Information Document
Facility Modelling Data and List of Electrical and Physical Parameters for Transmission System Model
ID #2010-001R

Information documents are not authoritative. Information documents are for information purposes only and are intended to provide guidance. In the event of any discrepancy between an information document and any authoritative document[1] in effect, the authoritative document governs.

1 Purpose

This information document relates to the following authoritative documents:

- Section 304.6 of the ISO rules, *Unplanned Transmission Facility Limit Changes* ("Section 304.6"); and
- Section 502.15 of the ISO rules, Reporting Facility Modelling Data ("Section 502.15").

The purpose of this information document is to provide the *List of Electrical and Physical Parameters for Transmission System Model* pursuant to subsection 2(1) of Section 502.15 and associated guidance information. Additionally, to provide contact information for the purposes of providing modelling data, records, written submissions or other information to the AESO in accordance with Section 502.15, and of notifying the AESO of an unplanned limit change to a transmission facility in accordance with Section 304.6.

2 The AESO's Modelling of the interconnected electric system

The AESO maintains:

(a) a transmission-system object model;

(b) a state-estimator model component to the energy management system; and

(c) a geographic transmission system mapping database.

Together these models constitute a comprehensive model of the interconnected electric system which is essential to the safe planning and operation of the interconnected electric system.

2.1 The List of Electrical and Physical Parameters

Pursuant to subsection 2(1) of Section 502.15, the AESO's List of Electrical and Physical Parameters for *Transmission System Model*, is included in this information document in Appendix 1.

Appendix 1 also includes guidance information that describes the objects in the list and the:

(a) attributes of and associations between those objects;

(b) terminology and nomenclature for referencing modelling objects;

(c) units of measure for expressing those attributes; and

(d) limitations on how objects and attributes are expressed.

The modelling data and records provided in accordance with the *List of Electrical and Physical Parameters for Transmission System Model*, support the AESO's maintenance of a comprehensive data model of the interconnected electric system.

[1] "Authoritative document" is the general name given by the AESO to categories of documents made by the AESO under the authority of the *Electric Utilities Act* and associated regulations, and that contain binding legal requirements for either market participants or the AESO, or both. Authoritative documents include: the ISO rules, the reliability standards, and the ISO tariff.

3 Modelling Data and Records Submission Process

Pursuant to subsection 2(2) of Section 502.15, the AESO expects that records associated with the modelling data include the provenance and effective dates of the data, and any other supporting documents.

A legal owner may provide modelling data and records as described in the *Project Data Update Package - Instruction Manual* ("PDUP IM"), for new facilities or modifications to existing facilities made pursuant to Section 502.15 and which relate to a connection project under the AESO's connection process or the AESO's market participant choice process. The PDUP IM is available on the AESO website.

In accordance with subsection 2(3) of Section 502.15, the forms to be submitted to the AESO are available on the AESO website. It is recommended that legal owners consult the PDUP IM in order to properly input the modelling data into these forms.

4 Contact Information

4.1 Section 502.15

The AESO request the records described in subsections 2 and 3 of Section 502.15 be provided by the legal owner to the AESO at both of the following email addresses: PSMM@aeso.ca and OPTRAProjects@aeso.ca.

The AESO request the records described in subsection 3 of Section 502.15 also be provided by the legal owner to the AESO at the following email address: ops.coordination@aeso.ca.

4.2 Unplanned Transmission Facility Limit Changes

When notifying the AESO pursuant to subsection 2(1) of Section 304.6, the operator of a transmission facility is expected to contact the AESO's System Operations team using the phone number the AESO specifies.

When notifying the AESO pursuant to subsection 2(2) of Section 304.6, the operator of a transmission facility is expected to contact the AESO using the following email address: ops.coordination@aeso.ca.

Appendices

Appendix 1 – List of Electrical and Physical Parameters for Transmission System Model and Guidelines

Appendix 2 – Distributed Energy Resource Modelling Guideline

Revision History

Posting Date	Description of Changes
2021-07-26	Combined the Guideline on the Electrical and Physical Parameters for Transmission System Model List and the List of Electrical and Physical Parameters for Transmission System Model into Appendix 1. Increased size from 4.5 to 5 MW for generating units, aggregated generating facilities, large motors and battery energy storage facilities to require submission of modelling data in Appendix 1, section 4.5. Added Appendix 2 Distributed Energy Resource Modelling Guideline and amended Appendix 1, section 4.5.5 Distributed Energy Resources. Administrative amendments to align with current AESO drafting principles, correct references, typographical errors and outdated information.
2018-12-20	Amended section 4.2 updated to include update of line data. Amended Appendix 1 section 5.2 to clarify modelling of voltage regulators. Amended Appendix 1 section 5.5 to clarify the applicability of various types of machines. Amended Appendix 1 sections to reflect adoption of FAC-008-AB-3, *Facility Ratings* (“FAC-008”).
2017-03-23	Appendix 1 updated to reflect revised List; Bus ranges added to Table 1 of Appendix 1; Overviews added to Appendix 1 for clarity; Glossary removed from Appendix 1; and Administrative amendments
2016-09-28	Administrative amendments
2016-07-26	Initial release

Appendix 1 – List of Electrical and Physical Parameters for Transmission System Model and Guidelines

This *List of Electrical and Physical Parameters for Transmission System Model* provides the modelling data and records associated with each type of transmission system object. Each section contains the following guidance information regarding each type of transmission system object:

(a) a short definition of the data categories covering that equipment type where necessary;

(b) a check list of the required data indicated by check boxes; and

(c) short paragraphs expanding on, or explaining, the check list items where necessary.

Changes to the nomenclature for some transmission system modelling objects have been made to align with International Electrotechnical Commission standard IEC 61970-301:2020, *Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base*[2]. The former nomenclature is identified by an asterisk (*) and is included in parentheses after the standard nomenclature. Object nomenclature used in this guideline is identified in **bold underlined** print.

1 Load and Generation Measurement

1.1 Measurement Point

Overview: A “Measurement Point” is the point where electric power flows into or out from the transmission system into the facilities of the system access contract holder.

Checklist:

- ☐ Unique **MP_ID**

Explanation:

The Measurement Point identifier or **MP_ID** is defined by the Metering Services Provider. The data submitter obtains the **MP_ID** from the Metering Services Provider and forwards it to the AESO. The AESO may assign an interim, temporary **MP_ID** in consultation with the data submitter. In the case of “Behind-the-Fence” loads a unique **MP_ID** beginning with the letters “*BTF_*” will be assigned by the AESO. “Behind-the-Fence” loads are considered loads which are served by self-generation and; therefore, represent power both generated and used at the same site without passing through a revenue meter.

1.2 Load

Overview: A “Load” is a non-rotating sink asset or source asset of electricity consumption (MW).

Checklist:

- ☐ The bus to which load connects
- ☐ North American Industrial Classification System code
- ☐ Load response characteristic
- ☐ Load at energization

[2] International Electrotechnical Commission standard: IEC 61970-301:2020, *Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base,* effective June 26, 2020, as amended from time to time, Available on www.iec.ch.

Explanation:

(a) Loads are to be aggregated to the first non-transmission bus or generation bus upstream of the physical loads.

(b) "Unmetered Volumes", which are also called "Behind-the-Fence" loads, are to be submitted in the same way as any other load.

(c) Every load is characterized by some industrial type, or group of industries, as identified in the North American Industrial Classification System.

(d) North American Industrial Classification System code is typically one of the codes listed in Table 1 for industry loads.

(e) Specify a separate energyConsumer.name (ELEMENT_CODE) for each different industry to be represented.

(f) If submitting a North American Industrial Classification System code of "99", specify the load response characteristic as a breakdown of constant power, constant impedance, and constant current, in percent for both real and reactive components, to a total of 100%, with a default value of 100% constant power if no other information is available. Submit unmetered volumes in the same way as any other load.

Table 1 North American Industrial Classification System Codes for Typical Industry Load Types

North American Industrial Classification System Code	Industry Type
11	Agriculture
32	Manufacturing – general
33	Heavy Manufacturing
40	Commercial and Services
71	Arts, Entertainment and Recreation
113	Forestry and Logging
211	Oil and Gas Extraction
486	Pipelines
814	Private Households
22131	Farming – Irrigation
99	Unspecified

(g) Specify a separate Element Code for each different industry to be represented.

(h) Load at energization is the estimate of peak load after reaching steady state on day 1 of energization.

2 Transmission Facilities

Overview: A "transmission facility" is a substation or transmission line.

Checklist:

- ☐ **FACILITY_CODE**
- ☐ Geographic location
- ☐ **operatorCompany** **(OWNER*)**

Explanation:

(a) The **FACILITY_CODE** is the unique identifier assigned to each transmission facility by the AESO. The identifier can be up to 20 characters consisting only of capital letters, the digits 0 through 9, periods, and hyphens. The data submitter may request a particular identifier. The preferred **FACILITY_CODE** is a simple, pronounceable, unambiguous word; or a short number optionally combined with one or more letters, for example:

- ROSSDALE
- D05
- 14.83L

(b) The AESO will issue one or more new **FACILITY_CODE**, as appropriate, when transmission facility is segmented or merged. The data submitter may consult with the AESO regarding any new **FACILITY_CODE**.

(c) Geographic location describes the detailed location of the transmission facility. A data submitter may submit geographic location data either as a shape file or as a 1:10,000 scale map showing the line route or substation polygon. The geographic location includes a GPS location for any substation; and GPS locations may be submitted for every structure of a transmission line, or for the line termination and for points where the line route significantly changes direction.

(d) ***operatorCompany*** is the legal corporate name of the entity that holds title to the transmission facility.

2.1 Substations and Switching Devices

Overview: A substation is a facility designed for transformation or switching operations. A switching device is a device designed to close, or open or both, one or more electric circuits.

