

TRANSMISSION CODE

Energy Market Authority of Singapore

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TRANSMISSION CODE

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1 GENERAL AND ADMINISTRATIVE PROVISIONS

1.1 The Purpose of this Code

1.1.1 This *Code* sets the minimum conditions that the Transmission Licensee must meet in carrying out its obligation to provide *transmission services* and to provide non-discriminatory access to the Transmission Licensee's *transmission system*. The *Code* also describes the rights and obligations of the Transmission Licensee in respect of the provision of *transmission services*, together with the rights and obligations of the users of *transmission services*.

1.1.2 This *Code* also sets out the technical requirements to be met by those who are connected to the Transmission Licensee's *transmission system*.

1.2 To Whom this Code Applies

1.2.1 This *Code* is applicable to:

- (a) The Transmission Licensee, who is subject to and required to comply with this *Code* by a condition of its electricity licence;
- (b) Generation Licensees who are subject to and required to comply with this *Code* by a condition of their electricity licence;
- (c) Wholesaler (Generation) Licensees who are subject to and required to comply with this *Code* by a condition of their electricity licence;
- (d) Wholesaler (Demand Response Programme) Licensees who are subject to and required to comply with this *Code* by a condition of their electricity licence;
- (e) Market Company Licensee who is subject to and required to comply with this *Code* by a condition of their electricity licence;
- (f) A *connected person* who is required to comply with this *Code* or certain provisions of this *Code* under the terms of a *Connection Agreement* or *Retailer Use of System Agreement* with the Transmission Licensee or by a condition of its electrical installation licence; and
- (g) The *Power System Operator*, either under the provisions of this *Code* or under the terms of the *Operating Agreement*.

1.2.2 A Licensee may, by condition of its electricity licence imposed pursuant to section 9(7)(a)(iii) of the *Act*, be exempted from compliance with this *Code*, in whole or in part. A Licensee that has been so exempted shall not, subject to such conditions or restrictions as the *Authority* may determine, be required to comply with the provisions of this *Code* that are the subject of the exemption unless and until such exemption is withdrawn or modified.

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1.2.3 Such *installations* in existence before the date on which this *Code* comes into force which meet the standards and specifications of the 1998 Transmission Code or have waivers from the provisions of the 1998 Transmission Code, shall be deemed to meet the provisions of this *Code* until such time as the *Authority* shall determine that the provisions of this *Code* shall be binding or an exemption under section 1.2.2 shall be given.

1.3 Definitions

1.3.1 In this *Code*, unless the context otherwise requires:

“Act” means the Electricity Act;

“active power” means the product of voltage and current and the cosine of the phase angle between them measured in units of watts and standard multiples thereof;

“alternate fuel” means a fuel type other than primary fuel (including natural gas);

“*application fee*” means such fee payable by a *connection applicant* to the Transmission Licensee upon submission of a written application for a connection to the *transmission system*;

“Automatic Voltage Regulator” (AVR) means a continuously acting automatic excitation system to control the terminal voltage of a *generating unit*;

“authorised person” means an appropriately qualified *Licensed Electrical Worker* (LEW) or a staff of an electricity licensee duly authorised by the electricity licensee’s management to undertake *high voltage* electrical work;

“Authority” means the Energy Market Authority of Singapore established under the Energy Market Authority of Singapore Act;

“auxiliaries” means any item of electrical plant that is not directly a part of the boiler plant or *generating unit* or substation primary equipment or *HVDC facility*, but which is required for the boiler plant’s or the *generating unit*’s or the substation’s primary equipment’s or *HVDC facility*’s functional operation;

“BS” means British Standard;

“business day” means any day other than a Saturday, a Sunday or a public holiday as defined in the Interpretation Act and, where expressed by reference to the jurisdiction of a person other than Singapore, means any day other than a Saturday, a Sunday or a day on which banks are authorized or required to be closed in the jurisdiction of that person;

“Certificate of Compliance” means a document issued by an *authorised person* as required under Section 5(2) of the Electricity (Electrical Installations) Regulations 2002;

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“circuit breaker” means a mechanical switching device capable of making, carrying and breaking an electricity current under normal circuit conditions, and or making and carrying for a limited time and breaking an electricity current, under specified abnormal circuit conditions including short circuit;

“Code” means this Transmission Code;

"Combined-Cycle Plant" means a *generation facility* that consists of one or more Gas Turbines (GT); one or more boilers (or Heat Recovery Steam Generator (HRSG)) with a portion of the required energy input to the boiler provided by the exhaust gas of the GT(s) for use by the Steam Turbine(s) to produce electricity;

“common usage” means the difference between total metered electricity use in a *master-metered installation* over a period of time and the sum of all electricity use for all accounts of *sub-metered consumers* associated with the *installation* of such *sub-metered consumers* in the same *installation* over the same period of time;

“competent person” means a person who has sufficient technical knowledge or experience in working in *high voltage installations* to enable him to avoid danger when working in such *installations*;

“connect” means, in respect of a *connected person's installation*, to put into place a physical link between the relevant *connected person's installation* and the relevant *connection point*,

and “connection”, “disconnection”, “reconnection” and all grammatical variations thereof shall be interpreted accordingly, provided that the term “disconnection” shall be interpreted to mean the removal of the physical link or discontinuing the flow of electricity to or from an *installation*;

“connected person” means the person who controls the use of an *installation connected* directly or *connected* via the internal electrical system of another party, to the Transmission Licensee’s *transmission network* or *distribution network*;

“Connection Agreement” means an agreement pertaining to conditions for connection and access to the *transmission system*, entered into between the Transmission Licensee and any person whose *installation* is connected or intended to be connected directly or indirectly to the *transmission system*, and to the terms and conditions relating to charges for *transmission services*;

“connection applicant” means, in respect of a *generation facility*, a Generation Licensee or Wholesaler (Generation) Licensee and, in respect of a consumer *installation*, a person acting through an *authorised person* but (for the avoidance of doubt) shall exclude a *sub-metered consumer*;

“connection point” means the point on the *transmission system* where the *service connection* is terminated;

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“Critical Information Infrastructure” or “CII” means a computer or computer system, as defined in the Cybersecurity Act 2018, that has been designated by the Commissioner of Cybersecurity;

“demand” means the demand of MW and MVar of electricity (i.e., both *active power* and *reactive power*);

“distance protection” means a mode of detection of abnormal conditions and initiation of fault clearance or actuating signals or indicators that function when the circuit admittance, impedance or reactance increases or decreases beyond a pre-determined value;

“distribution network” means that part of the *transmission system* at 22kV and below;

“earthing device” means an apparatus or device provided for *earthing* purposes;

“earthing” means the provision of an electrical conductivity between one or more conductors and earth;

“electrical switch” means the *circuit breaker*, load switch or other mechanism by which load current or an electrical circuit may be broken, or by which electricity flow may be activated or deactivated;

“electricity licence” has the same meaning as in the *Act*;

“EMC” means Energy Market Company;

“energise” means

- in the case of a *generation facility* or an *HVDC facility* or a consumer’s *installation* other than an *installation* indirectly connected to the *transmission system*, the closing of a *circuit breaker* or other *isolating device*, owned and controlled by the Transmission Licensee; or
- in the case of a consumer’s *installation* that is indirectly connected to the transmission system, the closing of a *circuit breaker* or other *isolating device* owned and controlled by the electrical installation licensee who is connected directly to the *transmission system*.

and ‘energisation’, ‘de-energisation’ and ‘re-energisation’ and all grammatical variations thereof shall be interpreted accordingly;

“Energy Management System (EMS)” means the computer system in *Power System Operator’s* Control Centers used for monitoring and controlling the *transmission network* and for monitoring and dispatching *generating units* to meet *power system demand*;

“external generation facility” means a *generation facility* located outside Singapore, and not forming part of or connected to an *external system* that is connected to the System through an *interconnector* dedicated to it. An external *generation facility* may

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supply its local *network* but shall not be electrically connected to an *external system* (where there are one or more other *generation facilities*);

“external party” means a person whose *external system* or *external generation facility* is connected or to be *connected* to the *transmission system* through an *interconnector*;

“external system” means an electricity system located outside Singapore, and comprising electricity generation and transmission facilities, which is connected to the *transmission system* through an *interconnector*;

“frequency” means the number of alternating current cycles per second (expressed in Hertz) at which a *power system* is operating;

“generating station” means any *installation* used for, or for purposes connected with, the production of electricity;

“generating unit” means any apparatus used for, or for purposes connected with, the production of electricity;

“generation facility” means one or more *generating units*, including its associated equipment such as *switchgears*, *transformers* and all *auxiliary equipment*;

“Generation Licensee” has the same meaning as in the *Act*;

“good utility practice” means any of the practices, methods and acts engaged in or approved by a significant portion of the international electric utility industry during the relevant time period, or any of the practices, methods or acts which, in the exercise of reasonable judgement in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, *reliability*, *security*, safety and expedition. *Good utility practice* is not intended to be limited to the optimum practice, method or act to the exclusion of all others, but rather extends to acceptable international practices, methods and acts exercised generally by the electric utility industry under similar conditions;

“high voltage” means a voltage exceeding 1000V a.c. or 1500V d.c. between conductors, or 600V a.c. or 900V d.c. between each conductor and Earth;

“HVDC facility” is an *installation* wherein electricity is transmitted from one end to another with rectification and inversion of power from AC to DC and DC to AC in between, which may comprise one or more HVDC poles, including its associated equipment such as *switchgears*, AC & DC harmonic filters, *transformers* and all *auxiliary equipment*;

“HVDC pole” means part of an *HVDC facility* consisting of all the equipment in the HVDC substations and the interconnecting transmission lines or cables, if any, which during normal condition exhibit a common direct polarity with respect to earth. A pole may consist of one or more converters or valve groups in series;

“IEC” means International Electrotechnical Commission;

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“Importer Licensee” means a person who is authorised by an *electricity licence* to import electricity;

“installation” means any plant, apparatus, structure, equipment or thing used for the generation, transmission, supply or use of electricity;

“interconnector” means a set of feeder circuits for the transmission of electricity to or from the *transmission system* from or to an *external system* or *external generation facility* outside Singapore, and 'interconnection' shall be interpreted accordingly;

“intermittent generation facility” is any *generation facility* whose power output, in the course of its ordinary and proper operation, cannot be directly or indirectly controlled, or varied at will;

“Interruptible Load Provider” means a market participant who provides reserve from a load facility;

“isolating device” means a device for achieving isolation;

“Licensed Electrical Worker” or “LEW” means a person who holds a valid electrical worker licence permitting him to perform personally such electrical work as is specified in their licence;

“Licensee” means:

- (i) a *Generation Licensee*;
- (ii) an *Importer Licensee*;
- (iii) a *Market Company Licensee*;
- (iv) a *Transmission Licensee*;
- (v) a *Wholesaler Licensee*;

“LNG” means Liquefied Natural Gas;

“Market Company Licensee” means the company which holds an *electricity licence* authorising it to operate any wholesale electricity market pursuant to section 42 of the *Act*;

“master-metered consumer” means a consumer that is responsible for the *common usage* of a *master-metered installation* which is connected to the *transmission system*;

“master-metered installation” means an *installation* in which supply is received by a *master-metered consumer* and *sub-metered consumers*;

“near miss” means an unplanned incident that did not result in, but had the potential to cause either a power failure, voltage dip, damage to electrical cable, outage of

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generating unit/transmission equipment, or decrease in available generation capacity/transmission capacity. A *near miss* does not include averted equipment failures observed or discovered or suspected through maintenance, condition monitoring, commissioning or re-commissioning works;

“NEMS” means National Electricity Market of Singapore;

“network” means a section of the *transmission system* delineated from another section of the *transmission system* by a characteristic such as the voltage;

“Operating Agreement” means the agreement made between the *Power System Operator* and the Transmission Licensee or any other party, as the case may be, which gives the *Power System Operator* the authority to direct the operations of their facility in the *PSO* controlled system;

“outage” means the removal of equipment from service or unavailability for connection of equipment for any reason, and includes a forced *outage*, a planned *outage* or both, as the context may require;

“Owners Engineer” means the *generation facility* in-house professional engineer;

“Power System Operator” or “PSO” means the *Authority* acting in its capacity as the person responsible for ensuring the *security* of supply of electricity to consumers and arranging for the secure operation of the *transmission system* in accordance with the market rules and applicable codes of practice as described in section 3(3)(e) of the *Act*;

“power system” means a system comprising the *transmission* and *distribution networks*, generation and consumer *installations*, and *external systems* connected to the *transmission system*;

“protective devices” means apparatus, within the *protection system* installed for an electrical *installation* and includes, but not limited to, protective relays, instrument transformers, DC supply, wiring, trip and control and alarm circuits and ancillary equipment;

“protection system” means a combination of *protective devices* designed to secure, under predetermined conditions, usually abnormal, the disconnection of an element of the *power system* and/or to give an alarm signal;

“reactive power” means the product of voltage and current and the sine of the phase angle between them measured in units of volt-amperes reactive;

“reliability” means, in respect of electricity service, the ability to deliver electricity within *reliability* standards and in the amount desired, and means, in respect of the electricity system, the *power system* or the *transmission system*, the ability of the electricity system, the *power system* or the *transmission system* to operate within *reliability* standards in an adequate and secure manner;

“reserve” means generation capacity or load reduction capacity that can be called upon to replace scheduled energy supply that is or becomes unavailable as a result of an

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unexpected *outage*, or to augment scheduled energy as a result of unexpected *demand* or other contingencies;

“Retailer Use of System Agreement” means an agreement entered into between the Transmission Licensee and a Retail Electricity Licensee who has elected to provide its customers with a consolidated billing service in accordance with the Market Support Services Code and the Retailer Code of Conduct under which the Retail Electricity Licensee accepts liability for the payment of transmission charges owed to the Transmission Licensee by a contestable consumer that is a customer of the Retail Electricity Licensee;

“Remote Terminal Unit” or “RTU” means a multiple micro-processor based system that gathers status/analog data from field devices and performs control function on field devices. The gathered data is channeled by a modem to the host computer at the master station for further processing;

“safety coordinator” means an authorised person nominated by the Transmission Licensee and by each *connected person* to be responsible for the co-ordination of safety precautions prior to when work and/or testing is to be carried out on a *service connection* or equipment directly connected to such *service connection*;

“security” means the ability of the *power system* to withstand sudden disturbances including, without limitation, electric short circuits or unanticipated loss of equipment or components;

“service connection” means two or more insulated electrical conductors which provide, or are intended to provide, an electrical link between the *transmission system* and a *connected person's installation*;

“site responsibility schedule” means a schedule prepared by the Transmission Licensee showing the ownership, operating and safety responsibilities in respect of a *service connection*;

“site safety procedures” means the safety procedures implemented by the Transmission Licensee or by a connected person to govern work carried out in respect of a *service connection* or equipment directly connected to it;

“SS” means Singapore Standard;

“Statement of Turn-On” means a document issued by an *authorised person* as required under Section 5(4) of the Electricity (Electrical Installations) Regulations 2002;

“sub-metered consumer” means a consumer, other than a *master-metered consumer*, that receives a supply in a *master-metered installation* via the electrical system owned by a *master-metered consumer*;

“system test” means a test carried out by a connected person, or by the Transmission Licensee which involves simulating conditions or the controlled application of irregular, unusual or extreme conditions on their system or any part of the *transmission*

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system, and any commissioning and acceptance tests of *generating unit, HVDC facility, plant and apparatus*;

“total harmonic voltage distortion” means the departure of a wave form from sinusoidal shape that is caused by the addition of one or more harmonics to the fundamental, and is the square root of the sum of the squares of all harmonics expressed as a percentage of the magnitude of the fundamental *frequency*;

“Transmission Licensee” has the same meaning as in the *Act*;

“transmission network” means that part of the *transmission system* operating at 66kV and above;

“transmission services” means services provided by the Transmission Licensee pursuant to section 20(2) of the *Act*;

“transmission system” means the system of interconnected electric lines owned by a Transmission Licensee for the purpose of conveying electricity;

“turn-on” means, the closing of an incoming *electrical switch* controlled by the *connected person*, to allow flow of electricity to or from the relevant *installation*, and “turn-off”, and other grammatically variations of these terms, shall be interpreted accordingly;

“Under Frequency Relay” (UFR) means a continuously monitoring relay that will operate, giving an alarm or initiation signal upon measured frequency moves outside set point limit.

“unit protection” means a *protection system* which is designed to operate only for fault conditions within a clearly defined zone of the power system.

“Wholesaler Licensee” means a person who is authorised by an *electricity licence* to trade in any wholesale electricity market operated by the Market Company, for the purpose of:

- (i) selling electricity generated by the *Licensee* under the exemption set out in the Electricity (Electricity Generation Licence) (Exemption) (No. 2) Order;
- (ii) providing ancillary services or any electricity-related product or service through a load reduction.

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1.4 Interpretation

- 1.4.1 Unless otherwise defined in this *Code* and appearing in italics, words and phrases shall have the meaning ascribed to them in the *Act*, and words and expressions used in this *Code* shall be construed as if the Interpretation Act (Cap.1) applied to them.
- 1.4.2 Headings are for convenience only and shall not affect the interpretation of this *Code*.
- 1.4.3 A reference in this *Code* to any statute, subsidiary legislation, proclamation, ordinance, by-law, resolution, rule, order, supplements, gazette notification or directive includes all statutes, subsidiary legislation, proclamations, ordinances, by-laws or resolutions, rules, orders, supplements, gazette notifications or directives varying, consolidating, re-enacting, extending or replacing it.
- 1.4.4 A reference in this *Code* to a document or provision of a document includes a modification or supplement to, or replacement or novation of, that document or that provision of that document, as well as any exhibit, schedule, appendix or other annexure thereto.
- 1.4.5 A reference in this *Code* to a body, whether statutory or not, which ceases to exist or whose functions are transferred to another body includes a reference to the body which replaces it or which substantially succeeds to its functions, powers or duties.
- 1.4.6 A reference in this *Code* to the word “including” or a grammatical variation thereof means “including but not limited to”.

1.5 Hierarchy of Codes

- 1.5.1 The hierarchy of codes of practice shall be as follows:
- (a) Transmission Code;
 - (b) Regulated Supply Service Code;
 - (c) Market Support Services Code;
 - (d) Metering Code; and
 - (e) Code of Conduct for Retail Electricity Licensees.
- 1.5.2 In the event of a conflict between conditions contained in more than one code of practice, the condition in the higher code of practice referred to in section 1.5.1 shall prevail.
- 1.5.3 In the event of a conflict between conditions contained in this *Code* and conditions contained in an electricity licence issued pursuant to section 9 of the *Act*, the conditions in the electricity licence shall prevail.

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1.5.4 In the event of a conflict between conditions contained in this *Code* and conditions contained in:

- (a) the market rules;
- (b) the market manuals; or
- (c) the system operation manuals;

the conditions in this *Code* shall prevail.

1.6 Modifications to This Code

1.6.1 In furtherance of the authority contained in section 16(2) of the *Act*, the process by which this *Code* may be modified from time to time by the *Authority* shall be as follows:

- (a) Before making any modification to this *Code*, the *Authority* shall:
 - (i) state that the *Authority* proposes to make a modification in the manner specified in the notice;
 - (ii) state the reasons why the *Authority* proposes to make the modification, including whether the need for the modification was the subject of a prior representation made by a Licensee or third party; and
 - (iii) specify the period from the date of the giving of the notice (not being less than 28 days) within which written representations with respect to the proposed modification may be made.
- (b) If no written representation is received by the *Authority* within the period specified in the notice referred to in section 1.6.1 (a) or if all written representations made in response to such notice are subsequently withdrawn, the *Authority* may modify this *Code* as specified in such notice.
- (c) Where the *Authority* receives any written representation under section 1.6.1(a), the *Authority* shall consider all such representations, as a whole, and may:
 - (i) reject the representations;
 - (ii) amend the proposed modification in accordance with the representations;
 - (iii) form working committee(s), with representation from Electricity Licensees, to review the proposed modification to the *Code*. The working committee shall make its recommendation on the proposed modification for the *Authority's* consideration; or
 - (iv) withdraw the proposed modification.
- (d) The *Authority* shall, before modifying this *Code*, respond with reasons to all written representations received in respect of the modification that were not

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subsequently withdrawn, and advise the outcome of the *Authority's* deliberations in respect of the modification.

- (e) A modification to this *Code* shall not come into force until such time as the *Authority* has complied with section 1.6.1(d), where applicable, and 10 *business days*, or such longer period of time as may be specified by the *Authority*, have elapsed since the date on which the *Authority* gave notice of the modification as required by section 16(2) of the *Act*.

1.6.2 Nothing contained in section 1.6.1 shall prohibit any Electricity Licensee or any other party from notifying the *Authority* of suggested *Code* changes.

1.7 Coming into Force

1.7.1 This Code shall come into force on the appointed day.

2 OPERATING AGREEMENTS

2.1 Operating Agreements

- 2.1.1 An agreement, of standard form, shall be entered into between the *Power System Operator and* the Transmission Licensee or any other party, as the case may be, which gives the *Power System Operator* the authority to direct the operations of their facility in the *PSO* controlled system.

3 RETAILER USE OF THE TRANSMISSION SYSTEM AGREEMENT

3.1 Retailer Use of System Agreement

3.1.1 The Transmission Licensee shall, subject to the relevant conditions of the Transmission Licence and Retail Electricity Licence, enter into a *Retailer Use of System Agreement* with any Retail Electricity Licensee who intends to provide retailer-consolidated billing services to a contestable consumer.

3.1.2 The conditions imposed in the *Retailer Use of System Agreement* shall be the same for all such retailers.

4 CONNECTION TO THE TRANSMISSION SYSTEM

4.1 Application for a New or Modified Generation/HVDC Facility Connection – General Conditions

- 4.1.1 A *connection applicant* applying to connect its *generation facility* to the *transmission system* or modify its existing *generation facility* connected to the *transmission system* is required to submit a formal application through an *authorised person*, together with the *application fee* payable, to the Transmission Licensee. The application shall contain the information described in Appendix C. After having submitted the application, the *connection applicant* shall promptly notify the Transmission Licensee in writing of any subsequent material additions or changes to the information submitted.
- 4.1.2 Upon receipt of the application from the *connection applicant*, the Transmission Licensee:-
- (a) shall forward such application to the *Power System Operator* (where the proposed connection is to the *transmission network*) upon receiving the application;
 - (b) may require additional information to be submitted by the *connection applicant*;
 - (c) shall perform the necessary analysis and studies of the connection application to determine a connection scheme that does not have any adverse effect on the secure, stable and reliable operation of the *transmission system* and any other *installation*, or *external party* already connected or seeking connection to the *transmission system*;
 - (d) shall advise the *connection applicant* whether the sites identified by the *connection applicant* are suitable for new *connections*. If a *connection point* has been identified for each of the respective sites at which a *connection* may be made, the Transmission Licensee shall advise the *connection applicant* the indicative connection charges, connection scheme and the connection facilities to be provided; and
 - (e) shall ensure that any requirements expressed by the *Power System Operator* have been satisfied.
- 4.1.3 The Transmission Licensee shall forward the proposed connection scheme (where the proposed connection is to the *transmission network*) to the *Power System Operator*. The *Power System Operator*, upon receiving the proposed connection scheme from the Transmission Licensee:-
- (a) may require additional information to be submitted by the *connection applicant* and/or the Transmission Licensee;
 - (b) shall conduct analysis and studies to determine the impact of the proposed *connection* of the *generation facility*/modification to existing *generation facility* on the *security*, stability and *reliability* of the *power system*;

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(c) shall within 20 *business days* of receiving the proposed connection scheme from the Transmission Licensee, advise the Transmission Licensee whether it endorses or rejects the proposed connection scheme. If the *Power System Operator* rejects the proposed connection scheme, it shall inform the Transmission Licensee in writing of its reason(s) for such rejection; and

(d) where deemed necessary, shall advise the *connection applicant* the requirements of the proposed *generation facility or modification* to the existing *generation facility* to ensure the *security*, stability and *reliability* of the *power system*. The *connection applicant* shall confirm in writing to the *Power System Operator*, with a copy to the Transmission Licensee, its acceptance of the requirements specified by *Power System Operator* and ensure that the requirements are met.

