TECHNICAL ASSESSMENT OF TRANCHE 1 PROJECTS

A. Project locations

Tranche 1 will upgrade four power plants and build three transmission lines. Their locations are shown in Figure 1.

Figure 1: Geographic Locations of Subprojects Shown in PGCB Grid Map

MT= Mymensingh-Tangail, CRK=Chandraghona-Rangamati-Khagrachari, BN=Brahmanbaria-Narshingdi
B. Energy Efficiency Improvement of Power Plants

An open cycle gas turbine power plant uses natural gas to produce a gas-air mixture at high pressure, which is burned inside a combustion chamber, and then input to a multi-stage rotating turbine. The operating temperature of a modern gas turbine can be as high as 950°C. The energy in gas-air mixture is absorbed into the rotating turbine. The turbine drives an electricity generator. Thus, the energy content in the input fuel is converted to electricity. The exhaust from the turbine is typically at 550°C, thus carries a considerable amount of heat. This waste heat is released to the atmosphere. Gas turbine technology has several advantages over conventional power generating technologies which use steam as the carrier of energy. These advantages are (i) lower investment per unit of capacity, (ii) faster construction schedules, and (iii) in day to day operation, the ability to start from cold condition to raise the output to full power level within a few minutes. Accordingly, gas turbines are used for power generation to serve national grids, for both base load requirements as well for daily peaking requirements. As the waste heat is released to atmosphere, the fuel/gas cycle in a gas turbine is identified as an “open cycle”.

The temperature of waste heat released is high. In any thermal exhaust, if the temperature is higher than 200°C, there is a potential to capture the waste heat and to use it for heating in an industrial process, or in case of higher temperatures, to produce electricity. At the exhaust temperature of 550°C, the waste heat from an open cycle power plant is of “high quality”, and it can be used to produce electricity. In a combined cycle power plant, the waste heat from the gas turbine is sent through a waste heat boiler, more commonly known as a heat recovery steam generator (HRSG), to produce steam. In a conventional power plant, the boiler is fed with fuel and the hot gases from the combustion of fuel passes through the boiler to produce steam. In a waste heat boiler or a HRSG, there is no fuel supply, but the hot gas exhaust from the nearby gas turbine passes through the HRSG to produce steam. Steam generated in the HRSG is then supplied to a turbine to produce electricity, in the same way it is done in a conventional steam power plant. As the fuel-gas cycle of a gas turbine is followed by the water-steam cycle of a steam turbine, this kind of a power plant is known as a “combined cycle” power plant. Figure 2 describes the key components of a combined cycle power plant.

Figure 2: Key components of a combined cycle power plant

Compared with a gas turbine power plant, the water-steam cycle in a HRSG requires cooling water. The construction period on site is also longer, typically two years, compared

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1 Gas turbines may also be designed to burn liquid fuels, such as kerosene, diesel, or heavy fuel.
with a few months for a gas turbine, owing to the need for more civil and mechanical engineering work compared with a gas turbine. Unlike a gas turbine, the HRSG-turbine cannot be brought to full power with a few minutes. It requires several hours to raise the output of a HRSG to full output. Therefore, combined cycle power plant are not suitable for daily starts and stops, owing to the longer time required to increase power output and the loss of energy during the period of run-up. Limited part-load operation is possible, where the power plant can be operated at different load levels between a minimum power output and its maximum rated power output. Here too, the efficiency would be lower. Therefore, combined cycle power plants are best operated at full capacity throughout the day for a continuous period of time.

5. A total of four open cycle, gas-fired power plants (two operational for about ten years, one commissioned in March 2012, and the fourth one to be commissioned in 2013) will be converted to combined cycle operation. The power plants and their capacities after conversion would be, (i) Khulna (225 MW), (ii) Baghabari (150 MW), (iii) Sylhet (225 MW), and (iv) Shahjibazar (105 MW). Details of the power plants are given in Table 1. In assessing the technical feasibility of the open cycle gas turbine power plants proposed to be financed in tranche 1, the following factors were examined. (i) the operating performance of the power plants (for Baghabari and Shahjibazar, which are operational) and the expected performance of Sylhet and Khulna power plants, (ii) the availability of space for the proposed expansion, (iii) proposed method of cooling water supply to the steam cycle, (iv) proposed interconnection to the grid, and (v) availability of grid capacity to transmit the power towards the intended load centres.