Checklist:

- ☐ All component substation single-line diagrams, indicating for each switching device the:
- ☐ Type of equipment
- ☐ Type of control
- ☐ SCADA Communications block diagram in accordance with subsection 8(10) of Section 502.8 *SCADA Technical and Operating Requirements*
- ☐ ***substation.description*** (***SUBSTATION_NAME**)
- ☐ **LAND_LOCATION**
- ☐ ***subGeographicRegion*** (***AREA_CODE**)

Explanation:

(a) A single-line diagram shows all **ELEMENT_CODE**s, locations of switching devices with their switch numbers, electrical connectivity of all elements, and ratings of each component of the current path, metering and control current transformers and voltage transformers. Switching devices are identified on a single-line diagram using annotation or symbols for:

(i) equipment, such as circuit breakers, disconnects, circuit switches; and

(ii) controls, such as synchrocheck, synchronizer, motor operated, and supervisory controls.

The data submitter may submit multiple Single Line Diagrams to cover all required information.

(b) **substation.description** is included only where the owner assigns names to its substations. The AESO will, upon request, provide assistance in selecting a **substation.description** (***SUBSTATION_NAME**). **Substation.description** is a pronounceable text string of 50 characters or less, consisting only of the letters, digits 0-9, spaces, and hyphens. Substation names may not include corporate names. Substation names may not include variations on geographical names that are already used for other substations.

(c) **LAND_LOCATION** is the Dominion Land Survey designation at minimum resolution to the quarter-section, and preferably the legal sub-division.

(d) **LAND_LOCATION** is to conform to the following format: LL-SS-TT-RRWP, where:

(i) LL is the legal subdivision or quarter-section

(ii) SS is the section number

(iii) TT is the township

(iv) RR is the range

(v) P is the parallel

2.2 Transmission Lines

Overview: A transmission line termination point is where it connects to a substation bus or where it crosses into the territory of an adjacent owner of a transmission facility. A transmission line may have two or more terminals.

Checklist:

- ☐ Structure list or line survey
- ☐ Transmission line segment summary
- ☐ Structure drawings

Explanation:

(a) A structure list or line survey describe the line construction structure by structure.

(b) A transmission line comprises one or more line segments. The transmission line segment summary consists of a drawing or table showing how the segments connect.

(c) Structure drawings are comprised of dimensioned drawings of every tangent structure type mentioned on the structure list or line survey.

3 topologicalNode (*Buses)

Overview: A ***topologicalNode*** is a node that serves as a common connection for two or more circuits. A ***topologicalNode*** may comprise any number of zero-impedance equipment such as switches, ***connectivityNodes***, and busbars or physical bus segments which are subsumed into the ***topologicalNode***.

Checklist:

- ☐ Unique **topologicalNode.name** (*<u>**BUS_ID**</u>)
- ☐ **nominalVoltage** (*<u>**NOMINAL_VOLTAGE**</u>)
- ☐ **equipmentContainer.name** (*<u>**FACILITY_CODE**</u>)

Explanation:

(a) A new ***topologicalNode.name*** will generally follow the pattern used by existing ***topologicalNode***s in the same area. The ***topologicalNode.name*** is an integer assigned by the AESO consistent with the following:

Table 2 Standard Bus Ranges

BUS-RANGE DESCRIPTION	BUSRANGE BUSRANGE_HIGH	
	From_	To _
General transmission buses	1	999
	1000	1999
	540001	549999
Distribution buses	2000	4999
	15000	19999
	20001	29999
	30000	39999
	40000	49999
	550001	558999
Transformer midpoint buses	5000	8999
	10000	14999
	559001	559999
Temporary buses	9000	9999
Isolated system buses	50000	59999
Collector system buses	60000	69999
	560001	569999
Resource adequacy generation buses	70000	79999
	570001	579999
Unassigned	80000	99999
	580001	599999
Projects at Stage 1 of the connection process	990001	999001

(b) ***nominalVoltage*** on the transmission system is one of 500 kV, 240 kV, 138 kV, or 69 kV. ***nominalVoltage*** may differ somewhat from the actual operating voltage of the transmission system at any location. The owner of an electric distribution system will assign nominal bus voltage on the distribution-voltage bus.

(c) ***equipmentContainer.name*** (*__FACILITY_CODE__) is the exact ASCII text string previously assigned by the AESO for the facility containing the ***topologicalNode***.

4 Equipment (*ELEMENTS)

4.1 General requirements for conductingEquipment (*Elements)

Overview: A ***conductingEquipment*** is a current-carrying device that, by virtue of having inherent impedance, contributes to the admittance matrix of the power-flow model.

Checklist:

- ☐ **Equipment.name (*ELEMENT_CODE)**
- ☐ **equipmentContainer.name (*FACILITY_CODE)**
- ☐ **operatorCompany (*OWNER_NAME)**
- ☐ **normallyInService** (*__NORMALLY_INSERVICE__)
- ☐ Equipment or project in-service date
- ☐ Equipment or project decommissioning date, if known

Explanation:

(a) The ***equipment.name*** is the unique identifier assigned to each piece of conducting equipment. The identifier can be up to 20 characters consisting only of capital letters, the digits 0 through 9, periods and hyphens. The AESO may, upon request, provide assistance in selecting a unique identifier. Preferred identifiers are a simple, pronounceable, unambiguous word; or a short number optionally combined with one or more letters.

(b) ***equipmentContainer.name*** provides clarity in identifying which facility contains the element. The ***equipmentContainer.name*** is the exact ASCII string the AESO previously assigned as the ***FACILITY_CODE*** for the facility containing the equipment.

(c) ***operatorCompany*** is the legal corporate name of the entity that holds title to the element.

(d) ***normallyInService*** is identified as TRUE if the equipment is normally energized and able to carry current; and is identified as FALSE if the equipment is normally on standby or de-energized.

(e) If the equipment is put in service by a maintenance change-out, the data submitter is to submit the date on which the change-out takes effect. If the equipment is put in service by an AESO project, the AESO will associate the equipment with that project number and energization number. Note that one energization may cover a period no longer than 3 months.

(f) If the equipment is decommissioned by a maintenance change-out, the data submitter is to submit the date on which the change-out takes effect. If the equipment is decommissioned by an AESO project, the AESO will associate the equipment with that project number and energization number. Note that one energization may cover a period no longer than 3 months.

4.1.1 Element-to-Measurement Point Mapping

Overview: Each measurement point is cross-referenced to elements that either sink asset or supply asset the metered power. Every **MP_ID** serves one or more elements, either machines or loads.

Checklist:

- ☐ __MP_ID__
- ☐ **conductingEquipment.names** (*__ELEMENT_CODE__s)
- ☐ Portion of __MP_ID__ delivered to or from each **conductingEquipment**.

Explanation:

(a) **MP_ID** is the unique identifier assigned by the metering services provider

(b) ***conductingEquipment.name*** is the exact ASCII string the data submitter previously assigned for the equipment.

(c) The portions of the **MP_ID** summed over all the ***conductingEquipment*** that serve that **MP_ID** equal to one hundred percent (100%).

4.1.2 Applicable Dynamic Control Systems

Overview: A dynamic control system is an automated system that operates within a 0.01 second to 10.0 second timeframe, to achieve prescribed relationships between selected system variables by comparing functions of these variables to effect control of an identified element. For the purposes of this appendix, the transfer function inherent to a machine itself is considered a "control system".

Checklist:

- ☐ **conductingEquipment.name** (***ELEMENT_CODE**)
- ☐ Control system type
- ☐ Manufacturer
- ☐ Model
- ☐ Control system block diagram

Explanation:

(a) **conductingEquipment.name** is the exact ASCII string the data submitter previously assigned for the equipment.

(b) Control system type is one of those listed in Table 3 below:

Table 3 Standard Control Types

CONTROL_SYS	Applies to
Compensator	Large individual machines
Exciter	Large individual machines
Exciter limiter	Large individual machines
Generator/condenser	Machines
Synchronous/induction motors	Machines
Stabilizer	Large individual machines
Turbine governor	Large individual machines
Remedial action scheme	All element types
Load	Loads
Converter controls	Direct current converter
Other power electronics	All elements

(c) The equipment manufacturer generally provides the data submitter with the control system block diagram.

The AESO may identify the protection data that is to be provided to the AESO on a case-by-case basis through discussions with the legal owner. In general, underfrequency load shedding relays, under voltage load shed relays, synchrocheck relays, and synchronizers are essential to transmission modelling.

4.1.3 Applicable PSS/E or PSLF Software Model Data

Overview: Submit dynamic model data that accurately represents the element's dynamic behaviour and appears on the WECC list of accepted standard Siemens PTI Siemens Power System Simulation for Engineering ("PSS/E") and GE – Positive Sequence Load Flow ("PSLF") software library models[3]. A user-written model may be submitted along with the library model.

Checklist:

- ☐ **conductingEquipment.name** (***ELEMENT_CODE**)
- ☐ Model name
- ☐ Description of model
- ☐ Model block diagram
- ☐ Parameter names
- ☐ Parameter values
- ☐ Source-code or compiled object

Explanation:

(a) The **conductingEquipment.name** is the exact ASCII string that was previously assigned for the equipment.

(b) "Model Name" is the name of a standard library model on the WECC approved models list, to be submitted for every dynamic control system, regardless of whether a user-written model is submitted.

  (i) In the case of power electronic control systems that the AESO determines cannot be adequately represented by a standard library model complete with its submitted parameters, an adequate detailed user-written model is to be submitted in addition to the standard library model.

  (ii) This user-written model is to be adequate for dynamic study of the transmission system in the 0.01 seconds to 10 seconds timeframe and need not simulate proprietary detail of the flexible alternating current transmission system device. Any detailed user-written model submitted to the AESO may be distributed with the AESO dynamic data files.

