EXPLANATORY NOTES FOR GENERATING FACILITY/UNIT

Table 1: Generation Facility Standing Capability Data:

The following data are required according to Appendix 6E – Standing Capability Data, Chapter Six of Singapore Electricity Market Rules:

- Name of Generating Plant E.1.1.1
- Maximum Generating Capacity E.1.1.2 (This shall be the maximum continuous rating of the generation facility at ambient temperature of 32^{o}C)
- GT/ST capacity (The maximum generating capacity breakdown into GT MW and ST MW. This applies only to Multi-shaft plant configuration.)
- Maximum ramp-up rate E.1.1.3 (This shall be expressed in MW/min rounding to one decimal place.)
- Maximum ramp-down rate E.1.1.4 (This shall be expressed in MW/min rounding to one decimal place.)
- Maximum Reserve capacity E.1.1.5 (This shall be specified for frequency drop of 0.6 Hz. For generation facility undergoing commissioning and/or unable to provide reserve, this shall be entered as "N.A".)
- Maximum combined generation capacity and reserve capacity E.1.1.6 (This shall be specified for frequency drop of 0.6 Hz. For generation facility undergoing commissioning and/or unable to provide reserve, this shall be entered as "N.A".)
- Reserve proportionality factor representing the ratio of the Reserve capability at lowest energy output level and Lowload (the lowest energy output level), calculated to three decimal places.E.1.1.7. (For generation facility undergoing commissioning and/or unable to provide reserve, this shall be entered as "N.A".)

$$\mathrm{Re}\,serve\,\mathrm{Pr}\,oportionalityfactor = \frac{\mathrm{Re}\,serveCapability@\,Lowload}{Lowload}$$

- Maximum regulation capacity E.1.1.8 (For generation facility undergoing commissioning and/or unable to provide regulation reserve, this shall be entered as "N.A".)
- Maximum energy output at which AGC can operate E.1.1.9 (For generation facility undergoing commissioning and/or unable to provide AGC, this shall be entered as "N.A".)
- Minimum output at which AGC can operate E.1.1.10 (For generation facility undergoing commissioning and/or unable to provide AGC, this shall be entered as "N.A".)
- Time delay before responding to contingency event E.1.1.11 (For generation facility undergoing commissioning and/or unable to provide reserves during contingency, this shall be entered as "N.A".)
- Low Load E.1.1.12 (For generation facility undergoing commissioning and/or unable to provide reserve, this shall be entered as "N.A".)
- Reserve capacity E.1.1.13 (This shall be specified for frequency drop of 0.6 Hz rounding off to three decimal places. The specified reserve envelope shall satisfy the convexity check. (For generation facility undergoing commissioning and/or unable to provide reserve, this shall be entered as "N.A".)
- Minimum Stable Load (MSL) E.1.1.14 being the minimum stable load level of the *generation facility* at which the *generation facility* can maintain stable operation.

- Where the *generation facility* has or seeks to have its minimum stable load level modelled in the MCE for dispatch purpose, ie if 'Yes' is indicated, the *Generation Licensee* shall ensure that the *generation facility* is capable of reaching MSL within one dispatch period.

Table 2: Generation Facility Operational Parameters

- Generator Types (steam/gas turbine/CCP) are
  - Conventional Steam Turbine Unit
  - Combustion Gas Turbine – Open Cycle Gas Turbine Unit
  - Combined Cycle Plant (To state CCP configuration, i.e GT & Steam combination e.g. Single or Mulit shaft configuration)
  - Combined Steam & Power Generating Plant – Cogen Plant (To state Cogen configuration)

  A brief description of power plant configuration shall be provided.