### Table 1: Power Plants to be Converted in Tranche 1, Component 1

<table>
<thead>
<tr>
<th>Activity in Component 1</th>
<th>Commissioning year of existing power plant</th>
<th>Present capacity (MW)</th>
<th>Capacity after upgrade (MW)</th>
<th>Present operating efficiency: Net, on LHV* basis</th>
<th>Estimated operating efficiency of new power plant: Net, on LHV* basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Conversion of Khulna power plant from open cycle to combined cycle</td>
<td>presently under construction, scheduled commissioning mid-2013</td>
<td>150</td>
<td>225</td>
<td>35.98% (expected)</td>
<td>50%</td>
</tr>
<tr>
<td>1.2 Conversion of Baghabari power plant generating unit no 2 from open cycle to combined cycle</td>
<td>2001</td>
<td>100</td>
<td>150</td>
<td>28.30%</td>
<td>50%</td>
</tr>
<tr>
<td>1.3 Conversion of Sylhet power plant from open cycle to combined cycle</td>
<td>2012</td>
<td>150</td>
<td>225</td>
<td>36% (expected, as the power plant was commissioned in March 2012, no operational data is available)</td>
<td>50%</td>
</tr>
<tr>
<td>1.4 Conversion of Shahjibazar power plant generating unit Nos 8 and 9 from open cycle to combined cycle</td>
<td>2000</td>
<td>70</td>
<td>105</td>
<td>27%</td>
<td>50%</td>
</tr>
</tbody>
</table>

*a LHV = lower heating value. This is the basis of considering the heat content of fuel, when defining the efficiency of a power plant. HHV is the higher heating value. For natural gas, efficiency defined at LHV is typically 10% higher than the efficiency defined at HHV.

6. The technical assessment was conducted by making site visits to each power plant, examining operational records and conducting discussions with the power plant managers and operations staff, review of information available the Detailed Project Proposals (DPPs),
information available in the planning documents published by BPDB, and where relevant, and by reviewing load flow studies conducted by PGCB, to verify the transmission capabilities of the network.

1. Conversion of Khulna Power Plant

The Khulna open cycle power plant is being built within the Goalpara power station premises in the town of Khulna in Khulna District. The Bhairab river is close by, and the nearest river port is Mongla, 40 km downstream on the Bhairab river. The power plant is owned by North West Power Generation Company Ltd. (NWPGCL), an enterprise of the Bangladesh Power Development Board (BPDB). This 150 MW open cycle power plant (manufacturer: ALSTOM, frame: GT13E2) is under construction at the time of preparing this MFF, and commissioning is expected in May 2013. Construction work on site has commenced and is at a preliminary stage. The power plant has been designed to operate on either natural gas or diesel. The configuration is 1x150 MW open cycle combustion turbine, with a net output of 157.7 MW and a full-load net heat rate of 10,005 kJ/kWh at site conditions, when fired with natural gas. Accordingly, the net efficiency of the open cycle stage is expected to be 35.98%.

8. The proposed project will build the following key equipment: (i) 1x75 MW heat recovery steam generator, (ii) 1x75 MW steam turbine generating set, (iii) 1x120 MVA step-up transformer and interconnection to the grid at 132 kV, and (iv) balance of plant and all associated auxiliary systems. The energy input to the steam generator will be the exhaust heat from the gas turbine, and supplementary use of fuel is not necessary. Once completed, the nominal rating of the power plant is estimated to be 225 MW, whereas the exact output at site conditions would be established during the detailed design stage. The nominal net efficiency of the power plant expected after the upgrade is 51%, reflecting a net heat rate of 7059 kJ/kWh. The output of the power plant will be dispatched into the national grid through the existing Khulna central substation at 132 kV.

9. Supply of natural gas to the power plant will be through the Bheramara-Khulna gas pipeline, which is presently under construction. The capacity expansion will not require any additional gas supplies, because it will be recovering waste heat from the gas turbine. There are two storage tanks being built on-site, each of 5000 tonne capacity to store diesel, in case the power plant is required to operate on diesel. This storage capacity would be adequate to operate the power plant continuously for a period of 11 days. However, operation on diesel for prolonged periods is not expected owing to the high cost of diesel compared with natural gas.

10. The cooling system for the HRSG will require cooling water, which will be drawn from ground water sources for make-up. More specific details of the cooling system, water requirements and availability would be studied in the initial environmental examination (IEE).