  (iii) Models are to be submitted for one or both of the PSS/E software and the PSLF software. The Institute of Electrical and Electronics Engineers ("IEEE") models may be submitted in addition to the PSS/E and PSLF models. If models are submitted in only one of PSS/E or PSLF the party responsible for submitting the data is to consult with AESO regarding converting the data to the other format.

(c) A description is to accompany each model, providing a high-level assessment of the model's accuracy and the scenarios under which it is applicable.

(d) A model block diagram is to be submitted for all user-written models, except for standard library models.

(e) Parameter names are to be the same as specified for the model in the relevant software documentation.

(f) All parameter values are to be provided; do not leave any parameter values blank.

[3] The WECC list of accepted standard PSS/E and PSLF library models is available at www.wecc.org .

(g) The source code is a text listing of programmatic commands that represent a control system model. The compiled object is the machine code produced by a compiling the source code, which can then be called by the power system simulation program to simulate the control system behaviour and is often distributed as a ".dll" file type.

(h) Model source code or compiled object is to be submitted for all user-written models, except for standard library models.

4.2 Transformers

Overview: "Transformer" refers to a voltage transformer, phase-shifting transformer, voltage regulator or grounding transformer. Transformers have significant scope for variation from one transformer to the next. The data is requested in a standard format that can accommodate both common transformers and their variations; and more unusual transformers. Voltage regulators are modelled as the transformer tap changer of the associated power transformer. Test reports are not required for regulators.

Checklist:

- ☐ Transformer nameplate
- ☐ Test report

Explanation:

(a) A ***powerTransformer*** contains multiple windings and optionally tap-changers. A single name-plate describes all the ***conductingEquipment*** that the ***powerTransformer*** contains.

(b) Test data in the test report is defined in C57.12.00, IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers. Test data is to be provided for both positive and zero sequence. If the transformer has a tertiary delta winding, test data is provided for the tertiary delta winding closed and for the tertiary delta open circuited. Transformer impedances are not required for regulators.

4.2.1 Transformer Windings

Overview: Refer to the AESO's *Transformer Modelling Guide* for derivation of the transformer equivalent circuit and windings.

Checklist:

- ☐ **equipment.name** (***ELEMENT_CODE**)
- ☐ Winding identifier
- ☐ Connection (delta/wye)
- ☐ Neutral grounding status
- ☐ Grounding impedance
- ☐ Ratings
- ☐ Rated voltage
- ☐ Identification of the bus to which winding connects

Explanation:

(a) ***equipment.name*** is the exact ASCII string previously assigned to the ***powerTransformer*** that contains this winding.

(b) Provide the 2 seasonal normal ratings and 4 seasonal emergency ratings, as well as the terminations for each winding identifier consistent with the methodology documented in accordance with FAC-008-AB-3.

(c) Submit the winding connection as either wye or delta for each winding. For other connections, please contact the AESO at PSMM@aeso.ca.

(d) For each winding, neutral grounding status is "TRUE" if the winding is grounded and "FALSE" if the winding is ungrounded. The grounding impedance shall be resistance and reactance values expressed in ohms. Indicate solidly grounded windings by a grounding impedance of zero.

(e) The ratings of the windings may be:

   (i) Identical, for example, in a 2-winding transformer, primary and secondary windings are equally rated;

   (ii) Related, for example, the 2 secondaries of a split-secondary are each half the rating of the primary;

   (iii) Arbitrary, for example, the windings of a 3-winding transformer may all be differently rated.

   Each winding may have one or more ratings, expressed in MVA. Provide all ratings for each winding, including provisional ratings. For each rating, indicate the condition under which the rating is valid. Clearly indicate which ratings are available and which are provisional. If the transformer capacity is limited by separate equipment, then also provide the limiting condition and its rating.

4.2.2 Transformer Tap Changers

Overview: Windings may be associated with tap-changers. For each tap-changer on a winding, provide all of the following information:

Checklist:

- ☐ Tap points
- ☐ Tap-changing strategy (manual, automatic)
- ☐ On-load tap changing (True/False)
- ☐ Control band
- ☐ Actual tap

Explanation:

(a) The voltage rating of each tap, for a voltage controlling tap-changer, the phase shift for each tap, for a phase-shifting transformer, or indicate that no tap-changer exists for this termination; and

(b) the tap-changing strategy used, by choosing on of the strategies provided below in Table 4.

Table 4 Standard Tap-Changing Strategies

TAP_CHANGING_CODE	TAP_CHANGING_DESCR
OFF	Off-load tap changing (having external controls on the transformer tank but requiring de-energization)
OLTC-M	On-load tap changing, manual-local
OLTC-S	On-load tap changing, supervisory (i.e. manual-remote)
OLTC-A	On-load tap changing, automatic (i.e. under-voltage regulation)
FIXED	Fixed taps that have no external control
PHASE-P	Phase shifting, controlling MW
PHASE-Q	Phase shifting, controlling MVAr

(i) Indicate which transformer termination is intended to be controlled by the tap-changing action, usually the "X" bushing of a distribution load transformer. If a remote bus is intended to be controlled, enter the bus number. Provide the voltage range for tap-changer control, in per-unit of the system nominal voltage.

(ii) For a voltage controlling tap-changer, specify the control band as the maximum and minimum allowed voltage at the controlled bus. For a phase-shifting tap changer specify the control band as the power flow into the termination.

(iii) Model the voltage regulator as a tap-changer on the directly connected winding.

4.2.3 Transformer Impedances

Overview: Refer to the AESO's *Transformer Modelling Guide* for derivation of the transformer equivalent circuit. The equivalent circuit is to include positive and zero sequence resistance and reactance for every series branch in the equivalent circuit. The equivalent circuit is to include conductance and susceptance to ground for every shunt branch in the equivalent circuit.

Checklist:

- ☐ Transformer equivalent circuit
- ☐ Positive and zero-sequence real and reactive impedances
- ☐ Positive and zero-sequence real and reactive shunt admittances
- ☐ Short-circuit impedances and load losses
- ☐ Open-circuit excitation currents and no-load losses
- ☐ Phase angle shift
- ☐ Significant off-neutral impedance of tap-changing transformers

Explanation:

(a) The equivalent circuit impedances are expressed in per-unit based on rated voltage of the transformer and on the MVA rating that was used to establish impedances.

(b) Express short-circuit impedance in % and load loss in kW.

(c) Express open-circuit excitation in % and no-load loss in kW.

(d) If the transformer is a voltage transformer, submit the phase angle shift as a fixed value. If the transformer is a phase-shifting transformer, submit the phase angle limits. If the impedance of a transformer with taps differs by 15% or more from the impedance at the rated tap, then the tested impedance shall be submitted at the maximum and minimum taps in addition to the neutral tap, and at enough of the intervening taps so that the total difference from one submitted impedance to the next is always 25% or less.

(e) The AESO will assign a 2-character circuit identifier for each impedance branch in the equivalent circuit.

4.3 Reactor and Capacitor Shunt Device

Overview: A "Reactor and Capacitor Shunt Device" is a simple switched or fixed shunt device.

Checklist:

- ☐ Bank nameplate
- ☐ Capacitance (Farads)
- ☐ Inductance (Henrys)
- ☐ Rated MVA (Capacitive)
- ☐ Rated MVA (Inductive)
- ☐ Rated voltage
- ☐ Control strategy
- ☐ Control bus
- ☐ Maximum control-band voltage
- ☐ Minimum control-band voltage
- ☐ Connection (delta/wye)
- ☐ Neutral grounding status
- ☐ Grounding impedance

Explanation:

(a) Express the rated MVA at the reactive or capacitor bank rated voltage.

(b) Express the control strategy as one of the strategies provided below in Table 5:

Table 5 Standard Shunt-switching Strategies

Strategy	Explanation of Strategy
Fixed	The shunt cannot be switched
Manual	The shunt can be switched on or off by personnel on site
Supervisory	The shunt can be switched on or off remotely
Automatic	The shunt switches on or off under control of an automated control system

(c) The "Control Bus" is the bus at which the voltage is monitored for the purpose of controlling this shunt device. Refer to the bus by the **BUS_CODE** assigned to the bus by the AESO.

(d) Express maximum and minimum voltages of the control band in per-unit of the system nominal voltages in kV at the control bus.

(e) Express grounding resistance and reactance in ohms, with zero indicating a solidly grounded bank.

4.4 Line Segments

4.4.1 Line Segments Construction

Overview: A "Line Segment" is a portion of a transmission line that has consistent physical attributes of conductor and cross-section throughout the length of the segment.

Checklist:

- ☐ **conductingEquipment.name**
- ☐ Line segment length (km)
- ☐ Conductor type
- ☐ # of conductors per bundle
- ☐ Bundle spacing (m)
- ☐ Average sag (m)
- ☐ Typical tangent structure
- ☐ Typical structure height (m)
- ☐ Positive-sequence real and reactive impedances and susceptances
- ☐ Zero-sequence real and reactive shunt admittance

Explanation:

(a) A tap off a line that enters a substation, irrespective of length, is to be designated as a separate line segment. However, if a line segment is:

(i) less than 500 metres and less than 20% of the line's total length from substation to substation;

(ii) less than 50 metres; or

(iii) less than 5% of the line's total length from substation to substation,

it can be considered part of the adjacent line segment.

(b) Conductor type is defined by name as shown in Table 6. If using a different conductor type, the conductor data sheet is to be submitted.

Table 6 Conductors

CONDUCTOR_NAME
CHICKADEE
COCHIN
COREOPSIS
COSMOS
CROWSNEST
CURLEW
DOVE
DRAKE
HADDOCK
HAWK
HORNBILL
IBIS
LINNET
MERLIN
OSPREY
PARTRIDGE
PELICAN
PENGUIN
PIGEON
RAVEN
SPARROW
TRILLIUM
WAXWING

(c) The tangent structure is designated with a reference to the relevant structure drawings.