4.1.4 The Transmission Licensee shall use its best endeavours to respond to the *connection applicant* within the following time schedule regarding the proposed connection scheme duly endorsed by the *Power System Operator*.

Connection Voltage	Time Schedule
230kV and 400kV	80-100 <i>business days</i>
66kV and below	60 <i>business days</i>

4.1.5 Upon the *connection applicant* accepting the proposed connection scheme, the Transmission Licensee shall notify the *connection applicant* of the terms and conditions of *connection* or modification to the existing *connection* and of the charges, if any, payable to the Transmission Licensee to carry out the relevant works under the *Connection Agreement*, and shall provide to the *connection applicant* a copy of the *Connection Agreement*.

4.1.6 The Transmission Licensee shall not connect any *generation facility* to the *transmission system* if the *connection applicant* fails to comply, or the Transmission Licensee determines on reasonable grounds that the *connection applicant* is not capable of complying, with the procedures and requirements for *connection* to and use of the *transmission system* set forth in this *Code* and the *Connection Agreement*.

4.1.7 The conditions for *connection* of a *generation facility* shall apply in the case of a *reconnection*.

4.2 Application for a New or Modified Consumer Installation Connection – General Conditions

4.2.1 A *connection applicant* applying to connect its consumer *installation* to the *transmission system* or modify its existing consumer *installation* connected to the *transmission system* is required to submit a formal application through an *authorised person*, together with the *application fee* payable, to the Transmission Licensee. The application shall contain the information described in Appendix B (and Appendix C, where applicable). After having submitted the application, the *connection applicant*

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shall promptly notify the Transmission Licensee in writing of any material additions or changes to the information submitted.

4.2.2 Upon receipt of the application from the *connection applicant*, the Transmission Licensee:-

- (a) may require additional information to be submitted by the *connection applicant*;
- (b) shall perform the necessary analysis and studies of the connection application to determine a connection scheme that does not have any adverse effect on the secure, stable and reliable operation of the *transmission system* and any other installation, or external party already connected or seeking connection to the *transmission system*;
- (c) shall advise the *connection applicant* of the indicative connection charges, connection scheme (including connection voltages) and the connection facilities to be provided; and
- (d) shall ensure that any requirements expressed by the *Power System Operator* have been satisfied.

4.2.3 The Transmission Licensee shall forward the proposed connection scheme (where the proposed connection is to the *transmission network*, or is for the connection of *generating unit(s)* of rated capacity 1MW and above or solar photovoltaic *generating unit(s)* of capacity 1MWac and above to the consumer's *installation* that is connected to the *transmission network*) to the *Power System Operator*. The *Power System Operator*, upon receiving the proposed connection scheme from the Transmission Licensee:-

- (a) may require additional information to be submitted by the *connection applicant* or the Transmission Licensee;
- (b) shall conduct analysis and studies to determine the impact of the proposed *connection* of the *installation* or modification of the existing *installation* on the *security*, stability and *reliability* of the *power system*;
- (c) shall within 20 *business days* of receiving the proposed connection scheme from the Transmission Licensee, advise the Transmission Licensee whether it endorses or rejects the proposed connection scheme. If the *Power System Operator* rejects the proposed connection scheme, it shall inform the Transmission Licensee in writing of its reason(s) for such rejection; and
- (d) where deemed necessary, shall advise the *connection applicant* of the requirements for the *installation* or modification of the existing *installation* to ensure the *security*, stability and *reliability* of the *power system* and the *connection applicant* shall confirm in writing to the *Power System Operator*, with a copy to the Transmission Licensee, its acceptance of the requirements specified by *Power System Operator* and ensure that the requirements are met.

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4.2.4 The Transmission Licensee shall use its best endeavours to respond to the *connection applicant* (duly endorsed by the *Power System Operator*, where applicable) within the following time schedule regarding the proposed connection scheme.

Connection Voltage	Time Schedule
230kV and 400kV	80-100 <i>business days</i>
66kV	60 <i>business days</i>
22kV and below	10 <i>business days</i> (time schedule would be longer where it involves the connection of centrally dispatchable generation facility to a consumer's installation)

4.2.5 Upon the *connection applicant* accepting the proposed connection scheme, the Transmission Licensee shall notify the *connection applicant* of the terms and conditions of *connection* or modification to the existing *connection* and of the charges, if any, payable to the Transmission Licensee to carry out the relevant works under the *Connection Agreement*, and shall provide to the *connection applicant* a copy of the *Connection Agreement*.

4.2.6 The Transmission Licensee shall not connect any installation to the *transmission system* if the *connection applicant* fails to comply, or the Transmission Licensee determines on reasonable grounds that the *connection applicant* is not capable of complying, with the procedures and requirements for *connection* to and use of the *transmission system* set forth in this *Code* and the *Connection Agreement*.

4.2.7 The conditions for *reconnection* of a consumer's *installation* shall be in accordance with the requirements developed by the Transmission Licensee.

4.3 Connection Agreement

4.3.1 The Transmission Licensee shall enter into a *Connection Agreement*, that describes the terms and conditions, with any person whose facilities or equipment are or are intended to be connected, directly or through the internal electrical system of any other consumer, to the *transmission system*. The form of the *Connection Agreement* may depend upon the nature of the *installation* to be connected and the voltage level at which it is connected.

4.4 Energisation of the Service Connection

4.4.1 The *connection application* shall, no less than 14 *business days*, prior to the date on which the *energisation* of the *service connection* is to take place:-

- (a) complied fully with the safety requirements of this *Code*;

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- (b) complied fully with the technical requirements of this *Code* and shall, in particular, have submitted the data and information stipulated in Appendix B and/or Appendix C and/or Appendix D, where applicable;
 - (c) submitted to the Transmission Licensee a written request for approval to *energise* the service *connection* and the proposed date of *energisation*;
 - (d) submitted to the Transmission Licensee a written confirmation that the *installation* to be connected to the *transmission system* for which *connection* is sought conforms fully with the requirements of the *Connection Agreement*; and
 - (e) submitted to the Transmission Licensee a written confirmation that it has obtained all necessary authorisations for the construction and operation of the *installation* in accordance with the provisions of all applicable laws and regulations in the Republic of Singapore have been met;
- 4.4.2 The Transmission Licensee shall not *energise* any *service connection* unless it has, on or before the date of *energisation* of the *service connection*,:-
- (a) complied fully with the safety requirements of this *Code*;
 - (b) received approval from the *Power System Operator*, where applicable, to *energise* the service *connection*;
 - (c) is satisfied that the *connection applicant* has a contractual obligation to pay for *transmission services* in respect of the *installation*;
 - (d) is satisfied that the *connection applicant* has a contractual obligation to pay for the supply delivered to the *installation*;
 - (e) is satisfied that the provisions of the Metering Code have been met and that metering equipment, pursuant to the provisions of the Metering Code, has been installed and is fully operational; and
 - (f) received prior to *energisation*, a *Certificate of Compliance* from an *authorised person* acting on behalf of the *connection applicant*.
- 4.4.3 The Transmission Licensee shall arrange with the *connection applicant* for a joint inspection and testing of the *connection applicant's circuit breaker* and any associated apparatus attached to the *service connection*, if the Transmission Licensee considers that such inspection or testing is necessary to ensure that *energisation* of the *service connection* shall not have an adverse impact on the secure and reliable operation of the *transmission system*. The date of such joint inspection or testing shall not be less than 14 *business days* prior to the date of *energisation* of the *service connection*.
- 4.4.4 Where the Transmission Licensee is not satisfied that the *circuit breaker* or any associated apparatus referred to in section 4.4.3 is ready for *energisation*, the Transmission Licensee shall notify the *connection applicant* and provide reasons for its determination. The *connection applicant* shall make such changes to the *circuit breaker* and/or associated apparatus as required and shall inform the Transmission Licensee

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when a further inspection can take place. The Transmission Licensee and the *connection applicant* shall agree on a date for such further inspection where such date shall be no later than 14 *business days* after the *connection applicant* has completed the required modifications to the *circuit breaker* and/or associated apparatus.

4.4.5 Following the Transmission Licensee's acceptance of the *Certificate of Compliance* and if the Transmission Licensee is satisfied that the *circuit breaker* and all associated apparatus referred to in section 4.4.3 is ready for *energisation*, the Transmission Licensee, the *Power System Operator* (where applicable), and the *connection applicant* shall schedule a date to *energise* the *service connection*.

4.4.6 The Transmission Licensee shall advise the Market Support Services Licensee accordingly of the date of *energisation* of the *service connection*.

4.5 Electrical Turn-on of an Installation

4.5.1 In the case of an *installation* of a *connection applicant* other than an *installation* indirectly *connected* to the transmission system, following *energisation* of the *service connection*, the Transmission Licensee shall issue a *Statement of Turn-On* after which *turn-on* of the relevant *installation* may be performed. Such *turn-on* shall be effected by an *authorised person* appointed by the *connection applicant*.

4.6 Electrical Commissioning of a Generation Facility

4.6.1 For the commissioning of a *generation facility*, the Generation Licensee shall submit to the *Power System Operator*, 14 *business days* in advance from the date its new/repowered *generating facility* is scheduled for synchronisation to the *power system*, a tentative commissioning tests program including those tests listed in Appendix C (giving details of the schedules and the test to be carried out at various load levels) for on-load commissioning of its new/repowered *generating facility*. A final version of the commissioning program shall be established one week before the commencement of the commissioning. The *Power System Operator* shall have the authority to re-schedule any of the required tests to minimise system risk and the reason for such re-scheduling shall be given to the Generation Licensee.

4.6.2 The *Power System Operator* shall allow a Generation Licensee to proceed with on-load commissioning of its new/repowered *generation facility* connected to the *transmission system* if the Generation Licensee has satisfactorily complied with the following conditions:-

(a) that the Generation Licensee, where applicable, has registered its new/repowered *generation facility* with the Market Company in accordance with the provisions laid down in the Market Rules, and it has provided the necessary *generation facility* information required by the Market Company as part of the Facility Registration Process;

(b) that the Generation Licensee has a commissioning program established in accordance with the provision set out in section 4.6.1 of this *Code*.

- 4.6.3 Upon completion of the testing and commissioning of the *generation facility*, the Generation Licensee shall submit and update the *Power System Operator* with the final site setting of the *generation facility*, as well as the testing and commissioning reports as set forth in Appendix C.

4.7 Documentation of Guidelines

- 4.7.1 The Transmission Licensee shall prepare, maintain and make available a document that specifies the guidelines for a *connection applicant* applying for *connection* of its consumer *installation* to the *transmission system* or for modification of an existing *installation* connected to the *transmission system*.
- 4.7.2 The Transmission Licensee shall file a copy of the document referred to in section 4.7.1 with the *Authority*.

4.8 Conditions for Connection of an Interconnector

4.8.1 Application for Connection of an Interconnector

The application procedures stipulated in section 4.1 shall apply for an *external party* wishing to connect to the *transmission system* through an *interconnector*.

4.8.2 Data Requirements

The *external party* shall supply to the Transmission Licensee and *Power System Operator*, such information regarding the *external system* and *external generation facility* and *HVDC facility* as specified in Appendix C and/or Appendix D and/or Appendix J, as applicable.

4.8.3 Limit of Power Transfer

The power transmitted through an *interconnector* and the spinning *reserve* required to be provided (applicable to *external generation facility* only) shall not exceed the system stability, *security* and *reliability* limits or the firm transfer capability of the *interconnector*, whichever is lower, as determined by the *Authority*. The total power import through all *interconnectors* into the *transmission system* shall not be more than the limit, as determined by the *Authority*.

4.8.4 Joint Operation Committee

A Joint Operation Committee shall be formed with each of the *external parties*. The Joint Operation Committee shall comprise the *external party*, the Transmission Licensee and the *Power System Operator*. Regular meetings shall be conducted to update and address all system planning, operation and maintenance matters.

4.8.5 General Technical Requirement

- (a) External *generation facilities* shall be designed to ensure technical compatibility with the *power system* integrity. This shall include short circuit current contribution to the *network* and other specific requirements, which shall be

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determined by the Transmission Licensee and the *Power System Operator* on a case-by-case basis.

- (b) *Circuit breakers* shall be provided at both ends of the *interconnector*. Other equipment, which may be required, shall be determined by the Transmission Licensee and the *Power System Operator* on a case-by-case basis.
- (c) The number of feeder circuits forming the *interconnector* shall meet single contingency criterion.
- (d) Synchronizing facilities shall be provided at both ends of an *interconnector* by the respective parties.

4.8.6 External Generation Facilities

- (a) All *external generation facilities* shall comply with all technical requirements stated in this *Code*.
- (b) All *external generation facilities* shall be centrally dispatchable.
- (c) All *generating units* of *external parties* shall be *frequency* sensitive and shall contribute to system spinning *reserve* in the same manner as specified in Appendix F.
- (d) All *external parties* shall provide a central control system for dispatching of all their *generation facilities* in a manner such that the power transmitted through the *interconnector* shall be as instructed by real-time signals sent by the *Power System Operator*.
- (e) The *external party* responsible for an *external generation facility* shall be required to obtain approval from the *Authority* and the Transmission Licensee, if it intends to convert that *external generation facility* into an *external system*.

4.8.7 Additional Technical Requirements for *External System*

- (a) An *external party* shall provide adequate spinning *reserve* to cater for a sudden loss of the largest *generating unit* in its *external system* without causing any under *frequency* tripping of the *interconnectors* or in that *external system*. This shall allow the Area Control Error to return to zero at least every ten minutes.
- (b) An *external party* shall be responsible for *network* reinforcement and system protection in its *external system* to ensure stable and secure operation of the integrated system.
- (c) An *external party* shall be responsible for the provision of an Automatic Generation Control facility with *frequency* and tie-line biased control capability in the *external system* to enable control of power flow through the *interconnector* to be within $\pm 5\%$ tolerance.

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- (d) An *external party* shall provide adequate reactive compensation in its *external system* to ensure minimum reactive and capacitive power flowing through the *interconnector*.
- (e) An *interconnector* shall be designed with adequate capacity and appropriate overload protection to cater for short time power flow in the event of sudden tripping of the largest *generating unit* in the system or in the *external system* during partial availability of the *interconnector* circuits.

4.8.8 Protection Requirements

- (a) An *external party* shall ensure that the *protection systems* on its *external generation facilities* and *interconnectors* comply with the requirements stated in section 6.3 and Appendix F or otherwise determined by the *Power System Operator* and/or the Transmission Licensee based on the specific *interconnector* facilities adopted.
- (b) An *interconnector* is to be equipped with *under-frequency* and *over-current* protection at each end by the respective parties. Power swing relays and out of step relays, if required, shall be installed by the *external party* within the *external system* for system stability protection purpose. The settings for the *under-frequency*, power swing relays and out of step relays shall be provided by the *Power System Operator* and the *external party*. The settings for the *over-current* protection shall be provided by the Transmission Licensee and the *external party*.

4.8.9 Communication Requirements

- (a) An *external party* shall, in relation to its *external system* and *external generation facilities*, install, maintain and operate two independent voice communication links between the *external party's* Network Control Centre and *Power System Operator's* Control Centre. These voice links shall be the direct lines (to be provided by an independent service provider) associated with this Control Centre and shall be used for operational purposes only. All communication equipment/links as may be required by the protective relaying scheme shall be installed and maintained by the *external party*. Where required, such equipment or links shall be compatible with the applicable communication equipment or links of the Transmission Licensee and/or the *Power System Operator*.
- (b) An *external party* shall, in relation to its *external system* and *external generation facilities* install, maintain and operate a facsimile machine for operational purposes. Such facsimile machine shall have a dedicated telephone line and number, located in the *external party's* Network Control Centre. The *external party* and the *Power System Operator* shall inform each other of the number of their facsimile machine used for operational purposes.

4.8.10 Maintenance Requirements

- (a) An *interconnector* shall be maintained in accordance with the general guidelines stated in section 9.

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- (b) Any request for shutdown of an *interconnector* shall be submitted to the *Power System Operator* for approval. The *Power System Operator* shall coordinate all switching operations relating to an *interconnector*.

4.8.11 Performance Monitoring Facilities of Interconnector:

The Transmission Licensee shall provide, install and maintain at its own cost, high-resolution recorder(s) at the *interconnector* substations in the transmission system interfacing with an external party to monitor and record the *interconnector* performance during system disturbances. The recorder shall be capable of monitoring and recording, including:

- (a) *active and reactive power* flow of each *interconnector*;
- (b) substation busbar voltage and *frequency*; and
- (c) *circuit breaker* and *protective devices* status.

The requirements of high-resolution recorder(s) are given in Appendix F. The Transmission Licensee, upon receiving notification from *PSO*, shall furnish such records/data in softcopy via email in the format as specified in Appendix F9.2(g) within 24 hours.

5 DISCONNECTION OR DISCONTINUANCE

- 5.1 The Transmission Licensee shall not *disconnect* any *service connection* from the *transmission system* or discontinue the supply of electricity to any *installation* except as permitted by, and in accordance with, the *Act*, its electricity licence, this *Code*, a *Connection Agreement* or *Retailer Use of System Agreement*.
- 5.2 The Transmission Licensee shall, comply with any direction of a Market Support Services Licensee to *disconnect* the *service connection* or discontinue supply to a non-contestable consumer which is given pursuant to section 24(1) of the *Act* or pursuant to the Market Support Services Code.
- 5.3 The Transmission Licensee shall only *disconnect* a contestable consumer's *service connection* or discontinue the supply of electricity to such consumers in accordance with section 24(4) of the *Act*, the terms of its *Connection Agreement* or as directed by a Market Support Services Licensee pursuant to the Market Support Services Code.
- 5.4 Where the Transmission Licensee has *disconnected* any consumer's *service connection* or discontinued the supply of electricity to any *installation* in accordance with section 5.2 or section 5.3, the Transmission Licensee shall inform the relevant consumer of such action as soon as reasonably practical.
- 5.5 Where the Transmission Licensee has *disconnected* any consumer's *service connection* or discontinued the supply of electricity to any *installation* in accordance with section 5.2 or section 5.3, the Transmission Licensee shall not *re-connect* or *re-energise* that consumer's *service connection* unless the consumer complies with the requirements of section 24(5) of the *Act* and the terms of its *Connection Agreement*.

6 OPERATING AND TECHNICAL OBLIGATIONS

6.1 Responsibilities

- 6.1.1 The transmission licensee shall maintain, operate and enable the secure operation of the *transmission system*. It shall also be responsible for the secure operation of the *distribution network* i.e. the part of the *transmission system* operating at 22kV and below.
- 6.1.2 The *Power System Operator* shall be responsible for the secure operation of the *transmission network* i.e. the part of the *transmission system* operating at 66kV and above, and all centrally dispatchable *generating units*.
- 6.1.3 The Transmission Licensee and any connected person shall maintain and operate its installations and auxiliaries to ensure they will not cause any adverse impact to the stability, security and reliability of the power system. The maintenance and operation of the installations and auxiliaries shall be in accordance with good utility practice, taking into consideration the respective original equipment manufacturers' recommendations.
- 6.1.4 The Transmission Licensee and Generation Licensees shall:
- (a) report any near miss to the Authority within 4 weeks from the occurrence of the near miss; and
 - (b) collate reports of near misses encountered by their contractors while working on the Licensees' cable/equipment/plant/facility and submit these reports to the Authority within 4 weeks from the occurrence of the near miss.

The Authority may, where it considers necessary, require a Licensee to share the learning points of the near miss with other Licensees. For the purposes of this clause, embedded generating units are exempted from this requirement.

The reporting of near miss is not intended to determine/apportion blame or liability but is for the industry to share and learn from the incidents and make necessary improvements so as to enhance the reliability of their equipment and plants/facilities.

- 6.1.5 The Transmission Licensee, Generation Licensee and *any connected person* shall ensure that they have adequate and sufficiently trained and qualified manpower, to maintain and operate their *installations, generation facilities* and *auxiliaries* at all times. Where there is attrition of manpower, they should be replenished as soon as reasonably possible.

6.2 Standards and Standing Operating Procedures

- 6.2.1 All plant and equipment shall:
- (a) be in compliance with all applicable technical requirements of this *Code* and shall be designed and constructed in accordance with *good utility practice*;

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- (b) be capable of operating under normal and contingency conditions of the *transmission system* as set forth in Appendix G; and
- 6.2.2 All *connected persons* shall ensure that their electrical installations comply with the standards set forth in Appendix I where applicable, or such other standards as may be acceptable to the Transmission Licensee.
- 6.2.3 The Transmission Licensee and Generation Licensees shall ensure that their plants and equipment comply with the requirements set forth under sections 8.4.1 and 8.4.2 respectively.
- 6.2.4 The *Power System Operator* shall develop a system level Standing Operating Procedure (SOP) for ensuring the secure operation of the power system in the event of natural gas supply disruption and revise the SOP from time to time, if necessary. The SOP shall be developed and revised by the *Power System Operator* in consultation with the generation licensees, gas transporter and any other relevant parties. Generation Licensees with *generation facility* that uses natural gas as the primary fuel and any other parties identified in the SOP shall comply with this SOP.

6.3 Protection

- 6.3.1 A *connection applicant* applying to be *connected* to the *transmission system* shall install *protection systems* for the *service connection* in accordance with the Transmission Licensee's requirements. No *energisation* shall occur unless the specifications of the *protection systems* for the *service connection* conform with the Transmission Licensee's requirements and that the *protection systems* have been tested and are ready for commissioning.
- 6.3.2 Each *connection applicant* shall ensure that the *protection systems* referred to in section 6.3.1 shall be compatible with and able to be fully coordinated with the *protection systems* on the *transmission system*. The *connection applicant* shall ensure that such *protection systems* are properly set and maintained in accordance with *good utility practice*, this *Code* and the relevant *Connection Agreement*.
- 6.3.3 The Transmission Licensee and *connected person* shall ensure that their *protection systems* and operating time comply with the requirements set out in Appendix F.
- 6.3.4 For on-load commissioning or re-commissioning of the *unit protection systems* involving both the Transmission Licensee and the *connected person*, the Transmission Licensee shall be responsible for co-ordinating the commissioning or re-commissioning of the *unit protection systems* and shall determine whether the *unit protection systems* have been successfully commissioned. The *connected person* shall provide the necessary resources and actively participate in the commissioning or re-commissioning of the protection systems.

