undertaken to accomplish each “Task” that impacts the environment and also gives the location of the environmental impact in brackets.
- “Impact of activity and its type” describes the impact on environment of each activity and lists it type – temporary, permanent, planning etc. in brackets.
- “Mitigation Measure for the Impact” lists environmental mitigation measures taken to mitigate the impact.
- “Work process” provides a write up on the work done by EPC contractor for each “Task” and the human aspect involved during task completion.
- The right side of the Table contains pictures from actual working sites that are mapped to each relevant “Activity”.
Figure 10: Process Flow Chart for Construction of Hydropower project

CONSTRUCTION OF RUN-OF-RIVER HYDROPOWER GENERATION FACILITY

PRECONSTRUCTION

1. Geotechnical Exploration, Construction Planning, Forest Clearances, Approvals

FACILITIES SETUP

2. Quarry, raw materials, crushers logistics
3. Establishing worker camps, management
4. Machine shops, stores, portals for vehicles, etc.
5. Storage of oils, chemicals, cylinders, etc.

SURFACE CONSTRUCTION

6. Construction of access roads to all project sites
7. Construction of buildings at project site
8. River Diversion Works
9. Muck Dumping Areas

UNDERGROUND CONSTRUCTION

10. Intake tunnels and sedimentation chambers
11. Air intake—Underground Work Management
12. Water Conductor Underground/surface component
13. Pressure shafts, surge shafts, balancing reservoir, transformer gallery/Powerhouse cavity, Main Access Tunnel—Underground

ERECTION

14. Power House, Power Evacuation
15. Erection and Operation of Gates

COMMISSIONING

16. Stabilization and containment of soil erosion, Reservoir Management, and Floods Management in catchment
17. Forest, Fisheries, Wildlife, Resettlement issues

Stages of Run-of-River Hydropower Project Design, Construction and Related Environmental Impacts and Mitigation
**Table 7: Hydropower Project: Stepwise Project Activities, Construction Impacts, Mitigation and Work Process Involved**

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging of Adits/Drift near barrage axis, powerhouse (See Picture a.)</td>
<td>Improper drilling/tunneling along barrage axis, powerhouse, bed rock etc. may trigger landslide and cause pollution of surface and ground water quality</td>
<td>Conduct rock analysis (See Picture b.), dam safety studies, forest case preparation, approval from Environment authorities, River management, electricity authorities, conduct investigations such as drifts, drilling in riverbed.</td>
<td>This activity takes 1-2 years to develop studies, get approval from concerned authorities, develop detailed design reports, conduct EIAs etc.</td>
</tr>
<tr>
<td>Drilling of bedrock at the barrage (See Glossary 11) to test its strength. (See Picture c.) (Location: Project area)</td>
<td>Disturbance to fragile rock strata leading to landslides, local community protesting establishment of hydropower project due to increased river flood in future, erosion etc. (See Pictures d.-f. for potential adverse impacts). Impact any wildlife in the area. (Type: Temporary)</td>
<td>Review alternative axes/locations that would have adequate rock structure to meet dam safety requirements.</td>
<td>Revenue officers to prepare land details and list of Project affected persons (PAPs). PAPs are scared of losing scarce land without getting commercial rates.</td>
</tr>
</tbody>
</table>

**PRECONSTRUCTION**

1. **Geotechnical Exploration, Construction Planning, Forest clearances, Approvals**

   Exploratory drifts (See Glossary 38) (small tunnel to collect samples of rocks). Bore holes to check the strength of the rock near the dam (See Glossary 37) axis, power house. Geophysical investigation at dam area, Seismic refraction studies, study of different alternatives.

<table>
<thead>
<tr>
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<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging of Adits/Drift near barrage axis, powerhouse (See Picture a.)</td>
<td>Improper drilling/tunneling along barrage axis, powerhouse, bed rock etc. may trigger landslide and cause pollution of surface and ground water quality</td>
<td>Conduct rock analysis (See Picture b.), dam safety studies, forest case preparation, approval from Environment authorities, River management, electricity authorities, conduct investigations such as drifts, drilling in riverbed.</td>
<td>This activity takes 1-2 years to develop studies, get approval from concerned authorities, develop detailed design reports, conduct EIAs etc.</td>
</tr>
<tr>
<td>Drilling of bedrock at the barrage (See Glossary 11) to test its strength. (See Picture c.) (Location: Project area)</td>
<td>Disturbance to fragile rock strata leading to landslides, local community protesting establishment of hydropower project due to increased river flood in future, erosion etc. (See Pictures d.-f. for potential adverse impacts). Impact any wildlife in the area. (Type: Temporary)</td>
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</tr>
</tbody>
</table>
d. Small rivulets merging into river

e. Sheared rocky overhang
f. Existing village atop cliff
### FACILITIES SET UP

#### 2. Quarry, Raw Material, Logistics Planning,

Development of in-house quarry (See Glossary 90), crushing, concreting by the project developer to ensure maximum utilization of rocky material generated from digging and tunneling works.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</thead>
<tbody>
<tr>
<td>Clearing of land for development portals (See Glossary 80)</td>
<td>Cutting of trees, development of portals, impact on biodiversity, aquatic life due to quarrying, powerhouse, mucking, construction material etc. may encroach community land. (Type: Permanent)</td>
</tr>
<tr>
<td>Quarry development for raw material.</td>
<td>Quarrying will impact on terrestrial ecology, aquatic ecology (See Picture a.) (Type: Permanent)</td>
</tr>
<tr>
<td>Establishment of crushers, concrete mixtures at site.</td>
<td>Working of crushers/concrete making plants at project site will impact on air quality, noise, soils and geology (See Picture b.-d.) (Type: Temporary)</td>
</tr>
<tr>
<td>Access roads to facilities (Location: Hydropower project land and its vicinity)</td>
<td></td>
</tr>
</tbody>
</table>

#### Impact Mitigation

- Consider better choice of location to avoid encroachment of common property resources etc.
- Ensure crushers and concrete plants have proper pollution control measures.
- Ensure quarrying causes minimal damage to ecosystems- both riverine and land based.
- Perform compensatory afforestation in the area.

#### Work process

- This activity initially takes 3–4 months to ascertain the alternative location, the location of portals, the preparation of forest case, nonavailability of land ownership details causing delays in preparing the Forest approval case.

---

*a. Riverbed quarry material in submergence area*
b. Crusher at Site

c. Small Crusher In operation at site

d. Concrete Batch Mixing Plant
### 3. Establishing worker camps, management

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Establish worker camps with all amenities for workforce at various project sites. (See Picture a.)</td>
<td>Generation of toilet waste, scrap, unusable/nonrecyclable waste, sewage, kitchen waste from worker camps.</td>
</tr>
<tr>
<td>Establish other facilities such as medical, drinking water, camp location, transportation etc. at the project site. (See Pictures b. c. &amp; d.) (Location: Worker Camp)</td>
<td>Pollution of water bodies, river/stream by wastewater from camps and its impact to aquatic life in the area downstream. Poaching of animal life, harvesting of wood by workers. (Type: Temporary)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

- Contract provisions necessary to provide adequate drinking, washing and toilet facilities, and proper camps, safe disposal of kitchen waste, sanitation waste using sanitary soak-pits (See Glossary 107) (See Pictures e. & f.).
- To reduce waste in hilly areas, composting could be done on small scale (e.g. See Pictures g. & h.).
- Contract provisions specifying minimum setback requirements for construction camps from water bodies, reserved areas etc.

#### Work process

Depending on the number of working sites and number of staff to be accommodated, it takes 2-3 months to completely setup a fully functional camp for workers, and officers.

---

**a. Worker Camp, Quarry material storage**
b. Using ropeways to cross streams in high hills

c. Clearing of trees and borewell for camps

d. Worker/transportation/contractor issues

e. Toilet Facilities at site
Stages of Run-of-River Hydropower Project Design, Construction and Related Environmental Impacts and Mitigation

f. Soak pits for offices, camp

g. Composting

h. Composting of kitchen waste
**FACILITIES SET UP**

### 4. Machine Shops, stores, portals for vehicles etc.

For most construction related machinery, mechanized cranes are used for unloading/loading parts and equipment. Work portals are benches of land prepared through cutting and filling are used for work areas. These work portals are developed using reclaimed areas from muck dumping, where workshops, mechanized equipment could be parked or repaired.

<table>
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<tr>
<th>Activity causing Impact and Location</th>
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</thead>
<tbody>
<tr>
<td>Levelling of storage place. Transportation of equipment and using heavy cranes to unload equipment. Vehicles parked in portals (Picture a.) (Equipment storage at project site). Setting up equipment storage area, workshops for steel, concrete, forming works (See Pictures b. to g.) (Location: Stores, machine shops)</td>
<td>Cutting and filling of soil, erosion, soil runoff and its impact on surface water quality. impact on air quality/noise levels due machines. Generation of solid waste disposal, liquid waste disposal such as sewage/toilet waste, scrap, unusable/nonrecyclable waste, oils, slurry from workshops etc. Adverse impacts on fauna in the area. (Type: Temporary)</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Selection of approved locations for material storage yards and Worker camps away from the environmental sensitive areas. The vehicles used for unloading, transportation of equipment to site must comply with national pollution control standards. Development of access roads away from crowded community areas thereby not causing accidents on the road and project sites Location of construction equipment, storage area, worker camps to be selected to ensure no impact to fauna in the area.</td>
<td>Creating storage facility, unloading normally takes between 6 months to three years. Portals used as parking equipment/trucks that makes frequent trips for construction material, concrete, equipment and materials delivery etc.</td>
</tr>
</tbody>
</table>

![Specialized equipment parked in work portal](image1)

![Iron bar cutting machine](image2)
c. Electrical fittings
d. Workshop scrap collection
e. Stores
f. Shaping and bending workshop
g. Machine lathe for making roof bolts
### FACILITIES SET UP

#### 5. Storage of Oils, Chemical, Cylinders etc.

Hydraulic oil, machine oils, transformer oil and battery banks are essential part of storage facilities at project facility.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</thead>
<tbody>
<tr>
<td>Storage of lubricants, used oil, grease, cylinders etc. Generation of recyclable and nonrecyclable solid waste at project site. (see Picture a.) (Location: Workshop)</td>
<td>Impact on air surface/ground water quality, impact on soils and geology, aquatic ecology due oil leaching, burning, unsafe disposal and storage at site. (See Pictures b.-f.) (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Proper storage facilities constructed to avoid overflow or contamination with natural flow paths especially during the rainy season.

Storage of bulk fuel should be on covered concrete pads away from the public and worker camp. Fuel storage areas and tanks must be clearly marked, protected and lighted.

All oils to be normally located within secure and impervious areas with a storage capacity of 110% spare oil and have mitigation plan for any oil spillage at site.

**Work process**

Workshops and stores are critical areas where most pollution occurs due to unsafe maintenance practices. Project Proponent normally has accounting system for usage of oil and procedures for oil monitoring mechanism.

Proper health and safety procedures are listed in the contract provisions for an EPC contractor.

---

_a. Oil dispensing system_

_b. Oil wastes at site_
Stages of Run-of-River Hydropower Project Design, Construction and Related Environmental Impacts and Mitigation

c. Waste oil
d. Cylinder storage
e. Waste generation
f. Burning of waste
### SURFACE CONSTRUCTION

#### 6. Construction of Access Roads to all project sites

Construction of project roads to all subcomponents – adits, tunnels, powerhouse, project colony, dumping areas etc.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</table>
| Roads to water conductor, diversion structure, adits, main access tunnel, powerhouse, turbine room, workshops, camps, stores, muck dumping areas constructed to ensure complete access to construction vehicles.  
See Picture a.)  
(Location: Complete Project site)                                                                                                                                                                                               | Emissions from construction vehicles, equipment and diesel generation (DG) sets, and emissions from transportation traffic (See Pictures b. & c.). Exposure to air and noise pollution from work areas. Spillage of soil runoff into river streams, water bodies and harm fish in the area.  
>Type: Temporary                                                                                                                                                                                                                     | Development of access roads away from crowded community areas thereby not causing accidents on the road and project sites.  
Ensure proper sprinkling of water and drainage is made along the road and proper roads and bridges are constructed. (See picture d. and e.)  
Ensure vehicles and equipment plying at the site have Pollution under Control certificates. (See Picture f.)                                                                                                          | Frequent truck trips are required during the construction period for removal of excavated material and delivery of select concrete and other equipment and materials.  
Normally, a schedule for watering of roads, removal or muck from underground tunnels to dumping areas is prepared by site manager.                                                                                      |

![a. Road to project site](image)  
![b. Concrete Mixer Machine](image)
c. Vehicular Pollution  

d. Road bridges  

e. Spraying of water of project roads  

f. Pollution under Control certification for vehicles
7. Construction of Buildings at project site

Construction of camps, office, residences at project site, drainage, road and other facilities.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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<tbody>
<tr>
<td>Construction of project offices, transit campsites, staff quarters, stores, kitchen etc. (Location: Project offices, camp sites)</td>
<td>Water logging, cutting of trees and filling of muck in areas to create office complex. Exposure to air and noise pollution from work areas. Generation of toilet waste, scrap, unusable/nonrecyclable waste. sewage, kitchen waste from worker camps. Pollution of water bodies, river/stream by wastewater from camps and its impact to aquatic life in the area downstream. Poaching of animal life, harvesting of wood by workers. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Contract provisions specifying minimum setback requirements for construction camps from water bodies, reserved areas etc. Housing to be situated away from project sites, but also situated away from forest areas, crowded community areas thereby not affecting an influx of outsiders into closed communities.