(d) The structure height is measured from the ground to the lowest conductor.

(e) Submit line segment impedance in ohms.

(f) Submit line segment susceptance and terminal-shunt admittance in Siemens.

(g) The submission includes the assumed ground resistivity (ohm-m) on which the values are calculated.

4.4.2 Line Segment Ratings

Overview: None

Checklist:

- ☐ Conditions
- ☐ Ratings
- ☐ Limiting factors

Explanation:

(a) The ampere ratings of the line segment for each of summer normal, summer emergency, winter normal and winter emergency conditions consistent with the methodology documented in accordance with FAC-008-AB-3.

(b) The line segment rating as limited by the unconstrained line conductor thermal rating is identified for each condition. If the line segment has a more limiting rating, then identify the most limiting factor that limits the rating of the line segment. The line segment is considered to terminate at the breaker or breakers. Submit the rating corresponding to that limiting factor for each condition. Describe all applicable limiting factors as one of the factors that are provided below in Table 7:

Table 7 Capacity-limiting Conditions

CONDITION_DESCR
Circuit breaker
Current transformer
Line conductor thermal rating
Ground clearance
SLAPAC dampers
Underbuild
Disconnect Switch
Jumpers
Buswork
Protection setting
Connectors

If some other factor limits the capacity of the line segment, then describe the factor in detail in a letter to the AESO.

4.4.3 Line Mutuals

Overview: None

Checklist:

The following is submitted for each line segment branch in the pair of line mutuals:

- ☐ **conductingEquipment.names** of the 2 line segment branches
- ☐ Real and reactive mutual impedances (ohms)
- ☐ Start-of-parallel distance (m)
- ☐ End-of-parallel distance (m)
- ☐ Assumed direction of flow for the mutual calculation

Explanation:

(a) When 2 line segments form any part of a parallel between 2 transmission lines, where:

(i) the length of the cumulative parallel is greater than 20% of the length of either line, from substation to substation; and

(ii) the separation of the parallel is less than 500 m,

the mutual impedances are submitted on a line segment-by-line segment basis.

(b) Direction of flow is indicated by reference to the ***topologicalNode***s at the line ends by declaring which ***topologicalNode*** current is presumed to be flowing from.

(c) Start-of-parallel is the distance from the “from” end of the line segment branch to the point where the mutual coupling begins. If the entire length of the line segment branch parallels the other line segment branch this value will be 0.

(d) End-of-parallel is the distance from the “from” end of the line segment branch, to the point at which the parallel ends. If the entire length of the line segment branch parallels the other line segment branch, this value will be the same as the line segment branch length.

(e) Direction of flow is indicated by reference to the ***topologicalNode***s at the line ends by declaring which ***topologicalNode*** current is presumed to be flowing from.

4.5 Generating Units, Aggregated Generating Facilities, Large Motors and Battery Energy Storage Facility

Overview: A “Machine” is defined as a rotating generator, motor, or large power electronic converter set for the purposes of facility modelling. In the case of a collector-based generating facility, “collector” such as wind, or mini-hydro; “Machine” means the aggregated equivalent machine representing the power plant.

Table 8 summarizes the pertinent subsections of this section 4.5 for each type of machine.

Table 8 Summary of Relevant Sections for Generation or Machine Types

Relevant Section	Machine Type	Interconnected Electric System Connection	Applicable maximum authorized real power size (MW)
4.5.1	Generating unit	Directly connected to the transmission system or an industrial complex	Greater than or equal to 5 MW for individual unit
4.5.2	Aggregated generating facility		Greater than or equal to 5 MW for each aggregated generating facility
4.5.3	Battery energy storage facility	Directly connected to the transmission system or an industrial complex	Greater than or equal to 5 MW
4.5.1	Motors	Directly connected to the transmission system	Greater than or equal to 5 MW for each individual unit
4.5.1 and 4.5.4		In an industrial complex	Greater than or equal to 1 MW for each individual unit and greater than or equal to 5 MW for the aggregated motors at each point of delivery
		Connected to an electric distribution system at greater than or equal to 1 kV	
4.5.1 and 4.5.5	Generating unit	Connected to an electric distribution system	Greater than or equal to 5 MW at each point of delivery
4.5.2 and 4.5.5	Aggregated generating facility		

4.5.1 Large individual machines

Overview: “Large individual machines” are generating units or large electric motors of greater than or equal to 5 MW directly connected to the transmission system or directly connected to an industrial complex.

Checklist: (as applicable to the specific machine or converter type)

- ☐ Nameplate
- ☐ Manufacturer's datasheet, including at a minimum:
  - ☐ Rated machine capacity (MVA)
  - ☐ Rated voltage (kV)
  - ☐ Maximum authorized real power (MW)
  - ☐ Minimum stable generation (MW)
  - ☐ Reactive power capability curve
  - ☐ Inertia constant
  - ☐ Positive-sequence saturated and unsaturated subtransient reactance
  - ☐ Positive-sequence saturated and unsaturated subsynchronous reactance
  - ☐ Positive-sequence saturated and unsaturated synchronous reactance
  - ☐ Transient time constant
  - ☐ Subtransient time constant
  - ☐ Negative sequence resistance
  - ☐ Negative sequence synchronous reactance
  - ☐ Zero-sequence resistance
  - ☐ Zero-sequence synchronous reactance
  - ☐ Station service load (MW required when generation output is 0 MW)
  - ☐ Unit service load (incremental load (MW) per unit of generation (MW))
  - ☐ Saturation
  - ☐ "G" for "generator or "M" for "Motor"
  - ☐ The bus to which machine connects
  - ☐ The "D" curve (for generators)
  - ☐ The "V" curve (for generators)
  - ☐ Power variation curve as a function of temperature
  - ☐ Nameplate of exciter (for synchronous generators)
  - ☐ Model validation test report

Explanation:

(a) Machine inertia constant is the combination of the generator and driver (or for the motor and the connected load).

(b) Express machine impedances in per-unit on machine power (MVA) rating and machine voltage (kV) rating.

(c) For synchronous machines, submit both direct-axis and quadrature-axis impedances and time constants.

(d) Express saturation either as saturation factors or as a saturation curve.

4.5.2 Aggregated Generating Facility

Overview: It is expected that the data associated with an aggregated generating facility, that has a total aggregated capacity of greater than or equal to 5 MW and is either directly connected to the transmission system or connected to an industrial complex, is provided separately for each collector group in accordance with Figure 1.

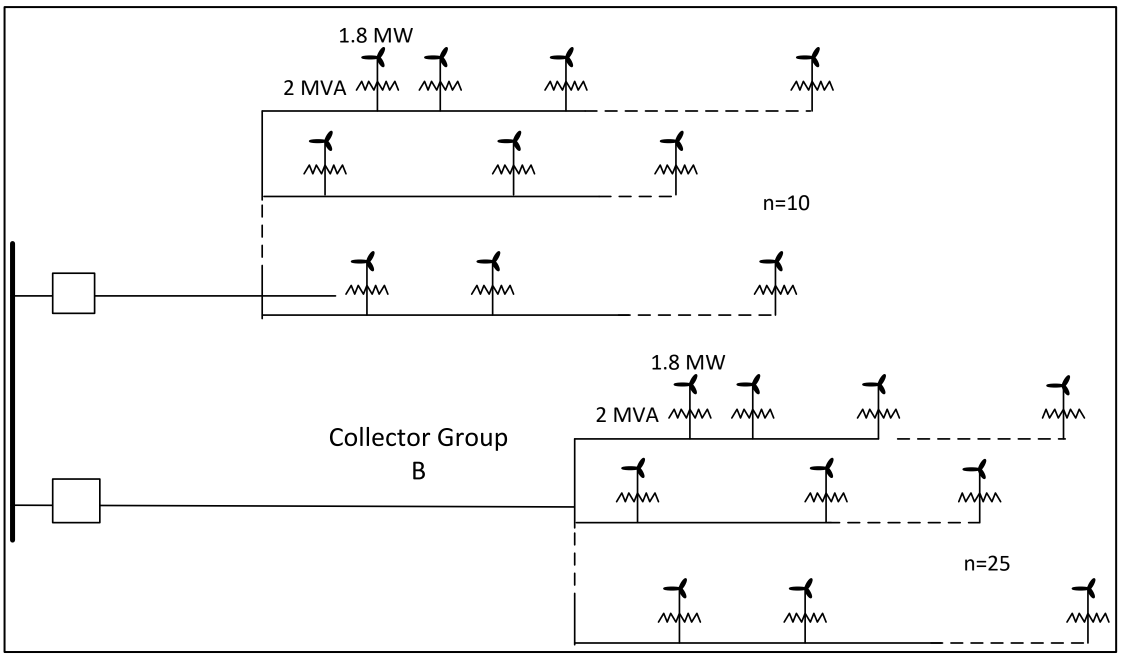


Figure 1: Typical Collector System Generators

Checklist: (as applicable to the specific machine or converter type)

- ☐ Reduced representation diagram of collector system
- ☐ Positive-sequence total real and reactive impedance of the collector system
- ☐ Zero-sequence total real and reactive impedance of the collector system if grounded
- ☐ Positive-sequence real and reactive shunt admittance of the collector system
- ☐ Zero-sequence real and reactive shunt admittance of the collector system if grounded
- ☐ Step-up transformer Impedances
- ☐ Typical generator nameplate
- ☐ Count of individual generators
- ☐ Maximum authorized real power at collector bus (MW)
- ☐ Generator's manufacturer's data sheet, including at a minimum:
  - ☐ Generator type
  - ☐ Maximum real power output

- ☐ Minimum real power operation
- ☐ Maximum reactive power output
- ☐ Minimum reactive power output
- ☐ Equivalent positive-sequence impedance for three-phase fault calculations
- ☐ Equivalent zero-sequence impedance for single-phase fault calculations
- ☐ Houseload
- ☐ Generator impedance
- ☐ Generator step-up transformer data
- ☐ Shunt device nameplate for shunt devices residing within turbine units
- ☐ Shunt device manufacturer’s data for shunt devices residing within turbine units
- ☐ Count of individual shunt devices

Explanation:

(a) The reduced model represents each collector group as the equivalent impedance of the collector network, a single aggregate wind generator and a single aggregate step-up transformer representing the sum of the individual turbines and turbine step-up transformers on that collector group. Figure 2 below shows the reduced model of the collector systems shown above in Figure 1.