- Installed capacity shall reflect the generation facility rated MW and MVA.
- Maximum Generation Capacity (Emergency) shall be the maximum capability of the generation facility within the duration specified without damaging the facility
- Generating unit's works units (auxiliaries and station load). Total power required for auxiliaries and internal load intended to be supplied by *generation facility*.
- Voltage Level of Connection Point to Grid
  This normally refers to the High voltage end of Generating Unit's Transformer.
- Maximum transient ramp-up rate
- Maximum transient ramp-down rate
  This is the maximum loading/deloading rate, which do not have to be sustained in the long term. It is applicable to *generation facilities* that are capable of supporting transient loading conditions via its thermal inertia. E.g. generating unit that provides Regulation service.
- Minimum Stable Load (MSL)is the minimum stable load level of the generating unit to maintain a stable operation.
  Typical values of MSL:
  - For conventional steam turbines, MSL is normally around 50% to 60% of its Nominal Rated Capacity.
  - For combustion gas turbines (Open Cycle) MSL is normally around 20% to 30% of its Nominal Rated Capacity.
  - For CCPs & Cogens MSL depends very much on the configuration. For Full Block (all GTs & STs are in service), it is normally around 50% to 60% of its Nominal Rated Capacity.

- Droop Factor
  This is the *generation facility's* frequency bias (governor sensitivity) as p.u. (percentage) value. It is normally within the range of 3% to 5%.

- AGC command Reaction Delay
  This is the number of seconds before a command starts to take effect on the facility after receiving a step change (raise/lower) command from the Automatic Generation Control (AGC) System.

- Step Change in Facility Set-point per AGC command
  This is the MW step change of *generation facility* in response to a 0.1 Second raise/lower pulse-width issued by the AGC system. It is usually measured at the most responsive region of the *generation facility*.
  The AGC system would issue commands equivalent to pulses of width varying from 0.1 second to 1.0 second, depending on above characteristic of the *generation facility* and the required step change as a result of fluctuation in load frequency of the system.

- Average Turbine Time Constant
  This is the facility's average response time in seconds, which measures the time response of unit to reach 63% of its steady state value. E.g. if the facility receive a command (pulse) to raise its output by 10MW, and it takes 6 seconds to increase its output by 6MW, then the Average Turbine Time Constant would be 6 seconds assuming there is no command delay.

- Prime Mover Time Constant
  This is the basic turbine time constant of the *generation facility*. It is normally same as the Average Turbine Time Constant above.

- Maximum Step Change in Facility Output/Max. Stored Energy in Boiler
  This is the maximum allowed MW step change in generation. It normally represents the maximum stored energy in drum type boiler. AGC system would issue raise/lower commands to the *generation facility*, at interval of 4 seconds for the required step change in output until this Maximum is reached.

- Governor Dead Band
  This value, in MW, represents the backlash present in the governor linkage system. AGC system would normally not issue raise/lower command to the *generation facility* if the difference between the desirable output and actual output is less than the Governor Dead Band.

Generating Facility Startup Data

- Time Facility has been Offline to have status Hot/Warm/Cold
  This states the profile to be used when a *generation facility* is in Hot, Warm or Cold state (determined by the number of hours since the facility was last shutdown). In the following example, Hot: <8 hours and Cold: >32 hours mean that the facility is Hot if the facility's last shutdown was less than 8 hours ago, Warm if the facility's last shutdown was between 8 and 32 hours ago and Cold if the facility's last shutdown was more than 32 hours ago.

- Minimum Shutdown Time
  This is an operation parameter of a *generation facility* that represents the minimum time that the *generation facility* must be shutdown (from de-synchronisation to next synchronisation) before being restarted.

- Time from Notification given to Synchronisation to the Grid
  Conventional Steam Turbine Generating Unit typically takes hours to synchronise to the Grid after receiving instruction from System Control; while Combustion Gas Turbine (Open Cycle) Generating Unit can be synchronised to the Grid in less than 15 minutes.
- Startup curve (from Synchronisation to Full Load)
  The piecewise-linear startup curve shall be defined by a series of coordinate pairs of time from start and MW loading such that by joining adjacent coordinate pairs, the startup curve can be reproduced. The data to be provided shall represent the actual technical capability of the generating unit. It should not be the profile tested as part of the commissioning tests which follows despatch schedule.