11. The capacity at the Khulna central 132 kV substation is adequate to receive the output of the Khulna power plant (225 MW in total) and deliver the power to the grid. This information was verified by load flow studies conducted by System Planning Division of PGCB Ltd. The load flow analysis was conducted for year 2015, for the evening peak and with all generating plants on economic dispatch. No line overloads were observed when the 75 MW capacity expansion is added to the system, in the load flow for year 2015. More detailed analysis including (i) a load flow analysis for years 2020 and 2025, (ii) stability, and (iii) short-circuit studies should be conducted at the project detailed design stage.
2. Conversion of Baghabari Power Plant

12. The Baghabari power plant is located in the Shirajganj District of the Rajshahi Division. The power plant is owned by Bangladesh Power Development Board (BPDB). There are two other open cycle power plants on site and a barge-mounted open cycle power plant at an adjacent site. The power plant to be upgraded is presently a 1x100 MW open cycle power plant (manufacturer: GE, frame 9171E) commissioned in November 2001. The power plant has been designed to operate on either natural gas or diesel. However, the power plant is presently operated entirely on natural gas, and presently the diesel delivery system has been diverted to another power plant, and the dual fuel facility is no longer available. The power plant reported an operating efficiency in the range 28.3% to 30.2% in the four months ending February 2012, and an availability in the range 83% to 97% over the same period. The power plant is presently operated on base load. The exhaust temperature is 560°C.

13. The proposed project will build the following key equipment: (i) 1x50 MW heat recovery steam generator, (ii) 1x50 MW steam turbine generating set, (iii) step-up transformers and interconnection to the grid at 132 kV, and (iv) balance of plant and all associated auxiliary systems. The energy input to the steam generator will be the exhaust heat from the gas turbine, and supplementary use of fuel is not necessary. Once completed, the nominal rating of the power plant is estimated to be 150 MW, whereas the exact output at site conditions would be established during the detailed design stage. The nominal net efficiency of the power plant expected after the upgrade is 50%. The output of the power plant will be dispatched into the national grid through the Baghabari substation at 132 kV.

14. Space for the expansion is not available within the existing boundaries of the power plant. The adjoining land has been purchased by BPDB and its ownership is now with the power plant. However, BPDB has not taken possession of the land as yet, and agricultural activities by previous owners are continuing on this land, until the expansion project is launched.

15. Supply of natural gas to the power plant is presently boosted from 10 bar to 24 bar, using a gas booster station located within the power plant. The capacity expansion will not require any additional gas supplies, because it will be recovering waste heat from the gas turbine. The power plant will use cooling water from ground water sources. More specific details of the cooling system, water requirements and availability would be studied in the IEE.

16. The capacity at the Baghabari 132 kV substation is adequate to receive the output of the additional 50 MW of capacity and deliver the power to the grid. There is an additional bay in the substation for this purpose. However, load flow studies conducted by System Planning Division of PGCB Ltd. for year 2015, indicate that there will be line overloads when the 50 MW capacity expansion is added to the system. The overloaded lines are Baghabari-Shirajganj and Baghabari-Shahzadpur. This can be overcome by using the spare capacity of the 132 kV/230kV interbus transformers between the Baghabari 132kV/230kV substations. This arrangement has been modelled by PGCB and has been found to be satisfactory. More detailed analysis including (i) a load flow analysis for years 2020 and 2025, (ii) stability and (iii) short-circuit studies should be conducted in the project detailed design stage.

3. Conversion of Sylhet Power Plant

17. The Baghabari power plant is located in the Hobiganj District of the Sylhet Division. The power plant is owned by Bangladesh Power Development Board (BPDB). The power plant to be upgraded is presently a 1x150 MW open cycle power plant (manufacturer: GE, frame 9171E) commissioned recently, in March 2012. The power plant has been designed to operate on natural gas. Operating information is not available, as the power plant was
commissioned recently. The designed net heat rate is about 10,000 kJ/kWh, indicating a net efficiency of about 36%. The power plant is scheduled to be operated on base load.

18. The proposed project will build the following key equipment: (i) 1x75 MW heat recovery steam generator, (ii) 1x75 MW steam turbine generating set, (iii) step-up transformers and interconnection to the grid at 132 kV, (iv) balance of plant and all associated auxiliary systems. The energy input to the steam generator will be the exhaust heat from the gas turbine, and supplementary use of fuel is not necessary. Once completed, the nominal rating of the power plant is estimated to be 225 MW, whereas the exact output at site conditions would be established during the detailed design stage. The nominal net efficiency of the power plant expected after the upgrade is 50%. The output of the power plant will be dispatched into the national grid through the Sylhet substation at 132 kV.