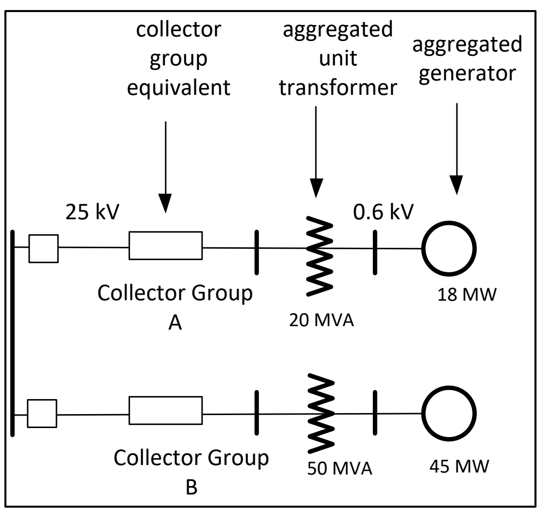


Figure 2 Equivalent Collector System

(b) Collector equivalent impedances are expressed per-unit on collector nominal voltage and a 100 MVA base.

(c) The individual data for a single wind turbine generator, and a typical generator nameplate, is to be submitted for each group of identical generators. If all wind turbine generators in a wind aggregated generating facility are identical, only one nameplate and one set of manufacturer's data need be submitted.

(d) Generator type will be one of: conventional synchronous, conventional induction, wound rotor induction with variable rotor resistance, doubly fed induction, or full converter.

(e) Generator impedances are expressed in per-unit on the machine rated MVA base

(f) Include with the collector-system generator data only those shunt devices that are distributed throughout the collector system within or at the turbine generator locations. Refer to section 4.3 of this Appendix to submit data for any shunt devices.

(g) Refer to section 4.2 of this Appendix to submit the data for the generator step-up transformer. If all wind turbine generators in a wind aggregated generating facility are identical, only one set of data need be submitted.

(h) The requirements to submit controls system data and dynamic modelling data apply to equivalent collector-system generators.

4.5.3 Battery Energy Storage Facility

Overview: The AESO expects data to be submitted by a legal owner of battery energy storage facility that is governed by Section 502.13 of the ISO rules, *Battery Energy Storage Facility Technical Requirements* and Section 502.14 of the ISO rules, *Battery Energy Storage Facility Operating Requirements* and that have a maximum authorized discharging power and a maximum authorized charging power greater than or equal to 5 MW. The AESO expects that this data will be submitted separately for each collector group in accordance with Figure 3.

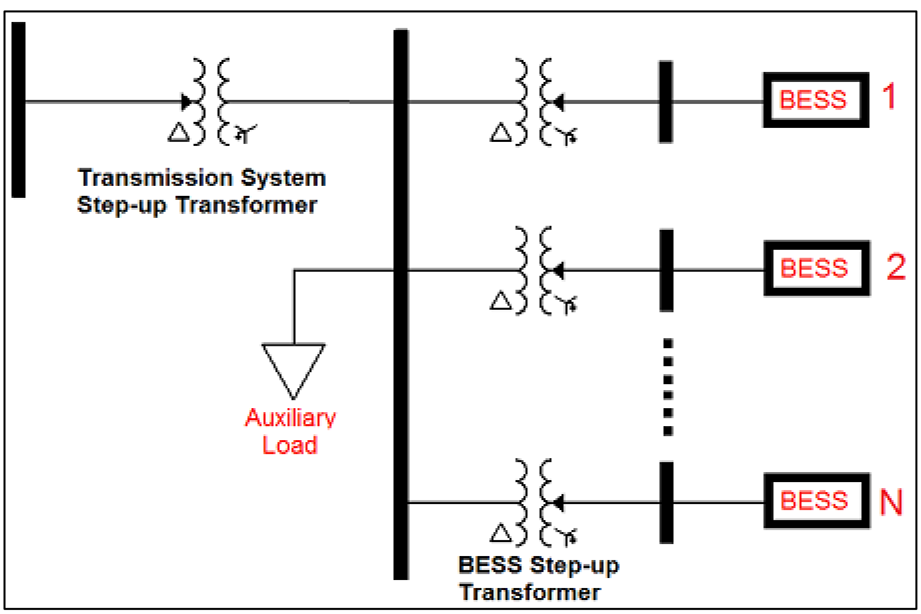


Figure 3 Typical Battery Energy Storage Facility

Checklist:

- ☐ Reduced representation diagram of collector system
- ☐ Maximum authorized charging power (MW)
- ☐ Maximum authorized discharging power (MW)
- ☐ Generator's manufacturer's data sheet, including at a minimum:

- ☐ Number of battery energy storage system converter units
- ☐ Unit converter rating (MVA)
- ☐ Rated terminal voltage (kV)
- ☐ Maximum temporary ratings and time characteristics
- ☐ Minimum real power operation
- ☐ Maximum reactive power output
- ☐ Minimum reactive power output
- ☐ Equivalent positive-sequence impedance for three-phase fault calculations
- ☐ Equivalent zero-sequence impedance for single-phase fault calculations
- ☐ Converter type
- ☐ Equivalent converter series impedance
- ☐ Battery type
- ☐ step-up transformers

☐ Auxiliary load characteristics

☐ Maximum continuous operation under maximum authorized discharging power (hours)

☐ Model validation report

Explanation:

(a) Maximum authorized charging power and maximum authorized discharging power are defined in the AESO's *Consolidated Authoritative Document Glossary*.

(b) Maximum reactive power output and minimum reactive power output are calculated based on the maximum authorized charging power and maximum authorized discharging power.

(c) The equivalent positive-sequence impedance is the impedance of the converter filter behind the converter step-up transformer. The total impedance of this equivalent impedance and converter step-up transformer determines the three-phase fault level at the point of connection.

(d) Each battery energy storage converter unit consists of a step-up converter transformer, a converter, and a set of battery racks.

(e) The auxiliary load consists of the converter cooling load and the substation base load. The cooling load, which is the major part of the auxiliary load in the battery energy storage facility, is usually a motor load and is a function of the power converted by the converter. When the converter operates at its maximum capacity, the cooling load and consequently the auxiliary load is maximum. The auxiliary load may have non-linear characteristics when compared to a converter load; however, for the purpose of modelling a simplified liner model as described in the following equation is preferred.

$$P_{Auxiliary} = m \times P_{Converter} + P_{Base\ Load}$$

Where
$P_{auxiliary}$ = Auxiliary load power (MW)
m = slope
$P_{converter}$ = Converter unit power (MW)
$P_{base\ load}$ = Base load power (Mw)

Figure 4, provided below, shows the characteristics of this simplified load relationship.

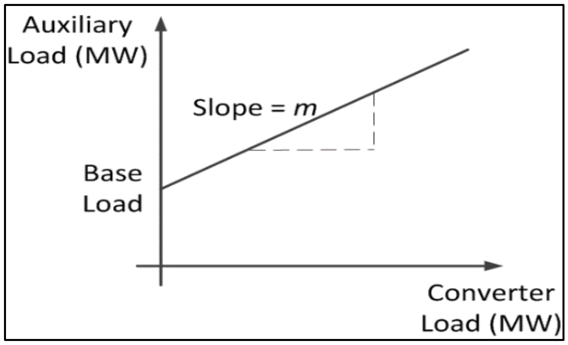


Figure 4 Auxiliary Load Characteristics Versus Converter Load (MW)

(f) The auxiliary load may have a low power factor because it is a motor load. The load power factor or the reactive power at the auxiliary load value should be provided.

4.5.4 Industrial Complex Aggregated Machines and Distribution Connected Motors

Overview: Aggregated machines are modelled as a totaled MVA equivalent for each type of machine such as induction motors, synchronous motors, and motors controlled by a power electronic drive that are located on the load side of a point of delivery where:

(a) the individual machines are connected at a voltage of greater than or equal to 1000 V;

(b) the individual machines have a capacity that is greater than or equal to 1 MW; and

(c) the total connected capacity is greater than or equal to 5 MW.

If any of the previous 3 conditions are not true, the aggregated machine data does not need to be submitted.

Checklist:

The checklist includes all applicable items of large individual machines or an aggregated generating Facility and:

- ☐ ½-cycle fault contribution on the high voltage side of the Point of delivery
- ☐ 3-cycle fault contribution on the high voltage side of the Point of delivery
- ☐ Aggregate low-voltage induction motors ratings in MVA
- ☐ Aggregate medium-voltage induction motors ratings in MVA
- ☐ Aggregate medium-voltage synchronous motors ratings in MVA
- ☐ Aggregate synchronous generators ratings in MVA
- ☐ Aggregate induction generators ratings in MVA

Explanation:

(a) ½-cycle fault contribution is the asymmetric fault current, in amperes, coming from the industrial complex for a fault on the transmission system side of each of the supply transformers.

(b) 3-cycle fault contribution is the symmetrical fault current, in amperes, coming from the industrial complex for a fault on the transmission system side of each of the supply transformers.

(c) Where multiple transformers supply a site, the faults are to be applied simultaneously to all supplying transformers.

(d) Aggregate MVA is the sum of the rated MVA of all induction motors or generators in the specified class.

(e) Low-voltage motors are those motors directly connected at a voltage of less than or equal to 1000 V, excluding all motors connected through variable-frequency drives.