Contract provisions necessary to safe disposal of kitchen waste, sanitation waste using sanitary soak-pits etc.

**Work process**

Development of housing away from project sites to ensure health and safety of staff and the community. The construction of the facility takes 6-12 months depending on the type and number of building required.

---

*a. Construction of buildings near project sites*
b. Offices, transit camp, stores, etc.
### SURFACE CONSTRUCTION

#### 8. River Diversion Works

Several surface level aspects need to be constructed such as spillways (See Glossary 109), diversion tunnel, diversion barrage, power houses, tailrace, foundations, reservoir, cofferdams (See Glossary 21), intake tunnels, fish ladder (See Glossary 44) and sedimentation chambers, flushing ducts (See Glossary 45). Main access tunnel, adits and link tunnels, gates etc. The RCC foundations are casted using prefabricated designs and concrete is poured using customized machines. (See Pictures a.- i.)

<table>
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<tr>
<th>Activity causing Impact and Location</th>
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<tbody>
<tr>
<td>Cutting of trees, development of portals, quarrying, project components, construction material, concrete preparation, installations of structures for water flow diversion etc. (Location: Various project sites)</td>
<td>Hydrological impacts of diverting water flow resulting in altered river ecosystem, prevention of upstream fish movement, inundation area, reduced river flows between barrage and tailrace outlet. Decline in water quality along river, tunneling area, seasonal drains and natural sources.</td>
</tr>
<tr>
<td>ADverse impact to biodiversity, flora and fauna due to cutting of trees, quarrying operations in the area. (Type: Permanent)</td>
<td>Dust, vehicular exhaust, blasting, loss of agricultural and forest land, inundation of old roads, plying of heavy vehicles makes roads unusable. (Type: Temporary)</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>Concrete waste, wooden waste and metal scrap to be collected and disposed of offsite in compliance with applicable regulations and rules. Ensure proper drainage system is constructed to avoid surface runoff. Restoration of any water supply, natural water spring damaged even if not directly attributable to project activity due to blasting, tunneling. Ensure proper tree afforestation, biodiversity conservation programs including developing buffer zones/green belts are conducted around the project area.</td>
<td>To construct a diversion barrage it is necessary to divert the river from its natural bed to give access to the river bottom in a dewatered condition during the nonmonsoon period. This process can take up to 3-4 seasons of monsoons (i.e. effectively 3-4 years if monsoons come once a year). Surface construction project activities have a longer implementation period and help employment, development of better power, facilities, roads near the project area.</td>
</tr>
</tbody>
</table>

![a. Spill (See Glossary 108) at existing dam site, gates](image1)

![b. Diversion tunnels](image2)

---

**Energy Sector Group Handbook**
c. Barrage for run of river project
d. Powerhouse, tailrace
e. River diversion barrage
f. View from hilltop to river level near diversion tunnels and diversion barrage
g. Concrete Mixing and Injector Machine
h. Trench Weir (water diversion structure)

i. Barrage under construction
## SURFACE CONSTRUCTION

### 9. Muck Dumping Areas

Muck generated from excavation of any project component is required to be disposed in a planned manner so that it takes a least possible space and is not hazardous to the environment.

<table>
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<tr>
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<tbody>
<tr>
<td>Cutting of trees, mucking in open designated areas. (Location: Open designated areas)</td>
<td>The muck disposal sites cause increased sedimentation in the rivers (though insignificant compared to natural sedimentation) and totally spoils the visual aesthetics of the area. Adverse impact to biodiversity, flora and fauna due to cutting of trees, mucking operations in the area. (Type: Permanent) Dust, vehicular exhaust, loss of agricultural and forestland, dumping activity makes roads unusable. Shifting of distribution lines, water supplies, etc. if passing through identified mucking areas. (Type: Temporary)</td>
</tr>
</tbody>
</table>

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<tr>
<td>Muck is disposed in low-lying areas or depressions. Suitable retaining walls are constructed to develop terraces to support the muck on vertical slope and for optimum space utilization. Loose muck is compacted layer wise to avoid flowing into river and streams. These sites are rehabilitated as soon as the disposal sites are full. (See Pictures a.–c.).</td>
<td>Trees at dumping sites are cut before muck disposal, however, shrubs, grass or other types of undergrowth in the muck disposal at sites perish. Once disposal site is full, soil stabilization and tree/grass plantation is carried out for rehabilitation of the area.</td>
</tr>
</tbody>
</table>
b. Retaining walls for muck management

c. Dumping site with retaining wall
### UNDERGROUND CONSTRUCTION

**10. Intake tunnels and sedimentation chambers-underground/surface components**

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<tr>
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<tbody>
<tr>
<td>Cutting of trees, development of portals, quarrying, construction material etc.</td>
<td>Hydrological impacts of altered river ecosystem, prevention of upstream fish movement during construction period, inundation of construction area. Decline in water quality along river, seasonal drains and natural sources. Loss of agricultural and forest land. (Type: Permanent)</td>
</tr>
<tr>
<td>Constructing of adits, tunnels alongside river body (See Picture b.) (Location: Surface area near water intake)</td>
<td>Air pollution due to cutting, blasting, dust, vehicular exhausts and increase in noise levels. Shifting of distribution lines, water supplies, etc. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Restoration of any water supply, natural water spring damaged even if not directly attributable to project activity due to blasting, tunneling.
- Ensure proper drainage system is constructed inside underground structures. Contractor to handle and manage construction activities underground as well as over ground to ensure that there is no adverse impact to the natural environment and biodiversity of the area.

**Work process**

- To construct underground structures, it is necessary to divert the river from its natural bed to give access to the river bottom in a dewatered condition for the major period of construction of the project.

---

*a. Open Sedimentation tanks*
b. Underground balancing reservoir sedimentation tank, silt flushing tunnel, Main Access Tunnel, switchyard

c. High boom crane
11. Air Intake - Underground Work Management

Construction of all underground aspects of the project - headrace tunnel, tailrace, main access tunnel, adits, surge shaft, orifice, pressure shafts, powerhouse cavity, transformer hall requires blasting and clearing of muck from underground facilities. The air needs replenishment and cleaning to make the environment safe to work.

<table>
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<tr>
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<tbody>
<tr>
<td>Underground activities such as blasting, cutting, drilling, mucking, construction etc. (Location: Underground)</td>
<td>Dust emission from blasting, cutting, drilling, mucking and vehicular exhausts increase the air pollution underground thereby making the working conditions unsafe for workers. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Ensure proper circulation of clean air using proper equipment inside all underground components that need blasting, tunneling, digging and excavating. (See Pictures a., b., & d.)

Medical facilities, use of masks etc. (See Picture c.) are made available for workforce by EPC contractor and air quality monitoring is conducted regularly.

**Work process**

Contractor should handle and manage underground construction activities as per permitted air quality standards so that the workers working underground are not at risk.

Air quality monitoring is measured regularly after each blasting process.

---

**Images:**

- a. Air intake fan for underground areas
- b. Air circulation inside
- c. Air Pollution after underground blasting
- d. Air Circulation fan for underground tunnels
### UNDERGROUND CONSTRUCTION

#### 12. Water conductor-Underground and surface components

Water Intake to the underground tunnels is mainly through a sealed D shaped water conductor.

<table>
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<tbody>
<tr>
<td>Underground activities such as blasting, cutting, drilling, mucking, and construction of water conductor using reinforced cement concrete (RCC), pressure shafts etc. (Location: Both over-ground and underground tunnel sites)</td>
<td>Surface cutting, altered river ecosystem due to river water diversion, inundation area Blasting, tunneling, mucking, Generation of scrap-concrete, steel, loose soil, dust, vehicular exhaust (Type: Temporary)</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>Restoration of any water supply, natural water spring damaged even if not directly attributable to project activity due to blasting, tunneling.</td>
<td>Contractor should handle and manage underground construction activities without contamination to natural environment.</td>
</tr>
</tbody>
</table>

Ensure proper drainage system is constructed.

#### a. D shaped water conductor
b. Water channel from sedimentation chamber to water conductor

c. Water conductor from sedimentation tanks

d. Under-construction RCC structure of Picture c. on the left
### UNDERGROUND CONSTRUCTION

#### 13. Pressure shafts, surge shafts, balancing reservoir, transformer gallery/powerhouse cavity, Main Access Tunnel (MAT)- underground

Construction of headrace tunnel, adit, dewatering facility, surge shaft, riser, orifice, pressure shafts, penstock (See Glossary 71), civil works of power house, power house cavity, powerhouse cavity, transformer hall, tail race tunnel, outlet structure and installation of hydraulic gates and valves.

<table>
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<tbody>
<tr>
<td>Cutting, drilling, blasting rock underground and its removal to surface dumping sites. (See Picture a.)</td>
<td>Geological impacts of blasting underground, rupturing of any natural water aquifer, inundation of tunnels making the work area unsafe for workers underground. (Type: Permanent)</td>
</tr>
<tr>
<td>Erection of concrete linings on the sides of the tunnels, pressure shafts, orifice, power house and transformer hall, roof bolting to stabilize roof etc. (See Pictures b. – h.) (Location: Underground)</td>
<td>Dust from drilling, blasting, cutting, vehicular exhaust accumulation underground. (Type: Temporary)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

<table>
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<tbody>
<tr>
<td>Restoration of any natural water spring damaged even if not directly attributable to project activity due to blasting, tunneling activity of the project. Ensure proper drainage system with pumps to remove underground water.</td>
<td>EPC contractor normally has fixed schedules for blasting, removal of dust and the resumption of muck removal followed by further drilling.</td>
</tr>
<tr>
<td>Ensure proper air intake and outtake is maintained by EPC contractor at all project components.</td>
<td>Specialized equipment is used for roof bolting and concreting roof (See Picture c. and also Task 4 - Picture a.)</td>
</tr>
<tr>
<td>Ensure proper PPEs are supplied to workforce.</td>
<td></td>
</tr>
</tbody>
</table>

---

*Image a.* Manual drilling work for fixing explosives inside tunnel
b. Steel lining in MAT

c. Roof bolting and concrete roofing
d. Main Access Tunnel (MAT)-underground underground

e. Power house cavern
f. Riser in surge tank above the orifice

g. Transformer and powerhouse cavity

h. Vertical pressure shaft
### ERECTION

#### 14. Power house, Power Evacuation

All electrical equipment - generator, stator (See Glossary 113), rotor (See Glossary 97), scroll case (See Glossary 103), runner (See Glossary 99), draft tube (See Glossary 37), switchyard substation, terminating gantry, step-up transformer, power evacuation line and other equipment. Powerhouse generator, stator are usually underground along with the step up transformer. Surface switchyard evacuates power using transmission lines is situated near the power house.

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<tr>
<td>Cutting of trees, development of bench for substation (Picture a.), quarrying, powerhouse, mucking, construction material etc. for surface activity. Installation of transformer, control room for underground GIS substation inside the tunnel. (See Picture b.) (Location: Underground Transformer hall, control room and surface switchyard)</td>
<td>Contamination of underground tunnels and or nearby drainage system by transformer oil, fuels, chemicals, battery water etc. can occur during erection and operation due to leakage or accident. Surface drainage to ensure the loose oil does flow into the river from surface switchyard. (Type: Permanent) Loose connections can lead to underground fire and accidents. (Type: Temporary)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

Proper drainage facilities and concrete lined pits are erected to contain the oil for both underground and on surface to avoid overflow or contamination of river water. Maintain account of the usage of oil through oil monitoring mechanism, and have mitigation plan for any oil spillage. Firefighting equipment maintained in working order at site.

#### Work process

Substation transformers are normally located within secure and impervious areas with a storage capacity of 110% spare oil. Control room and transformer connectivity is done mostly trained personnel from the manufacturer for equipment interconnections, wiring and testing.

---

*a. Switchyard for hydropower evacuation*
b. Underground Control Room and GIS substation
### 15. Erection and operation of Gates

Underground gates: Turbines, Diversion Tunnel Gates, Barrage and Sluice Gates (See Glossary 106), Barrage Bay and sluice bay, Trash racks and Trash Cleaning Machines, Intake gates (See Glossary 57), Sedimentation Chamber Gates, Flushing Conduit Gates, Emergency Valves, Main Inlet Valves, Draft Tube Gates, Wicket gates (See Glossary 129), Outlet Gates, Access Doors

Surface gates: Spillway gates, Control gates (See Glossary 27) etc.

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<tr>
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</thead>
<tbody>
<tr>
<td>Cutting of trees, development of spillways, surface roads, reservoir formation. Constructing of RCC structures for gates on the river body (See Picture a. &amp; b.) (Location: Spillway and gates)</td>
<td>Hydrological impacts of altered river ecosystem, prevention of upstream fish movement during construction period, inundation of construction area. Decline in water quality along river, seasonal drains and natural sources. Loss of agricultural and forest land. Air pollution due to cutting, blasting, dust, vehicular exhausts and increase in noise levels. (Type: Permanent)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

Restoration of any natural water spring damaged even if not directly attributable to project activity. Ensure proper drainage system is constructed and to manage construction activities to ensure that there is no adverse impact to the natural environment and biodiversity of the area.

#### Work process

To construct structures, it is necessary to install gates for diverting the river from its natural bed to give access to the river bottom in a dewatered condition for the major period of construction of the project. Pictures c. & d. relate to operation of gates during generation of power as observed in control room monitors.