19. Space for the expansion is available within the existing boundaries of the power plant. The adjoining land belongs to BPDB and some housing on the land would require to be cleared, to allow for the buffer zone once the power plant is built. Additionally, land would be required during construction for the site work, and such land for temporary use is available in the vicinity of the power plant.

20. Supply of natural gas to the power plant is from the gas mains and no boosting facility is required. The capacity expansion will not require any additional gas supplies, because it will be recovering waste heat from the gas turbine. Cooling water requirements are presently met by ground water sources. Once converted to combined cycle operation, the cooling water system makeup would also be from ground water sources.

21. The capacity at the Sylhet 132 kV substation is adequate to receive the output of the additional 75 MW of capacity and deliver the power to the grid. There is a bay in the substation earmarked for this purpose. Load flow studies conducted by System Planning Division of PGCB Ltd. for year 2015, indicate that when the 75 MW capacity expansion is added to the system, the power can be dispatched to the grid at all times. However at present, the output of the Sylhet power plant cannot be fully dispatched during off-peak periods, because of overloading of the Sylhet-Fenchugang lines. This constraint would be relieved when the on-going improvements to the 230 kV network is completed. More detailed analysis including (i) a load flow analysis for years 2020 and 2025, (ii) stability and (iii) short-circuit studies should be conducted in the project detailed design stage.

4. Conversion of Shahjibazar power plant

22. The Shahjibazar power plant is located in the Hobiganj District of the Sylhet Division. The power plant is owned by Bangladesh Power Development Board (BPDB). There are several power plants on site (BPDB) and adjacent sites (IPPs), feeding into the Shahjibazar substation. The project will convert two open cycle power plants on site to combined cycle operation. The power plants to be upgraded is presently a 2x35 MW skid-mounted open cycle power plants (manufacturer: GE, frame 6) commissioned in October 2000, designated as unit nos. 8 and 9. The power plant has been designed to operate on natural gas and no diesel backup is available. The present output is about 2x35MW. The power plant reported an operating efficiency of about 27% in February-March 2012, and an availability of 99% over the same period, and 91% (unit 8) and 98% (unit 9) in year 2011. The power plant is presently operated on peaking mode, and the reported monthly capacity factors of 64% to 75% over February-March 2012. The exhaust temperature is 550°C.

23. The proposed project will build the following key equipment: (i) 1x35 MW heat recovery steam generator, (ii) 1x35 MW steam turbine generating set, (iii) step-up transformers and interconnection to the grid at 132 kV, (iv) balance of plant and all
associated auxiliary systems. The energy input to the steam generator will be the exhaust heat from the gas turbine, and supplementary use of fuel is not necessary. Once completed, the nominal rating of the power plant is estimated to be 105 MW on a 2-on-1 arrangement, whereas the exact output at site conditions would be established during the detailed design stage. The nominal net efficiency of the power plant expected after the upgrade is 48%. The output of the power plant will be dispatched into the national grid through the Shahjibazar substation at 132 kV.

Space for the expansion is not available within the immediate boundaries of the power plant. The adjoining land belongs to by BPDB and it has a workshop and other buildings belonging to BPDB. These will be cleared to locate the expansion. Supply of natural gas to the power plant is from the nearby gas fields. The capacity expansion will not require any additional gas supplies, because it will be recovering waste heat from the gas turbine. The power plant will use cooling water from ground water sources.

The capacity at the Shahjibazar 132 kV substation is adequate to receive the output of the additional 35 MW of capacity and deliver the power to the grid. There is an additional bay in the substation for this purpose. However, load flow studies conducted by System Planning Division of PGCB Ltd. for year 2015, indicate that loading on Shahjibazar-Brahmanbaria are at their limit, and are likely to be overloaded during off-peak, when the 50 MW customer demand at Shahjibazar reduces. A re-arrangement of the transmission network and the on-going development of the 230 kV network will resolve this limitation, as evidenced in load flow studies. More detailed analysis including (i) a load flow analysis for years 2020 and 2025, (ii) stability and (iii) short-circuit studies should be conducted in the project detailed design stage.

### C. Transmission and Substation Development

Transmission and substation facilities to be developed in tranche 1 are summarized in Table 2. Their geographic locations are shown in Figure 1.