6.4 System Tests

- 6.4.1 *Systems tests* are tests to be carried out by a *connected person* or Transmission Licensee which involve simulating conditions or the controlled application of irregular, unusual or

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extreme conditions on the *connected person's installation*, any part of the *transmission system*, or any commissioning and acceptance tests of *generating facility*, plant and apparatus. *System tests* do not include commissioning and re-commissioning tests of a minor nature, and those which do not have an effect on the *power system*.

- 6.4.2 A *connected person* or the Transmission Licensee shall ensure that the *system test* requirements specified in Appendix E are met.

6.5 Voltages

- 6.5.1 Substation/switchhouse facilities shall be designed for use at the voltage level at the applicable *connection point*, where:

- (a) standard *transmission network* voltage levels consist of 400kV, 230kV and 66kV which may vary within $\pm 5\%$ for 400kV, and $\pm 6\%$ for 230kV and 66kV;
- (b) standard *distribution network* voltages consist of 22kV, 6.6 kV, 400V and 230V that may vary within $\pm 6\%$; and
- (c) transient voltage variation due to switching or tripping of *transmission system* equipment may exceed the above limit.

- 6.5.2 If an *installation* is to be connected to the *transmission system*, the Transmission Licensee shall notify the *connection applicant* of the proposed location of the connection and the voltage at the *connection point*.

- 6.5.3 The voltage at the *connection point* shall be proposed by the Transmission Licensee based on the quantity of power to be injected or withdrawn at the *connection point* and its impact on the performance of the *power system*.

- 6.5.4 The Transmission Licensee shall specify the DC transmission voltage of the *HVDC facility*, or it may at its sole discretion allow the *connected person* to select a DC transmission voltage level of its own choice, subject to meeting all the technical conditions and standards stated in this Code.

6.6 Reactive Power Requirements

- 6.6.1 The Generation Licensee responsible for each *generating unit* connected to the *transmission system* shall ensure that each *generating unit* has the capability of operating at a power factor from 0.95 leading to 0.85 lagging as measured at the terminals of the *generating unit* prior to the step-up transformer. For grid-connected solar photovoltaic *generating unit(s)*, the *connected person* shall ensure that the inverter(s) has the capability of operating at a power factor from 0.9 leading to 0.9 lagging.

- 6.6.2 The *connected person* in respect of any *installations* taking supply at *high voltages* shall implement power factor correction measures at their facilities, if deemed necessary by the Transmission Licensee, to maintain a power factor of no less than 0.85.

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6.6.3 The Transmission Licensee and *connected person* responsible for each *HVDC facility* connected to the *transmission system* shall ensure that the steady state tolerance on reactive power exchange with the *transmission system* expressed in MVAR shall be no greater than +/-5% of the rated MW of the *HVDC facility*.

6.7 Harmonics and Power Quality

6.7.1 All *connected persons* shall install equipment or devices to suppress harmonics and electrical noise produced by their electrical plant if the harmonics or electrical noise produced by such plants exceed the limits specified in Appendix F.

6.7.2 A *connected person* shall submit to the Transmission Licensee the expected noise and harmonics levels from their electrical plant upon request by the Transmission Licensee.

6.7.3 A *connection applicant* or *connected person* seeking *connection* at, or upgrading a connection at 66kV or higher voltages shall submit to the Transmission Licensee the following:

- (a) the expected noise and harmonics levels from the electrical plant upon submission of the application for *connection* or for upgrading of the *connection*; and
- (b) following *connection*, noise and harmonics levels annually or at such intervals as may be specified by the Transmission Licensee.

6.7.4 Any *connected person* shall at their own cost:

- (a) provide stand-by power supply or stand-by generator(s) and other means to serve their plant and *installation* if their operations cannot tolerate any failure, reduction, interruption, variation or inconsistency in the supply of electricity; and
- (b) provide power quality devices, such as uninterruptible power supply (UPS), voltage stabiliser, voltage restorer, or any other means to serve their plant if their operations cannot tolerate any voltage fluctuations or distortions in supply.

6.8 Neutral Grounding System

6.8.1 The Transmission Licensee shall specify the neutral grounding system required of an *installation* connected to the *transmission system*, such that the neutral grounding system of the *connection applicant's installation* are compatible with that of the *transmission system*.

6.8.2 No *connection* shall occur until an *authorised person* acting on behalf of the *connection applicant*, has certified that the specifications and design of the neutral grounding system complies with the requirements of the Transmission Licensee and that those neutral grounding systems have been put in place.

6.8.3 If the *connection applicant* is unable to comply with the neutral grounding system requirements specified by the Transmission Licensee, the *connection applicant* shall inform and provide alternative proposals for the consideration of the Transmission

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Licensee. The Transmission Licensee shall evaluate such alternative proposals as the *connection applicant* may make and give its approval to such alternatives as the Transmission Licensee may accept.

6.8.4 No *connection* shall occur until the Transmission Licensee has approved the specifications and detailed plans of the neutral grounding system provided under section 6.8.3 and those neutral grounding system have been put in place.

6.8.5 The configuration of the *HVDC facility* shall use a metallic earth return.

6.9 Disconnecting Device

6.9.1 As a pre-condition for *connection*, the Transmission Licensee may require the *connection applicant* to install disconnecting devices between the *transmission system* and the connection applicant's *installation*.

6.10 Equipment Nomenclature

6.10.1 The Transmission Licensee shall develop and maintain a uniform system of nomenclature for equipment and apparatus that forms a part of the *transmission system*.

6.10.2 The Transmission Licensee shall apply the system of nomenclature referred to in section 6.10.1 to specify unique numbering and nomenclature for all equipment comprising the *transmission system*.

6.10.3 The Transmission Licensee shall notify the *connection applicant*, or *connected person* seeking to make a modification to an existing connection to the *transmission system*, in writing, of the nomenclature requirements and conventions to be used to identify components of the electrical plant that the person intends to install at a site, no less than six months prior to the proposed installation date of the new or modified connection.

6.10.4 At least three months before the proposed installation date referred to in 6.10.3, the *connection applicant* or *connected person* must provide the Transmission Licensee and the *Power System Operator* (where applicable) with:

(a) its proposed nomenclature for the components of the electrical plant that it intends to connect to the *transmission system*; and

(b) a single line diagram showing each *high voltage* apparatus to be connected, using the numbering and nomenclature described in 6.10.4(a).

6.10.5 The Transmission Licensee shall respond in writing to the person within one month stating whether the information provided by that person in accordance with 6.10.4 has been accepted. Acceptance shall occur if the nomenclature is clear, unambiguous, unique and consistent with the requirements and conventions referred to in 6.10.3. If the numbering and nomenclature is not acceptable then the Transmission Licensee shall provide the person with the nomenclature that must be used.

6.11 Switchhouse Facilities, Gas Receiving Facilities and Generation Facility Design by Generation Licensee

- 6.11.1 The Generation Licensee shall comply with the requirements set forth in sections. 6.11.2 to 6.11.4.
- 6.11.2 The *generating unit's* step-up transformers and *generating unit's* switchboard (or switchgear) for connecting the *high voltage* side of the *generating unit's* step-up transformers and the associated switching and protection/control equipment shall be designed such that no single failure/*outage* shall cause simultaneous *outage* of two or more *generating units* connected to the switchboard. All switchboards shall be designed in accordance with Appendix I1.4, unless the Generation Licensees submit with justifications the use of a different switchboard configuration for the *Power System Operator's* consideration.
- 6.11.3 The gas receiving facility and/or dedicated LNG regasification facility that is not connected to the gas supply system, including its associated equipment, fuel gas compressor(s), LNG regasification equipment/systems and protection/control equipment for the supply of natural gas to the generating station for power generation shall be designed and operated in such manner that no single failure/*outage* shall cause simultaneous *outage* of two or more generating units at the generating station.
- 6.11.4 All *generating units* shall be designed such that:
- (a) the *generating unit* is based on relevant *IEC, BS* or other equivalent standards and all other requirements for operation in the *power system*. *Connection* of a *generating unit* onto the *transmission system* shall not cause any unacceptable consequences that jeopardize *power system* stability, *security* and *reliability*. Under such a case, a *generating unit* may not be permitted to be *connected* to the *power system*. For the same reasons, those permitted to be *connected* to the *power system* may not be permitted to operate under certain *power system* conditions or as base load units;
 - (b) *each generating station* with any *generating unit(s)* of rated capacity 100MW and above is required to have Black Start Capability unless exempted by *Power System Operator*;
 - (c) the short circuit current contribution to the *connection point* shall be controlled to be strictly within the limits stipulated by the Transmission Licensee;
 - (d) the *generating unit* is capable of sustained operation within the *frequency* range set forth in section Appendix F; and
 - (e) the *generating unit* has a minimum *frequency* response capability as set out in Appendix F.
 - (f) *each generation facility* that uses natural gas as the primary fuel shall be designed with the capability of initiating on-load changeover either automatically through gas pressure setting or manually to alternate fuel that is stockpiled on-site. The fuel changeover trigger setting shall have sufficient margin above that of the *generation facility's* low gas pressure trip setting to ensure that the *generation facility* remains

connected to the power system and operates at or above its minimum stable loading level during the entire process of fuel changeover operation. The *generation facility* shall continue to supply electricity to the power system after completion of the fuel changeover process. In addition, each newly commissioned generation facility, (b) any existing generation facility under-going life extension of 5 years or longer or (c) repowering, which is to be registered with EMC on or after 1 January 2021 shall also adhere to requirements as set forth in Appendix F13.

- (g) the *generating unit* is capable of sustained operation within the voltage range set forth in Appendix F.

6.12 Remote Monitoring and Automatic Generation Control

6.12.1 The Transmission Licensee, Generation Licensee and *connected person* responsible for each *HVDC facility* shall provide the *Remote Terminal Unit(s)* at their substations, switchhouses or *HVDC facilities*, which shall provide the *Power System Operator* with remote monitoring, control and data acquisition of the equipment in the substation, switchhouse or *HVDC facility* as set out in Appendix H. Facilities for remote control are required only for substations and *HVDC facilities*. Information required includes status of *circuit breakers*, isolators, *earthing switches*, *protection systems*, ancillary equipment and other devices or equipment as specified by the *Power System Operator*. Measurements of power flow, *frequency*, voltages, transformer taps and other quantities as specified by the *Power System Operator* are also required.

6.12.2 The Generation Licensee shall provide the *Remote Terminal Unit(s)* for remote monitoring of their *generating units'* output and operating conditions as well as facilities for automatic control of generating unit's output from *Power System Operator's Energy Management System* as specified in Appendix H.

- (a) The Transmission Licensee and *connected person* responsible for each *HVDC facility* shall provide the *remote terminal unit(s)* for remote monitoring of their *HVDC facilities'* operating conditions, as well as facilities for automatic control of *HVDC facilities'* from *Power System Operator's Energy Management System* as specified in Appendix H.

6.12.3 The Transmission Licensee, Generation Licensee, and *connected person* responsible for each *HVDC facility* shall provide all the equipment at their respective site, including the communication equipment. The Transmission Licensee shall provide data communication lines from the computer room in the control centers of the *Power System Operator* to the transmission substation, *HVDC facility* and *generating station* switchhouses as specified by the *Power System Operator* for the purposes of real-time power system monitoring and control. The *connected person* responsible for each *HVDC facility* shall be responsible for the data communication lines from their *HVDC facility* to the Transmission Licensee's termination box located in their *HVDC facility*. The Generation Licensee shall be responsible for the data communication lines from the Generation Licensee's equipment to the Transmission Licensee's termination box located in the *generating station's* switchhouse. The termination box, which shall be

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provided by the Transmission Licensee, shall also be used for termination of the Transmission Licensee's data communication lines. In the event of relocation of the termination box or diversion of the data communications lines, the Licensee that initiates the relocation or diversion shall bear all the costs necessary for the relocation or diversion including the costs incurred by any other affected Licensee to divert the data communication lines at the affected Licensee's end caused by the relocation or diversion. All the equipment at the site shall be equipped with battery backup of at least 4-hour operation time. In addition, the AC power shall also be backed up by the standby generator at the site, if the site is equipped with such a facility.

- 6.12.4 The Transmission Licensee, Generation Licensee, and *connected person* responsible for each *HVDC facility* seeking to conduct any work on their *remote terminal unit* must submit to the *Power System Operator* for approval a written proposal that clearly states the nature, purpose and duration of the work.
- 6.12.5 The Transmission Licensee, Generation Licensee, or *connected person* responsible for each *HVDC facility* shall submit to the *Power System Operator* a test report of the commissioning of the *remote terminal unit*.
- 6.12.6 The *Interruptible Load Provider* shall provide the *Power System Operator* with real-time status and measurements at its interruptible load facility. The information shall include the status of circuit breakers and contactors, status of *UFR* ("armed" or "unarmed") and the status of any other devices as specified by the *Power System Operator*. Measurements of power and frequency for the incoming feeders from the grid and for the designated loads within the load facility, and measurements of any other quantities as specified by the *Power System Operator* shall also be provided.
- 6.12.7 *Connected person* with solar photovoltaic system of installed capacity equal to or exceeding 1MWac at each site/facility, shall provide the Power System Operator with the following signals sampled and transmitted at 1 minute intervals.
- Active Power; and
 - Solar irradiance.

Detailed requirements are stated in Section H4.3.

6.13 Performance Monitoring Facilities for 230kV and 400kV Substations/Switchhouses

- 6.13.1 The Transmission Licensee and Generation Licensee shall provide, install and maintain at their own cost, the performance monitoring facilities/transient recorders at its 230kV and 400kV substations/switchhouses. The performance monitoring facilities shall be capable of monitoring and recording the dynamic performance of its equipment during system disturbances. The Transmission Licensee and Generation Licensee shall provide such information to the *Power System Operator* upon request. The recorder shall be capable of capturing, but not limited to the following :-
- (a) substation/switchhouse busbar voltage, current and *frequency*; and

(b) *circuit breaker and protection devices status.*

6.14 Performance Monitoring Facilities for Interruptible Load Facilities

6.14.1 The *Interruptible Load Provider* shall provide the *Power System Operator* with records of status and measurements before and after activation of its interruptible load facility. The records shall include the status of circuit breakers and contactors, status of *UFR* (“armed” or “unarmed”) and the status of other devices as specified by the *Power System Operator*. Records of power and frequency for the incoming feeders from the grid and for the designated loads within the load facility, and measurements of any other quantities as specified by the *Power System Operator* shall also be provided.

6.15 Cyber Security for Critical Information Infrastructure (CII)

6.15.1 The Transmission Licensee, Generation Licensees, Wholesaler (Generation) Licensees, Wholesaler (Demand Response Programme) Licensees, Market Company Licensee and *connected person* responsible for each *HVDC facility* shall put in place adequate cyber security measures to ensure that designated *Critical Information Infrastructures (CIIs)* are properly maintained, operated and secured, so as not to compromise, or cause any adverse impact, to the *security, reliability* and stability of the power system including interruption of electricity supply or electricity generation due to inadvertent system or equipment failure, human error or through malicious actions of other parties.

6.15.2 The cyber security measures shall include those described in Appendix K.

7 PAYMENT SECURITY

7.1 Power to Require Security

- 7.1.1 Subject to section 7.1.4, the Transmission Licensee may mitigate the risk of non-payment by a consumer, Generation Licensee or Retail Electricity Licensee by requiring that such person provide reasonable *security* for the payment to it of all money which may become due in respect of *transmission services*, which may include:
- (a) cash deposits;
 - (b) an irrevocable letter of credit;
 - (c) bankers' guarantee or other financial guarantee in form and substance acceptable to the Transmission Licensee; or
 - (d) any combination of the above.
- 7.1.2 Without limiting the generality of section 7.1.1, the Transmission Licensee may, at its discretion, accept *security* bond ratings or other form of credit from a Generation Licensee or a Retail Electricity Licensee in lieu of the types of *security* described in section 7.1.1. In exercising this discretion, the Transmission Licensee shall not discriminate among persons with comparable risk profiles.
- 7.1.3 If a consumer, Generation Licensee or Retail Electricity Licensee provides *security* in the form of a cash deposit, the Transmission Licensee shall not pay interest on the deposit.
- 7.1.4 The maximum amount of *security* that the Transmission Licensee may require from a consumer, a Generation Licensee or a Retail Electricity Licensee shall be determined based on the Transmission Licensee's estimate of the maximum financial exposure faced by it, determined in accordance with section 7.1.5.
- 7.1.5 Subject to section 7.1.6, the Transmission Licensee's maximum exposure in respect of a consumer, a Generation Licensee or a Retail Electricity Licensee shall be estimated by the Transmission Licensee as follows:
- Step 1: Estimate the total bill for transmission service charges for the person for an average month based on historical information; any change in conditions that would result in different use of the *transmission system*; and the rates or tariffs currently in effect.
 - Step 2: Multiply the amount determined in Step 1 by 1.5 (or any other amount, as approved by the *Authority*).
 - Step 3: Add the amount that may become due to it in respect of the provision of all or any electrical plant or main by the Transmission Licensee.
- 7.1.6 Where the Transmission Licensee engages a Market Support Services Licence as an agent to collect *transmission services* charges, the maximum exposure in respect of a

contestable consumer or a Retail Electricity Licensee shall be in accordance with the provisions set out in section 13 of the Market Support Services Code.

- 7.1.7 In establishing the level of *security* to be provided by a person, the Transmission Licensee may differentiate between classes or subclasses of consumers, Generation Licensees or Retail Electricity Licensees to the extent those classes or subclasses have different credit risks.

7.2 Failure to Provide Security

- 7.2.1 Where a person fails to provide the *security* required to be given prior to commencement of receipt of *transmission services* (as determined in accordance with this section 7), the Transmission Licensee:

- (a) may not *energise* the *connection applicant's service connection* to the *transmission system*; or
- (b) may refuse to provide or procure the provision of all or any main or electrical plant (as the case may be); or
- (c) may refuse to provide that Retail Electricity Licensee with retailer-consolidated billing services (as defined in the applicable code of practice) with transmission services, and may charge contestable consumers serviced by that Retail Electricity Licensee directly for *transmission services*.

- 7.2.2 Where a person already receiving *transmission services* fails to give the *security* required under this section 7, the Transmission Licensee may by notice require that person, within 10 *business days* after the service of the notice, to give it reasonable security for the payment of *transmission services*. The Transmission Licensee may *disconnect* the person's *service connection*, discontinue the supply of electricity to the *installation* of that consumer, or discontinue the provision or procurement of all or any electrical plant or main for that consumer for so long as the failure continues. In case of a *disconnection* of a *service connection*, or discontinuation of supply to an *installation*, the Transmission Licensee shall advise the Market Support Services Licensee of the date and reason for the *disconnection* or discontinuation accordingly.

7.3 Updating Security Estimates

- 7.3.1 The Transmission Licensee shall update periodically its estimate of its financial exposure to persons to whom it is supplying *transmission services* in accordance with section 7.1.4 based on current estimates of the amounts projected to be owed to it in respect of *transmission services*.

- 7.3.2 The Transmission Licensee may update its estimate of its financial exposure as frequently as it wishes but no less than:

- (a) at least once every year for a consumer or a Generation Licensee; and
- (b) at least once every three months for a Retail Electricity Licensee.

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- 7.3.3 If, as a result of an updated estimate determined under sections 7.3.1 and 7.3.2, the maximum amount of *security* in respect of a person has fallen below the amount currently held in respect of that person by more than 10 percent, the Transmission Licensee shall so notify the person as soon as possible. The person may modify its *security* arrangement with the Transmission Licensee in light of and to reflect the decrease in the maximum amount of *security*. Where the *security* held in respect of such a person is in the form of a cash deposit, the Transmission Licensee shall, if so requested by the person, return the excess amount to the person within 20 *business days* of the date of receipt of the request.
- 7.3.4 If, as a result of an updated estimate determined under sections 7.3.1 and 7.3.2, the maximum amount of *security* in respect of a person increases above the amount currently held in respect of that person by more than 10 percent, and the Transmission Licensee wished to increase the *security* requirement accordingly:
- (a) the Transmission Licensee shall immediately notify the consumer or Retail Electricity Licensee and work with the applicable party to remedy the situation; and
 - (b) if after a period of 20 *business days* after the service of such notice, an amount remains owing from the relevant party and the parties have not otherwise agreed on a remedy, the Transmission Licensee may notify the consumer or Retail Electricity Licensee that it may discontinue the supply of electricity and subsequently *disconnect* the *service connection* in respect of that consumer or Retail Electricity Licensee for so long as the amount remains owing. The Transmission Licensee shall advise the Market Support Services Licensee of the date and the reason for *disconnection* or discontinuation accordingly.
- 7.3.5 The Transmission Licensee shall, in respect of a person who is no longer receiving *transmission services*, notify the person as soon as possible of the *security* held in respect of such a person. The person may elect to get a refund of its *security* arrangement with the Transmission Licensee, and the Transmission Licensee shall, if so requested by the person, return the outstanding *security* amount to the person within 20 *business days* of the date of receipt of the request.
- 7.3.6 Where a consumer has elected to discontinue receiving *transmission services*, the Transmission Licensee shall refund the outstanding security amount within 20 *business days* of the date of receipt of the requested discontinuance.

7.4 Default Process

- 7.4.1 In the event of a default in the payment owed by a contestable consumer or a Retail Electricity Licensee to the Transmission Licensee for *transmission services*, the Transmission Licensee shall not realise on any *security* held in respect of the contestable consumer or a Retail Electricity Licensee until 5 *business days* have elapsed from the date of notification given pursuant to section 7.4.2.
- 7.4.2 The Transmission Licensee shall, on the *business day* following a default in payment owed by a contestable consumer or a Retail Electricity Licensee for *transmission*

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services, notify the contestable consumer or a Retail Electricity Licensee that payment was not received and work to remedy the situation. If the amount owing remains unpaid 10 *business days* after the date of the giving of such notice and the parties have not agreed on a remedy, the Transmission Licensee may:

- (a) in the case of the contestable consumer, notify the consumer that it shall discontinue the supply of electricity and subsequently *disconnect* the *service connection* from the *transmission system*;
- (b) in the case of a Retail Electricity Licensee, notify the Retail Electricity Licensee that it proposes to exercise one or more of the remedies available to it under the terms of a *Retailer Use of System Agreement* entered into pursuant to section 3.1.1.

7.4.3 The Transmission Licensee may charge interest on any overdue amounts at such rate as may be approved by the *Authority* from time to time.

7.4.4 The Transmission Licensee may charge the contestable consumer or a Retail Electricity Licensee person for the costs of *disconnection* and other direct costs associated with the discontinuance of *transmission services* to the person or the recovery of payments held to be in default.

7.4.5 The Transmission Licensee shall advise the Market Support Services Licensee of the *disconnection* date and reason for *disconnection*.