---

a. Under construction gated structure  
b. Operating spillway gates  
c. Operation of gates and generation of power in two turbines  
d. Generation at one turbine
### COMMISSIONING

16. Stabilisation and containment of soil erosion in project area, Reservoir Management and Floods Management in the Catchment

Reservoirs formed by dams on rivers are subjected to sedimentation. The process of sedimentation embodies the sequential processes of erosion, entrainment, transportation, deposition and compaction of sediment.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow or water less that the mandatory e-flow will damage the aquatic life and also disturb downstream river users. Reservoir formation, cutting of hillside for project aspects. (See Pictures a.-d.) (Location: Reservoir and total catchment area)</td>
<td>Less than mandatory environmental flow due to low water conditions resulting loss of aquatic life. The eroded sediment from catchment when deposited on streambeds and banks causes braiding of river reach. The removal of top fertile soil from catchment adversely affects the agricultural production. Land-slides caused due to slippage of soil and rocks on the sides. (See Pictures e.-g.) (Type: Permanent)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Ensure reservoir management to avoid siltation; water discharge maintained as per regulations - mean environmental flow maintained to ensure no adverse impact to aquatic life.

Catchment area treatment plan (CAT) (See Glossary 17), a study of erosion and sediment yield from catchments as deposition of sediment in reservoir reduces its capacity, and thus affecting the water availability for the designated use.

**Work process**

The CAT plan implemented along with the project construction and involves – terrestrial and aquatic biodiversity management, afforestation, aquifer treatment, management of water resources of the area, techniques to control erosion and landslides in the catchment area of hydropower project.

---

*a. Rock bolting of lose rocks near powerhouse*
b. Foundation stabilization blocks

c. Under construction outfall from gates through a “key shaped” structure
d. Cutting of hillside for headrace portal

e. Siltation of Reservoir
f. Riverside wire mesh retention crates filled with rock to avoid erosion

g. Flooding in catchment area (See Glossary 16)
### COMMISSIONING

#### 17. Forest, Fisheries, Wildlife, and Resettlement issues

Compensatory afforestation, resettlement structures, livelihood, availability of water for local needs, terrestrial and aquatic life management.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</thead>
<tbody>
<tr>
<td>Trees coming under submergence area and other project components, impact on fish in the river, wildlife in the project area, and resettlement involved are usually quite large in hydropower projects. (Location: Project Catchment area)</td>
<td>Altered river ecosystem and decline in river water quality along river, seasonal drains and natural sources. Prevention of upstream fish movement in river/streams. Prelocate Project Affected Families whose land is being acquired, PAPs loose homestead &amp; loose land) (See Picture a.) and loose livelihoods (See Pictures b. &amp; c.). Inundation of old roads, dumping activity makes roads unusable. (Type: Permanent)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erecting fish ladder in the barrage to facilitate fish migration to the upstream area of barrage. Resettlements to be located in designated areas away from wildlife areas, dense vegetation with proximity to river. Old roads and pathways, stream and natural springs to be rehabilitated.</td>
<td>During construction phase, large number of machinery and construction workers will have to be mobilized. Similarly, the operation of various construction equipment and blasting is likely to generate air and noise pollution. These activities can lead to disturbance to local populace as well as wildlife. EPC contractor maintains records of all impacts and measures implemented to ensure local grievance is heard and implemented adequately.</td>
</tr>
</tbody>
</table>

#### a. Resettlement area
b. Bathing areas

c. Sandmining areas
Small and Micro Hydropower Projects

63. The impacts of small and micro hydropower projects is much less as compared to the large and medium size hydropower projects. Some photographs for the project components for small and micro hydropower projects is also shown below in Table 8.

Table 8: Small Hydropower Projects Construction Activity

a. Trench Weir for inlet water

b. Penstock, surge tank, 33 kV power evacuation line
d. Gate and minimum environmental water flow
e. 5 MW (each) Francis Turbines

f. Powerhouse, tailrace and switchyard
VI

Stages of Solar Photovoltaic (SPV) Power Generation Project Design, Construction and Related Environmental Impacts and Mitigation

64. This section discusses various project design aspects and lists various stages of construction process along with the environmental impacts, type, impact and impact mitigation measures for Solar Photovoltaic (SPV) power generation projects.

65. Normally, the following type of solar power generation techniques are used:

- Solar Photo-voltaic Panels (SPV).
- Concentrating Photovoltaic (CPV) (See Glossary 23).
- Concentrated solar thermal power (CSP) (See Glossary 24).
- Rooftop SPV installations.
- Distributed SPV generation.

66. The following section deals with usage of solar photovoltaic array (See Glossary 73) for power generation.

A. Solar Photovoltaic (SPV) Generation Plant

Design Criteria

67. Design of the solar plant requires that the project should meet the following environmental criteria listed below:

(i) Projects not to be located within national parks, wildlife sanctuaries and nature reserves, or wetlands, unless unavoidable for technical reasons.
(ii) Any monument of cultural or historical importance not affected by the project.
(iii) Projects do not create any threat to the survival of any community with special reference to tribal community.
(iv) Minimise impacts to large habitations, densely populated areas, crossings of national highways, railway lines, and airport areas, other EHV lines, hydrocarbon pipelines etc. to the extent possible.
(v) Requires minimal clearing of any existing forest resources in the project area – wherever it is unavoidable, can be minimized and compensated as per regulatory criteria.

(vi) Any community utility services like playgrounds, schools, cemetery etc. and any other similar establishments etc. will not be adversely affected.

(vii) Since there will be extensive land required, the project must ensure that it does not lead to any inequalities (i.e. landless etc.), disturbs ecological balance in the project area. It must have the consent of local villagers as it must not encroach into village lands etc.

(viii) Project should not create water scarcity for the local populace by taking local pond or ground water use that is unauthorised.

(ix) Since the project needs to evacuate power to pooling stations, it is necessary that the project must meet all design criteria listed for transmission line.

(x) The site must be accessible, nearly flat/barren and must have suitable physical attributes – nearest distance from road, power evacuation point, water access point etc.

68. Figure 11 provides a schematic for the entire Solar photovoltaic power generation project.

**Construction Practice, their Environmental Impacts, Mitigation and Work Process**

69. The Flow Chart in Figure 12 displays activities as they progress while constructing a solar power generation project. On the left are the “Steps” involved in the process of project implementation such as “Pre Construction, Facilities Setup, Construction, Erection, Commissioning, and Post Commissioning”. The “Tasks” performed are numbered in a sequential manner i.e. 1-17 (as shown by arrows). Some “Tasks” are grouped together in a particular “Step” in the order of their occurrence in a project cycle. Their placement (i.e. 1&3, 2&4) has no particular significance. For example, The construction related environmental impacts usually occur during implementation of “Tasks” 2-14. These “Tasks” are usually performed by the Engineering Procurement and Construction (EPC) contractor, who is monitored by Project Implementation Consultants (PIC) for a project proponent. Tasks 15-17 are performed by an Operations and Maintenance (O&M) operator.

70. Table 9 provides information about each of the step involved in hydropower generation project design, construction, testing and commissioning, about the environment impacts and their proposed mitigation, and work process involved. In the Table, layout of the each box is represented as follows:

- The colored box on top left of the Table represents the “Steps” matching the color of boxes in the Figure 12.
- “Tasks” lists work undertaken to accomplish the “Steps” shown in Figure 12. This followed by explanation of the task conducted.
- “Activity causing Impact and Location” lists the activity undertaken to accomplish each “Task” that impacts the environment and also gives the location of the environmental impact in brackets.
- “Impact of activity and its type” describes the impact on environment of each activity and lists it type – temporary, permanent, planning etc. in brackets.
- “Mitigation Measure for the Impact” lists environmental mitigation measures taken to mitigate the impact.
- “Work process” provides a write up on the work done by EPC contractor for each “Task” and the human aspect involved during task completion.
- The right side of the Table contains pictures from actual working sites that are mapped to each relevant “Activity”.

3.5.2.7.1.2 Energy and Environment – photovoltaic power generation
Figure 11: Schematic Diagram of the Solar Photovoltaic Power Generation System

Solar Power Generation

Power Substation at Plant

Power Transmittion Line to Grid
Figure 12: Process Flow Chart for Construction of Solar Photovoltaic Power Generation Project

CONSTRUCTION OF SOLAR PHOTOVOLTAIC (SPV) POWER

SURVEY
1. Meteorological resource assessment for energy generation/Surveys

FACILITIES SETUP
2. Widespread levelling of land
3. Worker camps
4. Unloading, site storage, and workshop

CONSTRUCTION
5. Road access
6. Water boring or water from local ponds
7. Buildings and facilities at solar plant
8. Foundations for solar panels

ERECTION
9. Mounting structure design and engineering
10. Detailing of cabling system, earthing and lighting protection system
11. Control Room and facility building
12. Erecting solar modules, investors, and balance of system components
13. Power evacuation

COMMISSIONING
14. Testing and commissioning of solar power plant
15. Removal of dust from panels

POSTCOMMISSIONING
16. Post commissioning monitoring, O&M support
17. Observe safety risks involved for roof top installations
### Table 9: Solar Power Project - Stepwise Project Activities, Construction Impacts, Mitigation, and Work Process Involved

#### PRECONSTRUCTION

**1. Meteorological resource assessment for energy generation/surveys**

Information on field solar insolation (See Glossary 60) data required for solar park design, all suitable features of the site observed—slope, angle of sun, drainage, wind direction, location of associate facilities that can be marked on topographical map (1:50,000) and planning map.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning for cutting of trees, slope/level development of land to ensure direct irradiance (See Glossary 59) from sun, placement of facilities in shadow area, invertors (See Glossary 58), transformer, siting for construction material, stores etc. during construction. (Location: Solar plant land)</td>
<td>Potential impact on physical resources - Topography, possible loss of biodiversity, interference with public utilities, local grazing and agricultural areas, paths etc. (Type: Planning stage)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

Global Positioning system (GPS) survey to determine the site layout (See Picture c.). The data regarding soil, topography, contour, land cutting and filling required, distance from water body and distance from major roads, details of trees being affected needs to be collected. Plan to include details for water sprinkling (which is difficult due to desert type environment at site), limiting bare soils, proper maintenance of equipment, vehicles etc.

Better GPS and Irradiation survey to determine the site layout.

**Work process**

This activity takes the first initial 3-4 months to ascertain the location, suitability of the location.

Consider better choice of location to avoid costly land purchase and damage to common property resources etc.

Modelling and collection of storm history of the area to determine dust losses as well as frequency of cleaning required.

---

a. Small solar weather station

b. Solar park weather station

c. Site survey for leveling, GPS etc.
FACILITIES SET UP

### 2. Widespread levelling of land

Removal of any vegetation, trees from the site

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Removal of trees and scarce vegetation in the area. Land cutting and filling, digging and removing excess soil to nearby areas. (Location: Solar plant land area)</td>
<td>Air pollution due to removal of trees, vegetation, land cutting and filling, digging and removing excess soil to nearby areas. (See Picture a.). Agriculture and grazing activity will be affected. Loosening of top soil will enhance soil erosion during the rainy season and windy seasons. (Type: Permanent)</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<td>Any excess material will only be used as fill material offsite when the disposal site can be restored in a manner that prevents erosion and does not block any drainage path. Almost all productive agricultural avoided as much as possible for optimal usage of panel area inside the SPV plant. (See Picture b.) Tree plantation along the boundary of the plant and areas that do not cast shadows on plant must be done reduce dust pollution.</td>
<td>The land area is levelled using mechanized equipment due to the requirement of extremely flat area (See Picture c.) Unavailability of water to reduce air pollution during levelling (through sprinkling) is not possible due to extreme desert like conditions. The source of water in such areas include underground boring, or ponds/irrigation canals meant for local village use.</td>
</tr>
</tbody>
</table>

![Levelling of land for SPV plant](image-url)
b. Typical layout plan of (SPV) plant

c. Leveling of area and marking of structure foundations
### 3. Worker Camp

Worker groups in the area include local village labors and workers who live near the sites. Some semi-skilled, skilled workers are normally stationed at camps whereas professional staff are normally stationed in towns and commute daily to the sites.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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<tbody>
<tr>
<td>EPC contractor establishes temporary labor camps (See Picture a.) outside the boundary of the SPV plant. (Location: Worker camp)</td>
<td>Scatter of kitchen waste, toilet waste, scrap, unusable/nonrecyclable waste in the area, liquid waste disposal in camps and its spillage into local depression areas. Adversely impact ecological resources through poaching of wildlife and using wood from trees as firewood causing ecological damage in the area. (Type: Temporary)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

Contract provisions specifying minimum setback requirements for construction camps from water bodies, reserved areas etc.

Provision of adequate washing and toilet facilities with sanitary soak-pits by the contractor to the workers is obligatory.

#### Work process

The worker camps as shown in picture are erected for the construction period in an adjoining land which is rented from local owners.

The EPC contractor may hire up to 100-500 workers depending upon the size of the plant. The size of reach facility in the camp thereby varies accordingly. (See Picture b.)