**Table 2: Transmission and Substations to be Developed in Tranche 1, Component 2**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Details</th>
<th>Line length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New transmission line from Mymensingh to Tangail (MT line) and improvements to associated substations</td>
<td>132 kV, double circuit</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New transmission line from Chandraghona to Khagrachari through Rangamati (CRK line) and two new substations at Khagrachari through Rangamati</td>
<td>132 kV, double circuit</td>
<td>80</td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New transmission line from Brahmanbaria to Narshingdi (BN line) through Nabinagar, and improvements to associated substations</td>
<td>132 kV, double circuit</td>
<td>55</td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The transmission proposals provided by PGCB were reviewed for their importance for the Bangladesh network to improve transmission capacity and reliability, and to transfer power generated from lower cost, power sources to load centers. The evaluation was conducted with (i) information available in the master plan report and individual DPPs, (ii) discussions with the transmission planning engineers of PGCB, and (iii) by reviewing the load flow studies conducted with and without each subproject proposed to be built in the project. The outcome of the evaluation was in agreement with the proposals provided by PGCB. The following specific details were reviewed during the study. All the lines proposed are for the 132 kV transmission network. Several substations too have been proposed.
1. **Mymensingh-Tangail (MT) Transmission Line and substations**

28. Mymensingh is a key substation to which Rural Power Company Ltd (RPCL) power plants are connected. RPCL is about 6 km away from the Mymensingh substation. In addition to meeting the customer demand at Mymensingh, RPCL also supplies power to Netrokona and Jamalpur, to the north-east and north-west of Mymensingh, respectively. The proposed MT transmission line will be about 100 km long. The existing substations at RPCL Mymensingh and Tangail will be extended. Once completed, the transmission line will relieve the load on several lines in the region and provide a reliable transmission facility for power flowing towards the south of the country.

29. Substation extensions have been proposed at both end of the line (at RPCL Mymensingh and at Tangail. These extensions are required for the connection of the new line. Beyond that, no delivery from the new line to the distribution network has been planned. Both Mymensingh and Tangail have delivery to distribution networks, and this line would strengthen the supply capacity off each substation.

2. **Chandraghona-Rangamati-Khagrachari (CRK) Transmission Line**

30. Rangamati and Khagrachari are districts north of Chandagghona, in southern Bangladesh. The distance from Chandraghona to Khagrachari is about 100 km, and the entire region is served through three 33 kV lines: Chandraghona-Rangamati (30 km), Hathazari-Khagrachari (105 km) and Hathazari-Rangamati (105 km). The estimated demand northward of Chandraghona is about 60 MW. The above demand cannot be served over 33 kV lines alone, and significant load shedding currently occurs to manage the load level on the existing 33 kV lines. The estimated peak demand served by the existing 33 kV network is 23 MW (8 MW in Khagrachari and 15 MW in Rangamati). Accordingly, the suppressed demand is estimated to be 37 MW. The delivery voltage at Khagrachari is estimated to be 85% of 33 kV, which is relatively low. The estimated line loss at peak time is 4 MW, which is 13% of input to the 33 kV line, and the estimated annual energy loss is 25 GWh (14% of input) in the present network of 33 kV lines serving this area. These losses will be eliminated with the proposed project and the existing 33 kV lines will continue to function as distribution lines from the two new substations, to serve customers in the region with a higher quality of supply.

31. New substations are planned at Rangamati and Khagrachari, the key districts to be served by the new line. These two substations are new outdoor substations with a supply capacity of 50 MVA each (firm capacity 25 MVA each). Considering the demand at each location is about 30 MW at present, the planned substation capacity will be adequate to serve the present demand and an increase of about 30% above the present demand in each district. While this substation capacity is adequate for now, considering the low electrification rate and the likely pick-up of suppressed demand in these two districts when a stronger transmission connection is built through the project, more space should be provided at the two new substations built at Rangamati and Khagrachari for future expansion. Chandraghona substation will be upgraded to enable the new line to take off.

3. **Brahmanbaria-Narsingdi (BN) Transmission Line**

32. Power from Brahmanbaria and other power plants north-east of Dhaka flow towards the load centers in Dhaka through Ashuganj and Ghorasal 230 kV and 132 kV substations. At peak time, the 132 kV lines originating from Brahmanbaria are close to their operating capacity. There is no reliability of this system where both circuits are loaded to the limit. The proposed interconnection between Brahmanbaria and Narshingdi will relieve the 132 kV network and provide a direct line to transfer power toward load centers north of Dhaka, and
feed into the Dhaka 132 kV ring. The proposed line is expected to reduce power losses by 4 MW at peak and 6 MW off-peak.

33. Extension of substations has been proposed at Brahmanbaria and Narshingdi, as required to build the new line. No new substations are planned along the line. However, a 50 MVA addition of transformer capacity has been proposed for the existing Narshingdi substation.