8 TRANSMISSION SYSTEM PLANNING AND DEVELOPMENT

8.1 Responsibility

- 8.1.1 The Transmission Licensee shall be responsible for the annual development of proposals for the augmentation and expansion of the *transmission system* in accordance with guidelines and criteria set forth in this section of the Transmission Code. The plan shall take into account forecasts of demand made by the *Authority*, proposals for additional generation capacity or withdrawal of capacity advised by the *Authority*, requests by *Power System Operator* and proposals by consumers for forecast additional demand.
- 8.1.2 The Transmission Licensee, in formulating, its Ten-Year Transmission Development Plan or any adhoc transmission network development proposal (including but not limited to any proposal for asset renewal or network enhancement), shall ensure that the *network* design and any addition of *network* elements shall not jeopardise the *security, reliability, stability* and adequacy of the *power system*. The Transmission Licensee shall prepare and submit, each year, a Ten-Year Transmission Development Plan to the *Authority* for approval. As and when necessary, or as and when required by the *Authority*, the Transmission Licensee shall submit such adhoc transmission network development proposal to the *Power System Operator* and the *Authority* for endorsement and approval respectively. The *Authority* may grant approval subject to such conditions as it deems necessary. The Transmission Licensee shall complete approved proposals in the Ten-Year Transmission Development Plan and approved adhoc transmission network development proposals in accordance with such conditions as may be imposed by the *Authority* by the approved completion dates, unless otherwise specified by the *Authority*.
- 8.1.3 To facilitate Transmission Licensee's preparation of its Ten-Year Transmission Development Plan, the *Authority* shall, provide Transmission Licensee with the rolling ten-year electricity demand by the end of May (M month) of each year and the generation planting schedule¹ for the next 10 years by the end of (M+1) month.
- 8.1.4 The *Power System Operator* shall review and revise, if necessary, the minimum security standards as detailed in Appendix G, by the end of (M+1) month, taking into consideration requirements to shutdown *network* elements for maintenance and *network* modification.
- 8.1.5 The proposals for which the Transmission Licensee is responsible shall include:
- (a) a detailed plan for the 66kV network for the next 5 years and a detailed plan for 230kV/400kV networks for the next 10 years for *transmission networks* expansion, enhancement, upgrading, replacement and re-configuration;

¹ Generation planting schedule shall include addition of new generating units and planned generating units retirement.

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- (b) mode of *transmission network* operation such as *network* configuration and parallel operation of *network* blocks;
- (c) provision of ancillary equipment and systems to ensure system stability and *security* and that contingency requirements can be met;
- (d) cost details and phasing of each *transmission network* development project, and total capital expenditure and basis for *distribution network* development. The Transmission Licensee shall demonstrate that the *transmission system* development is cost effective and not excessive;
- (e) justification for any addition or changes of *transmission network* development proposals from the previous year's submission. The Transmission Licensee shall also demonstrate that these changes are cost effective and not excessive;
- (f) the Transmission Licensee shall conduct a presentation and briefing session to the *Power System Operator* and the *Authority* outlining its preliminary Ten-Year Transmission Development Plan by the end of (M+4) months; and
- (g) a report on the Ten-Year Transmission Development Plan shall be submitted to the *Power System Operator* and *Authority* by the end of (M+6) months. The report shall include:
 - (i) load flow studies of the 66kV network for the next 5 years and 230kV/400kV networks for the next 10 years (in both hardcopy and softcopy, where appropriate) comprising assumptions and basis used in the studies; load flow data and studies results including contingencies analysis; 66kV 5-yr *transmission network* expansion plan diagram; 400kV/230kV 10-yr *transmission network* expansion plan diagram; list of legends for substation abbreviations, substation bus number, actual substation name; a Singapore map indicating location of existing/proposed 400kV, 230kV, 66kV substations; and single line diagram for each proposed or modified 400kV, 230kV, 66kV substations; and
 - (ii) fault level studies (in both hardcopy and softcopy, where appropriate) comprising assumptions and basis used in the studies; sequence data and fault level report on the 3-phase and 1-phase fault for each 400kV, 230kV and 66kV substation; and consideration of fault current infeed from *interconnectors*.

8.1.6 The Transmission Licensee shall not proceed to implement any development proposal until:

- (a) it has submitted the proposal to the *Power System Operator* and *Authority* for endorsement and approval respectively; and
- (b) it has received approval from the *Authority* to proceed with the proposed development or any modified proposed development that is approved by the *Authority*.

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- 8.1.7 The *Power System Operator* shall assess the system *security* and stability, taking into consideration the proposed generation planting schedule and the Transmission Licensee's rolling Ten-Year Transmission Development Plan. The *Power System Operator* shall, if necessary, require the Transmission Licensee to revise the Ten-Year Transmission Development Plan within one month from receipt of the plan to ensure that system *security* and stability is maintained and *network reliability* meets the *security* standards. The *Power System Operator* shall provide the Transmission Licensee with all reasonable details of such requirement. The Transmission Licensee shall revise the plan accordingly and resubmit to *Power System Operator* within two weeks from receipt of *Power System Operator's* comments. The *Power System Operator* shall endorse the revised Ten-Year Transmission Development Plan within two weeks from receipt of Transmission Licensee's re-submission, if it is satisfied with the plan.
- 8.1.8 The Authority, in consultation with *Power System Operator*, shall review the Transmission Licensee's Ten-Year Transmission Development Plan (endorsed by *Power System Operator*), to ensure that the Ten-Year Transmission Development Plan is not excessive based on the security standards. The Authority shall, if necessary, require the Transmission Licensee to revise the Ten-Year Transmission Development Plan within 1 month from receipt of *Power System Operator's* endorsed Ten-Year Transmission Development Plan, and provide the Transmission Licensee with all reasonable details of such requirement. The Transmission Licensee shall revise the plan accordingly and resubmit to the Authority within two weeks from receipt of the Authority's comments. The Authority shall use its best endeavour to approve, as soon as possible, the Transmission Licensee's re-submitted Ten-Year Transmission Development Plan if it is satisfied with the plan.
- 8.1.9 On an annual basis or as and when required by the Authority, the Transmission Licensee shall submit such proposed *distribution network* projects that are required by the Authority for the Authority's approval. The Authority may grant approval subject to such conditions as it deems necessary. The proposed *distribution network* projects shall include but shall not be limited to asset renewal and network enhancement projects. The Transmission Licensee shall complete the approved *distribution network* projects in accordance with such conditions as may be imposed by the Authority by the approved completion dates, unless otherwise specified by the Authority.

8.2 Basis for Transmission and Distribution System Planning and Development

- 8.2.1 Notwithstanding section 8.1.1, the Transmission Licensee may engage in the development proposals, at its own instigation, for the reinforcement or extension of the existing *transmission system* for reasons which include, but are not limited to:-
- (a) an increase in supply requirements of an existing licensee or consumer or Generation Licensee that already is connected to the *transmission system*; and
 - (b) the introduction of a new *connection point* or modification of an existing *connection point* between the electrical system of a consumer or Generation Licensee and the *transmission system*.

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- 8.2.2 In the transmission system development proposals, the Transmission Licensee shall, *inter alia*:
- (a) make a full assessment of the costs and benefits of the various possibilities to enhance/develop the *transmission system* and recommend the most cost effective development proposal; and
 - (b) report on the impact of Use of System charges of any such development on the various classes of consumers.
- 8.2.3 Nothing in the foregoing shall prevent the *Authority* giving the Transmission Licensee authority to proceed with defined types of expansion without requiring approval for each specific proposal.

8.3 General Objectives for Transmission System Planning and Design

- 8.3.1 The Transmission Licensee shall plan and design the *transmission system* such that:
- (a) the *transmission network* can meet the requirements set forth in Appendix G and the *demand* levels forecast by the *Authority* while operating within the *security* limits set by the *Power System Operator* without causing system instability, cascading, or interruption of load in the event of an *outage* (whether scheduled or unscheduled) of any single *generating unit*, transmission circuit or transmission transformer within a transmission substation; and
 - (b) the 22kV and 6.6kV *distribution network* can cater for single contingent *outage* of circuits.

8.4 Equipment Design Standards

- 8.4.1 The Transmission Licensee shall base its *transmission system* and equipment design on the standards detailed in Appendix I or international standards, such as *IEC*, *BS* and *SS* or other equivalent international standards.
- 8.4.2 The Generation Licensee shall ensure that its *generation facilities* and *generating station* premises have adequate protection and preventive measures against lightning strike and fire, and comply with the requirements of *IEC*, *BS*, *SS*, or other equivalent international standards.

9 INSPECTIONS AND MAINTENANCE

9.1 Requirements

- 9.1.1 The Transmission Licensee shall inspect, test, monitor and maintain the *transmission system* and all related facilities and equipment owned by the Transmission Licensee in order to determine whether the *transmission system* and such facilities and equipment comply with all applicable standards and requirements set forth in this *Code*, in all *Connection Agreements*, in the *Operating Agreement*, and in the market rules.
- 9.1.2 The Transmission Licensee shall perform the inspection, testing, monitoring and maintenance activities referred to in section 9.1.1 using *competent persons* adequately trained to protect both themselves and the public.
- 9.1.3 The Transmission Licensee shall rectify any defects discovered during the inspection, testing or monitoring activities referred to in section 9.1.1 within a reasonable period of time after the discovery of the defect but, in any event, within the periods of time, if any, specified in the *Operating Agreement* or any *Connection Agreement*.
- 9.1.4 The Transmission Licensee shall implement an internal review procedure to ensure that any defects identified during the inspection, testing or monitoring activities referred to in section 9.1.1 and any necessary follow-up activities have been rectified in an appropriate manner.
- 9.1.5 As and when required by the *Authority*, the Transmission Licensee shall at its own cost engage an independent auditor to conduct a technical audit of any one or more of its *installations*, or to review its standing operating procedures, or to audit or review any other technical, operational or other matter as may be specified by the *Authority*, for the purpose of ensuring the stability, *security* and *reliability* of the *transmission system*.
- 9.1.6 The Transmission Licensee shall ensure that it has sufficient inventory of critical spares for the timely replacement of faulty parts of any of its network facilities or assets so that the facility or asset can be returned to service in the shortest possible time. The Transmission Licensee shall also ensure that it has sufficient inventory of essential consumables to enable continual operation of the Transmission Licensee's network facilities and assets.

9.2 Application to other Licensees

- 9.2.1 Such other Licensee who may own or operate *installations* which are deemed to be a part of the *power system* shall inspect, test, monitor and maintain such *installations*, all related facilities and equipment owned by the Licensee in order to determine whether the *installation* and such facilities and equipment comply with all applicable standards and requirements set forth in this *Code*, in all *Connection Agreements*, and in the market rules.
- 9.2.2 The Licensee shall perform the inspection, testing, monitoring and maintenance activities referred to in section 9.2.1 using *competent persons* adequately trained to protect both themselves and the public.

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- 9.2.3 The Licensee shall rectify any defects discovered during the inspection, testing or monitoring activities referred to in section 9.2.1 within a reasonable period of time after the discovery of the defect but, in any event, within the periods of time, if any, specified in any *Connection Agreement*.
- 9.2.4 The Licensee shall implement an internal review procedure to ensure that any defects identified during the inspection, testing or monitoring activities referred to in section 9.2.1 and any necessary follow-up activities have been rectified in an appropriate manner.
- 9.2.5 The Generation Licensee shall ensure that it has sufficient inventory of critical spares for timely replacement of faulty parts of any *generation facility* so that the *generation facility* can be returned to service in the shortest possible time. The Generation Licensee shall also ensure that it has sufficient inventory of essential consumables to enable continual operation of the Generation Licensee's *generation facilities*. Without prejudice to the generality of the foregoing, the Generation Licensee shall in particular ensure that each *generation facility* which is a *combined-cycle plant* or gas turbine shall have one complete set of spare air filters within Singapore at all times.
- 9.2.6 As and when required by the *Authority*, the Generation Licensee shall at its own cost engage an independent auditor to conduct a technical audit of its *generating station*, any one or more of its *generation facilities*, or to review its standing operating procedures, or to audit or review any other technical, operational or other matter as may be specified by the *Authority*, for the purpose of ensuring the stability, *security* and *reliability* of its *generating station* and *generation facilities*.

9.3 Record Keeping

- 9.3.1 With the exception of recordings made by any SCADA systems or an *Energy Management System*, the Transmission Licensee and *connected person* referred to in section 9.2 shall maintain records setting out the results of all inspections, testing, monitoring and maintenance activities referred to in section 9.1.1 for six years from the date of the inspection, testing, monitoring or maintenance activity and shall make those records available to the *Authority* upon request.
- 9.3.2 Where the *Power System Operator* uses a *Energy Management System* in the operation of the *transmission network*, it shall maintain routine monitoring records produced by the *Energy Management System* for such a period as may be agreed between the Transmission Licensee and the *Power System Operator*, and in any case for a period of not less than six years.
- 9.3.3 Where the Transmission Licensee uses a SCADA system in the operation of the *distribution network*, it shall maintain routine monitoring records produced by the SCADA system for such a period as may be agreed between the Transmission Licensee and the *Power System Operator*, and in any case for a period of not less than six years.

9.4 Cable Damage Preventive Measures

- 9.4.1 The Generation Licensee shall implement measures to ensure that electricity cables belonging to the Transmission Licensee, which are laid in the *generating station* premises, are protected from damage by any earthworks carried out in the premises, including but not limited to the following:
- (a) providing clear markings of 400kV, 230kV and 66kV cables routes within the *generating station* premises;
 - (b) establishing a standard operating procedure (“SOP”) for earthworks carried out within *generating station* premises in compliance with the cable damage prevention provisions in the Electricity Act; and
 - (c) implementing, as part of the SOP, a Permit-to-Work (“PTW”) system to ensure that contractors seek the Generation Licensee’s approval before they commence earthworks.
- 9.4.2 The Transmission Licensee shall keep up-to-date digital mapping or records of their high and low voltage cables installed in and under public places, in such form as is accessible by government agencies, other utilities service providers, or such other persons who require such information for locating the high and low voltage cables prior to commencement of earthworks, or for infrastructure planning works or for other purposes as required by government agencies and agreed to by the *Authority*. The Transmission Licensee shall also ensure that its digital mapping or records of high and low voltage cables are accurate and comply with the relevant requirements in the Singapore Land Authority’s Utility Survey Standard.

10 SAFETY COORDINATION, ISOLATION AND EARTHING PROCEDURES

10.1 General Principles

- 10.1.1 Safety procedures shall be adopted in respect of any *service connection* or equipment directly *connected* to it so as to ensure the safety of personnel and/or plant at any time that work and/or testing is carried out at or near the *service connection* or equipment
- 10.1.2 The Transmission Licensee shall, in accordance with the requirements set forth in this section, coordinate the activities of persons responsible for *transmission system* testing, monitoring and maintenance or for the testing, monitoring and maintenance of facilities or equipment *connected* to the *transmission system* to ensure that when testing and maintenance is to be carried out on such facilities or equipment, all necessary isolation and *earthing* is established and maintained.
- 10.1.3 The provisions of sections 10.2 to 10.6 inclusive shall apply to *connection points* in the *transmission system*.
- 10.1.4 Safety procedures to apply in the *distribution network* for work and/or testing to be carried out at or near the service connection or equipment directly *connected* to it shall be developed by the Transmission Licensee in consultation with consumers.

10.2 Scope

- 10.2.1 The Transmission Licensee (and/or *Power System Operator*, as the case may be) and *connected person* shall co-ordinate, establish and maintain the necessary isolation and *earthing* when work and/or testing is to be carried out on the transmission or distribution system, or *connected person's* electrical system. For the purposes of this section, the term "Party" shall refer to the Transmission Licensee or the relevant *connected person*.
- 10.2.2 This section does not define the safety rules to be adopted by the Transmission Licensee or the *connected person*, but sets out procedures which shall govern the interface between them. In particular, it lays down the rules for agreeing on the safety procedures (the *site safety procedures*), which shall be adopted on either side of a *connection point* between the Transmission Licensee and *connected person*.
- 10.2.3 Where one Party is required to approve the *site safety procedures* of another Party in terms of section 10.3, such approval does not imply that the approving Party takes any responsibility for the adequacy or otherwise of the *site safety procedures*. The approval in such case only implies that there is nothing in the *site safety procedures* that negates or frustrates any provision of the *site safety procedures* of the approving Party for the relevant *connection point*.

10.3 Approval of Site Safety Procedures

- 10.3.1 Prior to the energising of a new *service connection*, the Transmission Licensee and the *connection applicant* shall each supply the other with a copy of the *site safety procedures* which it intends to adopt on its side of the *service connection* for approval by the other party.

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- 10.3.2 The Party from whom approval is sought will, within 7 days of receipt of the *site safety procedures*, send written comments to the issuing Party giving:
- (a) its approval of the *site safety procedures*; or
 - (b) its reasons for refusing to give approval and the changes which it would wish to see to enable it to grant approval.
- 10.3.3 If the Party from whom approval is sought requires more stringent isolation and/or *earthing* provisions then, to the extent that these provisions are not unreasonable, the other Party shall make such changes to its *site safety procedures* as soon as is reasonably practicable.
- 10.3.4 If, subsequent to the approval of any *site safety procedure*, the issuing Party wishes to change any provision of the procedure, it shall prepare a version of the procedure showing the original text and clearly indicating the changes required to this text and shall seek approval of this procedure as if this procedure had not been previously approved. Subject to the provisions of the following paragraph, the revised procedure shall not be implemented until the necessary approvals have been received.
- 10.3.5 If an approved *site safety procedure* has been found to be unsound, revisions to this procedure (only to the extent that these are required to ensure the safety of personnel or plant) may be implemented immediately, subject only to the *safety coordinators* of the other Party or Parties having been informed of these changes and having confirmed that the changes do not increase the risk to their own personnel or plant and are understood.
- 10.3.6 Operational procedures for work on *transmission system* and equipment connected to the *transmission system* should not be less stringent than the requirements and rules as detailed in Transmission Licensee's "Rules for the Control and Safe Operation of High & Medium Voltage Apparatus", copies of which can be obtained from the Transmission Licensee.

10.4 Safety Coordinators

- 10.4.1 Prior to the energising of a *service connection* the *connected person* and Transmission Licensee will, in respect of the *service connection*, appoint an *authorised person* to act as *safety coordinator*, and a second *authorised person* to act as *safety coordinator* at any time that the first named *authorised person* is unavailable.
- 10.4.2 The Transmission Licensee and the *connected person* shall inform each other, in writing and without delay, of the identity of the *authorised persons* appointed by them as *safety coordinators*. In the event of an intention to replace the *authorised person* appointed as *safety coordinator*, the other party to the *service connection* shall be notified of the identity of the new *safety coordinator* without delay.
- 10.4.3 The *safety coordinator* shall be responsible for co-ordination of all matters concerning safety (but not limited to the approval of *site safety procedures*). A *safety coordinator* may be responsible for more than one *service connection*.

10.5 Isolation and Earthing Principles

10.5.1 Without prejudice to the need to prepare and agree on *site safety procedures* for each *service connection*, the Transmission Licensee and each *connected person* shall adopt isolation and *earthing* principles no less stringent than those outlined below.

10.5.2 Isolation facilities shall be provided as follows:

- (a) where isolation is achieved by means of an *isolating device*, the isolating position shall be maintained in such a way as to minimise the risk of inadvertent, accidental or unauthorised operation and that when put in this position, a notice or “tag” to that effect shall be attached; and
- (b) clearance to work on any apparatus which requires such isolation to be achieved shall only be issued when the procedure in preceding section has been completed.

10.5.3 *Earthing* facilities shall be provided as follows:

- (a) where *earthing* is achieved by means of an *earthing device*, the *earthing* position shall be maintained in such a way as to minimise the risk of inadvertent, accidental or unauthorised operation and that when put in this position, a notice or “tag” to that effect shall be attached; and
- (b) clearance to work on any apparatus which requires this *earthing* to be achieved shall only be issued when the procedure in section 10.5.2 (a) has been completed.

10.5.4 Notwithstanding the above, any proposal relating to the addition, replacement or removal of transmission network equipment shall be forwarded by the party requesting the work to the *Power System Operator*, and no addition, replacement or removal of equipment shall be undertaken until the *Power System Operator* has approved such action in writing.

10.5.5 Notwithstanding the above, for any proposal for switching, taking out of equipment or putting in of equipment, the *safety coordinator* shall forward to the Transmission Licensee or *Power System Operator*, where applicable, their proposal for final clearance in writing before the switching can be carried out.

10.6 Supervision of Contract Work in Transmission Installations

10.6.1 For work in *energised* switchhouses and substations at voltages of 66kV and above, the Transmission Licensee and *connected person* shall ensure that contract personnel working in such *installations* are competent to work in such *installations*.

10.6.2 Owners of *installations* at voltages of 66kV and above shall ensure that their contractors' staff are properly supervised by a Supervisor who is either an experienced specialist from the manufacturer's works or a *competent person* who has had considerable and sufficient experience in carrying out such works in *installations* at voltages of 66kV and above. The contractors' supervisor shall be present whenever any work is carried out in an *energised installation*, at voltages of 66kV and above, by the contractor.

10.7 Safety Procedures

10.7.1 The Transmission Licensee, Generation Licensee or *connected person* shall establish and maintain adequate safety measures and procedures to ensure the safety of the public or personnel and/or prevention of death/injury to any person or damage to any property for any work or testing carried out on any electric line or equipment belonging to or under the management or control of the Transmission Licensee, Generation Licensee or *connected person*.

10.7.2 The Transmission Licensee, Generation Licensee or *connected person* shall comply with all applicable or relevant safety procedures, requirements and practices to ensure the safety of the public or personnel and/or prevention of death/injury to any person or damage to any property when any work or testing is carried out on any electric line or equipment belonging to or under the management or control of the Transmission Licensee, Generation Licensee or *connected person*.

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APPENDIX A

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APPENDIX B DEMAND AND LOAD DATA REQUIREMENTS

B1 Demand Data Requirements for Planning Purposes

B1.1 Each person who has entered into a *Connection Agreement* or who wishes to enter into a *Connection Agreement*, other than a Generation Licensee, for *connection* of their *installation* to the *transmission system*, or each retail electricity licensee who has entered into a *Retailer Use of System Agreement* or who wishes to enter into a *Retailer Use of System Agreement*, shall provide to the Transmission Licensee the following information with respect to growth in *demand* by those *installations*:

- (a) anticipated increases in *demand*; and
- (b) a breakdown in the increases referred to in section B.1.1(a) by type of load.

B1.2 Each *connected person*, other than a Generation Licensee, shall provide to the Transmission Licensee the following information with respect to developments at that *installation* that are anticipated to increase *demand* by 5 MW or more:

- (a) Location of the development;
- (b) Anticipated maximum active and *reactive power demand* of the development;
- (c) Projected *demand* growth associated with the development over the life of the development;
- (d) Type of load;
- (e) Typical daily load pattern; and
- (f) Typical annual maximum *demand* pattern.

B2 Particular Load Information

B2.1 Each *connected person*, other than a Generation Licensee, whose load includes motors or fluctuating load or voltage sensitive load that, in the view of the Transmission Licensee, have the potential to have an adverse impact on the operation of the *power system* shall provide to the Transmission Licensee the following information:

- (a) The capacity, starting current and supply voltage of any large motors;
- (b) The capacity, anticipated load fluctuation and supply voltage of plant at such *installation*;
- (c) The capacity and supply voltage of voltage sensitive plant or equipment causing harmonics and phase imbalance;

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- (d) *Protective devices* proposed for the *installation*; and
- (e) Such additional detailed data with respect of their proposed *connection point* as the Transmission Licensee may require to facilitate the *connection*.