![a. EPC contractor camp](image-url)
b. Facilities at labor camp
## FACILITIES SET UP

### 4. Unloading of material at site, storage and workshop

The solar plant sites are normally accessible through mechanized equipment as it is a plain area and the storage area required is not big.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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<tbody>
<tr>
<td>Establish toilets, workshops and storage places at site. (Location: Stores, machine shops). Storage of equipment and raw material to sites (See Picture a.) and using heavy cranes to unload equipment. Parking of trucks, equipment at storage area. (Location: Solar plant land)</td>
<td>Toilet waste, scrap, unusable/nonrecyclable waste. (See Picture b.), oils, slurry etc. from workshops. Vehicular pollution due to transportation, parking, repair, unloading/loading of equipment at storage site. (Type: Temporary)</td>
</tr>
</tbody>
</table>

### Impact Mitigation | Work process
---|---
Selection of approved locations for material storage yards away from the environmental sensitive areas. The vehicles used for unloading, transportation of equipment to site must comply with national pollution standards. | Creating storage facility, unloading, storage and usage normally would take between 6-8 months for any SPV project site to complete.

---

a. Storing of new SPV panels

b. Unpacked solar power panels
5. Road access

Approach roads and pathways to ensure proper access to all SPV panels for washing as well as all parts of the plant in case of any fire etc.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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<tbody>
<tr>
<td>Roads to project site from main road, internal roads/pathways to SPV panels, invertors, substation, workshops, camps, stores, constructed to ensure complete access to construction vehicles. See Picture a.) (Location: Complete Project site)</td>
<td>Emissions from construction vehicles, equipment and diesel generation (DG) sets, and emissions from transportation traffic. Dust and air pollution due to movement of heavy vehicles on unmated/nonconcreted/non sprinkling of watered road surfaces. See Pictures b. &amp; c.) (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of access roads away from crowded community areas thereby not causing accidents on the road and project sites. Ensure proper sprinkling of water and drainage is made along the road and proper roads are constructed. Ensure vehicles and equipment plying at the site have Pollution under Control certificates.</td>
<td>Frequent truck trips are required during the construction period for removal of excavated material and delivery of select concrete and other equipment and materials. Normally, a schedule for water sprinkling of roads and removal of excess soil is prepared by site manager.</td>
</tr>
</tbody>
</table>
b. Pollution due to heavy transport vehicles

c. Unmetalled roads between project areas
### 6. Water boring or water from local ponds

Water used for construction, worker camps, amenities, operations.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water for construction using bore well, tankers bringing water for a fee (usually drawn from bore wells, irrigation canals, or village ponds) (Location: Local Area)</td>
<td>Excess usage of water at site resulting in drastic fall in water table in the area/drying up community based water pond or misusing canal water meant for irrigation. (Type: Permanent)</td>
</tr>
</tbody>
</table>

#### Impact Mitigation

Proper approvals from government required for water use from canals or underground sources. This is required as the only source of water in such areas include underground bore wells or ponds/irrigation canals meant for local village use.

#### Work process

Water is scarce in desert areas where most solar plants are situated. Unavailability of water to reduce air pollution during levelling (through sprinkling) is not possible due to extreme desert like conditions.

![a. Construction water from borewell.](image1)

![b. Water tanker supplying water from borewell/irrigation canal/village pond](image2)
### 7. Buildings and facilities at solar plant

Construction of Camps, office, residences at project site, drainage, road and other facilities such as main Control Room etc. (Pictures a. and b.).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
</table>
| Construction of project offices, transit camp sites, staff quarters, stores, kitchen etc.  
(Location: Project offices, camp sites) | Exposure to air and noise pollution from under construction building areas.  
Generation of toilet waste, scrap, unusable/nonrecyclable waste.  
sewage, kitchen waste from buildings. Wastewater from camps and its impact on the area nearby.  
(Type: Temporary) |

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
</table>
| Suppress blowing of loose dust in the area through appropriate measures if possible.  
Contract provisions make it necessary to provide proper camps, safe disposal of kitchen waste, sanitation waste using sanitary soak-pits etc.  
Housing to be situated away from project sites, but also situated away from forest areas, crowded community areas thereby not affecting an influx of outsiders into closed communities. | Development of housing away from project sites to ensure health and safety of staff and the community. The construction of the facility takes 6 months or more depending on the type and number of building required. |

a. Temporary toilets and facilities at site.

b. Under-construction buildings at site.

Type of soil to ensure mounting structure requirement and to analyze the load bearing capacity of soil.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Digging of holes with drilling machines (See Picture a.), Concrete mixing and installation if studs for solar panel structures. (Pictures b.-f.) (Location: Solar plant yard area).</td>
<td>Air pollution due to drilling operations. Also, excess soil from foundations, though small will be laid out in areas that does not interfere with drainage of the area. Air and land pollution during concrete mixing operation (Type: Temporary)</td>
</tr>
</tbody>
</table>

### Impact Mitigation

Reduce air pollution during drilling by water sprinkling. Proper drainage system is constructed by EPC contractor who will also ensure the concrete preparation plant should not contaminate natural environment at site and nearby areas.

### Work process

The construction work for all foundations including concreting is done manually or using mechanized concrete machines takes about 3-4 months depending on the size of SPV plant.
c. Concrete batching plant
d. Hole dug for installation of studs
e. Levelling of studs for installation of posts
f. Pouring of concrete in structure foundation
## 9. Mounting structure design and engineering

Ensure proper SPV module-mounting structure must have strength to withstand mechanical and wind loads, corrosion etc. For rooftop solar – technical details regarding shading, tilt, glare, roof area, and sizing need to be taken care in detailed design. Usually, a solar tracking array (See Glossary 125) is installed to get the maximum solar irradiance in the daytime.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erection of posts, erection of structures, Digging of holes with drilling machines (See Picture a.), concrete mixing and installation if studs (See Pictures b.-d.) for solar panel structures followed by structures (See Pictures e. &amp; f.) (Location: Solar plant yard area).</td>
<td>Air pollution due to loose dust at the base of SPV panel structures. Improper sloping in the land may interfere with natural drainage of the area. Recyclable waste generated from erection of arrays. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce air pollution during drilling by water sprinkling. Proper drainage system is constructed by EPC contractor. Recyclable waste must be removed and stored for disposal offsite by the EPC contractor.</td>
<td>The erection work for structures is done within 1-2 months depending upon the size of SPV plant.</td>
</tr>
</tbody>
</table>

---

a. Erection of posts for structures
b. Erection of posts for structures

c. Installation of posts for structure installation

d. Typical constructed structures
e. Solar tracking structures

f. Waste generated to be stored offsite.
## ERECTION

### 10. Detailing of cabling system, earthing and lightning protection system

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of inverters, cabling, inters connecting wiring, earthing within facility and substation equipment. (See Pictures a.-c.) (Location: Electrical system within plant)</td>
<td>Improper insulation and equipment mismatch leads to line faults and interference with nearby structures causing faults and accidents. Short circuits, fire due to improper connectivity, overload or accident. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper sizing of equipment for ensuring appropriate installations etc. to avoid short circuits, hazard to workers in case of electrical sparking/heating Availability of fire extinguishers at site. (See Picture d.)</td>
<td>Ensure fully trained personnel handle interconnections, wiring, chemicals etc. Depending on the size of the plant, about 2-3 months would be required to complete the entire wiring for the plant.</td>
</tr>
</tbody>
</table>

- a. Inverters for conversion of DC voltage to AC voltage
- b. Power cables
- c. Step up transformer after inverter
- d. Firefighting equipment
11. Control room and facility building

The control room buildings have alternating current (AC) and direct current (DC) distribution room, battery & charger room, Inverters, substation automation (SA) system, Control Room (CR) panels, HV AC (heating, ventilation, and air conditioning) and normal & emergency AC & DC lighting, firefighting equipment etc. These facilities are connected to power transformers and substation at SPV plant (See Pictures a. & b.)

Activity causing Impact and Location | Impact of activity and its type
--- | ---
Digging and concrete casting of foundations for structures, transformers (See Picture a.), pillars/columns for buildings, trenches, cable trays, (See Picture b.) road, drainage etc. Installation of Power transformer on the Transformer bay (Location: Control Room, and switch yard area) | Solid waste generation at the substation site will include metal scraps, wooden packing material etc. Excess soil from foundations may interfere with drainage of the area. Contamination of land and or nearby water bodies by transformer oil, fuels, chemicals, battery water etc. can occur during erection and operation due to leakage or accident. (Type: Temporary)

Impact Mitigation | Work process
--- | ---
Concrete waste, wooden waste and metal scrap will be collected and disposed to offsite in compliance with applicable regulations and rules. Concrete lined pits are erected to contain the oil. Proper drainage facilities will be constructed to avoid overflow or contamination of water bodies, streams, river etc. especially during the rainy season. | Civil construction works normally take up to 3-12 months depending on size of the substation.
b. Step-up substation at SPV plant
12. Erecting solar modules, inverters and balance of system components.

Construction of power plant including solar field, infrastructure and complete electrical installations.
(See Pictures a. & b.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Erection of SPV panels on structures and connecting them to electrical circuits. (Location: SPV plant site)</td>
<td>Loose dust after erection if left untreated in the plant may cause air pollution/excessive dust. Improper connectivity between modules, earthing may cause sparking. Recyclable waste from packaging, wiring etc. generated during erection. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper levelling, ramming and growing of small grass on the ground under the panel structures to avoid dust during strong winds. Ensure waste is removed from the site entirely before operations. Earthing diagrams to ensure safety of man and equipment</td>
<td>Ensure fully trained personnel handle interconnections, wiring, chemicals etc. Completing all installation of panels would normally take between 2-3 months depending on the size of the plant.</td>
</tr>
</tbody>
</table>

a. Final Solar Panel fitting with solar tracking

b. Different Types of Solar Photo Voltaics (SPV)
### ERECTION

#### 13. Power Evacuation

Switchyard design to ensure proper strength of foundations for transformers, outgoing gantry and other equipment.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Erection of power evacuation line upto pooling substation – the evacuation voltage depends on the size of the plant. (See Pictures a.-c.) (Location: Tower line)</td>
<td>Depending on the plant size, the inverters will be connected in parallel to the step-up transformers in the switchyard. The invertors and transformer emit noise and heat. Erection of tower lines on private land will cause loss to agricultural land. (Type: Permanent)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>The connectivity to inverters inside yard to ensure low losses, proper cooling and cables to switchyard substation. Ensure proper survey of outgoing lines to a pooling substation to avoid any agricultural land, water bodies or any other environmentally sensitive area.</td>
<td>The length of the power evacuation has to be optimized to ensure low transmission losses. The rating of transformation equipment has to be sound to ensure near zero losses in generation and power sell off point.</td>
</tr>
</tbody>
</table>

![132 kV Power evacuation line](image-a.png)  
![33 kV Power evacuation lines](image-b.png)  
![Power Pooling substation](image-c.png)
### 14. Testing and commissioning of solar power plant

Testing of internal wiring to all panels, inverters, underground cabling from inverters to switchyard substation, step-up to subtransmission voltage for evacuation. (See Picture a. for completed SPV plant).

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing electrical connectivity from power generating panels for all project components up to the evacuation point. (Location: SPV plant)</td>
<td>Improper connections cause damage of equipment and fires. Improper distance from nearby structures causing shadows onto the panels. (Type: Temporary)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Mitigation</th>
<th>Work process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure proper safety protocols for testing and commissioning, checks on final commissioning of equipment are conducted. Proper equipment such as weather station (See picture b.) installed for ensuring utilization of solar irradiance.</td>
<td>EPC contractor employs skill technicians for testing and commissioning of the plant which involves modular tests on each aspect of plant, inverter and transformer operation, operation of each switchgear, and running of normal operations (shown in Pictures c.-d.).</td>
</tr>
</tbody>
</table>

![a. Completed SPV plant](image1)

![b. Weather Station](image2)
c. Readings from weather station

d. Plant operations overview
15. Removal of dust from panels

SPV panels need to be thoroughly cleaned before commissioning. Water is scarce in desert areas where most solar plants are situated. Also, due to dusty condition, there may be reduction in production capacity of the solar panels due to dust settlement. Hence washing them regularly is necessary for continued viability of the project. (See Pictures a. & b.)

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter from air pollution, agriculture, construction and traffic accumulates on the panels, as well as pollen and sea salt (in some cases if near seacoast. : SPV plant site)</td>
<td>Excess usage of water at site resulting in drastic fall in water table in the area/drying up community based water pond or misusing canal water meant for irrigation. Large number of persons required for regular washing of panels. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Proper approvals from government required for water use from canals or underground sources.
- Proper pathways inside the park a must to ensure proper cleaning of panels in the night hours when there is no generation.

**Work process**

As washing panels has to be done daily – mostly all cleaning is done in night hours when there is no generation due to no sunlight. Since there are no lighting available in park at night, it becomes difficult for the cleaning crew to clean panels in the dark.

---

**Pictures:**

a. Half array of panels are washed

b. Washing team that works round the clock in shifts
### POST COMMISSIONING

16. Post commissioning monitoring, operations and maintenance support

Details for hazardous waste landfill sites in the vicinity of project as well as membership details.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance of SPV panels, replacement of defective ones. Storage of transformer oils, disposal of wastes – recyclable and nonrecyclable. (Location: SPV plant)</td>
<td>Leakage of transformer oil, sparking due to loose connections from standby power set, damage of solar panels (See Picture a.), which are hazardous waste and cannot be disposed of at site. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

- Concrete lined pits erected to contain the oil.
- Disposal of waste solar panels to approved recyclers of the waste solar panel or its return to the manufacturer.
- Firefighting equipment maintained in working order at site.

**Work process**

- Ensure fully trained personnel handle interconnections, wiring, chemicals etc.

![Waste solar power panels](image.jpg)

a. Waste solar power panels
17. Observe safety risks involved for roof top installations.