(f) Medium-voltage motors are those motors directly connected at a voltage of greater than 1000 V, excluding all motors connected through variable-frequency drives.

(g) It is expected that aggregate MVA values include any machine that is also modelled as a large individual machine.

4.5.5 Distributed Energy Resources

Overview: Aggregated distribution energy resources have a totaled MVA equivalent to distribution-connected generators located on the distribution side of a point of delivery, where the total distribution-connected capacity is greater than or equal to 5 MW.

The AESO has established the following two approaches for modelling distributed energy resources:

(a) Legal owner provides detailed model of the distributed energy resources; or

(b) Legal owner selects one of the typical parameter sets and includes the recommended typical parameters provided in Appendix 2.

Refer to Appendix 2 of this information document for further details about these approaches.

Checklist:

<u>**Data common to both approaches**</u>:

☐ Generic Prime Mover Type.

☐ Provide generation general characteristics as listed in Table 9 in accordance to the Prime Mover Type.

Table 9 Required Data by Prime Mover Type

<table>
<tr><th>Generation Type</th><th>Indicate the Machine type</th><th>Indicate if it is inverter-coupled</th><th>Indicate if the Heat Recovery System is installed</th><th>Indicate the Reactive Power Control Method</th></tr>
<tr><td>Solar</td><td rowspan="3">N/A</td><td rowspan="2">Yes</td><td>No</td><td rowspan="7">Voltage Control or Power Factor Control</td></tr>
<tr><td>Storage</td><td>Yes/No</td></tr>
<tr><td>Wind</td><td rowspan="5">Yes/No</td><td rowspan="2">No</td></tr>
<tr><td>Hydro</td><td rowspan="4">Synchronous or Induction</td></tr>
<tr><td>Gas</td><td rowspan="3">Yes/No</td></tr>
<tr><td>Diesel</td></tr>
<tr><td>Biomass</td></tr>
</table>

- ☐ Maximum authorized real power (MW)
- ☐ Minimum stable generation (MW)
- ☐ Reactive power capability (MVAr)
- ☐ Positive-sequence resistance and subtransient reactance
- ☐ Frequency control mode
  - ☐ No frequency control; or
  - ☐ Droop mode and droop setting
- ☐ Type of Exciter (for synchronous generators)
  - ☐ Power factor and power factor setpoint; or
  - ☐ Voltage control and voltage control set point.
- ☐ Generator interconnection ride-through requirement
  - ☐ IEEE 1547-2003 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
  - ☐ IEEE 1547-2014 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems - Amendment 1
  - ☐ IEEE 1547-2018 IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. Ride Through: Abnormal Operating Performance Categories, Category II
- ☐ Impedance of feeder from distributed energy resource to transmission point of delivery
- ☐ Distribution Feeder Data
  - ☐ Equivalent or reduced representation diagram of distribution feeder
  - ☐ Positive-sequence total real and reactive impedance of the distribution feeder
  - ☐ Zero-sequence total real and reactive impedance of the distribution feeder, if grounded
  - ☐ Minimum load on the feeder
  - ☐ Total generation capacity installed on the same feeder

<u>Additional Data requirement for Approach 1</u>:

Synchronous Generation Data: The same requirements provided in section 4.5.1 of this appendix for large synchronous generating unit applies

Inverter-based Generation Data: The same requirements provided in section 4.5.2 of this appendix for aggregated generating facilities applies

Step-Up Transformer:

- ☐ Transformer impedances
- ☐ Transformer equivalent circuit
- ☐ Positive and zero-sequence real and reactive impedances
- ☐ Positive and zero-sequence real and reactive shunt admittances
- ☐ Short-circuit impedances and load losses
- ☐ Open-circuit excitation currents and no-load losses

- ☐ Phase angle shift
- ☐ Significant off-neutral impedance of tap-changing transformers

4.6 High-voltage Direct Current Converter Terminals

Overview: Data requirements are to be established through discussion with the AESO.

4.7 Series Compensation

Overview: Series compensation is a series component, typically a reactor or capacitor, which modifies the series reactance of a line.

Checklist:

- ☐ Nameplate
- ☐ Reactive power (MVAr) rating
- ☐ Rated voltage
- ☐ Rated current
- ☐ Control strategy

Explanation:

Discuss the control strategy with the AESO to identify which details are to be submitted.

4.8 Static VAr Compensators

Overview: A “Static VAr Compensator” is a shunt-connected capacitive or inductive conducting equipment whose output is automatically and rapidly adjusted to maintain or control some parameter of the electrical power system, typically voltage.

Checklist:

- ☐ Nameplate
- ☐ Maximum/minimum MVA (Capacitive)
- ☐ Maximum/minimum MVA (Inductive)
- ☐ Rated voltage
- ☐ Control strategy
- ☐ Control bus
- ☐ Maximum control-band voltage
- ☐ Minimum control-band voltage
- ☐ Connection (Delta/Wye)
- ☐ Neutral grounding status
- ☐ Grounding impedance

Explanation:

(a) Reactive power (MVAr) rating is to be expressed at the shunt-connected equipment rated voltage.

(b) The control strategy is one of the strategies summarized in Table 10.

Table 10 SVC-Switching Strategies

☐ Strategy	☐ **Explanation** of Strategy
Manual	The SVC output can be adjusted by personnel on site
Automatic	The SVC output is adjusted under the control of an automated control system
Supervisory	The SVC output can be adjusted remotely via a supervisory control and data acquisition system

(c) The “Control Bus” is the bus at which the voltage is monitored for the purpose of controlling this shunt device. Refer to the bus by the (**BUS_CODE**) assigned to the bus by the AESO.

(d) The maximum and minimum voltages of the control band are expressed in per-unit of the system nominal voltage (kV) at the control bus.

(e) Grounding resistance and reactance, expressed in ohms, with 0 indicating a solidly grounded bank.

5 Other FACTS Devices

Overview: “FACTS Devices” or “Flexible AC Transmission System Devices” refer to power electronic based systems and their associated static equipment that provide control of one or more alternating current transmission system parameters to enhance controllability and increase power transfer capability.

Checklist:

- ☐ Nameplate
- ☐ Component single-line diagram
- ☐ Manufacturer’s test report
- ☐ Manufacturer’s data Sheet
- ☐ Details established by discussion with the AESO
- ☐ Description of operation

Explanation:

(a) A component single-line diagram is used to show all the main circuit components of the FACTS installation, including transformers, line segments, capacitors, and reactors.

(b) Provide a text description of the operation of the FACTS installation, to a level of detail to be discussed with AESO.

(c) Submit the data for any transformers, line segments, capacitors, reactors, or dynamic control systems associated with the FACTS device as detailed in the relevant section of this appendix.

Appendix 2 – Distributed Energy Resource Modelling Guideline

This Appendix 2 provides information for legal owners of distributed energy resources and other market participants on the modelling of these distributed energy resources in power flow and dynamics simulations and provides a set of typical data for the purpose of a connection project.

The AESO is focused on the impact of distributed energy resources on the reliability of the interconnected electric system. This impact is defined in part by the distributed energy resource capabilities such as voltage support, fault current contribution, the incremental losses to the transmission system, and to a lesser degree, frequency support through inertia and governor controls.

As such, the AESO requests legal owners to provide a specific set of distributed energy resource modelling data for each resource type when the distributed energy resource with Maximum Capacity (MC) is greater than or equal to 5 MW or in the AESO connection process.

1 Power Flow Models

For modelling purposes, a set of identical generators can be aggregated into a single equivalent generator for a pool asset. The AESO expects that if there is more than one type of generator, the market participant can aggregate each generator type separately into a single equivalent generator. The gross onsite load associated with the distributed energy resources facility may be modelled separately.

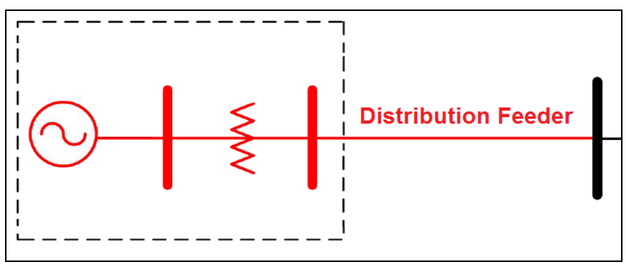


Figure 1 Power Flow Model of a Distributed Energy Resources Connection with One or More Identical Generating Units

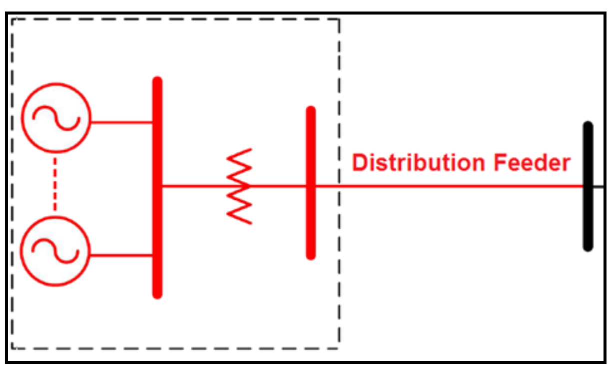


Figure 2 Power Flow Model of a Distributed Energy Resources Connection for Non-identical Generating Units

The AESO recommends market participants provide the AESO with the power flow model data in Table 1 for each equivalent generator described above.