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APPENDIX C GENERATING UNIT REQUIREMENTS

C1 Preliminary Generating Unit Data to be Submitted for Consideration of Connection to the Transmission System

Each Generation Licensee or Wholesaler (Generation) Licensee responsible for the *generation facility*, with the exception of solar photovoltaic systems, and seeking connection to the *transmission system* shall provide the information required in accordance with the format set forth in C.1.1 to C.1.3 of this Appendix for both primary and *alternate fuel* (for *generating units* that are capable of operating and required to operate on *alternate fuel*). For solar photovoltaic *generating unit*, the Generation Licensee or Wholesaler (Generation) Licensee shall provide the information required in accordance with the format set forth in C7 of this Appendix.

C1.1 General

- (a) Names of *generation facilities*.
- (b) Total generation capacity (MW & MVA).
- (c) Brief description of the configuration of the *generation facilities* including types of *generation facilities* (steam, gas turbine or combined cycle) and number for each type.
- (d) Schedule date of commissioning for each *generation facility*.
- (e) Total power required for *auxiliaries*.
- (f) Internal load intended to be supplied by proposed *generation facility*, if any.

C1.2 For each *generation facility*

- (a) Name of *generation facility*.
- (b) Type of unit (steam, gas turbine or combined cycle).
- (c) Rated capacity in MW & MVA.
- (d) Maximum available output in MW.
- (e) Minimum stable load in MW.
- (f) Short circuit current contribution at the point of common coupling and basis of computation.
- (g) Power required for *auxiliaries*.

C1.3 *Generating unit* performance parameters

- (a) Name of *generation unit*.
- (b) Unit Number.

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(c) *Generating Unit*

- Manufacturer _____
- Rated terminal voltage _____ kV
- Rated MVA Capacity _____ MVA
- Rated power factor
 - Over-excited (lagging) _____
 - Under-excited (leading) _____
- Short-circuit ratio at rated voltage and current _____
- Direct axis short-circuit time constants
 - Transient (T_d') _____ seconds
 - Sub-Transient (T_d'') _____ seconds
- Direct axis open-circuit time constants
 - Transient (T_{do}') _____ seconds
 - Sub-Transient (T_{do}'') _____ seconds
- Quadrature axis open-circuit time constants
 - Transient (T_{qo}') _____ seconds
 - Sub-Transient (T_{qo}'') _____ seconds
- Direct axis synchronous reactance (X_d)
 - Unsaturated _____ %
- Direct axis transient reactance (X_d')
 - Unsaturated _____ %
 - Saturated _____ %
- Direct axis sub-transient reactance (X_d'')
 - Unsaturated _____ %
 - Saturated _____ %
- Quadrature axis unsaturated reactance
 - Synchronous (X_q) _____ %
 - Transient (X_q') _____ %
 - Sub-transient (X_q'') _____ %

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- Potier reactance (X_p) _____ %
 - Leakage reactance (X_l) _____ %
 - Negative phase sequence reactance (X_2) _____ %
 - Zero phase sequence reactance (X_0) _____ %
 - Armature winding short-circuit Time constant (T_a) _____ seconds
 - Main field current at no load and rated voltage _____ Amps
 - Main field current at full load, rated voltage and rated power factor overexcited _____ Amps
 - Resistance of main field windings at operating temperature of ____°C ____ Ohms
 - Machine damping factor (K_D) _____
 - “Turbine + *Generating Unit*” Inertia Constant (H) _____ MW * seconds / MVA
 - Saturation curves
 - To indicate the corresponding field current values at 1.0 pu and 1.2 pu of terminal voltage on the air-gap and open circuit curves.
 - V-curve
 - Reactive capability curve
 - Factory test reports and field test result, if any
- (d) *Generating unit* step-up transformer
- Rated MVA Capacity _____ MVA
 - Rated voltage
 - Primary _____ kV
 - Secondary _____ kV
 - Nominal voltage ratio, primary/secondary _____
 - Positive sequence impedance at
 - Maximum tap _____ %
 - Minimum tap _____ %
 - Nominal tap _____ %
 - Zero phase sequence impedance _____ %
 - Tap changer range
 - + _____ %
 - _____ %

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- Tap changer step size _____ %
 - Tap changer type on load / off load
 - Winding connection and Vector Group _____
 - Magnetising curve
 - Earthing resistor of transformer (if any)
 - At Primary side _____
 - At Secondary side _____
 - Report on predicted transformer energisation performance including electromagnetic transient studies unless otherwise agreed with the PSO.
- (e) Excitation System
- Voltage regulator model name: _____
 - Functional description and block diagram showing transfer function of individual element of the excitation system and the Automatic Voltage Regulator.
 - The setting and block diagram showing transfer function of individual element of the minimum and maximum excitation limiters.
 - The setting of limiters is to be plotted in the *Generating Unit* Reactive Capability Curve.
 - Exciter saturation data, if available (or applicable).
 - Commissioning tests or other field test results.
- (f) Power System Stabilizer (PSS)
- Functional description and block diagram showing transfer function of individual element of the PSS
 - Report on methodology in deriving the PSS setting, including simulation results and tuning procedures
 - Commissioning tests or other field test results
- (g) Steam Turbine Units
- Rated MW Capacity
 - Power fraction for High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP) turbines.
 - Control design
 - Functional description and block diagram showing transfer function of individual element of the governor/turbine/boiler

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- Test data/report:
 - Control and intercept valve curves:
 - position vs. signal
 - valve opening vs. signal
 - Closing/opening speed tests
 - Load rejection tests
 - Load step response tests
 - *Frequency* response tests
- General boiler control strategy, including:
 - Whether constant or variable pressure
 - If constant pressure, boiler follow, turbine follow, or coordinated control
 - If coordinated control, *frequency* and pressure biases
 - If variable pressure, pressure and control valve position as a function of load level
- (h) Gas Turbine Units (Open Cycle and Closed Cycle)
 - Rated MW Capacity
 - Performance data and curves:
 - Power vs. Fuel Consumption
 - Exhaust Temperature vs. Fuel Consumption
 - Power vs. Ambient Temperature
 - Power vs. Speed
 - Inlet Guide Vane effects
 - Control design
 - Functional description and block diagram showing transfer function of individual element of gas turbines units (including effect of Ambient Temperature). The model is to be submitted in both PSSE source code (i.e. flecs code) format and MATLAB Simulink format.
 - Test data/report:
 - Load rejection tests
 - *Frequency* response tests
- (i) Steam Turbine Units on Combined Cycle

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- Rated MW Capacity
 - Power fraction for High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP) turbines.
 - Control Design
 - Functional description and block diagram showing transfer function of individual element of the steam turbine units
 - Control strategy following outages of one or more gas turbine units
 - Steam unit power vs. exhaust temperature, air flow and power of gas turbine units
 - Test data/report:
 - Load rejection tests
 - Change in steam turbine unit output for a sudden change in gas turbine unit output (including gas turbine unit outage)
- (j) *Generating Unit Protection* - Functional description and settings of *generating unit* protection including:
- Loss of excitation relays
 - CT ratio
 - VT ratio
 - Setting
 - Under-frequency relay setting
 - Over-frequency relay setting
 - Other relay setting such as under-voltage protection for auxiliary equipment eg. Motor etc

All data to be provided shall be in per unit magnitude with MVA base specified. *Generating unit* and *generating unit's* step-up transformer data shall be provided in Rated MVA Capacity base.

C1.4 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

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1. “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

- (a) “IEEE Recommended Practice for Excitation Systems for Power Stability Studies”, IEEE Standard 421.5-1992.
- (b) “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

1. “Dynamic Models for Fossil Fueled Steam Units in Power System Studies”, IEEE Transactions on Power Systems, Vol. 6, No. 2, May 1991.
2. “Dynamic Models for Combined Cycle Plants in Power System Studies”, IEEE Transactions on Power Systems, Vol. 9, No. 3. August 1994.
3. “Simplified Mathematical Representation of Heavy-Duty Gas Turbines”, “Journal of Engineering for Power, October 1983, Vol. 105.
4. “Simplified Mathematical Representation of Single Shaft Gas Turbines”, Turbomachinery International, July/August 1992.
5. “Boiler Models for System Dynamic Performance Studies”, IEEE Transactions on Power Systems, Vol. 6, No. 1, February 1991.

C2 Commissioning Test Schedule

Each Generation Licensee responsible for a *generation facility* to be *connected* to the *transmission system* shall provide the information required in accordance with sections C.2.1 to C.2.3 of this Appendix.

C2.1 Date *generating unit* is expected to synchronise to the transmission system.

C2.2 Date *generating unit* is expected to commence commercial operation.

C2.3 Commissioning Test Schedules: All test schedules to indicate date, time and unit’s output profile as well as low / medium / high risks of machine outage

- (a) Excitation Tests
- (b) Load Rejection Tests
- (c) Load Swing Tests

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- (d) On Load Trip Tests
- (e) Combustion Tests
- (f) Performance Tests
- (g) Load Runback Tests
- (h) HP/LP Heater Tests
- (i) Power System Stabiliser Tests
- (j) Vacuum Loss Runback Tests
- (k) Governor Valve Linearizing Tests
- (l) Boiler Feed-pump Runback Tests
- (m) FDF Runback Tests
- (n) Cold/Warm/Hot Start Tests
- (o) Automatic Generation Control Tests
- (p) Spinning Reserves Capability Tests
- (q) Others

C3 Black Start Generating Unit Capability Data

Each Generation Licensee responsible for a facility *connected to the transmission system* shall provide the information required in this section.

- (a) Name & Location of Black Start *generating unit*:
- (b) Type of *generating unit*: Diesel/Gas
- (c) Unit Number
- (d) Manufacturer
- (e) Model
- (f) Rated Terminal Voltage: _____ kV
- (g) Rated MVA capacity: _____ MVA
- (h) Rated Power Factor
 - Over-excited (lead)
 - Under-excited (lag)
- (i) Time from Notification given to Synchronisation: _____ Hours
- (j) Start-up curve (from Synchronisation to Minimum Stable Load)
 - Time from minimum stable load to full load: _____ Hours
 - Maximum Ramp Rate: _____ MW/min

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- (k) Capability Curve:
 - Reactive Power Capability Curve
 - Factory Test Reports and field test result, if any
- (l) Black Start capability test report shall include the following
 - Detailed Single Line Diagram of the Station/Unit Board, *Auxiliaries*, Emergency diesel *generating units* & Black-Start *generating units* connection
 - Detailed Test Procedures, from Initial isolation from the Transmission System, start-up of Black-Start *Generating Unit(s)* till synchronisation to the Transmission System.
 - Records of key timing, load (both real & reactive power) profile, voltage profile of black start *generating unit(s)* during run-up of *auxiliary* equipment, etc.

C4 Centrally Dispatched Generating Unit Minimum Capability Requirements

C4.1 All *generating units* of gross generating capacity exceeding 10MW or registered with the Energy Market Company as a *generation registered facility* shall be centrally dispatched. All centrally dispatchable *generating units*, shall be designed to have the following capabilities except where the Generation Licensees declare with technical justifications that certain capabilities are technically not possible and submit such request together with its supporting reasons for *PSO* consideration.

(a) Load Following Capability

All *generating units* shall be designed such that they can follow system load.

(b) Voltage and Reactive Control

Each *generation unit* should provide suitable *automatic voltage regulating* equipment compatible with the *network* for controlling the voltage specified in section 6.5.1 of this Code.

- the excitation system must be operated only in its constant terminal voltage mode of operation, with any constant *Reactive Power* output control mode or constant power factor output control always disabled, unless otherwise agreed with *PSO*;
- the response of the excitation system shall be fast and well damped. For open circuit step response of 5% step change in voltage reference, the *Generating unit* terminal voltage shall reach 90% of its final value within 1 second and have a maximum Settling Time of 5 seconds. Settling Time is defined as the time taken for the *generating unit* terminal voltage to settle and stay within an error band of $\pm 1\%$ of its increment value;

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- settling time following any disturbance that causes an excitation limiter to operate shall be within 5 seconds;
- droop compensation of up to 2/3 of the *generating unit's* step-up transformer reactance should be provided;
- excitation limiters shall not interfere with the proper operation of the *generating unit*.

(c) Contingency Availability

The *generation facility* should be able to perform the following operations during contingencies:

- Coming on line.
- Adjusting generation output.
- Remaining in operation and connected to the *transmission system*.
- Coming off-line where *generating unit* would contribute to overloading facilities or over generation conditions.

(d) Two-Shifting Capability

All *generating units* shall be designed with two-shifting capability for normal daily operations.

(e) Governor Response and Spinning Reserve

The Generation Licensee's *generating unit* shall be designed to possess the following capabilities:

- all *generating units* shall be *frequency* sensitive;
- capable of responding automatically to normal variation in the system *frequency* of $\pm 0.5\text{Hz}$;
- releasing the spinning *reserve* in the manner required by the *PSO* under the Market Rules and tested as per the verification tests stipulated in the System Operation Manual; and
- the speed governor must meet the following minimum requirements:
 - the speed governor must be capable of being set so that it can operate with governor droops within the range of 3% to 5%.

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- the speed governor deadband shall be within the range of ± 0.05 Hz. However, the governor shall respond to full *frequency* deviation once system *frequency* deviation exceeds this deadband;
- where a *generating unit* becomes part of an electrical island i.e. is isolated from the rest of the system, but is still supplying loads in the island, the speed governor must be able to contribute its share to maintain *frequency* in the island, unless *PSO* considers, on a reasonable ground, that it is technically not feasible;

(f) *Contingency Reserve Capability*

For *generating unit* providing *contingency reserve*, it must be capable of meeting a minimum ramp rate in order to achieve 10% of its Rated MW Capacity within 10 minutes, and shall be subjected to verification tests stipulated in the System Operation Manual.

(g) *Protective Relay Systems*

The protective relay systems for the Generation Licensee's *generating facility* switchgear, transformers and related equipment should be adequate to prevent equipment damage for contingencies occurring both within the *generating station* and outside the *generating station* on the *transmission system*. The Generation Licensee shall be responsible for the operation & maintenance of each protective relay system within the *generating station*. Reference is given in Appendix F.

(h) *Performance Monitoring Facility*

The Generation Licensee shall provide, install and maintain at its own cost high-resolution recorder(s) for monitoring and assessment of performance including speed governor's *frequency* response of each *generating unit* by *Power System Operator*. The recorder shall be capable of capturing, but not limited to the following:

- the transient and dynamic response of each of the *generating unit* in terms of real and reactive power output (MW and MVar);
- the voltage (Volt) and *frequency* (Hz) at the *generating unit* terminal; and
- the system voltage (Volt) at the high tension side of the *generating unit*'s step-up transformer.

The requirements of high-resolution recorder(s) are given in Appendix F. The Generation Licensee, upon receiving notification from *PSO*, shall furnish such records/data in softcopy via email in the format as specified in Appendix F9.2(g) within 24 hours.

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(i) Remote Monitoring and Automatic Generation Control

The Generation Licensee shall make provision at their facility for remote monitoring of the *generating units*' output and switchhouse equipment loading and operating conditions etc. as well as automatic control of generation output from *Power System Operator's EMS*.

(j) Power System Stabilizer (PSS)

For each *generating unit* with Rated MW Capacity at or above 60MW, a PSS shall be incorporated to provide additional damping of power oscillations. Proper operation of the PSS shall be confirmed by test. The PSS shall have dual inputs, namely measured electrical power and speed. PSS transducers (i.e., for measuring input signals) shall be linear over their operational range and its time constant shall not exceed 100 milliseconds. *Power System Operator* shall make available the system characteristic to Generation Licensees for tuning of PSS. Generation Licensees shall submit a report incorporating the methodology in deriving the setting of the PSS parameters, as well as the tuning techniques, to *PSO* for review before implementation on site.

C5 Generating Unit does not meet all the Minimum Capability Requirements

Generating units which are centrally dispatchable having some but not all the required capabilities as stated in section C.4 (a) to (j) may not be permitted to be connected to the *transmission system* in order not to jeopardize system stability, *security* and *reliability*. For the same reasons, those permitted to be connected to the *transmission system* may not be permitted to operate under certain system conditions or as base load units.

C6 Additional Requirements for A Combined-Cycle Plant With Multi-shaft Configuration For Consideration As Multiple Independent Generation Facilities

C6.1 This Appendix states the additional requirements for a *Combined-Cycle Plant* with multi-shaft configuration seeking to register as multiple independent *generation facilities*. A *Combined-Cycle Plant* with multi-shaft (n+n+1) configuration comprises n gas turbines (GTs), n heat recovery steam generators (HRSGs) and one steam turbine (ST), may seek to register as multiple independent *generation facilities*, where each *Generation Facility* may comprise of either

- i. only one *Generating Unit*; or
- ii. more than one *Generating Unit*.

C6.2 The Generation Licensee shall at its own cost, engage an independent specialist consultant other than its *Owners Engineers* and Engineering, Procurement & Construction (EPC) contractors, to conduct detailed design review, witness site

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verification tests, and certify that the *Combined-Cycle Plant* is in compliance with Appendix C6.3.

- C6.3 The verification tests shall be conducted and meet the acceptance criteria stipulated in the System Operation Manual.
- C6.4 The independent specialist consultant shall ensure a detailed test plan is prepared based on its detailed knowledge of the *Combined-Cycle Plant* from the design review conducted. Where the Generation Licensee wishes to use a new technology or additional tests, it may request discussion with the *Power System Operator* in respect of revising the existing testing methods or procedures to demonstrate meeting the performance requirements stipulated in Appendix C 6.3.
- C6.5 The Generation Licensee is required to submit to the *Power System Operator* the design review report together with the proposed test plan at least six months before the site verification tests.
- C6.6 Generation Licensee is required to conduct additional tests identified by the *Power System Operator*, if any, to demonstrate compliance with the requirement stipulated in Appendix C6.3.
- C6.7 The Generation Licensee is required to submit to the *Power System Operator*, a final report duly certified by its independent specialist consultant and the Generation Licensee. The report shall state all site test results recorded, and conclude whether the *Combined-Cycle Plant* is in compliance with the requirements stipulated in Appendix C6.3. In addition, the report shall also include details of any improvements recommended by the independent specialist consultant in the course of its review for the *Combined-Cycle Plant* to comply with the requirements.
- C6.8 Upon receipt of the report, the *Power System Operator* shall use its reasonable endeavors to complete the review of the final report submitted within 20 business days. Upon the *Power System Operator's* acceptance of the submitted report, the Generation Licensee shall submit standing capability data of the *Combined-cycle Plant* to the *Power System Operator* for approval to operate as multiple independent *Generation Registered Facility*.
- C6.9 However, during normal operation, if the outage of any single element/functional system of the *Combined-Cycle Plant* causes any of the following:
- i. tripping of more than one *generation facility*; or
 - ii. loss in generation of more than the active output power of largest generation facility of the *Combined-Cycle Plant*;

The PSO may notify Energy Market Company of any change to the system risk attributable to one or more *generation facilities* of the *Combined-Cycle Plant*. On *PSO's* notification, Energy Market Company shall, in accordance with the Market

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Rules, determine risk and operating reserve requirement taking into account such change in system risk. The Generation Licensee shall identify the cause of tripping, take necessary remedial actions and re-test to verify its compliance to the requirements stipulated in Appendix C6.3. A detailed report shall be submitted to the *PSO*. Upon the *PSO's* acceptance of the submitted report, the *PSO* shall notify EMC of the revised system risk attributable to such *generation facilities*. Energy Market Company shall, in accordance with the Market Rules, determine risk and operating reserve requirements taking into account such change in system risk.

C7 Additional Requirements for Solar Photovoltaic Generating Unit

C7.1 Each Generation Licensee or Wholesaler (Generation) Licensee or *connected person* responsible for the solar photovoltaic *generating unit* at each site/facility, shall provide the information set forth in this Appendix.

- (a) Name of *Generation Facility*
- (b) Maximum Generation Capacity (Aggregated capacity of all solar photovoltaic modules' AC inverters at the point of *connection* to the grid) (kWac)
- (c) Total PV modules' capacity (kWp)
- (d) Voltage Level of *connection* point
- (e) *Generation Facility's* site address/Postal Code
- (f) Rated Power Factor
 - Over-excited (lagging)
 - Under-excited (leading)
- (g) Solar photovoltaic module (for solar photovoltaic *generating unit* \geq 1MWac)
 - Type of photovoltaic module: (Monocrystalline / Polycrystalline / Amorphous / CdTe / CIGS/CIS and Others, please specify)
 - Module Tilt Angle
 - Module Azimuth Angle
- (h) Frequency and voltage protection settings
- (i) Reactive Power Control Capabilities (as per the inverters' settings)
- (j) Voltage reference point

C7.2 Each Generation Licensee or Wholesaler (Generation) Licensee responsible for solar photovoltaic *generating unit(s)* with an aggregated installed capacity of 10MWac or above at each site/facility, and seeking connection to the *transmission system* shall provide to the Transmission Licensee and the Power System Operator (where applicable) a dynamic simulation model that fulfils the requirements set forth in the System Operation Manual.

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APPENDIX D OPERATION INFORMATION ON EXTERNAL SYSTEM AND THE EXTERNAL GENERATION FACILITIES

D1 The following information and data relating to *external systems* and *external generation facilities* shall be updated and submitted by the *external party* to Transmission Licensee and *Power System Operator*, upon application for interconnection and subsequently by the end of February of each calendar year or upon any material change in the data previously submitted.

D1.1 *External system*

The information to be submitted shall cover the then current year and the following ten year period and shall include the following:

- (a) Actual and projected system *demand*
- (b) Daily and yearly typical *demand* profile
- (c) Generation installed capacities, types and locations
- (d) Criteria of system spinning *reserve* provision and spinning *reserve* allocation and composition in terms of type of *generating units*
- (e) Intended power transfer through the *interconnector*
- (f) Complete *network* diagram showing the connection of existing and future *generating unit* and active /reactive loads at substations
- (g) Complete *generating unit* models and parameters
- (h) Complete *network* data
- (i) An equivalent of the *external system* as seen from the *connection point* of the *interconnector*
- (j) A single-line diagram of the switchgear panels and *protection system* for the *interconnector* including settings at the *interconnector* substation in the *external system*

The data submitted shall be in both softcopy and hardcopy.

D1.2 External Generation Facilities

The information to be submitted shall cover the then current year and the following ten year period and shall include the following:

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- (a) Actual and projected active and reactive *demands* in local *network* including daily and yearly load profile, if applicable
- (b) Complete *network* diagram showing the connection of existing and future *generating units*
- (c) Complete *generating unit* models and parameters
- (d) Complete *network* data, if applicable
- (e) A single-line diagram of the switchgear panels and *protection system* for the *interconnector* including settings at the *interconnector* substation of the *external generation facility*.