Rooftop installations are located at great heights (See Picture a.) on commercial buildings and proper safety equipment has to be used for its installation and maintenance.

<table>
<thead>
<tr>
<th>Activity causing Impact and Location</th>
<th>Impact of activity and its type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of rooftop for installation of panel, wiring etc. Erection of Panels on rooftop and erection of inverters on ground/ suitable location. (Location: Rooftops)</td>
<td>Improper fitment giving glare to neighborhood buildings, unsafe during storms and rainy season. Health and safety risks to workers during erection, operation due to uneven roof, improper wiring arrangements. (Type: Temporary)</td>
</tr>
</tbody>
</table>

**Impact Mitigation**

**Work process**

- Ensure proper placement of all panels on roof, wirings, and other equipment on the ground or lower site fixed in safe manner (See Picture b.)

- Ensure proper fitment to avoid glare to adjacent buildings and safety related Standard Operating Procedures followed by project proponents for safe operation of panels.

- Ensure proper use of proper PPEs by workers, staff on rooftop during installation and operations.

- Site owner’s standard operating procedures for erection safety and health, handling, cleaning procedures for Roof top panels should be prepared and followed.

---

a. Huge rooftop site on top of industrial facility  
b. Rooftop access
This section aims to summarize the broad spectrum of construction related environmental impacts that have been discussed in earlier sections for the designated power sector projects.

A. General Cumulative Impacts During Construction, Operations and Maintenance Phase

The triggers that generate an impact in the physical environment due to construction (CON), operations and maintenance (O&M) in the designated power sector projects have been discussed in Table 10 below. The list of triggers mentioned in the table is merely illustrative and is not necessarily exhaustive and can be appended with site-specific impacts.

These impacts are segregated by physical resources, environmental resources, ecological resources and human environment based on the type of impact. The activities that needs focused due-diligence are marked as negative (‘-‘) during construction (CON) and O&M for various types of project attributes.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase</td>
<td>Triggers</td>
<td>CON</td>
<td>O&amp;M</td>
<td>CON</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>No significant negative impact</td>
<td>Negative impact that can be mitigated to acceptable levels</td>
<td>Significant positive effect</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Impact on Physical Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Impact on Topography</td>
<td>Natural vegetation, biodiversity, land-use, Physical Cultural Resources</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

continued on next page
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Impact on Climate</td>
<td>Hydrological balance, landslides, flooding etc.</td>
<td>CON</td>
<td>O&amp;M</td>
<td>CON</td>
<td>O&amp;M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Impact on Environmental Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Impact on Air Quality</td>
<td>Air Pollution</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>Impact on Noise Levels</td>
<td>Noise Pollution</td>
<td>0</td>
<td>--</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>c</td>
<td>Impact on Surface Water Quality</td>
<td>Water Availability, ineffective drainage, loose soil, oil etc. flows to water bodies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>d</td>
<td>Impact on Ground Water Quality</td>
<td>Leaching of oils, chemicals</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>e</td>
<td>Impact on Soils and Geology</td>
<td>Soil erosion, foundation design, resistivity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Impact on Ecological Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Terrestrial Ecology</td>
<td>Forests, trees, wildlife species, national parks, reserves, sanctuaries</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>b</td>
<td>Aquatic Ecology</td>
<td>Aquaculture Potential, Fisheries</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>c</td>
<td>Avifauna</td>
<td>Seasonal migratory birds</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>Impact on Human Environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Health and Safety</td>
<td>Pollution, shocks, accidents, lack of capacity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>Agriculture</td>
<td>Loss of agricultural land, crops/trees</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>c</td>
<td>Socio-economics</td>
<td>Employment opportunities, social betterment, income generation</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>d</td>
<td>Resettlement and Rehabilitation</td>
<td>Displacement of people, houses, homestead, livelihood</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>e</td>
<td>Archeological/ Cultural sites</td>
<td>Archaeological monuments, chance find</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>f</td>
<td>Traffic and Transport</td>
<td>Lack of Infrastructure, traffic management</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 10 continued
Table 10 continued

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>Interference with other utilities and traffic</td>
<td>Stoppage of Service</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Waste Disposal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Solid waste disposal</td>
<td>Land pollution – hazardous and nonhazardous, municipal solid waste</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>Liquid waste disposal</td>
<td>Water pollution - municipal wastewater, chemicals, oils</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

74. General cumulative impacts for various activities from start of construction to commissioning in a project as summarized from the Table 10 above are:

- All designated types of projects have negative impact on topography as they change the surroundings such as natural vegetation, land-use and aesthetics at least permanently.
- Most of them have negative impacts on air, noise, and soil quality during construction period, which are temporary in nature and exist only during the construction phase.
- ROR Hydropower projects affect the ground water, soils and geology, terrestrial and aquatic ecology more severely permanently as compared to surface water quality which is temporary in nature.
- Resettlement and rehabilitation of affected persons has higher relevance for power generation projects (hydropower and solar) as compared to power evacuation and distribution projects. Generation projects require vast land requirements are compared to transmission line projects that are linear in nature and land required is fragmented. The power substations require small pieces of land as compare to generation projects.
- ROR Hydropower and SPV solar power projects need to effectively manage their wastes during to construction and presence of workers at project sites.

B. Monitoring During Construction, Operations and Maintenance Phases

75. Monitoring of project activities during construction, and operations and maintenance (O&M) phase as per the approved environmental clearance documents (EIA/IEE etc.) are the responsibility of the project proponent (PP)/partner.

76. The EPC contractor, who is charged with project construction, is not required to monitor the project activities in the contract. Rather, it is the responsibility of the project proponent to monitor and report project progress and environmental monitoring reports to ADB.
Unfortunately, project proponent does not usually hire the required staff to implement and take corrective actions. Therefore, to effectively implement EMP provisions and conduct a proper monitoring program, the project proponent must empower the EPC contractor (through appropriate contract and budget provisions) to undertake the following activities as mentioned in column 3 of Table 11. The table below does not constitute to be an exhaustive list and can be appended depending upon project specific locations.

**Table 11: Project Monitoring Required During Construction, Operations and Maintenance (O&M)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Product Activity/Stage</th>
<th>Key project aspects to be monitored</th>
<th>Activities for EPC contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equipment layout and installation</td>
<td>Construction techniques and machinery, scrap generation etc.</td>
<td>EPC contractor to develop layout plans, installation schedules, monitor scrap generation, management of scrap.</td>
</tr>
<tr>
<td>2</td>
<td>Power House/ tunnel construction/ substation/ towers/solar array</td>
<td>Adhere to seasonal start and finish of major earthworks to avoid rains and flooding/ Monitoring stations installed (pH, BOD/COD. Suspended solids, other parameters as relevant).</td>
<td>Develop schedule for measuring parameters and report to PP as per monitoring schedule</td>
</tr>
<tr>
<td>3</td>
<td>Storage of chemicals and materials, explosives, hazardous waste</td>
<td>Location of hazardous material storage; spill report (type of material spilled, amount and action taken to control and clean up spill).</td>
<td>Impermeable concrete lined locations for storage, disposal practices etc. to be established by EPC. PP to ensure hazardous waste is disposed of to approved recyclers only.</td>
</tr>
<tr>
<td>4</td>
<td>Encroachment into farmland, houses etc.</td>
<td>Usage of existing utilities, status of existing facilities, status of facilities (earthwork), tree/crop compensation (amount paid, dates, etc.).</td>
<td>EPC contractor to document all land related issues for PP monitoring</td>
</tr>
<tr>
<td>5</td>
<td>Nuisance to nearby properties</td>
<td>Contract clauses, design basis and layout, reinstatement of land status (area affected), air, noise, water, access to property, tree/ crop compensation.</td>
<td>EPC contractor to report to PP on restoration, compensation, environmental parameters for air, water, noise.</td>
</tr>
<tr>
<td>6</td>
<td>Flooding hazards due to construction impediments of natural drainage, temporary blockage of drainage, spillage of construction waste, loose soil, oils etc. into river/drain</td>
<td>Temporary fill placement, construction material stacking, oils, chemicals storage areas.</td>
<td>EPC contractor to develop drainage plan (liquid waste management)</td>
</tr>
<tr>
<td>7</td>
<td>Equipment submerged under flood</td>
<td>Store room level to be above high flow level (HFL) - elevation difference in meters.</td>
<td>EPC contractor to maintain equipment above HFL taking into account future flooding</td>
</tr>
<tr>
<td>8</td>
<td>Muck management and rehabilitation of disposal site (mostly in hydropower projects)</td>
<td>Ramming and compaction of muck dumping sites with sprinkling of water.</td>
<td>EPC contractor to maintain logs on mucking, water sprinkling etc.</td>
</tr>
<tr>
<td>9</td>
<td>Mining area rehabilitation including maintenance (mostly in hydropower projects)</td>
<td>Quarry area management specially if situated in river bed area.</td>
<td>EPC contractor to seek necessary approvals to mine raw material, make community payments (if any)</td>
</tr>
</tbody>
</table>
C. Design of O&M Process after Completion of Construction

78. After the construction is complete, the Project Proponent and ADB implementation specialists must ensure that a proper O&M process is designed for the equipment and facility to ensure the processes comply with the host country laws, ADB’s SPS 2009, and conform to good international practices.

- Record adherence to projects’ environmental design and EMP requirements during construction: ensure violations from any regulatory requirements or any normal practise are resolved.
Health and safety conditions - disposal of waste-water, waste at site, disposal of scrap procedures, hygiene, and safe disposal of toilet and kitchen waste etc.

Compliance of measured baseline parameters related to air, water, soil, noise, river pollution parameters with national laws; ADB’s and international good practices for maintaining sound environmental standards for workshop, storage of oil, spare parts, etc.

Restoration of soil and other facilities such as top soil for transmission towers, solar plants; mucking sites for ROR hydropower and regrowth of vegetation at sites, maintain e-flow for hydropower to ensure fish survival etc., compensatory afforestation for all type of projects.

- Meet local community to discuss any environmental outstanding issues, effectiveness of grievance redress mechanism (GRM), and proposed corporate social responsibility (CSR) activities.

D. Recommended Follow-Up Activities for Better Environmental Management after Commissioning

79. Develop human resource roadmap for implementing Environmental Health and Safety Management System (EH&SMS) for project.

- Documentation on standard operating procedures (SOPs) for construction practices, human resources management, biodiversity management, safe disposal and handling of wastes generated at sites etc.

- Develop financial module (within Enterprise Resource Planning – ERP software for project activities) for tracking environmental performance indicators with respect to costs and assignment of responsibility. This will track the mitigation impacts on health, environment and safety aspects on real time basis and provide remediation measures and determine their failure/success.
This section provides a bird's eye view of the project implementation process normally followed by the project proponent.

The past experiences show that best construction practices are not always followed by project proponents; their identification of environmental impacts, implementation of mitigation measures and human interventions are weak. The discussions presented in previous sections would be important to guide project design, develop baseline information and monitor mitigation measures in new projects proposed by ADB in future.

The knowledge takeaways for ADB specialists from this report would involve using the handbook for reviewing the various stages of project construction, review the techniques used, their general impacts, and the potential mitigation measure.

A. Environment Related Impacts

Table 12 provides a general insight in such project activities that relate to environmental management. The four designated sectors can be equally affected by the following:

<table>
<thead>
<tr>
<th>No.</th>
<th>Detail</th>
<th>Type of Implementation issue</th>
<th>State of Implementation*</th>
<th>Action Required as per ADB SPS and National Laws</th>
<th>Lessons from regional projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compliance with regulatory approvals</td>
<td>Environment Technical Contractual</td>
<td>Compliance conditions not adhered to in totality during implementation</td>
<td>Complete compliance within specific timeframe for meeting ADB SPS requirements.</td>
<td>Project Proponent and EPC contractor do not adhere completely to the approval documents from regulatory authorities</td>
</tr>
<tr>
<td>2</td>
<td>Compliance with project environment management plan (EMP)</td>
<td>Environment Technical Contractual</td>
<td>EMP requirements not adhered to in totality during implementation</td>
<td>Complete compliance within specific timeframe for meeting ADB SPS requirements.</td>
<td>Project Proponent and EPC contractor do not adhere completely to approved environment documents</td>
</tr>
</tbody>
</table>

*Continued on next page
### I. Compliance Issues

<table>
<thead>
<tr>
<th>No.</th>
<th>Detail</th>
<th>Type of Implementation issue</th>
<th>State of Implementation*</th>
<th>Action Required as per ADB SPS and National Laws</th>
<th>Lessons from regional projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Compliance with project environment monitoring plan (EMoP)</td>
<td>Environment Technical Contractual</td>
<td>Baseline data on environment parameters not developed</td>
<td>Project Proponent must ensure baseline data development</td>
<td>EPC contractor does not adhere to EMoP.</td>
</tr>
<tr>
<td>4</td>
<td>Internationally recognized core labor standards</td>
<td>Environment Technical Contractual</td>
<td>No cognizance to International standards in monitoring</td>
<td>EPC, O&amp;M, and field Staff to monitor labor standards</td>
<td>Monitoring of activities as per ILO’s Core Labor standards not performed.</td>
</tr>
</tbody>
</table>