Generating Facility Shutdown Data

- Minimum On-Time
  This is an operation parameter of a generation facility that represents the minimum time that the generation facility must operate after synchronisation after it can be de-synchronised.
- Shutdown curve (from MSL to De- Synchronisation)
  The piecewise-linear shutdown curve shall be defined by a series of coordinate pairs of time from start and MW loading such that by joining adjacent coordinate pairs, the shutdown curve can be reproduced. The data to be provided shall represent the actual technical capability of the generating unit. It should not be the profile tested as part of the commissioning tests which follows despatch schedule. If there is more than 1 shutdown profile, please provide.

Table 3/3A: Generating Unit Technical Parameters

The following references give examples of the required modelling detail and structure. Modelling information that includes block diagrams must use standard symbols for blocks such as integration blocks, summation blocks, and so forth, as used in these references. When necessary, written material explaining the functions of equipment controls shall also be provided.

- Block Diagram Symbols for Dynamic Systems
  - "Conventions for Block Diagram Representation", IEEE Transactions on Power Systems, Vol. PWRS-1, No. 3, August 1986, pp. 95-100.
- Automatic Voltage Regulators and Power System Stabilizers
  - "IEEE Recommended Practice for Excitation Systems for Power Stability Studies", IEEE Standard 421.5-1992.
  - "Computer Models for Representation of Digital-Based Excitation Systems", IEEE Transactions on Energy Conversion, Vol. 11, No. 3, September 1996.
- Governor, Prime Mover, Energy Source
  - "Dynamic Models for Fossil Fueled Steam Units in Power System Studies", IEEE Transactions on Power Systems, Vol. 6, No. 2, May 1991.

- "Dynamic Models for Combined Cycle Plants in Power System Studies", IEEE Transactions on Power Systems, Vol. 9, No. 3. August 1994.
- "Simplified Mathematical Representation of Heavy-Duty Gas Turbines, "Journal of Engineering for Power, October 1983, Vol. 105.
- "Simplified Mathematical Representation of Single Shaft Gas Turbines", Turbomachinery International, July/August 1992.
- "Boiler Models for System Dynamic Performance Studies", IEEE Transactions on Power Systems, Vol. 6, No. 1, February 1991.

Generating facility Input/Output Data

The Heat (input/output) Rate curve of a unit shows the heat power input for an electrical power output and is a machine characteristic. The incremental heat rate curve is obtained by differentiating the Heat Rate curve. To be mathematically processed, this characteristic has to be monotonically increasing function of the power output (convex input/output curves).

Separate tables may be provided for each of the fuel type. In addition to the tabulated data, average heat rate curve shall also be provided.

The fuel type and its source(s) of supply for both primary and alternate firing shall be provided.

EXPLANATORY NOTES FOR INFORMATION ON NATURAL GAS FACILITY

General:

- For all information submitted, it must be accompanied with copies of the schematic diagram with changes highlighted.
- Specifically the *Generation or Wholesaler (Generation) Licensee* shall provide details of the following:
  - What is the general control methodology or operating philosophy used to operate the receiving/metering station (e.g. pressure or flow control)?
  - Operating Procedures - Detailed descriptions of the operating procedures, control logic and methodology used to operate the stations.

Table 13A: Gas Supply Description:

This section describes the data that are required for the modeling of the offtakes:

- Name of Natural Gas Supplier (s)
- Minimum contractual pressure – Minimum contractual pressure arrangement between gas supplier and offtaker.
- Maximum Daily Quantity (MDQ) – Maximum daily quantity of natural gas contracted by the gas seller to the gas buyer
- Daily Contractual Quantity (DCQ) - Average daily quantity of natural gas contracted by the gas seller to the gas buyer
- Target date for gas supply – Date for offtaker to receive gas supply.