D2 The following operation information shall be provided to the Power System Operator:

- (a) For *external system*, criteria for spinning *reserve* provision, allocation and composition in terms of type of *generating units* and response capability
- (b) After every incident of *generating unit outage* in the *power system* or in the *external systems / external generation facilities*, the following information shall be provided: -
 - Local system active and reactive *demand* before and after the incident
 - Generation unit commitment in the *external system* before and after the incident
 - *Active* and *reactive power* output curves for each *generating unit*
 - Protective relay settings on the *interconnector*
 - Settings of key system and plant control parameters such as setting of tie-line biased load *frequency* control
 - System *frequency* curve
 - Voltage profile and variation curves if it deviates from the nominal voltage range
 - Under-*frequency* relay settings and locations and amounts of load shed
- (c) The following operation information shall be provided to the *Power System Operator* and Transmission Licensee after every incident of *generating unit outage* or equipment *outage / fault* in the *external system / external generation facilities*:
 - Location and type of equipment *outage* and cause of *outage*

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- If *outage* is due to equipment fault, the nature of the fault
- *Active* and *reactive power* flow or fault current through the *interconnector* during the incident
- Settings of protection system on the *interconnector*

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APPENDIX E TEST REQUIREMENTS FOR GENERATION FACILITIES, TRANSMISSION FACILITIES, CONSUMER INSTALLATIONS AND EXTERNAL SYSTEMS

E1 Obligations

E1.1 *Connected persons* and the Transmission Licensee shall conduct tests in respect of electrical plant connected or intended to be connected to the *high voltage* part of the *power system* in accordance with the requirements of this Appendix.

E2 New Electrical Plant

E2.1 All new electrical plant to be *connected* to the *power system* shall be fully tested at site, if applicable, in accordance with the *BS, IEC, SS* or international standards. The testing and verification of the electrical plant to be connected to the *power system* shall be in accordance with the Transmission Licensee's requirements and/or *Power System Operator's* requirements (where applicable).

E2.2 The test circuit, methodology and procedures of any off-load pre-commissioning or on-load commissioning tests pertaining to electrical plant shall be in accordance with the Transmission Licensee's and/or *Power System Operator's* requirements, where applicable. Where the *connected person* or the Generation Licensee or the Transmission Licensee, as the case may be, wish to use a new technology, the proposing party may request discussion in respect of revising the existing testing methods or procedures to suit the latest proven development in technology.

E3 Existing Electrical Plant

E3.1 Any existing electrical plant which have been disconnected from the *power system* for repair, inspection, testing or any other reason shall be subject to the applicable off-load functional and proofing tests, and on-load re-commissioning tests where applicable.

E3.2 When requesting reconnection to the *power system*, the *connected person* or Transmission Licensee seeking reconnection shall provide to the *Power System Operator* and/or the Transmission Licensee, where applicable, reports of all tests conducted in accordance with *BS, IEC, SS* or international standards.

E4 Procedure on Submission of Proposal to Conduct a System Test

E4.1 Nature and Purpose

- (a) The person seeking to conduct a *system test* must submit to the *Power System Operator* and/or the Transmission Licensee, where applicable, a written proposal

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that clearly states the nature and purpose of the tests of the electrical plant that is the subject-matter of the proposal.

E4.2 Identification and Situation of Electrical Plant Involved

- (a) The person submitting a proposal pursuant to section E.4.1 must include in the proposal a clear description and detailed single line diagram(s) sufficient to identify the electrical plant that is the subject-matter of the proposal and indicate the potential risks associated with the *system test*.
- (b) The *Power System Operator* and/or the Transmission Licensee, where applicable, shall assess the proposal submitted to it under this section E.4.1 and shall notify the person submitting the proposal within 14 *business days* as to whether it approves the *system test* and any conditions upon which such approval has been granted. If approval is not granted, the party that disapproves the *system tests* shall provide to the person submitting the proposal the reasons for such non-approval.

E5 Test Panel And Supervision

E5.1 Test Panel

- (a) In the situation where the party approving the *system test* determines that a proposed *system test* in respect of which approval has been granted under section E.4 may adversely affect the secure, stable and reliable operation of the *power system*, a test panel comprising the *Power System Operator*, the Transmission Licensee and the person submitting the proposal pursuant to section E.4 shall be convened to implement and supervise the proposed *system test*.
- (b) The person submitting the proposal pursuant to section E.4 shall be the coordinator of the test panel. The coordinator is responsible for coordinating the performance of the *system tests* and shall be responsible for ensuring that proper and accurate entries are made of the test results in the relevant test reports.
- (c) The test panel established pursuant to section E.5.1 (a) shall be responsible for ensuring that the *system test* is performed in a proper manner and in accordance with the specified methodology and procedures.

E5.2 Witnessing by the *Power System Operator* and/or the Transmission Licensee

- (a) Where the *Power System Operator* and/or the Transmission Licensee, where applicable, is satisfied that a proposed *system test* in respect of which approval has been granted under section E.4 shall not affect the secure, stable and reliable operation of the *power system*, the *Power System Operator* and/or the Transmission Licensee, where applicable, at its discretion, may or may not send a representative

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to witness and supervise the performance of the proposed tests by the person submitting the proposal pursuant to section E.4.

- (b) The person submitting the proposal pursuant to section E.4 and performing the *system test* shall ensure that only qualified and *competent persons* are permitted to perform the *system test*.
- (c) The person submitting the proposal pursuant to section E.4 and performing the *system test* shall be responsible for ensuring that proper and accurate entries are made of the test results in the relevant test reports.
- (d) The *Power System Operator* may notify the Transmission Licensee or Generation Licensees of the performance of system test where such system test, in the opinion of the *Power System Operator* may have an impact on the Transmission Licensee's or Generation Licensees' operation.
- (e) The Transmission Licensee, with inputs from the *Power System Operator*, where applicable, may notify third parties (excluding Generation Licensees) of the performance of the *system test* where such *system test*, in the opinion of the *Power System Operator* or the Transmission Licensee, may have an impact on third parties' operation.

E6 Submission of Report

- E6.1 The coordinator of the test panel established pursuant to section E.5.1 (b), if any, or the person submitting the proposal pursuant to section E.4 and performing the *system test*, as the case may be, shall be responsible for compiling and submitting the report setting forth the results of the *system test* to the *Power System Operator* and/or the Transmission Licensee, where applicable.
- E6.2 The report referred to in section E.6.1 shall include a description of the electrical plant being tested, a description of the *system test* performed, the results of the *system test* and any recommended actions stemming from the tests.

E7 Postponement or Cancellation of Proposal

- E7.1 Once a proposal has been submitted pursuant to section E.4, any change in the date or time scheduled for performance of the *system test* that is the subject-matter of the proposal shall require the approval of the *Power System Operator* and/or the Transmission Licensee, where applicable. A request to change the date or time scheduled for the performance of the *system test* shall be submitted to the *Power System Operator* and/or the Transmission Licensee, where applicable, no less than 24 hours prior to the original time scheduled for the performance test. The person requesting for

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any change in the date or time schedule shall specify the reasons for the change and shall indicate the new date and time at which the *system test* is proposed to be performed. The *Power System Operator* and/or the Transmission Licensee, where applicable, shall only grant its approval to a change in the date or time scheduled for performance of a *system test* where it is satisfied that unforeseeable problems or problems outside the control of the person submitting the proposal have arisen such as to warrant the change. Where the *Power System Operator* and/or the Transmission Licensee, where applicable, does not approve a change in the date or time scheduled for performance of a *system test*, the *system test* shall be cancelled and a new proposal must be submitted in respect of the *system test* in order for the *system test* to be performed.

- E7.2 Where the *Power System Operator* and/or the Transmission Licensee, where applicable, approves a change in the date or time scheduled for the performance of a *system test* under section E.7.1, it shall notify the Transmission Licensee and/or the *Power System Operator* accordingly of the proposed new date and time at which the *system test* is proposed to be performed.
- E7.3 The *Power System Operator* and/or the Transmission Licensee, where applicable, may stop, delay or cancel the performance of a *system test* at any time if it determines that performance of the *system test* may adversely affect the stability, *security* and *reliability* of the *power system*. The *Power System Operator* and/or the Transmission Licensee, where applicable, shall so notify the person responsible for performing the *system test* and shall work with him to determine a new date and time at which performance of the *system test* shall not adversely affect the stability, *security* and *reliability* of the *power system*.

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APPENDIX F SPECIFIC OPERATING AND TECHNICAL REQUIREMENTS FOR GENERATION, TRANSMISSION AND CONSUMER INSTALLATIONS

F1 General Conditions for Generation Facilities

F1.1 Generation Licensee shall notify the PSO and Transmission Licensee at least 3 months before initial *energisation* and start-up testing of a *generation facility*. The Transmission Licensee shall not *connect* a *generation facility* unless the Generation Licensee has notified the Transmission Licensee within the applicable time to permit this testing.

F1.2 Generation Licensee shall operate the *installation* with all of its protective devices in service at all times.

F1.3 Generation Licensee shall submit validated parameters and models which include:

- (a) *generating unit*;
- (b) excitation system including excitation limiters;
- (c) power system stabiliser;
- (d) governor / turbine / prime mover;
- (e) boiler controls.

The parameters and models shall be validated via site tests for their *generating units*. The method of testing shall be designed to cover the linear and non-linear responses of the *generating unit*. The parameters and models are considered validated when the computer simulation results match the site test results. Simulation and site test results shall be overlaid on the same plots using the same scales.

Upon completion of site tests, Generation Licensee shall, within 1 month, submit the report comprises validated parameters, models together with the computer simulation results, and site test results to *PSO*.

F1.4 The design and operation of an *installation* shall not cause adverse impact on the integrity of the *transmission system*.

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F2 Quality Assurance Conditions for Generation Facilities, Transmission Facilities, HVDC Facilities and Consumer Installations

F2.1 Voltage Fluctuation

- (a) *Connected person* shall ensure that the operation of their *installations* shall not cause voltage fluctuation at a point of common coupling to exceed 3% of the nominal voltage for step changes, with the exception of the energisation of transformers, *HVDC facility* related equipment and reactors connected to the transmission network, which shall not cause voltage fluctuation at a point of common coupling to exceed 5% of the nominal voltage.
- (b) The Transmission Licensee shall ensure that the energisation of transformers, *HVDC facility* related equipment and reactors connected to the transmission network shall not cause voltage fluctuation at a point of common coupling to exceed 5% of the nominal voltage. Unless otherwise agreed with the PSO, the Transmission Licensee shall provide a report on predicted equipment energisation performance whenever a new type of power equipment is introduced or there are changes in the specifications of existing type of power equipment. This report shall include electromagnetic transient studies.
- (c) The planning limits for voltage fluctuation caused by *connected person*, e.g. owner of an arc furnace, shall be in accordance with the requirements set out in Engineering Recommendation P28 of UK.

F2.2 Harmonics

- (a) The owner of an *installation* shall ensure that starting surges or harmonics generated by *connected persons'* and Transmission Licensee's equipment at the *installation* must not cause the maximum *total harmonic voltage distortion* at the point of common coupling to exceed the following:
 - (i) At 400kV, a *total harmonic voltage distortion* of 1.5 percent with no individual odd harmonic greater than 1.0 percent and no individual even harmonic greater than 0.5 percent;
 - (ii) At 230kV, a *total harmonic voltage distortion* of 1.5 percent with no individual odd harmonic greater than 1.0 percent and no individual even harmonic greater than 0.5 percent;
 - (iii) At 66kV, a *total harmonic voltage distortion* of 3.0 percent with no individual odd harmonic greater than 2.0 percent and no individual even harmonic greater than 1.0 percent; and
 - (iv) At 22kV and 6.6 kV, a *total harmonic voltage distortion* of 4.0 percent with no individual odd harmonic greater than 3.0 percent and no individual even harmonic greater than 2.0 percent.

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- (v) At 400V and 230V, a *total harmonic voltage distortion* of 5.0 percent with no individual odd harmonic greater than 4.0 percent and no individual even harmonic greater than 2.0 percent.

F2.3 Phase Imbalance

- (a) Planned *outages* or operation of an *installation* shall not cause the maximum negative phase sequence component of the phase voltage to exceed 1 percent.

F3 Protection Systems

F3.1 The Transmission Licensee and *connected person* shall ensure that *protection systems* for its *installation* and the *service connection* applicable thereto shall meet the minimum requirements set forth in this section F3.

F3.2 All *transmission system protective devices* / schemes shall be suitable for the *installations* and the *service connection* being protected. In addition, busbar and breaker fail protection shall be provided for *installations* connected to the 400kV, 230kV of the transmission system and Transmission Licensee's 66kV source stations.

F3.3 The *protective device* for *unit protection* installed at the *installation* side of the *service connection* shall be the same make and model as the *protective device* installed on the Transmission Licensee's side of the *service connection*. For the *distribution network*, the *protective devices* for *unit protection* are subjected to approval by the Transmission Licensee.

F3.4 The Transmission Licensee and *connected person* shall ensure that the fault clearance times of the main *protective devices* on the *installation* and on the *service connection* from fault current inception to the *circuit breaker* arc extinction, shall not be more than the following:

- (a) 80 ms at 400kV;
- (b) 100 ms at 230kV; and
- (c) 140 ms at 66kV.

Where fault clearance requires the opening of the remote *circuit breaker* via inter-trip, the overall fault clearance time may be increased by up to 20 ms.

F3.5 In the event that the *circuit breaker*, forming part of the main *protective devices* referred to in section F3.4, fails to interrupt the fault current, breaker fail protection provided by the Transmission Licensee and *connected person* shall operate with a fault clearance time (from fault current inception to the *circuit breaker* arc extinction) not slower than 300ms.

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- F3.6 For a Generation Licensee, the back-up *protection systems*, i.e. overcurrent and earth fault, installed shall be capable of withstanding, without tripping, the loading incurred during the clearance of a fault in the *transmission system* by breaker fail protection or another back-up *protection system*.
- F3.7 Loss of excitation protection is to be provided for each *generating unit*. Where deemed necessary by the PSO, pole-slipping protection should also be provided.
- F3.8 The *connected person* shall ensure that their protective current transformers shall be of the applicable accuracy class necessary to meet the protective relay requirements.
- F3.9 All necessary communication equipment/links as may be required by the protective relaying scheme shall be installed. Where required by the Transmission Licensee, such equipment or links shall be compatible with the applicable communication equipment or links of the Transmission Licensee.
- F3.10 Depending on the length of *service connection*, the general requirements for transmission line protection which shall be satisfied by the *connected persons* or Transmission Licensee are as follows:
- (a) 400kV
 - Two current differential protection
 - One *distance protection*
 - (b) 230kV
 - One current differential or phase comparison protection
 - One *distance protection* or a second current differential with integrated *distance protection*
 - (c) 66kV
 - One or two current differential protection, depending on points of connection in the *network*
 - One IDMTL overcurrent/earth fault protection
- F3.11 For a *HVDC facility*, the back-up *protection systems*, i.e. overcurrent and earth fault, installed shall be capable of withstanding, without tripping, the loading incurred during the clearance of a fault in the *transmission system* by breaker fail protection or another back-up *protection system*.

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F4 Communication Equipment at a Generation Facility

- F4.1 The Generation Licensee shall install, maintain and operate two independent voice communication links between the Generation Licensee's Power Plant control room and *Power System Operator's* Control Centre. These voice links shall be the "hot line" and UHF wireless communication, and shall be used for system operational purposes only. All necessary communication equipment/links as may be required by the protective relaying scheme shall be installed and maintained by the Generation Licensee. Where required, such equipment or links shall be compatible with the applicable communication equipment or links of the Transmission Licensee and/or the *Power System Operator*.
- F4.2 The Generation Licensee shall install, maintain and operate a facsimile machine used for operational purposes, with a dedicated telephone line and number, located in the Generation Licensee's *generation facility* control room. The Generation Licensee and the *Power System Operator* shall inform each other of the telephone number of the facsimile machine used for operational purposes.
- F4.3 The Generation Licensee, with Generation Registered Facility at point of connection of 66kV voltage and above, shall provide compatible voice communication equipment located in the Generation Licensee's generation facility control room which shall be connected to the Transmission Licensee's voice communication system. The Generation Licensee shall be responsible for the communication lines from the Generation Licensee's generation facility control room to the Transmission Licensee's termination box that connects to the Transmission Licensee's voice communication system. The termination box shall be provided by the Transmission Licensee and shall be located in the generating station switchhouse. In the event of relocation of the termination box or diversion of the communications lines, the Licensee that initiates the relocation or diversion shall bear all the costs necessary for the relocation or diversion including the costs incurred by any other affected Licensee to divert the communication lines at the affected Licensee's end caused by the relocation or diversion.

F5 Communication Equipment at a Substation Other than a Generation Facility.

- F5.1 For *transmission network* substations, should the *Power System Operator* consider it necessary, the Transmission Licensee or the *connected person*, as the case may be, shall install, maintain and operate a voice communication link between the substation and *Power System Operator's* Control Centre.

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F6 Frequency Range of Generating Unit

F6.1 The *generating unit* shall be capable of sustained operation within the system *frequency* range which is normally controlled within the limits of 49.5Hz – 50.5Hz and, in exceptional circumstances, it could rise to 52Hz or fall to 47Hz.

F6.2 The *generating unit* shall operate within the frequencies range of 52 Hz to 47 Hz in accordance to the following:

<u>Frequency Range</u>	<u>Requirement</u>
• 52 Hz – 47.5 Hz	Continuous operation is required
• 47.5 Hz – 47 Hz	<i>Generating unit</i> is required to remain in operation for at least 20 seconds each time <i>frequency</i> falls below 47.5Hz

F7 Primary Reserve Requirement

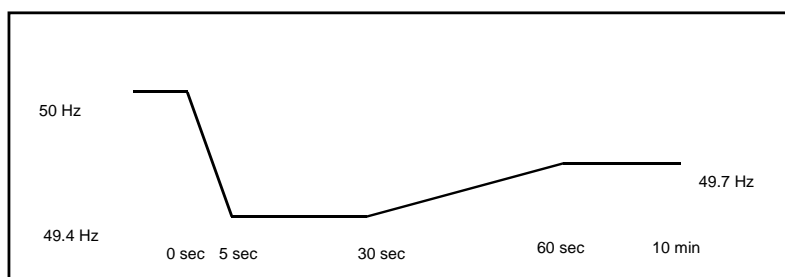
F7.1 This section states the minimum spinning *reserve* requirement in terms of primary *reserve* for each *generating unit* which has a Completion Date after 1 January 2000.

F7.2 For each *generating unit* which has a Completion Date before 1 January 2000 must endeavour to meet the minimum spinning *reserve* requirement subject to and in accordance with the provisions of section F.8, otherwise Generation Licensee shall submit the achievable spinning *reserve* capability to *PSO* for consideration.

F7.3 Nothing in this appendix is intended to prevent a *generating unit* from being designed to provide spinning *reserve* in excess of the minimum requirement specified below.

F7.4 Frequency Response Profile

F.7.4.1 The ability of a *generating unit* to release primary *reserve* is measured by artificially subjecting the *generating unit* to a test whereby “measured” *frequency* is of the form as illustrated in the following figure:



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F.7.4.2 *Primary Reserve* is defined as the change in MW output of the *generating unit* automatically by governor action in response to this change in *frequency*, measured at 9 seconds and sustainable for an additional 9 minutes and 51 seconds. If the change in MW output measured at 9 seconds is not sustained for the period of 9 minutes and 51 seconds, the *primary reserve* is the minimum change in MW output reached during that period.

F.7.4.3 The *primary reserve* release capability shall be verified via test procedure stipulated in the System Operation Manual.

F8 Spinning Reserve Requirements of Frequency Sensitive Plant

F8.1 Each *generating unit* must be capable of providing minimum *primary reserve* for both primary and *alternate fuel*. The Spinning Reserve Requirements for primary and *alternate fuel* are as follows:

	<i>Generating unit</i> MW Output as a % of Rated MW Capacity ²	<i>Primary reserve</i> as a % of Rated MW Capacity ²
(i)	90	5
(ii)	75 to Minimum Stable Load	9

F8.2 The *primary reserve* requirements for each *generating unit* MW output between Minimum Stable Load and 75%, 75% and 90%, and 90% and 100% of its rated MW Capacity shall be linearly interpolated from the requirements for the *generating unit* MW outputs between Minimum Stable Load and 75%, 75% and 90%, and 90% and 100% of its Rated MW Capacity² respectively. Additional details are provided in the System Operation Manual.

F8.3 Each *generating unit* must be capable of providing minimum *contingency reserve* of 10% of its Rated MW Capacity² within 10 minutes and shall be verified through test stipulated in the System Operation Manual.

² For *Combined-Cycle Plant*, Rated MW capacity shall be referenced to the rated MW Capacity of each *generating unit* operating at full load (i.e. the base load) while in operation under primary and *alternate fuel*.

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F9 Requirements for High Resolution Recorder for Performance Monitoring and Assessment of the Generation Facilities and Interconnectors

F9.1 The high resolution recorder installed shall be suitable for both dynamic and transient recording. The recorder shall be able to set at minimum sampling rate of 50Hz and 1kHz for dynamic and transient recording respectively. The basic signal to be recorded / monitored includes, but not limited to, the following:

For *HVDC Facilities*

- (a) *Active power (MW) and reactive power (MVar) flow at the point of connection of the HVDC facility with the transmission system*
- (b) *HVDC substation busbar voltage (both DC and AC voltages) and frequency*
- (c) *Circuit breaker and protection devices status*

For *Generating Units*

- (a) **Dynamic Recording**
 - *Active power (MW)*
 - *Reactive power (MVar)*
 - *Bus frequency at connecting Substation*
 - *Power system stabilizer output*
 - *AGC pulses*

Additional Signals for Steam Unit

- *Load Limiter Position*
- *MW Demand Control Signal*

Additional Signals for Gas Turbine Unit

- *Ambient and Exhaust Temperatures*
- *Fuel Demand Signals or Fuel Flow*

- (b) **Transient Recording**

- *Generating Unit Terminal Voltage (LV –side)*
- *Generating Unit Terminal Voltage (HV-side)*

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- *Generating Unit* Field Voltage
- *Generating Unit* field current

For Interconnectors

- *Active power* (MW) and *reactive power* (MVar) flow of each interconnector
- Substation busbar voltage and *frequency*
- *Circuit breaker* and protection devices status

F9.2 Specifications of Recorder

- (a) Sample Rate
 - Min 50Hz - 1kHz
- (b) Resolution
 - Analog Signals: 12 bits or 0.025% of full scale
 - *Frequency*: $\pm 5\text{mHz}$
- (c) Trigger Type
 - Maximum *frequency* / voltage
 - Minimum *frequency* / voltage
 - Rate of rising or falling of *frequency* / voltage
- (d) Pre-trigger Length
 - 30 second minimum for dynamic recording
 - 0.5 second minimum for transient recording
- (e) Event Storage Capacity
 - 400 events minimum
- (f) Event length
 - Minimum 15 minutes for dynamic recording
 - Minimum 5 second for transient recording
- (g) Event Data Format

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- ASCII or
 - Spreadsheet
 - IEEE Comtrade
- (h) Time Stamping
- A Global Position Satellite (GPS) clock shall be provided for time synchronisation and shall have a minimum resolution of 1 msec.
- (i) Software
- The software of the recorder shall have at least the capability to compute R.M.S values for voltage, current, *active power*, *reactive power* and power factor.