### II. Work Practices

<table>
<thead>
<tr>
<th>No.</th>
<th>Detail</th>
<th>Type of Implementation issue</th>
<th>State of Implementation*</th>
<th>Action Required as per ADB SPS and National Laws</th>
<th>Lessons from regional projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design and Preconstruction</td>
<td>Technical Contractual</td>
<td>Detailed Design by EPC contractor and PIC consultants</td>
<td>Design and preconstruction activities to mitigate any adverse impact</td>
<td>Design and preconstruction activities lack environmental focus.</td>
</tr>
<tr>
<td>2</td>
<td>Human Resources – EHS awareness at corporate and field</td>
<td>Environment Contractual</td>
<td>Lack of awareness of EHS in personnel assigned at sites</td>
<td>Training of site staff to understand how to measure environment parameters</td>
<td>Staff’s priority is to ensure project completion even at the stake of not adhering to EMP.</td>
</tr>
<tr>
<td>3</td>
<td>Standard Operating Procedures (SOPs) for various Health, Environment, Safety issues</td>
<td>Environment Technical Contractual</td>
<td>EPC/PIC fail to make procedures compliant to EHS</td>
<td>SOPs to be prepared in-house/Consultant for all processes at Corporate Finance, Projects, Contracts etc.</td>
<td>SOPs for EHS are virtually nonexistent</td>
</tr>
<tr>
<td>4</td>
<td>Contracts – Manufacturer, EPC, subcontractor, O&amp;M etc.</td>
<td>Environment Technical Contractual</td>
<td>Bidding Documents lack integration with EMP and Environmental Monitoring Plan (EMoP)</td>
<td>ADB funded projects have standard bidding documents that must include schedules to complement EMP, EMoP activities and list obligations of the contractor</td>
<td>EPC/PIC staff are not responsible for adhering to ADB’s documents. It is the responsibility of the project proponent.</td>
</tr>
<tr>
<td>5</td>
<td>Monitoring – EMP related to Construction activities, Grievance, Affected Persons etc.</td>
<td>Environment</td>
<td>Monitoring is not part of EPC contract</td>
<td>Internal staff for monitoring and reporting to ADB required</td>
<td>EPC contractor has no obligations for monitoring</td>
</tr>
<tr>
<td>6</td>
<td>Monitoring – EMP related to O&amp;M, Grievance, Environment Audit etc.</td>
<td>Environment</td>
<td>Monitoring is not part of O&amp;M contract. EMP reporting not prepared regularly</td>
<td>Internal Monitoring by project proponent required. If required, external experts to be engaged for monitoring.</td>
<td>O&amp;M contractor has no obligations for monitoring. Incomplete monitoring reports submitted periodically</td>
</tr>
</tbody>
</table>
### II. Work Practices

<table>
<thead>
<tr>
<th>No.</th>
<th>Detail</th>
<th>Type of Implementation issue</th>
<th>State of Implementation*</th>
<th>Action Required as per ADB SPS and National Laws</th>
<th>Lessons from regional projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Management of various plans: • Pollution prevention and abatement plan, • Emergency management plan, • Waste management plan, • Storm water management plan, • Occupation health and safety management plan, • Wildlife management, • Biodiversity support plan • Catchment Area Treatment plan and Dam safety (both for hydropower)</td>
<td>Environment Technical Contractual</td>
<td>Staff has no exposure to monitoring of these plans and parameters</td>
<td>EPC, O&amp;M, and field staff to adhere to requisite plans along with EMP/EMOP guidelines.</td>
<td>Regular monitoring of plans not tracked by ADB as well as EPC, O&amp;M and Project Proponent.</td>
</tr>
</tbody>
</table>

### III. Project Implementation

#### a. Manufacturer

<table>
<thead>
<tr>
<th>No.</th>
<th>Detail</th>
<th>Type of Implementation issue</th>
<th>State of Implementation*</th>
<th>Action Required as per ADB SPS and National Laws</th>
<th>Lessons from regional projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disposal and Recycling of Hazardous Waste Material – Solar Panels, Batteries, Oils, chemicals, transformer oil</td>
<td>Environment</td>
<td>Staff has no knowledge of recycling requirements as per law.</td>
<td>Need to monitor the amount of hazardous waste (HW) scrapped and disposed of the certified HW recyclers</td>
<td>EPC, O&amp;M and Project Proponent do not report the disposal data regularly in public domain.</td>
</tr>
<tr>
<td>2</td>
<td>Disposal of nonhazardous waste—recyclable and nonrecyclable.</td>
<td>Environment</td>
<td>Scrap being taken care by EPC. During operations, project staff has no knowledge of recycling requirements as per law.</td>
<td>Need to monitor the amount of nonhazardous waste generated and disposed of the certified recyclers</td>
<td>EPC, O&amp;M and Project Proponent do not report the disposal data regularly in public domain.</td>
</tr>
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### III. Project Implementation

<table>
<thead>
<tr>
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<tr>
<td><strong>b. Engineering Procurement and Construction (EPC) Contractor</strong></td>
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</tr>
<tr>
<td>1</td>
<td>Air and Dust pollution, Noise, Water and Soil.</td>
<td>Environment</td>
<td>Regular spraying of water difficult as water is scarce for dust suppression for solar; for others types, the practice is not regular</td>
<td>EPC contract to spell out the performance periodicity of all EMP, EMoP, all norms and Acts of host country.</td>
<td>Mitigation costs are hidden in total contract costs so EPC has no incentive to perform this unless monitored regularly.</td>
</tr>
<tr>
<td>2</td>
<td>Environmental Parameters – quality monitoring testing</td>
<td>Environment</td>
<td>Recording instruments not available</td>
<td>Install monitoring station and systems within stipulated time at each site</td>
<td>Daily Monitoring at site required is not done.</td>
</tr>
<tr>
<td>3</td>
<td>Standard Operating Procedures for Health and Safety</td>
<td>Environment</td>
<td>Sign boards and basic medical safety, PPEs available at site</td>
<td>Documentation in contract with EPC contractor required.</td>
<td>EPC and Project Proponent maintain basic minimum facilities as per law.</td>
</tr>
<tr>
<td>4</td>
<td>Disposal and Recycling of Panels and other hazardous waste</td>
<td>Environment</td>
<td>All work handed by EPC contractor. Proponent not aware of requirement</td>
<td>EPC contractor must return the broken panels/hazardous waste with proper tracking record before it goes to landfill site or disposal</td>
<td>Project Proponent must become member of HW disposal community</td>
</tr>
<tr>
<td>5</td>
<td>Worker facilities/amenities at project site</td>
<td>Environment</td>
<td>Record of facilities created for Worker, health camps, etc. not available</td>
<td>EPC contractor to report to project proponent for meeting all required monitoring reports</td>
<td>Daily Monitoring at site must be a priority.</td>
</tr>
<tr>
<td>6</td>
<td>Source/Amount of Water used drinking, construction purposes, and other amenities</td>
<td>Environment</td>
<td>Record of water usage, waste generated, health camps, washing facilities etc. not available</td>
<td>Documentation of all uses of water.</td>
<td>Water used from village or current drinking storage, or source and no inventory is done.</td>
</tr>
<tr>
<td>7</td>
<td>Solid Waste management</td>
<td>Environment</td>
<td>Lack of planning for waste management at sites</td>
<td>Monitoring as per ADB SPS 2009</td>
<td>EPC and Project Proponent maintain basic minimum facilities as per law.</td>
</tr>
</tbody>
</table>

**c. Project Implementation Consultant (PIC)**

<table>
<thead>
<tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>Planning for power evacuation system from a facility (transmission projects)</td>
<td>Environment Technical Contractual</td>
<td>ROW details for power line and details for land (barren/village/private/Government) incomplete due to pending forest cases.</td>
<td>Details for right of way (ROW) for evacuation required for meeting ADB SPS requirements.</td>
<td>Proponent and forest department not able to resolve forest cases within 1 year for most transmission projects.</td>
</tr>
<tr>
<td>2</td>
<td>Environmental Monitoring reports – both ADB and host country requirements</td>
<td>Environment</td>
<td>Monitoring reports being prepared. Recording instruments not available</td>
<td>Regular reporting required to ADB. Install monitoring station within stipulated time at the site.</td>
<td>EPC/PIC staff are not responsible for adhering to ADB’s documents. It is the responsibility of the project proponent.</td>
</tr>
</tbody>
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## III. Project Implementation

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Ensure EPC has proper site development for safe working by Worker/ nontechnical persons and dust reduction measures.</td>
<td>Environment</td>
<td>Vehicular dust and emissions, noise, safe drinking water, water logging to avoid vectors</td>
<td>Development facilities with better drainage, and reduction in dust</td>
<td>EPC and Project Proponent maintain basic minimum facilities as per law.</td>
</tr>
</tbody>
</table>

### d. Operation and Maintenance (O&M) Contractor

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air and Dust pollution</td>
<td>Environment</td>
<td>Regular spraying of water difficult as water is scarce for dust suppression</td>
<td>O&amp;M contract to spell out Air Act norms and AQMS.</td>
<td>Daily Monitoring at site not done.</td>
</tr>
<tr>
<td>2</td>
<td>Standard Operating Procedures for Health and Safety</td>
<td>Environment</td>
<td>Sign boards at site available, safety equipment used</td>
<td>Documentation in contract with O&amp;M contractor required</td>
<td>O&amp;M and Project Proponent need to monitor daily</td>
</tr>
<tr>
<td>3</td>
<td>Safe disposal of Panels (solar), hazardous materials (all)</td>
<td>Environment</td>
<td>Some record maintained</td>
<td>Part of monitoring requirements.</td>
<td>Reporting of disposal not disclosed in the monitoring report.</td>
</tr>
<tr>
<td>4</td>
<td>Environmental Monitoring reports</td>
<td>Environment</td>
<td>Irregular monitoring reports</td>
<td>Part of monitoring requirements.</td>
<td>Current monitoring reports are incomplete.</td>
</tr>
<tr>
<td>5</td>
<td>Worker facilities/ amenities at project site</td>
<td>Environment</td>
<td>Record on total facilities. not available</td>
<td>O&amp;M contract requires regular monitoring reports.</td>
<td>Current monitoring reports do not mention level of facilities.</td>
</tr>
<tr>
<td>6</td>
<td>Source/Amount of water used for panel cleaning (solar) and other amenities (all)</td>
<td>Environment</td>
<td>Record not kept</td>
<td>Water used from current drinking storage, no monitoring done.</td>
<td>Current monitoring reports are incomplete.</td>
</tr>
<tr>
<td>7</td>
<td>Environmental monitoring as per Government standards</td>
<td>Environment</td>
<td>Recording instruments not available</td>
<td>Install monitoring station within stipulated time at the site</td>
<td>EPC/PIC staff are not responsible for adhering to ADB’s documents. It is the responsibility of the project proponent.</td>
</tr>
</tbody>
</table>

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Table 12 continued

### e. Other Issues

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Employment to local community for road development, green belt development, contracts for walls, grass cutting etc.</td>
<td>Environment Technical Contractual</td>
<td>No monitoring of record of employment of locals</td>
<td>Reporting for ADB to be done periodically.</td>
<td>To be adhered by EPC, O&amp;M and Project Proponent</td>
</tr>
<tr>
<td>(2)</td>
<td>Infrastructure for health and sanitation</td>
<td>Environment Health and Safety</td>
<td>Availability of Equipment deficient</td>
<td>Provided in bidding documents.</td>
<td>To be adhered by EPC, O&amp;M and Project Proponent</td>
</tr>
<tr>
<td>(3)</td>
<td>Grievance Redress</td>
<td>Environment</td>
<td>Lack of mechanism in field. PAP has to approach head office for redress</td>
<td>GRC mechanism needs to be effective at field and HQ.</td>
<td>Project Proponent to ensure better access to proper redress to public</td>
</tr>
</tbody>
</table>

* Shows general weaknesses as noticed in several projects. Names of projects not mentioned.

### B. Some Non-Environmental Impacts

84. Normally most projects do induce construction related impacts, but careful site selection and proper mitigation, potential adverse environmental impacts can be avoided or minimized. However, there are some nonenvironmental impacts that need more attention. Table 13 lists some of these nonenvironmental impacts of some project activities:

Table 13: Non-environmental activities that adversely impacts local area

<table>
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<tr>
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<tbody>
<tr>
<td>(1)</td>
<td>Visual Pollution</td>
<td>Aesthetics</td>
<td>Location of wind farm, the power transmission line and distribution line has spoilt the tourist appeal of the place. Hydropower Projects or Transmission lines situated near the picturesque locations</td>
<td>Physical Cultural Resources (PCR) requirement</td>
<td>Project Proponent to take informed decision to avoid such instances. (attached below). Mostly not followed under host country laws.</td>
</tr>
<tr>
<td>(2)</td>
<td>Project Affected Persons want free power plus additional benefits from hydropower</td>
<td>Deemed benefit</td>
<td>This is fast becoming a norm as the local community feels that it has to part with its precious land without any future benefits.</td>
<td>Fair compensation but no policy on free power.</td>
<td>Government to make appropriate policy.</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>3</td>
<td>Involuntary acquisition due to large area of land requirements for hydropower and Solar power projects.</td>
<td>Price of land</td>
<td>Some villagers do not want to part with their land although the solar/hydropower/substation projects need big size contiguous lands.</td>
<td>Fair compensation</td>
<td>Project Proponent to take informed and timely decision to avoid delays in the project later.</td>
</tr>
<tr>
<td>4</td>
<td>Project Components encroach upon building, lands or effects of religious establishments</td>
<td>Religious sentiments</td>
<td>Religious trusts and establishments do not part with their land.</td>
<td>Fair compensation or replacement of land</td>
<td>Project Proponent to avoid such instances at the planning stage itself.</td>
</tr>
</tbody>
</table>

* Shows general weaknesses as noticed in several projects. Names of projects not mentioned.