Table 1 Distributed Energy Resource Power Flow Data

Generator Power Flow Data		
	Maximum Power (Pmax)	Minimum Power (Pmin)
	Maximum Reactive Power (Qmax)	Minimum Reactive Power (Qmin)
Machine Base (Mbase)	Source Impedance (Resistive) R Source [pu]	Source Impedance (Reactive) X Source [pu]
Power Factor Set Point	Reactive Control Mode Set to "**3-Fixed Q based on WPF**" for power factor control mode	
Voltage Control Set Point	Reactive Control Mode Set to "**0- Not a wind machine**" or "**1 – Standard QT, QB Limits**" for power factor control mode	
Distribution Feeder Power Flow Data		
Feeder Name or ID	Minimum load on the Feeder	Total installed distributed energy resources capacity on the same feeder
Positive Sequence Line R, X & B [pu]	Zero Sequence Line R, X & B [pu] if grounded	Applicable summer and winter ratings

2 Dynamic Models

The AESO understands that creating a dynamic model for distributed energy resources is challenging due to the level of support along the supply chain for these small units. As such, to assist market participants, the AESO has developed 2 suggested approaches for market participants to provide dynamic modelling data to the AESO.

Approach 1

A legal owner or project proponent may request, from the manufacturer, the relevant generating unit modelling information including generator, excitation and electrical control, prime mover governor or real power controller and voltage and frequency protection settings. The legal owner and project proponent may submit this information directly to the AESO. Please note, this information is typically not available from the manufacturer until the project is in a later stage (i.e. stage 3 or 5) of the AESO's Connection Process. The AESO applies this information to the model.

Approach 2

The legal owner or project proponent may use Approach 2 when no project-specific data for a distributed energy resource is available at earlier stages of the connection process. In this Approach 2, the AESO applies pre-defined typical parameters for the distributed energy resource modelling. Approach 2 is intended to assist market participants when establishing a set of reasonable assumptions prior to obtaining manufacturer data.

As per the NERC, *Reliability Guideline: Distributed Energy Resource Modeling*[4], at a minimum, the following information related to the distributed energy resource may be provided to the AESO[5].

(a) Type of generating resource, such as, reciprocating engine, wind, solar photovoltaics, gas unit, or battery energy storage;

(b) Distribution bus nominal voltage level and control where the distributed energy resource is connected;

(c) Feeder characteristics for connecting distributed energy resource to the distribution bus, if applicable;

(d) Capacity of each distributed energy resource including: maximum power output, reactive power capability, apparent power rating, rated power factor, capability curve of distributed energy resource reactive output with respect to different real power outputs down to Pmin;

(e) The version of the IEEE Standard 1547, *Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces,* such as, -version 2003, version -2014, version -2018 Cat I/II, version UL1741-SA, version CA Rule 21, or other relevant interconnection standard requirements that is related to the utility scale distributed energy resource;

(f) Actual or projected plant control modes in operation;

  (i) reactive power control mode:

    (A) voltage control with control bus and voltage setpoint; or

    (B) power factor control with control bus and power factor setpoint; and

  (ii) presence of frequency response and droop; and

(g) The prime-mover type classification of the utility scale distributed energy resource. Prime-mover types include:

  (i) Reciprocating engines with or without co-generation;

  (ii) Gas turbine with or without co-generation;

  (iii) Steam turbine with or without co-generation;

  (iv) Small synchronous hydro; and

  (v) Inverter-based distributed energy resources such as wind, solar photovoltaics, or battery energy storage systems.

The AESO applies this information to the model.

[4] NERC, Reliability Guideline: Distributed Energy Resource Modeling, Dated September 2017, Available on www.nerc.com.

[5] NERC, *Reliability Guideline: Distributed Energy Resource Modeling*, refers to a Transmission Planner and a Planning Coordinator. In Alberta, these functions are performed by the AESO.

2.1 Synchronous Generating Units Connected to an Electric Distribution System[6]

As per NERC, *Reliability Guideline: Distributed Energy Resource Modeling*[7], synchronous generating units connected to the electric distribution system are expected to be modelled using the GENTPJ model with Kis = 0. If modelling information is provided from the generating unit, that data may be used by the market participant to develop the GENTPJ model parameters. Otherwise, the AESO recommends the market participant apply best engineering judgment when developing reasonable modelling parameters based on the type of synchronous generating units.

Note, synchronous generating units connected to the electric distribution system prior to the IEEE Standard 1547-2018 Cat II are not required to have frequency response capability. Furthermore, frequency response is typically not required for synchronous generating units connected to the interconnected electric system. Therefore, the assumption of using only a generator model would represent the most conservative assumption for frequency and reactive power support from the synchronous generating units.

Synchronous generating units typically operate in constant power factor control mode with no droop control mode. To implement the constant power factor control mode, the market participant may model these synchronous generators in power flow as a wind machine code =3. In dynamics simulation the study engineer may convert the unit back to code 0 to accept the GENTPJ model.

Table 2 below sets out a sample set of typical data provided by market participants to the AESO for the of modelling synchronous generating units.

Table 2 Reciprocating Engine Generators

	GENTPJ Model					
	High Voltage reciprocating	**Medium Voltage reciprocating**	**Low Voltage reciprocating**	**Steam Turbine**	**Small Hydro**	**Gas Turbine**
Generator Voltage Range	7.2-13.8	4.16	380-690	Any	Any	Any
T'_{d0}	4.478	2.967	2.214	6	6	6.5
T'_{q0}		0.313		1	0	1
T''_{q0}		0.2		0.035	0.0650	0.03
H	1.2	1.2	1.2	3	1.7	4.2
D	0	0	0	0	0	0
X_d	2.242	2.227	2.647	1.8	1.45	1.6
X_q	1.62	1.217	1.71	1.7	1.05	1.5
X'_d	0.188	0.284	0.167	0.2	0.47	0.2
X'_q		1.217		0.4	1.05	0.3
X''_d	0.139	0.179	0.123	0.18	0.33	0.13

[6] All instances of the use of synchronous generating units in subsection 2.1 of Appendix 2 refer only to those synchronous generating units connected to an electric distribution system.

[7] See footnote 5.

X''_q	0.261	0.197	0.262	0.18	0.33	0.13
X_l	0.101	0.13	0.1	0.12	0.28	0.1
S(1.0)	0.2	0.2	0.2	0.2	0.2	0.1
S(1.2)	0.6	0.6	0.6	0.6	0.6	0.4
K_{is}	0	0	0	0	0	0
K J=K*VA		0.029	0.027			

Note: "VA" is on the machine rating.

2.2 Inverter-Based Distributed Energy Resources

A performance-based modelling approach may be used by a market participant to model the large number of inverter-based distributed energy resources. As some of inverter-based distributed energy resource are small with difficulties accessing modelling data, the AESO recommends the use of standardized model parameters in accordance with the distributed energy resource control and protection standard vintage.

A performance-based modelling approach for inverter-based distributed energy resources is the modelling method described in NERC, *Reliability Guideline: Parameterization of the DER A Model*[8],. For specific distributed energy resource projects, the parameters can be found in Chapter 2 of the document.

3 Distributed Energy Resource Representation in Base Cases

The purpose of this section is to inform study engineers how the AESO models distributed energy resource in the base cases.

The AESO base cases form the basic assumptions common to most transmission system studies on the interconnected electric system. Some studies require additional details or different representation of the interconnected electric system, including generating units in isochronous mode, inverter-base resources in weak grid operation, detailed high voltage direct current controls, dynamic load characteristics, voltage and frequency protections, inclusion of non-market participating distributed energy resources, and detailed electric distribution system characteristics. These additional modelling characteristics are not part of the base cases as they are not applicable to the majority of transmission system studies.

The AESO has the following principles as it relates to distributed energy resource modelling in base cases:

(a) that the model is suitable to assess any impact on transmission facilities;

(b) that the transmission facilities and electric distribution system are represented appropriately;

(c) the representation of observable physical electrical quantities; and

(d) to simplify data manipulation as much as possible.

[8] NERC, *Reliability Guideline: Parameterization of the DER A Model,* Dated September 2019, Available on www.nerc.com.

3.1 Existing System

The AESO base cases will represent the system topology support for these forecasted points. Thus, the base case model can be simplified to the system shown in Figure 3 for the simplest representation while maintaining all elements needed to allocate forecast load and generation.

Distribution feeder loss, electric distribution system load, distributed generation onsite load, micro-generation and onsite load are all implicitly included in the single load model. The inclusion of the distribution feeder loss also means that feeder impedances are also implicitly included in the single load model. Therefore, explicitly modelling the distribution feeder without removing the actual feeder loss would duplicate the effect of the losses.

While the feeder impedance has important impact on the voltage level and power flow on the feeder, the purpose of the AESO base case is to study the transmission system and the observable quantities at the transmission and distribution interface and ensure that it has accounted for the impact from feeder.

3.2 Connection Studies

Connection studies examine the effect of connecting new resources to the system. In such cases, either the physical system is new or there is an additional flow of energy not currently observed, thus the incremental impact is not included in the base case.

In the case of the feeder, in order to capture the effect of a new feeder or new energy flow on an existing feeder, the impacted feeder is modelled explicitly with the expected load and generation provided by the distribution facility owner. Once energized, this new feeder or new energy flow on an existing feeder would be part of observable quantities, thus, the feeder modelling is no longer required and forecast provided by the AESO.

3.3 Observable physical electrical quantities

Distributed energy resources may be installed in Alberta with or without interconnection to interconnected electric system in a number of ways. Table 3 provides a summary of the interconnection options for distributed energy resource in Alberta and how each type of market participation is represented in models.