F10 Voltage Operating Range of Generating Unit

F10.1 The solar photovoltaic *generating unit* shall be capable of disconnecting from the *transmission system* if under or over voltage is detected at the *connected person's* incoming switchboard* or at the *generating unit* terminal. The range of abnormal operating voltages and the corresponding minimum holding time before disconnection and maximum trip time shall be as follows:

Abnormal Voltage Range (% of nominal voltage)	Minimum Holding Time (second)	Maximum Trip Time (second)
$V < 50$	0.6	1.6
$50 \leq V < 88$	2.0	3.0
$110 < V < 120$	1.0	2.0

*For large installation (>1MWac) being connected to the HT network solely for the purpose of energy export, the voltage is detected at the *connected person's* incoming switchboard.

F11 Reconnection Time of Generating Unit

F11.1 Solar photovoltaic *generating unit* and other *generating unit connected* to the *distribution network* that is disconnected due to section F6.2 or section F10.1, may reconnect to the *transmission system* 1 minute after the voltage and frequency at its *connection point* have recovered and remained within the ranges listed as follows:

- (a) Frequency within 49.8Hz and 50.2Hz;
- (b) *Transmission network* voltage within $\pm 3\%$ of the nominal value or *distribution network* voltage within $\pm 6\%$ of the nominal value.

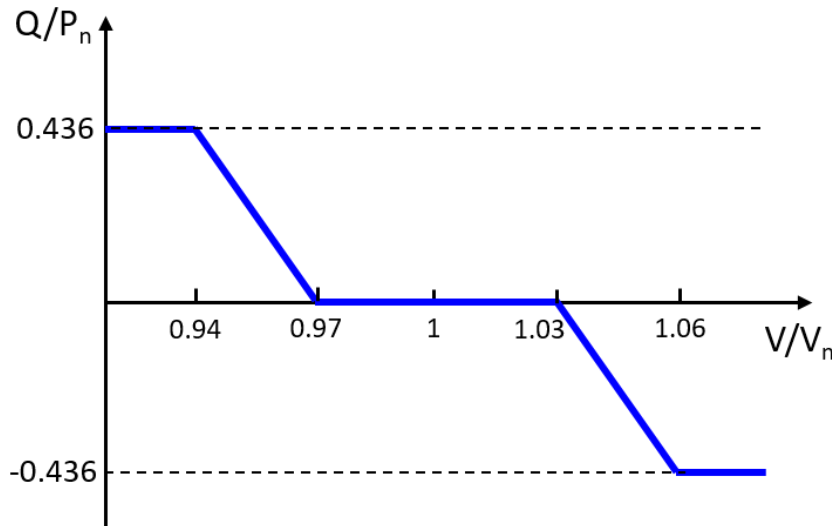
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F12 Additional Requirements for Solar Photovoltaic Generating Unit

F12.1 Reactive Power Output Control

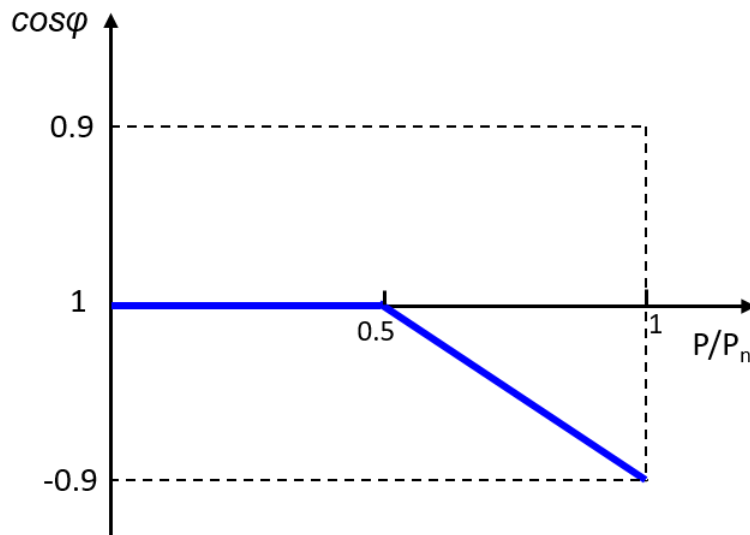
F12.1.1 The solar photovoltaic *generating unit* shall be designed with capability of controlling the *reactive power* supply at the ac terminals of the inverter with the following *reactive power* output control modes.

- (a) Fixed Power Factor control mode where the solar photovoltaic *generating unit* shall operate at a 0.9 leading power factor, or otherwise specified by the Transmission Licensee or *Power System Operator*;
- (b) Q(V) according to local voltage control mode where the solar photovoltaic *generating unit* shall vary the *reactive power* output with the voltage at the ac-side of the solar photovoltaic *generating unit's* inverter(s), at the characteristic curve as illustrated below. V is actual voltage measured at reference point, V_n is nominal voltage, Q is actual feed-in *reactive power*, and P_n is nameplate *active power* rating of inverter;



- (c) Q(P) according to actual feed-in *active power* where the solar photovoltaic *generating unit* shall vary its operating power factor with the *active power* output exceeds 50% of its rated *active power* capacity. P is actual feed-in *active power*; and

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- (d) Q control mode where the solar photovoltaic *generating unit* shall be capable of changing its *reactive power* output, within its *reactive power* capability range, at the *Connection Point* upon receiving a *Reactive Power* control (Q) set-point signal from the Transmission Licensee or *Power System Operator*.

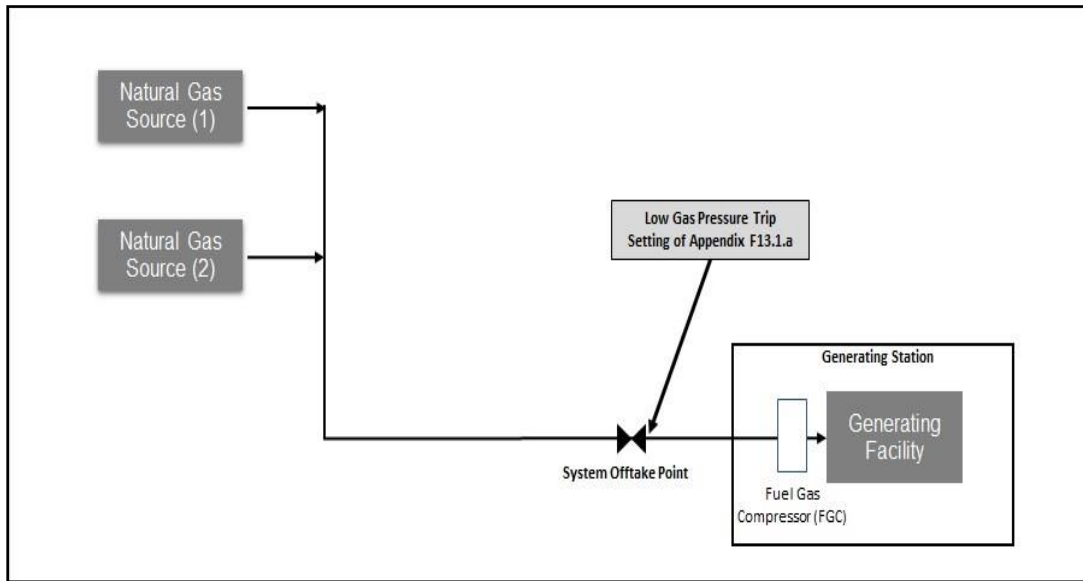
F13 Fuel Changeover Requirements

F13.1 This section states the design and technical requirements for each newly commissioned generation facility, (b) any existing generation facility under-going life extension of 5 years or longer or (c) repowering, which is to be registered with EMC on or after 1 January 2021. Each generation facility that uses natural gas as primary fuel shall:

- (a) be designed to operate at its rated MW Capacity with a low gas pressure trip setting no greater than 16barg measured at the System Offtake Point in accordance to the definition of the Gas Network Code (GNC) Section A (refer to Figure F13.1.a for illustration);

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Figure F13.1.a – Demarcation of System Off-take Point in accordance to Gas Network Code (GNC)



- (b) comply with the requirements in Table 13.1.b for fuel changeover (FCO) operations (refer to Figure 13.1.b for illustration);

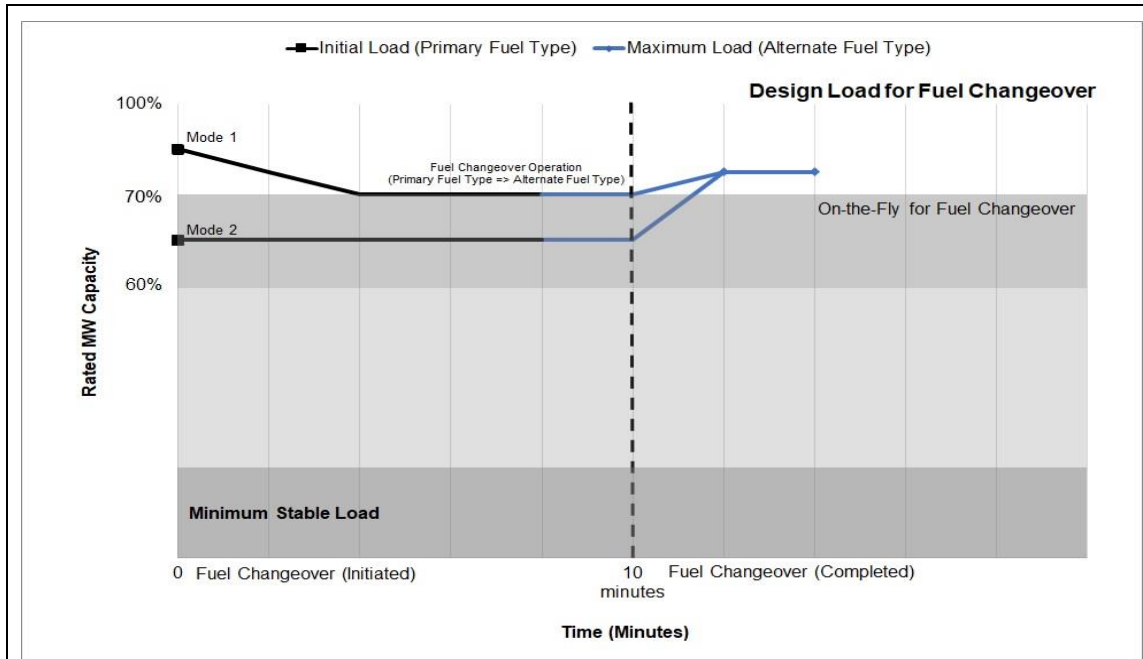
Table 13.1b

Generating Facility Rated MW Loading on Primary Fuel (%) prior to FCO initiation	Generating Facility Permissible Loading Level for FCO to Alternate Fuel (if de-loading is required)³ (%)
Above 80%	Deload to not lower than 70% loading
Between 60% to 70%	No change in loading

³ FCO can be initiated and performed without any de-loading within these range of MW loading level while operating under primary fuel.

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Figure F13.1.b – Design Load for Fuel Changeover over different modes of MW



Note:

Mode 1 - illustrates the fuel changeover profile & capability upon initialised by the generating facility to complete or achieve stable firing load (within 10-minutes) on alternative fuel (i.e. diesel) with change (deload in MW) load of the generating facility.

Mode 2 – illustrates the fuel changeover profile & capability upon initialised by the generating facility to complete or achieve stable firing load (within 10-minutes) on alternative fuel (i.e. diesel) without any change (in MW) load of the generating facility.

- (c) complete the FCO operation, including deloading to the designated loading level to enable FCO to commence if required, starting up of other support systems such as alternative fuel auxiliary system and etc., within ten (10) minutes upon initiation of fuel changeover process; and
- (d) upon completion of the FCO, the generating facility shall be capable of ramping up to its NEMS scheduled load prior to the initiation of the FCO process or to the maximum loading level of the generation facility operating in alternate fuel, whichever is lower; and subsequently, the generation facility shall be put on Automatic Generation Control (AGC) and free governor mode immediately.

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APPENDIX G SECURITY FOR THE TRANSMISSION SYSTEM

G1 Scope

G1.1 This appendix states the *security* requirements for the *transmission system* to cover the normal system operating conditions and three categories of contingencies as defined below:

- (a) System normal operating conditions where
 - (i) the voltage magnitudes at all *energised* busbars at any switchhouse or substation are within the equipment ratings;
 - (ii) the MVA flows on all *network* elements are within the equipment ratings
 - (iii) all *interconnector* are being operated within the equipment ratings;
 - (iv) the *frequency* at all *energised* busbars of the *transmission system* is within the normal operating *frequency* band; and
 - (v) all *network* elements are in service;
- (b) Single contingency conditions or more probable contingencies where a single *generating unit*, single transformer, single circuit or single reactor at the same substation or switchhouse is on forced or planned *outage*.
- (c) Less probable contingencies covering the following:
 - (i) loss of two *network* items of equipment in the system either simultaneously or consecutively;
 - (ii) loss of one busbar section of any transmission substation;
 - (iii) loss of largest *generating unit* and one transmission element either simultaneously or consecutively;
- (d) Extreme contingencies involving *outage* of either a generating station, an entire transmission substation/switchboard or a number of transmission circuits installed in the same trench/tunnel compartment/structure.

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G2 Planning Criteria

G2.1 The planning criteria of the *transmission system* shall be as follows:-

- (a) Under normal system operating conditions, all equipment shall operate within their normal thermal ratings;
- (b) Under single contingency conditions, all equipment shall, as far as possible, operate within their maximum continuous ratings and voltage limits immediately after the contingency. There should not be any power interruption, prolonged excessive overloading on the remaining *network*, inability in system voltage regulation, cascading of more than one network element or system instability;
- (c) Under less probable contingencies with normal fault clearing if applicable, the *power system* shall not suffer from voltage collapse, cascading of more than one *network* element, or system instability. Switching of *network* or adjustment of *generating units'* output may be necessary to relieve any *network* overloading. Load shedding may be activated to ensure system *security* and stability; and
- (d) Under extreme contingencies, the *power system* shall maintain steady state and dynamic stability. Means such as progressive automatic load shedding shall be provided to limit the impact of such severe disturbances.

G2.2 The 400kV and 230kV *network* shall be planned to cater for probable generation distribution in the system.

G2.3 In the case of a *generation facility* of total installed generation capacity exceeding 10MW or solar photovoltaic *generating facility* of total installed generating capacity exceeding 10MWac connected for the sole purpose of conveying electricity to the grid, under normal system operating condition, i.e. all *service connections* to the *generation facility* are available, the *service connections* of the *generation facility* shall be adequate to convey electricity up to the *generation facility's* total installed generation capacity and all connected import facility's capacity. Under the system operating condition where one *generation facility's service connection* is not available (scheduled or unscheduled), the remaining *generation facility's service connection(s)* shall be able to continuously convey 90% of its total installed generation capacity and all connected import facility's capacity. Adequate *generation facilities' service connections* shall be provided to ensure system *security*, stability and *reliability*. Prolonged *outage* of two *generation facilities' service connections* shall not result in system being unable to meet the *demand*.

G2.4 In the case of a *generation facility* of total installed generation capacity up to 10MW or solar photovoltaic *generating facility* of total installed generating capacity up to 10MWac connected for the sole purpose of conveying electricity to the grid, when all *service connections* to the *generation facility* are available, the *service connections* shall

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be adequate to convey electricity up to the *generation facility's* total installed generation capacity. In the event when any of the *generation facility's service connection* is not available (scheduled or unscheduled), the *generation facility* shall be able to export any amount of electricity to the grid, up to its installed generation capacity or be isolated from the grid in the case where the sole *service connection* is unavailable.

G2.5 In the case of a *generation facility* which is embedded within an existing consumer's *installation*, the net export of the consumer's *installation* will have to meet the requirements of the prevailing load connection scheme as per section 4.2.2 of this Code.

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APPENDIX H EMS MONITORING AND TELEMETERY INTERFACE REQUIREMENTS

H1 General Requirements

H1.1 All generation and transmission facilities that are required to interface to the *Energy Management System (EMS)* of the *PSO* shall provide several or all of the following functions:

- (a) SCADA functions
- (b) Automatic Generation Control (AGC) functions

H2 Remote Terminal Equipment

H2.1 *Remote Terminal Units (RTU)* shall be provided as the field equipment to interface to the *EMS* system. The provision of this equipment shall meet the following requirements:

- (a) Each substation or switchhouse shall have a dedicated *RTU* with the condition that the *RTU* shall not have more than 2000 status points and not more than 200 measurement points. Should the number of status or measurement points exceed these limits then a second *RTU* shall be provided. Notwithstanding this if the retrieval of the entire database of the *RTU* by the *EMS* exceeds 30 seconds then a second *RTU* shall be provided.
- (b) A *generating station* shall have a dedicated *RTU* with the condition that the *RTU* shall not be controlling more than 4 *generating units* or a total of more than 1000MW. Should the number of *generating units* or total generating capacity exceed this, then a second *RTU* shall be provided.

H2.2 Each dedicated *RTU* (new or replacement of existing *RTU*)⁴ shall be equipped with a Global Position Satellite (GPS) equipment for time synchronization and shall have a minimum resolution of 1 msec.

H3 Communications Requirements

H3.1 Communications between the remote terminal equipment located at the Transmission Licensee's substation and/or the connected person's intake substation/switchhouse and the EMS shall be through pilot wire or optical fibre communication lines provided by the Transmission Licensee and at least one of which shall be a pilot wire communication line. The equipment shall communicate using V.34 analog lease-line modems or X.27

⁴ With effect from 10/10/2007

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optical modems. The modems at the EMS will operate as originator while the remote terminal equipment modems will operate as answerer.

- H3.2 The remote terminal equipment must be capable of communicating with the control centres (Power System Control Centre and the Backup Control Centre) of the *PSO*. To achieve this, the *RTU* must be dual-ported and has separate independently-routed communication routes to the control centres. The *RTU* shall transmit information to the *EMS* at both centres simultaneously on both channels. The *EMS* shall determine which channel's information to use. The *RTU* shall be capable of receiving information and commands from the *EMS* at either channel; the *EMS* shall determine which channel to use. As such both channels at the *RTU* shall be available at all times.
- H3.3 It is the responsibility of the Transmission Licensee, Generation Licensee, Wholesaler (Generation) Licensee and *connected person* responsible for each *HVDC facility* to provide all the equipment at the remote site. The communication equipment shall include encryption devices to ensure secure communication on the communication lines. These encryption devices shall be of the same make and model as the devices installed at the *PSO* control centres.

H4 Monitoring and Telemetry Requirements

H4.1 Substation and Switchhouse

Status of the following equipment shall be provided:

- (a) All *circuit breakers*;
- (b) All isolators;
- (c) All earth switches;
- (d) Local/Remote status;
- (e) Protection devices, substation *auxiliaries* and equipment, equipment alarms;
- (f) Transformer taps (with the exception of 66/22 kV transformers); and
- (g) Other status, as required.

The following measurements shall be provided:

- (a) Phase (yellow phase) voltage of all station buses;
- (b) *Frequency* of all station buses (applicable only to switchhouses and substations with synchronisation facilities);
- (c) MW and MVar of all circuits;

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- (d) MW and MVar of high and low voltage sides of all transformers (with the exception of low voltage side of 66/22kV transformers);
- (e) MVar of all reactors;
- (f) Solar global irradiance (applicable only to Transmission Licensee) that comply with the minimum requirements as specified in Section H4.3(b). Transmission Licensee shall consult the Power System Operator on which transmission substation(s) require Solar global irradiance measurement device; and
- (g) Other measurements, as required.

For substations, the following remote control facilities shall be provided:

- (a) Circuit Breakers;
- (b) Transformer taps raise or lower (with the exception of 66/22 kV transformers); and
- (c) Other equipment, as required.

H4.2 Generating station

The status of the following equipment shall be provided:

- (a) *Generating unit circuit breakers;*
- (b) Local/Remote status;
- (c) Load limiter status;
- (d) Status of frequency response switch;
- (e) Emergency Shutdown Valve (ESDV) and the status of all valves on the Onshore Receiving Facility (ORF) and natural gas transmission pipeline supplying natural gas to the generation facility;
- (f) Pressure and gas flow at ORF and natural gas transmission pipeline supplying natural gas to the generation facility;
- (g) For a combined-cycle plant or gas turbine, the ambient temperature and the hot switch activation signal when fuel changeover is initiated, manually or automatically, from natural gas to its alternate fuel and the fuel type used; and
- (h) Other quantities, as required.

The following measurements shall be provided:

- (a) MW and MVar of all *generating units;*

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- (b) Unit terminal voltage of all *generating units*;
- (c) High/Low Limits of load limiter;
- (d) *Frequency* at *generating unit* terminal; and
- (e) Other quantities, as required.

The following remote control facilities shall be provided:

- (a) *Generating unit* raise or lower control; and
- (b) Other equipment, as required;

H4.3 Solar Photovoltaic System

The following measurements shall be provided:

- (a) Active Power (gross) at the AC-side of the solar photovoltaic system; and
- (b) Solar irradiance from sensor installed in close proximity to the PV panels.

The solar irradiance sensor shall comply with the following minimum specifications:

- Irradiance range: 0 – 2000Wm⁻² or better
- Accuracy of direct power output: >90% for clear sky
- Directional response (for beam irradiance): +/- 20Wm²
- Response time to reach 95% response: <30 seconds

H5 Data Representations

H5.1 Double Bit Status

The status of all components such as all *circuit breakers*, isolators and local/remote indications are 2-bit representations:

- (a) “00” or “11” represents undefined status while “01” represents “opened or local” and “10” represents “closed or remote”.
- (b) The 2-bits shall be derived from 2 actual relays and must not be calculated or derived from a 1-bit value.
- (c) A combined single value shall be provided for 3-phase equipment e.g. the indication for the CB shall be for all the 3 phases and not for a single phase.

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H5.2 Single Bit Status

The statuses of all earthing switches (for new or replacement of existing RTUs)⁵ and alarms are 1-bit representation:

- (a) “0” represents “opened or normal” while “1” represents “closed or alarm”.

H5.3 Measurements

All measurements are represented by 16-bit values:

- (a) Range values are -32767 to $+32767$ or 0 to 65535.
- (b) For substations, *HVDC facilities* and switchhouses, power flowing out is positive. For *generating units*, power flowing out is considered positive.
- (c) MW and MVar values for *generating units* are gross values taken before the *generating unit* step up transformer.
- (d) MW and MVar values for *HVDC facility* are gross values taken at the *point of connection* of the *HVDC facility* with the *transmission system*.
- (e) MW, V and A values on the DC side of each *HVDC pole*.

H6 Communication Protocol

The communication protocol between the remote terminal equipment and the *EMS* shall be the *IEC 870-5-101*. Specific requirements of the protocol are as follow:

- (a) All statuses are reported to the *EMS* spontaneously while measurements are periodically scanned.
- (b) The *RTU* shall be capable of communicating in both the balanced (default) and unbalanced mode.
- (c) The V.34 analog modems shall be capable of operating in the range from 1,200bps to 19,200bps (default is 19,200bps) and the X.27 optical modems capable of operating in the range from 1,200bps to 57,600bps (default is 57,600bps).
- (d) The link check between the *EMS* and the remote equipment is carried out every 10 seconds.
- (e) AGC raise and lower pulses use *IEC* type 48 and is a number ranging from -10 to $+10$. The relation between the pulse number and the MW value is dependent on the ramp rate and is determined during commissioning.