Table 13B: Offtaker's Metering/Receiving Station Description:

This section describes the data that are required for the modeling of the offtakes:

- Total consumption used for electricity generation - MW output and flow consumption during typical and maximum operation.
- Total consumption used loads – flow consumption for load during typical and maximum operation
- Nominal Operating Pressure at Regulation Station – Pressure measured at regulation station during normal operating condition.
- Maximum allowable operating pressure – Maximum allowable operating pressure limited by the technical constraint in offtaker's metering/receiving station.
- Maximum Design Flow Limit – Maximum allowable operating flow limited by the technical constraint in the offtaker's metering/receiving station.
- Flow limiter installed – Device use to set the maximum permissible gas flow into the offtaker's metering/receiving station.

Table 13C: Generating Unit Physical Description:

- Gas Consumption – Flow consumption of generating unit during typical and maximum operation.
- Low Pressure Trip Setting at Generating Unit Inlet – Pressure trip set point for each generating unit.
- Pressure drop across metering/receiving station and GT inlet – Pressure difference between metering/receiving station and GT inlet
- Arrangement in % between Primary/Secondary natural gas supplier if commingled during normal operation – Breakdown of natural gas between gas sources if the generating unit is consuming gas from more than one sources.
- Fuel Changeover Facility to provide details such as the diesel fuel system, ramp up rate, deloading rates, permissible loading in MW for the various fuel changover, and the fuel changeover time

Table 13D: Compressor Physical Description:

This section describes the data that are required for the modeling of the compressor:

- Compressor Low Pressure Trip Setting – Pressure trip set point where compressor will not in operation.
- Adiabatic Efficiency –Performance of a compressor during heat exchange.
- Centrifugal Compressor – Centrifugal Performance curve ID (CPID) for the compressor.
- Valve Loss – Valve loss during operation of compressor.
- Mechanical Efficiency– Ratio of the actual output mechanical power to the rated power of the compressor.
- Auxiliary Load – Additional load for the network element, to increase the power requirements.
- Ambient Temperature – Ambient air temperature value, which will be used for the driver's power calculations.
- Maximum Down Pressure – Maximum discharge pressure constraint allowed at the downstream node of the compressor.
- Minimum Up Pressure – Minimum suction pressure constraint allowed at the upstream node of the compressor.
- Maximum Power – Maximum power constraint to limit the horsepower available for the compressor's operation.
- Compression Ratio – $\frac{\text{Downstream pressure in absolute units}}{\text{Upstream pressure in absolute units}}$
- Maximum Speed – Maximum speed at which the compressor will be allowed to operate.
- Minimum Speed – Minimum speed at which the compressor will be allowed to operate.
- Maximum Flow – Maximum flow permitted through the compressor.
- Maximum Down Temperature – Maximum temperature set point for the downstream node of a compressor.

- Minimum Down Temperature – Minimum temperature set point for the downstream node of a compressor.
- Pressure drop across metering/receiving station and compressor – Pressure difference between metering/receiving station and compressor.

Table 13E: Heaters or Coolers Physical Description:

This section describes the data that are required for the modeling of the heaters or coolers:

- Maximum Down Pressure – Downstream node pressure constraint (discharge pressure) for the heater.
- Coefficient – Pressure loss through the heater, as a function of the flow rate through the heater.
- Maximum Down Temperature – Discharge temperature setpoint for the heater.
- Maximum Delta Temperature – Maximum differential temperature setpoint across the heater.
- Maximum Duty – Maximum Duty of a heater/cooler is used to control the amount of energy available to change the enthalpy of the fluid to meet the required temperature change.

Table 13F:Valve Physical Description:

This section describes the data that are required for the modeling of the valve:

- Tag Name – Description/Name given to the Valve.
- Valve operating regime during power supply failure – Valve operating regime in the event of power supply or control system failure; i.e. open, close or remain in the status before power failure.
- Valve operating time – Response time from full open to close and from close to full open.
- Upstream operating pressure range – Allowable operating pressure range limited by the technical constraint at the upstream of a regulator valve.
- Downstream operating pressure range – Allowable operating pressure range limited by the technical constraintat the downstream of a regulator valve.
- Maximum Flow – Maximum volumetric flow through valve.