Table 3 Distributed Energy Resource Characteristics by Market Participation

<table>
<tr><th colspan="3">Market Participation Type</th><th>Characteristics</th><th>AESO Registration</th><th>Modelling Representations</th></tr>
<tr><td colspan="3">Non-parallel operation</td><td>Do not synchronize with the electric distribution system for more than 150 ms.
(i.e. Back up generation)</td><td>No Pool Asset ID
No MPID
No SCADA
No settlement with AESO</td><td></td></tr>
<tr><td rowspan="4">Parallel operation</td><td colspan="2">Non-exporting</td><td>Load always exceeds distributed energy resource output and no power is exported to the grid.</td><td>No Pool Asset ID
No MPID
No SCADA
No settlement with AESO</td><td></td></tr>
<tr><td rowspan="3">exporting</td><td>Small Micro-Generation</td><td>Renewable or low emission distributed energy resource less than 150 kW and only has cumulative metering. Designed to offset annual energy consumption.</td><td>No Pool Asset ID
No MPID
No SCADA
AESO settles with retailer</td><td>Aggregated model provided by AESO if required</td></tr>
<tr><td>Large Micro-Generation</td><td>Renewable or low emission distributed energy resource greater than 150 kW or less than or equal to 5 MW site equipped with interval metering. Designed to offset annual energy consumption.</td><td>Pool Asset ID
MPID
No SCADA
AESO settles with retailer</td><td>Aggregated model provided by AESO if required</td></tr>
<tr><td>Distribution Connection Generation</td><td>Any energy source and any size including small scale generation and community generation</td><td>Pool Asset ID
MPID
AESO settles directly with the GFO
SCADA and Offering if greater than 5 MW</td><td>Modelling Data from market participants:
Asset location greater than 5 MW or
Locations subject to the AESO Connection Process</td></tr>
</table>

3.4 Supervisory Control and Data Acquisition Data and Revenue Meters

Figure 3 shows a simplified typical electric distribution system with supervisory control and data acquisition data [9] points, mostly on the transmission system and to a limited extent on the electric distribution system, and revenue meters[10] on both transmission system and electric distribution systems.

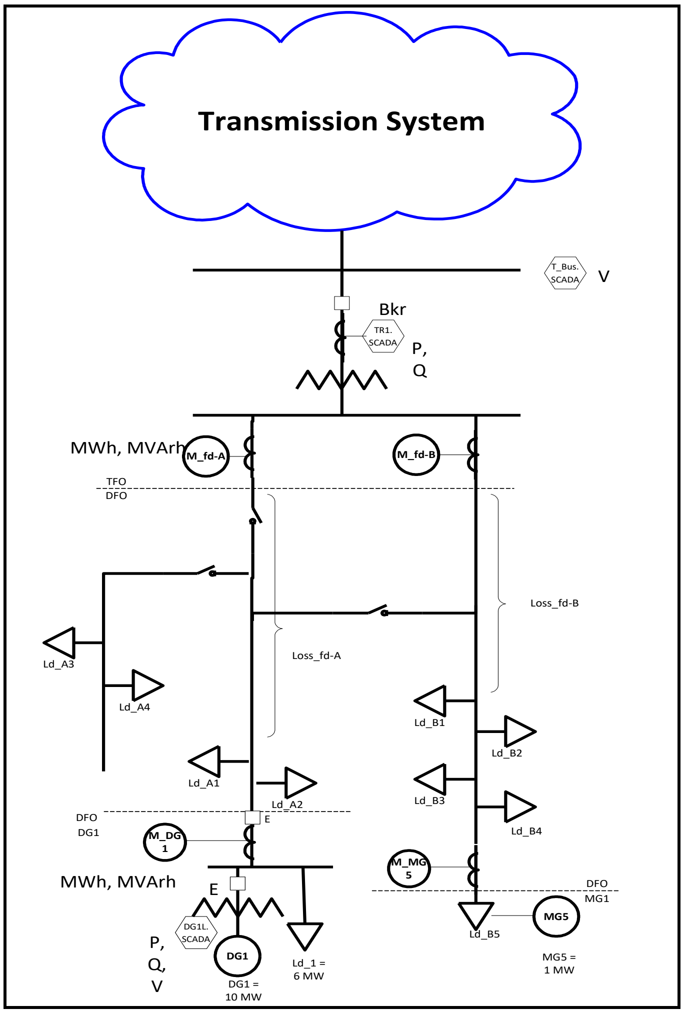
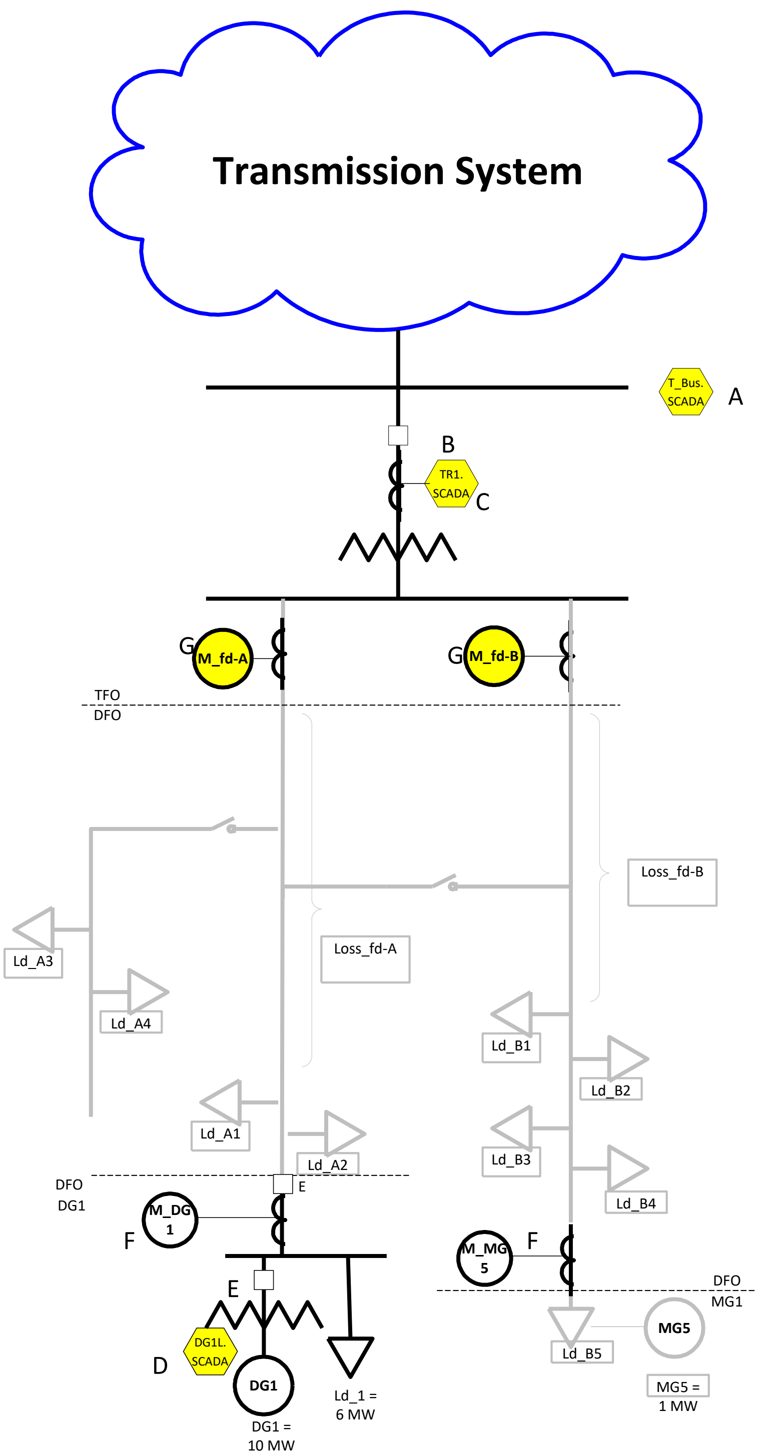


Figure 3 Simplified Conceptual Diagram of an Electric Distribution System with Distributed Energy Resources

The AESO's load forecast uses inputs from substation load revenue meters to forecast future loads. The AESO's generation forecast uses inputs from generating units participating in the energy markets. Generating units that do not participate in the energy market are implicitly forecast as a reduction in substation load. This is represented in Figure 4, where the yellow highlighted points are used.

[9] Refer to Section 502.8 of the ISO rules, *SCADA Technical and Operating Requirements,* available on www.aeso.ca for supervisory control and data acquisition data requirements.

[10] Refer to AUC Rule 021, Settlement System Code Rules, available on www.auc.ab.ca for details regarding what information a revenue meter is required to measure for settlement purposes.



Observable

60kV+ bus voltages

60kV+ breaker status

60kV+ transformer winding P, Q = net transformer loading

5MW+ distributed energy resource breaker/disconnect status

5MW+ distributed energy resource net P,Q outputs

Non observable

Individual feeder flow

Gross substation load

Microgeneration outputs

Feeder switches/disconnect status

Feeder losses

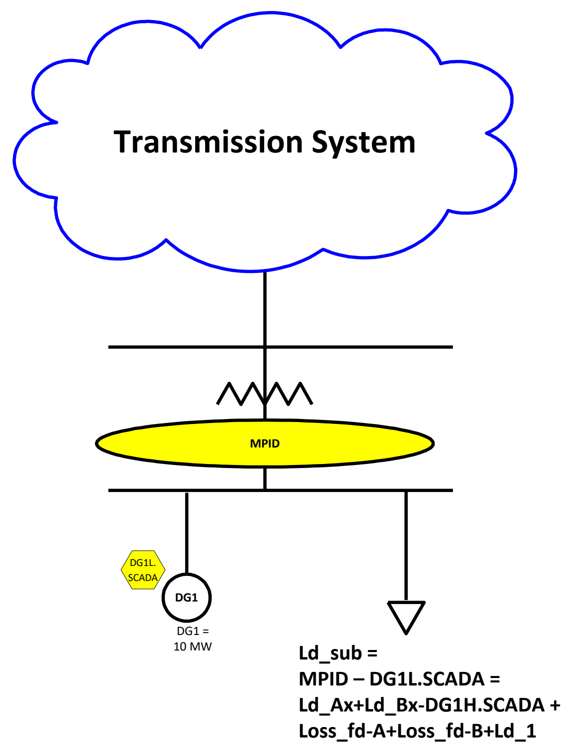


Figure 4 Observable Quantities and Simplified Distribution Modelling in AESO Base Cases