⁵ With effect from 10/10/2007

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- (f) Transformer raise/lower uses *IEC* type 47.
- (g) All time stamping shall be carried out at the remote and not at the *EMS*. At the remote, the time stamping shall be carried out at the source where the event takes place.
- (h) Changes to the physical layer, link layer and common Address of ASDU parameters as defined in the *IEC 870-5-101* standards shall not require re-entry and/or retesting of the IOA of all the individual status points and measurement points.
- (i) Status and measurements sent to the EMS shall be flagged as “not topical” by the RTU whenever there is a failure in the instrument or system providing the status or measurements to the RTU.

H7 Performance Standards

H7.1 Availability Requirements

- (a) Monitoring and control functions at the *RTU* shall have a minimum availability of 99.9%.
- (b) Communication between the *EMS* and the *remote terminal unit(s)* shall meet the monitoring and control availability requirement in (a) above. In addition each of the redundant communication link shall have an availability of at least 95.0%.

H7.2 Response Requirements

The following performance standards shall, on a continual basis, be achieved for all telemetry requirements:

- (a) Any change in the status in the field shall be reported spontaneously to the *EMS* within 1 seconds of the change.
- (b) All measurements shall be updated periodically. With the exception of AGC parameters, the updating cycle shall be 10 seconds. AGC parameters such as *generating unit* MW and MVar and busbar *frequency* shall be updated every 2 seconds.
- (c) AGC pulses from the *EMS* to the *generating units* are transmitted every 4 seconds.

H8 Information and Data Submittals

The following information and data is required:

- (a) Description of *RTU*, make, model etc.

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- (b) Single line diagram. Information on the naming convention used shall be clearly described. The diagram shall show the equipment, protection and telemetry points.
- (c) All points and alarms, which are available for monitoring and control, shall be submitted to the *PSO* for review and approval. The list shall include grouped alarms and their component alarms.
- (d) Compliance table with the *IEC 870-5-101* Interoperability List as stated in the System Operation Manual.
- (e) *IEC 870-5-101* Protocol Information Object Address Assignments as stated in the System Operation Manual.
- (f) Equipment characteristics and parameters such as impedance, rating etc.
- (g) Accuracy figures for CT, PT and A/D converters.
- (h) Conversion factors from raw measurements to engineering values.

H9 Testing and Commissioning

The following requirements are needed for testing and commissioning:

- (a) To facilitate AGC testing, a mechanism (software or hardware) is needed to isolate the AGC signals from the turbine control.
- (b) Copies of all commissioning tests are to be submitted.
- (c) The Transmission Licensee, Generation Licensee, Wholesaler (Generation) Licensee or *connected person* responsible for each *HVDC facility* shall have qualified personnel on site during commissioning to confirm and verify all data sent to the *EMS*.

Copies of all final as-built drawings, parameters and data are to be submitted.

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APPENDIX I TECHNICAL STANDARDS FOR FACILITIES

I1 Design Standards and Practices for Transmission Facility and Generation Facility

	400KV	230KV	66KV
I1.1 Switchgear			
1) Rated short circuit current	Min. 63 kA	Min. 63 kA	Min. 40 kA
2) Rated duration of short circuit	1 sec	1 sec	3 sec
I1.2 Transformers			
1) Transformation ratio	400/230kV	230/66kV	66/22kV
2) Transformer Vector Group	Yyond11	Yyond11	Yyond11
3) Neutral grounding	Solid grounding	Solid grounding at 230kV side and through 19.5 Ω Neutral resistor grounding at 66kV side.	Grounded through 6.5 Ω Neutral resistor grounding at 22kV side.
I1.3 Reactors			
1) Maximum Capacity	150 MVar	100 MVar	--
I1.4 Switchboard			
1) Switchboard configuration	One and half breakers for switchhouse and 400kV substation.	One and half breakers for switchhouse and 230kV portion of 400/230kV substation. Conventional double busbar for all others.	Conventional double busbar for switchhouse and substations.

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I2 List of Standards

The equipment shall be designed, manufactured and tested generally in accordance with the latest revision of the following standards except where specifically directed otherwise:-

I2.1 Switchgear :-

<u>Items</u>	<u>Standard</u>
Switchgear	IEC 62271-200 IEC 62271-1
Circuit Breakers	IEC 62271-100 BS EN 62271-100
AC Disconnectors (isolators)	IEC 62271-102 BS EN 62271-102
Busbars	BS 159
Current Transformers	IEC 61869 BS EN 61869
Voltage Transformers	IEC 61869 BS EN 61869
Instrument Transformers	IEC 61869-1 IEC 61869-2
Insulators	IEC 60273 IEC 60660
Bushings	IEC 60137 BS EN 60137
Relays	IEC 60255 BS 5992 BS EN 61810-1 BS EN 61810-2
Instruments	BS 89 BS EN 60051-1

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<u>Items</u>	<u>Standard</u>
Earthing	IEC 62271-102 BS 7430 SS 551
Motors	BS EN 60034 BS 60079-1
Control Gear	IEC 62271-1 IEC 62271-200 BS EN 60947-4-1
Wires and Wiring	IEC 60332-1-1 IEC 60332-1-2 BS 6231
Inductive Load Switching	IEC 62271-110
Surge Arresters	IEC 60099-4
Sulphur Hexafluoride (SF6)	IEC 60376 BS EN 60376 BS EN 60480
High Voltage Test Techniques	IEC 62271-203 BS EN 60060-1
Test Procedure	ANSI/IEEE C37.09
Cable Connections	IEC 62271-209
Solid Dielectric Power Cables	IEC 60502
Enclosures	IEC 62271-203 IEC 60529 CENELEC EN50 052 CENELECEN50 064 CENELECEN50 068 CENELEC EN50 069
Sound Level Meters	IEC 61672

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I2.2 Transformers :-

<u>Items</u>	<u>Standard</u>
Transformers	IEC 60076
Power Transformers	IEC 60076
Transformer Oil	BS 148 BS EN 60296 BS EN 60422
Tap Changers	BS EN 60214-1
High Voltage Test Technique	IEC 60060 BS EN 60060-1
Precision Sound Level Meters	IEC 61672
Measurement of Transformer Sound Levels	IEC 60076-10
Earthing	SS 551
Motor	BS EN 60034
High voltage bushings	BS EN 60137
Current transformers	BS EN 61869 IEC 61869
Neutral Ground Resistor	IEEE 32

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I2.3 Cables :-

<u>Items</u>	<u>Standard</u>
Nominal cross-sectional areas and composition of conductors	IEC 60228
Extruded solid dielectric insulated power cables for rated voltage from 1kV to 30kV	IEC 60502
Common test methods for insulating and sheathing materials of electric cables	IEC 60811
Electrical test methods for electric cables	IEC 60885
Impulse tests on cables and their accessories	IEC 60230
Calculation of the continuous current rating of cables	IEC 60287
XLPE insulation power cables for rated voltages of up to 600/1,000V	SS 443 IEC 60502-1
Tests on oil-filled and gas-pressure cables and their accessories	IEC 60141-1
Tests for power cables with extruded insulation	IEC 60840 IEC 60502 IEC 62067
Enclosures (degree of protection)	IEC 60529
Cable Connections	IEC 62271-209
Pipe threads where pressure tight joints are made on threads	ISO 7-2
Specifications of impregnated-paper-insulated low and medium pressure self contained oiled-filled cable	AEIC No. CS4

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<u>Items</u>	<u>Standard</u>
Specifications of impregnated paper and laminated paper polypropylene insulated cable	AEIC No. CS2
Standard for copper busbar, rod and shapes	ASTM B187
Standard specification for soft or Annealed copper wire	ASTM B3

IEC stands for International Electrotechnical Commission Publication, BS stands for British Standard, CP stands for British Standard Code of Practice and SS CP stands for Singapore Standard Code of Practice, TR stands for Technical Report and TS stands for Technical Specification.

If the specifications conflict in any way one or more of the above standards, the specifications shall have precedence and shall govern.

Where the number of the IEC or BS Standard is not specifically stated above, the IEC or BS Standard used shall be the one most appropriate to the class of equipment, material or work done specified by the Contractor.

I2.4 HVDC Facility :-

<u>Items</u>	<u>Standard</u>
Insulation co-ordination - Part 5: Procedures for high-voltage direct current (HVDC) converter stations	IEC/TS 60071-5
Terminology for high-voltage direct current (HVDC) transmission	IEC 60633
Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing	IEC 60700
High voltage direct current (HVDC) substation audible noise	IEC/TS 61973

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High-voltage direct current (HVDC) installations - System tests	IEC 61975
High-voltage direct current (HVDC) systems - Guidebook to the specification and design evaluation of A.C. filters	IEC/TR 62001
Design of earth electrode stations for high-voltage direct current (HVDC) links - General guidelines	IEC/TS 62344
Voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) power transmission - Electrical testing	IEC 62501
High-voltage direct current (HVDC) power transmission using voltage sourced converters (VSC)	IEC/TR 62543
High-voltage direct current (HVDC) systems - Application of active filters	IEC/TR 62544
Performance of high-voltage direct current (HVDC) systems with line-commutated converters - Part 1: Steady-state conditions	IEC/TR 60919-1
Performance of high-voltage direct current (HVDC) systems with line-commutated converters - Part 2: Faults and switching	IEC/TR 60919-2
Performance of high-voltage direct current (HVDC) systems with line-commutated converters - Part 3: Dynamic conditions	IEC/TR 60919-3
Converter transformers - Part 2: Transformers for HVDC applications	IEC 61378-2
Converter transformers - Part 3: Application guide	IEC 61378-3
Determination of power losses in high-voltage direct current (HVDC) converter stations with line-commutated converters	IEC 61803

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APPENDIX J HVDC FACILITY REQUIREMENTS

J1 Preliminary HVDC Facility Data to be submitted for consideration of connection to the transmission system

Each *connected person* responsible for the *HVDC facility* who seeks connection to the *transmission system* shall provide the information required in accordance with and in the format set forth in J1.1 to J1.3 of this Appendix.

J1.1 General

- (a) Names of *HVDC facilities*
- (b) Location of the HVDC converter station or *point of connection* to the *transmission system*
- (c) Total transmission capacity in MW
- (d) Brief description of the configuration of the *HVDC facility* including:
 - Technology (current/voltage source)
 - Number of poles
 - Pole configuration (e.g. monopole/bipole arrangement/back-to-back)
 - Return path arrangement
- (e) Total power required for *auxiliaries* at each end of each *HVDC facility*
- (f) Scheduled date of commissioning for each *HVDC facility*

J1.2 For each *HVDC Pole* of an *HVDC Facility*

- (a) Name of the *HVDC pole*.
- (b) Rated import capacity in MW
- (c) Rated export capacity in MW
- (d) Maximum available import in MW
- (e) Maximum available export in MW
- (f) Minimum import capacity in MW
- (g) Minimum export capacity in MW

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- (h) DC Converter type (e.g. current / voltage source)
- (i) Rated DC voltage per pole (kV)
- (j) Overload capacity of the pole (including duration limits if any, on the overload capacity).
- (k) Power required for *auxiliaries*.

J1.3 HVDC Pole Equipment Characteristics

For each *HVDC pole*, the following equipment characteristics shall be provided.

J1.3.1 HVDC Pole Converter Transformer(s)

- (a) Rated MVA Capacity MVA
- (b) Rated voltage (Primary kV, Secondary kV)
- (c) Nominal voltage ratio, primary/secondary
- (d) Positive phase sequence impedance at Maximum tap, Minimum tap, Nominal tap
- (e) Zero phase sequence impedance %
- (f) Tap changer range + % _____ - % _____
- (g) Tap-changer step size %
- (h) Tap changer type on load / off load
- (i) Winding connection and Vector Group
- (j) Magnetising curve
- (k) Earthing arrangement of transformer (if any) at primary side, at secondary side

J1.3.2 AC filter & Reactive Power Compensation

- (a) Total number of AC filters banks
- (b) Type of equipment (e.g. fixed or variable)
- (c) Single line diagram of filter arrangement and *connections* with component values of each of the elements
- (d) *Reactive Power* rating for each AC filter bank, capacitor bank or operating range of each item of reactive compensation equipment, at rated voltage

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- (e) Performance chart showing *Reactive Power* capability of the *HVDC Pole* in normal condition, as a function of MW transfer (with all filters and reactive compensation plant, belonging to the DC Converter Station working correctly)

J1.3.3 *HVDC Facility*

- (a) Single line diagram of the complete HVDC network (including both AC and DC sides)
- (b) Details of the complete HVDC Network, including resistance, inductance and capacitance of all DC cables or overhead lines
- (c) Details of any reactors (including reactor resistance),
- (d) Capacitors and/or filters that form part of the HVDC Network, with component values of each of the elements

J1.3.4 *HVDC Facility Control System*

Functional description and block diagram showing transfer functions and settings parameters of the *HVDC facility* control system in PSSE format (in flecs source code):

- (a) Static VDC-IDC (DC voltage - DC current) characteristics, for both the rectifier and inverter modes for a current source converter.
- (b) Static VDC-PDC (DC voltage - DC power) characteristics, for both the rectifier and inverter modes for a voltage source converter.
- (c) Transfer function block diagram including parameters representation of the control systems of each DC Converter and of the DC Converter Station, for both the rectifier and inverter modes.
- (d) Transfer function block diagram representation including parameters of the DC Converter transformer tap changer control systems, including time delays
- (e) Transfer function block diagram representation including parameters of AC filter and reactive compensation equipment control systems, including any time delays.
- (f) Transfer function block diagram representation including parameters of any Frequency and/or load control systems.
- (g) Transfer function block diagram representation including parameters of any small signal modulation controls such as power oscillation damping controls or sub-synchronous oscillation damping controls.
- (h) Transfer block diagram representation including parameters of the Reactive Power control at converter ends for a voltage source converter.

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- (i) Reactive Power Exchange Curve with the AC Grid at each end (for minimum to maximum power including overload power)
- (j) Filter Switching Scheme (if applicable)
- (k) Transfer block diagram representation including parameters of any other built-in control scheme

J1.3.5 HVDC Facility Protection

The protective relay systems for the *HVDC facility* including HVDC system switchgear, transformers and related equipment should be adequate to prevent equipment damage for contingencies occurring both within the HVDC station and on the *transmission system* outside the HVDC station. The Transmission Licensee and *connected person* responsible for each *HVDC facility* shall be responsible for the operation & maintenance of each protective relay system within the HVDC facility.

The Protection of HVDC facility and their connections to the Transmission System shall meet the requirements given in Section 6 and Appendix F of the Transmission Code. These are necessary to minimize the impact of faults from *HVDC facilities* on the *transmission system*.

Functional description and settings of *HVDC facility* protection shall include:

- AC side protection
- Converter Transformer Protection
- DC side protection

J1.3.6 Block Diagram Symbols Reference

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.

Reference: “Conventions for Block Diagram Representation”, IEEE Transactions on Power Systems, Vol. PWRS-1, No. 3, August 1986, pp. 95-100.

J2 HVDC Facility Connection Requirements

J2.1 Frequency Range of *HVDC Facility*

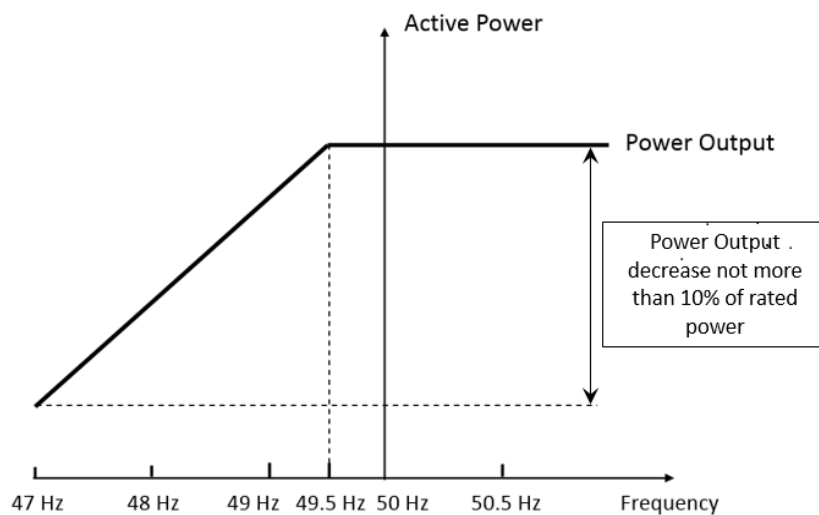
- (a) The *HVDC facility* shall be capable of sustained operation within the system *frequency* range which is normally controlled within the limits of 49.5 Hz - 50.5 Hz, and in exceptional circumstances, it could rise to 52 Hz or fall to 47 Hz.

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- (b) The *HVDC facility* shall operate within the *frequencies* range of 52 Hz to 47 Hz in accordance to the following:

Frequency Range Requirement

- 52 Hz - 47.5 Hz: Continuous operation is required
- 47.5 Hz - 47 Hz: The *HVDC facility* is required to remain in operation for at least 20 seconds each time *frequency* falls below 47.5 Hz
- For System *Frequency* changes within the range 49.5 to 47 Hz, a reduction in the output power by a quantity proportional to the *frequency* as shown in the following figure may be accepted such that if the System *Frequency* drops to 47 Hz the *Active Power* output does not decrease by more than 10% of the rated power of the *HVDC facility*.



J2.2 Phase Imbalance

The *HVDC facility* shall remain synchronized to the *transmission system* during a negative phase sequence unbalance of up to 1 percent in the *transmission system*.

J2.3 Sub Synchronous Oscillations

Sub synchronous oscillations: The *HVDC facility* shall not cause any sub synchronous resonance, undamped oscillations or harmful shaft torsional oscillations on existing generators on the *Transmission System*. The *HVDC facility* is required to be provided with sub synchronous resonance damping control or power oscillation damping control or any other identified additional control facilities.

J2.4 Commissioning Test Schedule

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Each *connected person* responsible for the *HVDC facility* to be connected to the *transmission system* shall conduct commissioning tests or other tests specified by the *Power System Operator*. The *connected person* for the *HVDC facility* shall provide the information required in accordance with sections J2.4.1 to J2.4.3 of this Appendix.

J2.4.1 Date *HVDC facility* is expected to synchronise to the *transmission system*.

J2.4.2 Date *HVDC facility* is expected to commence commercial operation.

J2.4.3 Commissioning Test Schedules: All test schedules to indicate date, time, pole's output profile as well as low/ medium/high risks of pole outage.

J2.5 Requirement of Minimum Short Circuit Level

Each *connected person* for a *HVDC facility* connected to the *transmission system* shall provide the minimum short circuit level at the AC bus for which the *HVDC facility* is designed at both ends.

J2.6 HVDC Facility participation to Power/frequency control

The *HVDC facility* shall be capable of contributing to frequency control by continuous modulation of *Active Power* supplied to the *Transmission System*, unless otherwise stated by the *Power System Operator*.

The frequency deadband and droop setting of a *HVDC facility* shall be capable of being set to obtain fast *frequency* control, subjected to the *Power System Operator's* acceptance.

J2.7 HVDC System Minimum Capability Requirements

All *HVDC facilities* shall be designed to have the following capabilities: -

- (a) Power Order Following Capability: All *HVDC facilities* shall be designed such that they can follow control signal issued by the *Power System Operator's Energy Management System*.

J2.8 Performance Monitoring Facility

The Transmission Licensee and *connected person* responsible for each *HVDC facility* shall provide, install and maintain at its own cost, high-resolution recorder(s) for monitoring and assessment of performance of each *HVDC Pole* of the *HVDC facility* by the *Power System Operator*. The recorder shall be capable of capturing, but not limited to, the following:

- (a) The transient and dynamic response of each of the *HVDC Pole* in terms of active and reactive power transmitted on the AC bus (MW);
- (b) The DC voltage (Volt) and current (Amp).

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The requirements of high-resolution recorder(s) are given in Appendix F9. The *connected person* responsible for each *HVDC facility*, upon receiving notification from the *Power System Operator*, shall furnish such records/data in softcopy via email in the format as specified in Appendix F within 24 hours.

J2.9 Remote Monitoring

The Transmission Licensee and *connected person* responsible for each *HVDC facility* shall make provisions at their respective substation and facility for remote monitoring of the *HVDC Poles'* output, substation equipment loading, operating conditions, etc. from the *Power System Operator's Energy Management System*.

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APPENDIX K CYBER SECURITY MEASURES

K1 External Connections and External Access

- (a) Remove all non-essential connections between a *Critical Information Infrastructure (CII)* and any external system, and implement network segregation for essential connections.
- (b) For essential connections requiring only a 1-way data flow out of the *CII*, to put in place devices or systems that will ensure that only a unidirectional flow out of the *CII* is permitted.
- (c) For essential connections requiring a 2-way data flow into/out of the *CII*, to put in place a 2-way non TCP/IP serial communication link.
- (d) Implement encryption for all site-to-site communications.
- (e) Implement strict syntactic and semantic checks (of allowed data set) such that data entering the *CII* does not contain any commands that can alter *CII* operations. In addition, strong authentication mechanisms e.g. transmission security and message integrity must be implemented.

K2 System Lockdown

- (a) Minimise the number of users with domain, system or local administrative privileges.
- (b) Disable all unused input/output ports, all unused internal drives or media devices, and all non-essential Operating System (OS) services.
- (c) Implement stringent controls on use of all removable media and laptops in *CII* environment. All removable media devices and laptops used in the *CII* shall be owned and managed by the *CII* Owners, and must be authorised only for dedicated use between specific servers, workstations, end-point devices, Programmable Logic Controllers (PLCs), RTUs, network switches and routers.

K3 Network and End-Point Protection

- (a) Monitor perimeter, network and security of the *CII* to detect any system anomaly. Cyber security logs including, but not limited to, system security logs, system health logs, devices/services activity logs and audit logs shall be kept for at least 18 months. These logs shall be piped to the Authority's Sectoral Detection and Early Warning System (SDEWS) at intervals specified by the Authority.
- (b) Install necessary firewalls, Intruder Detection System / Intruder Protection System (IDS/IPS) and network monitoring software.

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- (c) Application of whitelisting to prevent malicious software and other unapproved programs from executing.
- (d) Install anti-virus on all servers, workstations and end-points devices of *CII* Systems and ensure the virus definitions are up to date.
- (e) Ensure that all *CIIs* shall be regularly patched to resolve software applications and operating system vulnerabilities and that all patches are up to date, and ensure that interim mitigating controls shall be in place to address the vulnerabilities if the patches cannot be implemented promptly.

K4 Governance and Operation

- (a) *CII* Owners shall attain and maintain certification to ISO-27001 (or equivalent) for all their *CIIs*.
- (b) *CII* Owners shall provide updated copy of *CII's* network diagram and asset inventory lists annually or as and when there are changes to the network equipment in machine readable PDF format showing the following information but not limited to;
 - Hostname;
 - IP address of the equipment/devices.

K5 Others

- (a) Any other measures or directives issued by EMA.