**Figure 13: Visual Pollution**
85. ADB financing of each project mandates compliance with host country and ADB’s environmental regulatory frameworks and promotion of environmentally sound construction practices. During implementation, incorporation of effective corporate and human resources development and community development programs that have significant catalytic and demonstration effects. Environmental due diligence needs to be conducted for all power sector projects financed by ADB in the developing countries.

86. Some of the drawbacks noticed from implementation of past projects in the region include:

- Most projects suffer due to lack of capability of the project proponent and an inept mindset among its engineers and designers that extensive inclusion of environmental mitigation measures in the project design leads to very high construction and O&M costs in the long-run.
- During project construction, deviations to broadly accepted construction practices are quite normal by EPC contractor due to casual approach toward incorporation of environment, health and safety measures in project implementation.
- ADB as well as the host governments prescribe project mitigation measures based on generally accepted environmental impacts; not specifically based on impacts caused by construction practices being followed by the EPC contractor.
- Due to extensive focus on lowest price bidding for each contract, there are no guidelines that mandate use of better technology or innovation by the EPC contractor. This helps dis-incentivize them to innovate and/or suggest innovative environment friendly implementation as it would lead them to be more costlier in their overall costs as compared to other cheaper alternative bidders.

87. At the presentation at COP meeting in August 2014 meant for dissemination of the draft report, a critical need of understanding actual physical works on the ground by ADB officers was felt. A need for inculcating these experiences into a single Energy Community of Practice (COP) platform emerged as this knowledge would enable ADB’s energy Community of Practice (COP) platform to provide meaningful comments on environmental assessment documents and to provide realistic advice on proposals for effective development of mitigation plans.

88. Henceforth in this report, several construction practices followed in these designated sectors vis-à-vis the alternative methods available and their reasons for using them have been highlighted. These approaches are meant to deepen insights of “how” to effectively assess the environmental implications of the project construction practices, review possible project impacts and develop sound safeguards monitoring measures in line with applicable host country environmental safeguards and ADB’s SPS 2009.

89. To conclude, the ADB financing must be tied to introduction of innovation and technology while ensuring better quality and speedy completion of projects in an environmentally sustainable way. ADB has a mandate to ensure borrowers implement comprehensive safeguards management and mandatory monitoring programs designed to promote safe construction practices that are environmentally sound and innovative.
References

1. Project preparation documents for several ADB funded loan projects in South Asia.

2. Photographs from various active project sites that may or may not be ADB funded.

3. Figure 9 from Himachal Pradesh Power Corporation Limited (HPPCL), a state hydropower organization in India and an ADB project partner.

4. Glossary for transmission/distribution components from:
   

6. Glossary: Hydropower components from


8. International Electro-technical Commission

9. Other Glossary items have been compiled by author based on secondary sources as well as personal experiences of construction methodology noticed during project design and implementation.

10. The Glossary may not be a complete compendium of all technical terms used in the handbook.
Glossary of terms used

1. **Adit**: Adit or a drift is a horizontal or nearly horizontal entrance to a tunnel or mine (as opposed to a vertical shaft).

2. **Air Insulated Switchgear (AIS)**: Switches, circuit breakers, transformers and other apparatus may be interconnected by air-insulated bare conductors strung on support structures. The air space required increases with system voltage and with the lightning surge voltage rating. For medium-voltage distribution substations, metal-enclosed switchgear may be used and no live conductors exposed at all.

3. **Aluminum Conductor Steel Reinforced (ACSR)**: ACSR is cylindrical shaped concentrically stranded power conductor with one or more layers of aluminum wire on galvanized steel wire core. Also **Aluminum Conductor Composite Core (ACCC)** is a new generation conductor having one or more layers of trapezoidal shaped concentrically stranded aluminum wires on a central core of light weight carbon-glass fiber composite.

4. **Angle points**: A schedule of proposed points where the transmission line makes a deviation from a straight line along with the brief description of terrain and physical features that lie between each angle point section.

5. **Angle of Deviation in Towers**: Due to several limitations and obstructions, the tower line has to deviate from its shortest distance. This deviation is calculated in angle of deviation (0-60 degrees). There can be several deviation points in a long transmission line.

6. **Ariel Bunched Conductor (ABC)**: used in overhead distribution power lines that use several insulated phase conductors bundled together usually around a bare metallic neutral conductor.

7. **Auguring tool**: Augur is drilling tool for making holes in the ground.

8. **Automatic circuit re-closer**: A self-controlled device for interrupting and re-closing an alternating current circuit with a predetermined sequence of opening and re-closing followed by resetting, hold-closed, or lockout operation.

9. **Auxiliary Transformer**: Auxiliary Transformer is the small capacity power transformer that provides power to the auxiliary equipment of a power generating station and/or substation during its normal operation.

10. **Balance of System**: Represents all components and costs other than the photovoltaic modules/array. It includes design costs, land, site preparation, system installation, support structures, power conditioning, operation and maintenance costs, indirect storage, and related costs.

11. **Barrage**: A barrage unlike dam (See Dam) diverts water into a conductor pipe or spillway from a river/stream as per requirement of the hydropower project.

12. **Bee Line**: Initial transmission line survey is conducted along shortest distance between the two points – sending (generating end) and the receiving end (substation) of the transmission line.
13. **Bus Post Insulators and Bus bars**: bus post insulator is a stack of insulators and used in locations where minimum ground clearance of live conductor cannot be maintained. Bus bars are used for connecting the transformers, CT, CT, CR breakers to the incoming and outgoing transmission lines.

14. **Cable Trays**: A cable tray system erected in any building or civil construction that supports insulated electric cable using a system of support trays for interconnection of various equipment with control modules, distribution to input/output devices as well as signaling.

15. **Capacitor Voltage Transformers (CVT)/ Voltage Transformers (VT)**: is a transformer used in power systems to step down extra high voltage signals and provide a low voltage signal, for measurement or to operate a protective relay.

16. **Catchment Area**: The catchment area of a hydropower project constitutes of the entire area that drains into the river/stream that is used for generating power. Catchment area of one pant can supersede into catchment area of other upstream projects.

17. **Catchment Area Treatment (CAT) Plan**: CAT plan is implemented in the project area to minimize the impact of soil erosion in the catchment area into the reservoir, thereby reducing siltation of reservoir.

18. **Circuit Switchers**: Circuit switchers a set of switches for redirecting current in a substation. Circuit switchers provide equipment protection for transformers, lines, cables, and capacitor banks. They also are used to energize and de-energize capacitor banks and other circuits.

19. **Circuit breaker (CB)**: It is used as a protection device to interrupt fault currents automatically, and may be used to switch loads on and off, or to cut off a line when power is flowing in the ‘wrong’ direction.

20. **Clipping and fixing of accessories on transmission tower**: Before stringing of power conductor, several accessories need to be attached to the towers - Insulators, damping devices, clamp, CC rings, connectors, nut and bolts etc.

21. **Cofferdam**: A cofferdam is a temporary barrier constructed in the bed of the river to divert or to enclose an area during the construction period.

22. **Compensatory Afforestation (CA)**: Compensatory afforestation is carried by the project proponent in lieu of forestland being used for the project – transmission, hydropower, solar as well as distribution. Alternatively, a green belt is developed around the project area to conserve trees, flora and fauna.

23. **Concentrating photovoltaics (CPV)**: A solar technology that uses lenses or mirrors to concentrate sunlight onto high-efficiency solar cells.

24. **Concentrating solar power (CSP)**: A solar technology that use mirrors to reflect and concentrate sunlight onto receivers that convert solar energy to heat. This thermal energy is then used to produce electricity with a steam turbine or heat engine driving a generator.

25. **Conductor (Bundled)**: Bundle conductors consist of parallel cables usually in twin (two cables), quad (four cables), Hex (six cables) connected at regular intervals by different types of spacers in a cylindrical configuration.
26. **CC rings**: High voltage lines and circuits have accessories, terminations where wires or bus bars are connected to insulators that have exposed sharp edges or corners. Corona rings are installed at these points to prevent corona formation.

27. **Control Gates**: The control gates control the water that runs into the penstock that runs through the blades of the turbine to generate energy.

28. **Control Room**: In substation, a control room houses switching, protection and control equipment for substation switchyard equipment, power transformers etc.

29. **Control Wires**: Control wires are installed connecting the control house control panels to all the equipment in the substation. A typical substation control house contains several thousand feet of conduit and miles of control wire.

30. **Current Transformers (CT)**: When a large fault current flows through the circuit breaker, this is detected through the use of current transformers. The magnitude of the current transformer outputs may be used to trip the circuit breaker resulting in a disconnection of the load supplied by the circuit break from the feeding point. This seeks to isolate the fault point from the rest of the system, and allow the rest of the system to continue operating with minimal impact. Current transformers can be used to supply information for measuring power flows and the electrical inputs for the operation of protective relays associated with the transmission and distribution circuits or for power transformers.

31. **Dam**: Barrier constructed to store or divert water for different purposes, including electricity production. Dams are usually made of earth, rock or concrete.

32. **Dielectric**: (1) Any insulating medium that intervenes between two conductors. (2) A material that, having the property required to establish an electric field, is recoverable in whole or in part as electric energy.

33. **Diesel Generator set (DG set)**: DG set is the combination of a diesel engine with an electric generator used in places not connected to power grid or is an emergency power-backup if the grid fails.

34. **Disk insulators**: Disk insulators are used to attach electric power distribution/transmission lines to utility poles/towers through a system of suspension for tension. Each disk is designed to support particular voltage (typically 11 kV). These support the suspended wires without allowing the current to flow through the pole/tower to ground.

35. **Distribution Transformer (DTR) Substation**: These are located near to the end-users. Distribution substation transformers change the subtransmission voltage to lower levels for use by end-users.

36. **Double Earthing of Equipment**: Double earthing of equipment system of protection utilizes connections to two separate earthing systems/earthing mesh to provide minimum resistance to the flow of current from a short circuit or leakage or fault.

37. **Draft tube**: After the water exits the turbine the draft tube slows down the water to keep the turbine under a more constant pressure which increases turbine efficiency.

38. **Drift**: See Adits.
39. **Drum**: Drum or Reels holds the rolled conductor. A drum/Reel stand holds reels of conductor during the stringing operation. Reel stands, combined with tensioners proper back tensions on the conductor.

40. **Earth-mat**: In a substation, ground (earth) mat is a mesh of conductive material (metal rods) buried at depth of approximately 1.2 meter in ground to provide a uniform earthing to all switchgear connected to it by double earthing contacts, so that the operator on surface will not be exposed to a high differential voltage due to a fault in the substation.

41. **Electric current**: In electricity transmission, current delivered at a given voltage is measured in watts or kilowatts. In Alternating Current (AC) the flow of electric charge periodically reverses direction, whereas in Direct Current (DC), the flow of electric charge is in one direction only.

42. **Environmental services** includes sewage services, refuse disposal, sanitation and similar services, reducing vehicle emissions, noise abatement services, nature and landscape protection services and “other” environmental services. (Source: World Trade Organisation)

43. **Firewall**: is a fireproof barrier used to prevent the spread of fire between or through buildings, structures, electrical substation transformers.

44. **Fish ladder**: Series of pools arranged like steps that allow fish to pass upstream over a dam.

45. **Flushing Ducts/Flushing Gates**: The settled sediment in the sedimentation/desilting chamber is flushed out through the silt flushing tunnels (SFT) provided just below the chamber through flushing gates which allow an excess flushing discharge of 15 to 20% of the head race tunnel (HRT) discharge through the power intake for flushing of sediment.

46. **Forest Case Preparation**: Forest Management Plan that includes inventorizing the trees, flora and fauna of the area that will be impacted by any particular power project. The Forest case is submitted to government agencies to verify and approve afforestation (See Compensatory Afforestation) and other details that ensure the environmental footprint is minimized.

47. **Gas-insulated switchgear (GIS)**: For higher voltages, gas-insulated switch gear reduces the space required around live bus. Instead of bare conductors, bus and apparatus are built into pressurized tubular containers filled with sulfur hexafluoride (SF6) gas. This gas has a higher insulating value than air, allowing the dimensions of the apparatus to be reduced. In addition to air or SF6 gas, apparatus will use other insulation materials such as transformer oil, paper, porcelain, and polymer insulators.

48. **Generator**: An arrangement of magnets spinning inside a coil of wire to produce electricity.

49. **GPS**: Global Positioning System (GPS) is a space-based satellite navigation system that provides latitudinal and longitudinal locations information anywhere on Earth.

50. **Ground wire**: Overhead power lines have at least one earth wire, which is earthed (grounded) to the top of the structure to arrest any lightning strike on the conductors. This structure is earthed using double earthing to the soil.

51. **Grid-connected system**: A solar electric or photovoltaic (PV) system in which the PV array acts like a central generating plant, supplying power to the grid.
52. **HTLS Conductor**: A high-temperature, low-sag “HTLS” or High-Capacity, Low-Sag “HCLS” conductor is a bare overhead conductor that increases the efficiency, capacity and reliability of the electric transmission power grid. It usually uses a hybrid carbon and glass fiber core to replace the steel core strand.

53. **HVDS**: High Voltage Distribution system involves using High Voltage (See Voltages) over longer distribution system up to the consumer end and then stepping down transformers (See Distribution Transformers) that will reduce losses, pilferages and faults.

54. **HVDC**: A high-voltage, direct current (HVDC) electric power transmission system uses direct current (DC) instead of alternating current (AC) for the bulk transmission of electrical power. In HVDC system, typically two conductors are normally carried per line.

55. **Hydropower (“Hydro”)**: The process of generating electricity by capturing the potential energy of falling water through the use of a water wheel (turbine) to mechanically spin rotating magnets which create electrical current that can be distributed to users by transmission lines.

   - **Large Hydropower**: Although definitions vary, the U.S. Department of Energy (DOE) defines large hydropower as facilities that have a capacity of more than 30 megawatts.
   - **Small Hydropower**: The DOE defines small hydropower as facilities that have a capacity of 100 kilowatts to 30 megawatts.
   - **Micro Hydropower**: A micro hydropower plant has a capacity of up to 100 kilowatts. A small or microhydroelectric power system can produce enough electricity for a home, farm, ranch, or village.

56. **International Electro-technical Commission (IEC)**: IEC is the international standards organization for the preparation and publication of International Standards for all electrical, electronic and related technologies to be used by the industry worldwide. They are based on consensus between industry, technology developers, erectors, and end users.

57. **Intake gate**: Gated structure with hoisting arrangement at the barrage that controls the flow of water into the pressure tunnel in a hydropower project.

58. **Inverter**: A device that converts direct current electricity to alternating current either for stand-alone systems or to supply power to an electricity grid.

59. **Irradiance**: The direct, diffuse, and reflected solar radiation that strikes a surface. Usually expressed in kilowatts per square meter.

60. **Insolation**: Solar insolation is a measure of solar radiation energy received on a given surface area in a given time. Solar insolation levels are used to determine what size solar receiver is needed as the amount of insolation received at the surface depends on the angle of the sun, the atmosphere, altitude and the geographic location of the receiver.

61. **Isolators with and without earth Switch**: are device used in transmission substation required to facilitate maintenance of the lines, substation without posing any hazard to working persons on the equipment.

62. **Lattice structures**: A lattice tower is a freestanding framework of crossed metal strips usually arranged to form a diagonal pattern between the strips. These are used for electricity transmission tower lines.
63. **Lightning Arrestors (LA):** protects the insulation and conductors of the system from the damaging effects of power surges/lightning. When a lightning surge (or switching surge, which is very similar) travels along the power line to the arrester, the current from the surge is diverted through the arrester, in most cases to earth.

64. **Linear Project:** Linear projects those that involve linear access to small portions of land such as highways, pipeline, railroads, tunnels, transmission and distribution projects.

65. **Main Access Tunnel:** Tunnel that connects the surface roads to the main underground facilities.

66. **Main inlet valve:** It is situated between the turbine and the penstock and works as a gate in the water conducting system to cut the flow of water to turbine.

67. **Orifice:** The junction of surge tank with pressure shaft is restricted by means of an orifice which has a riser at the top to adjust the differential pressure.

68. **OPGW:** An optical ground wire or optical fiber composite overhead ground wire is used for grounding and communications in power transmission and distribution lines and is strung over the transmission towers.

69. **Paying out:** See Stringing.

70. **Peak Demand or Load:** Peaking power plants generally run only when there is a high demand, known as peak demand, for electricity.

71. **Penstock:** A closed conduit or pipe for conducting water to the powerhouse.

72. **Personal protective equipment (PPE):** refers to protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter. Protective equipment may be worn for job-related occupational safety and health purposes.

73. **Photovoltaic (PV) array:** An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.

74. **Physical Cultural Resources (PCR):** Defined as movable or immovable objects, sites, structures, groups of structures, and natural features and landscapes that have archaeological, paleontological, historical, architectural, religious, aesthetic, or other cultural significance. Physical cultural resources may be located in urban or rural settings and may be above or below ground or under water. Their cultural interest may be at the local, provincial, national, or international level. (Source: ADB SPS 2009)

75. **Pile Foundations:** A pile is a column of reinforced cement concrete (RCC) that extends downward deep onto the underground rock. Piled foundations consist of a number of piles connected by a ring of RCC structure called a ground beam which is normally horizontal in shape.

76. **Pin insulators:** A pin insulator is a porcelain, glass, plastic, polymer having a “grooved” shape that provides a means to hold the pole structure to the pin and electrically isolates the pole structure by securing the conductor to itself.
77. **Pipe Earthing also known as Earthing Electrode Pipes**: For Pipe type earthing, a galvanized iron (GI) pipe of 75 mm diameter, 10 feet long welded with 75 mm diameter GI flange having 6 numbers of holes for the connection of earth wires inserted into the ground by auger method (See Augur tool). The earth pit is filled with alternate layer of charcoal & salt. These are widely used in electrical installations- distribution/transmission line, transformer earthing and other such applications.

78. **Plinth**: A plinth is the base or platform upon which a column, structure or equipment such as transformer can be erected.

79. **Pooling substation**: The substation where pooling of generation of individual power generators is done for step up to higher level for further evacuation through long distance transmission lines.

80. **Portal**: Portal is the entrance to the underground tunnel at the surface.

81. **Potential Transformers (PT)**: Potential transformers are required to provide accurate voltages for meters used for billing industrial customers or utility companies.

82. **Power Conductor**: The overhead power conductor consists of bare aluminum wire conductors (reinforced with steel wire, or using composite material- carbon and glass fiber).

83. **Powerhouse**: The physical structure of an electric generating facility.

84. **Power Transformers**: Transformers raise or lower the voltage as needed to serve the transmission or distribution circuits.

85. **Pressure tunnel**: A passage that carries water from the reservoir to the surge tank.

86. **Personnel Protective Equipment (PPE)**: Equipment in a distribution system such as protective relays, cut-out switches, disconnect switches, lightning arresters, and fuses. These all work in concert to open circuits whenever a short circuit, lightning strikes or other disruptive event occurs.

87. **Pulling line**: A pilot wire or rope (steel or synthetic) used to pull the conductor into the aerial rollers for stringing.

88. **Puller**: Drum pullers are used in the stringing of conductors in conjunction with a back-tensioning devices such as a tensioner.

89. **Pumped-storage hydropower (PSH)**: Type of hydroelectric energy storage used by electric power systems for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost off-peak electric power is used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power. Although the losses of the pumping process makes the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest.

90. **Quarry**: An excavation/pit from which stone, rock, soils, sand, are obtained through cutting, blasting on a mountainside or ground. The riverbed quarry usually provide the building material during lean flow season and is harvested in by loaders and trucks.
91. **Quad Conductor**: See Bundled conductor.

92. **Reinforced Cement Concrete (RCC)**: It is a commonly utilized construction material that contains concrete with embedded steel bars for providing strength/magnify the capability of construction to carry heavy tensile and bending loads.

93. **Reservoir (Hydropower project)**: Body of water stored behind a dam.

94. **Revetment**: Revetment is a facing of stone, concrete or slab to protect the foundation of a tower, foot of a concrete wall, protecting the embankment against water current, or soil erosion or landslide on a mountainside etc.

95. **Right of way**: An electric transmission line right-of-way (ROW) is a strip of land used by Electrical utilities to construct, operate, maintain and repair the transmission line facilities.

96. **Roof bolting**: Roof bolts are drilled and fixed into the rock face inside a tunnel to support and improve the strength of the rock inside the tunnel.

97. **Rotor**: The moving part of an electric generator – NOTE: the rotor’s outer surface is covered with electromagnets and as the rotor turns inside the stator, the electrons in the copper windings “vibrate” such that their movement generates an electric current.

98. **Run-of-the-river hydropower (ROR)**: Type of hydroelectric generation whereby little or no water storage is provided. Run-of-the-river power plants may either have no storage at all, or a limited amount of storage, in which case the storage reservoir is referred to as pondage. A plant without pondage has no storage and is, therefore, subject to seasonal river flows and may operate as an intermittent energy source while a plant with pondage can regulate water flow and serve either as a peaking power plant or base load power plant.

99. **Runner**: The rotating part of the turbine that converts the energy of falling water into mechanical energy.

100. **SF6 Circuit Breakers**: These operate to switch electric circuits and equipment in and out of the system. These circuit breakers are filled with compressed sulfur-hexafluoride gas which acts to open and close the switch contacts.

101. **Sagging operations** begin as soon as the conductor stringing is completed, to establish the proper conductor tension for the conditions at the time the work is performed. The correct conductor tension and sag for various sag or control spans are detailed in the construction specifications or standards to provide proper clearances. The proper conductor tension can be obtained by establishing the proper sag in the control spans. Sighting methods using a surveyor’s transit or targets can be used to measure the sag in the conductor.

102. **SCADA (Supervisory control and data acquisition)** is a system operating with coded signals over communication channels.

103. **Scroll case**: A spiral-shaped steel intake guiding the flow into the wicket gates located just prior to the turbine.

104. **Sedimentation Chambers**: Sedimentation or De-silting chambers are constructed behind a water intake of hydropower plant for preventing sand erosion of the waterways and the turbines.
105. **Silt flushing tunnel (SFT):** SFT connects with the sedimentation/desilting chamber through the openings of designed size and spacing which are provided at bottom of the chamber.

106. **Sluice gates:** Used for hydropower projects, the sluice gates are used for controlling and measuring flow rates in channels and rivers.

107. **Soak-pit:** A soak pit, normally used for collecting waste water and sewage from toilets, is a covered, porous-walled chamber that allows water to slowly soak into the ground.

108. **Spill:** The release of water from a hydropower project without passing it through the powerhouse.

109. **Spillway:** The structure or portion of a larger structure that is used to release excess water over or around a dam.

110. **Stringing:** The overhead transmission conductor is strung across towers using a system of aerial rollers, blocks and pullers.

111. **Stringing blocks:** Larger diameter stringing blocks are required when installing conductors at all break-over towers and high running angles.

112. **Stringing aerial rollers:** A stringing block uses aerial roller array that can be suspended from an insulator or mount to a tower cross arm.

113. **Stator:** The stator is the stationary part of an electric generator – NOTE: the stator is comprised of a series of vertically oriented copper coils nestled in the slots of an iron core so that as the rotor spins its magnetic field induces a current in the stator’s windings thereby generating electricity.

114. **Step-up Transmission Substation:** Receives electric power from a nearby generating facility and uses a large power transformer to increase the voltage for transmission to distant locations.

115. **Step-down Transmission Substation:** These substations are located at switching points in an electrical grid. They connect different parts of a grid and are a source for subtransmission lines.

116. **Sub-transmission:** Sub-transmission circuit supply to distribution substations after step down from bulk transmission lines at subtransmission substations.

117. **Sulphur Hexafloride (SF6):** SF6 is inorganic, colorless, odorless, nonflammable and extremely potent greenhouse gas (about 20,000 times of methane gas) which is used in the electrical industry as a gaseous dielectric medium for high-voltage circuit breakers, switchgear, and other electrical equipment due to its much higher dielectric strength than air or dry nitrogen.

118. **Surge Arrestors:** Surge arrestors provided near transmission line entrances at the substations to achieve proper insulation.

119. **Surge Tank/Surge Shaft:** To avoid a sudden increase or decrease in pressure in the penstock, a tank is attached which stores water in it to ease the high pressure.

120. **Switchyard:** Used mainly for connections and interconnections, are essential for transmission, distribution, collection, and controlling the flow of electricity. The switchyard delivers power generated at the power plant to the electrical grid. Switchyards are generally classified by voltage level, circuit breaker and bus arrangements. Switchyards are often located directly adjacent to or near a power station.
121. **Tailrace**: The downstream channel that carries water away from a dam or powerhouse.

122. **Tailwater**: The water level downstream of the powerhouse or dam.

123. **Tensioner**: See Puller

124. **Tower Schedule**: Normally, a final alignment and pegging (location marking of towers) to be carried out. After spotting of towers, the ground clearance curves for conductor is drawn, a list of tower positions, type of tower, angle of tower is prepared using a workstation based on the tower locations.

125. **Tracking array**: A photovoltaic (PV) array that follows the path of the sun to maximize the solar radiation incident on the PV surface. The two most common orientations are (1) one axis where the array tracks the sun east to west and (2) two-axis tracking where the array points directly at the sun at all times. Tracking arrays use both the direct and diffuse sunlight. Two-axis tracking arrays capture the maximum possible daily energy.

126. **Trash racks**: A screen typically comprised of metal or concrete bars that prevents debris from entering the penstock in a hydropower project.

127. **Turbine**: A rotary engine that converts the energy of a moving stream of water, steam or gas into mechanical energy.

128. **Voltages**: The International Electro-technical Commission has classified the voltages into the following levels (IEC 60038):

   - Low Voltage - upto 1000 V
   - Medium Voltage - 1000 V to 35 kV
   - High Voltage - 35 kV to 220 kV
   - Extra High Voltage - 220 kV to 800 kV.
   - Ultra High Voltage - voltages above 800 kV.
   - In addition, the IEC defines a voltage band known as the Extra Low Voltage with an AC voltage less than 70 V.

129. **Water Intake**: The entrance to a turbine unit at a hydroelectric dam.

130. **Wicket gates**: Adjustable elements that control the flow of water from the scroll case into the turbine passage in a hydropower project.
Handbook on Construction Techniques

The report highlights a broad spectrum of environmental impacts triggered due to construction, operation, and maintenance and their mitigation for four sectors: (i) power transmission, (ii) distribution, (iii) run-of-river hydropower, and (iv) solar photovoltaic generation projects for dissemination among Asian Development Bank specialists working in the energy sector and environment fields.

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