Etudes d’Intégration des Energies Renewables dans les Reseaux Electriques de Transport

Jour 1: Reseaux de transport et PSS/E

Kwami Senam Sedzro, PhD

Curriculum

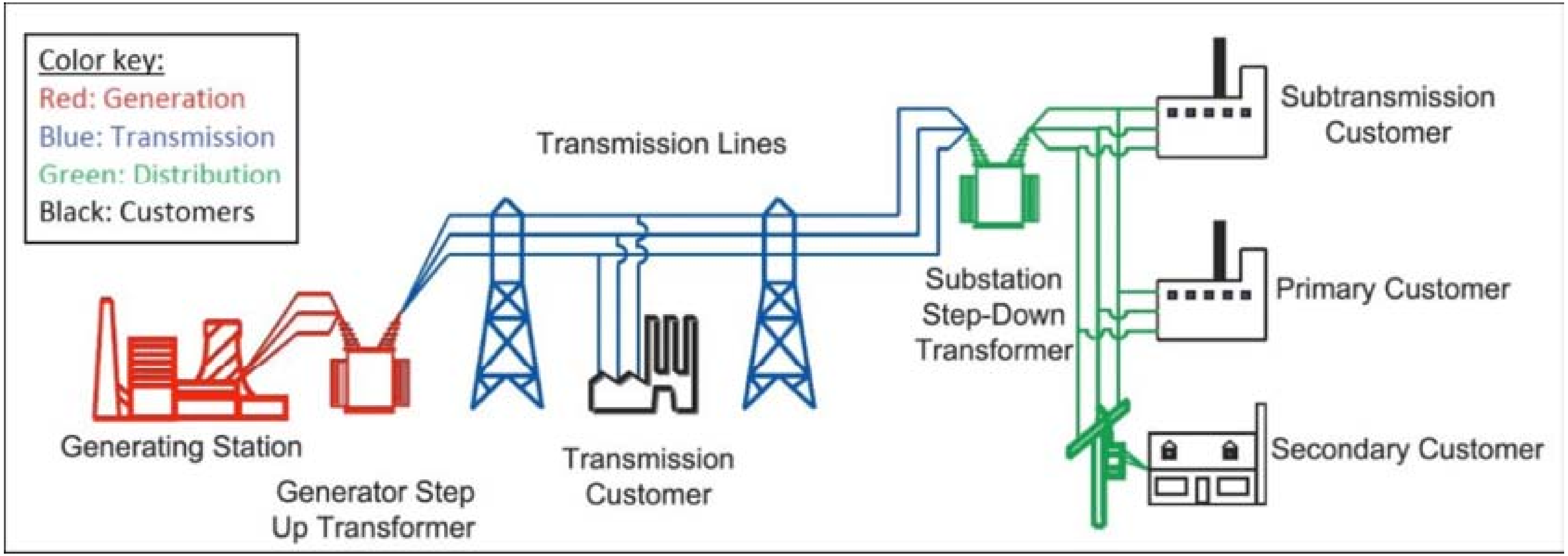
- **Jour 1: Réseaux Electriques de Transport et PSS/E**
  - Réseaux électriques de transport: Fonctions et composantes
  - Réseaux électriques de transport du futur
  - Intégration des énergies renouvelables
  - Le logiciel PSS/E
- **Jour 2: Modélisation et étude du réseaux de transport a l'aide du logiciel PSS/E**
  - Modélisation d'un réseau électrique de transport dans l'environnement PSS/E
  - Etude des réseaux électriques de transport avec PSS/E
- **Jour 3: Analyse de l'impact des énergies renouvelables sur les réseaux électriques de transport**
  - Modélisation des énergies renouvelables dans l'environnement PSS/E
  - Etude de l'impact des énergies renouvelables sur le réseau de transport – Ecoulement de puissances
- **Jour 4: Analyse de l'impact des énergies renouvelables sur les réseaux électriques de transport**
  - Etude de l'impact des énergies renouvelables sur le réseau de transport – Analyse des contingences
  - Etude de l'impact des énergies renouvelables sur le réseau de transport – Analyse des puissances de court-circuit
- **Jour 5: Introduction aux études des stabilité dynamique des réseaux de transport**
  - Introduction aux études des stabilité dynamique des réseaux de transportSolar photovoltaic modelling

Réseaux Electriques de Transport et PSS/E

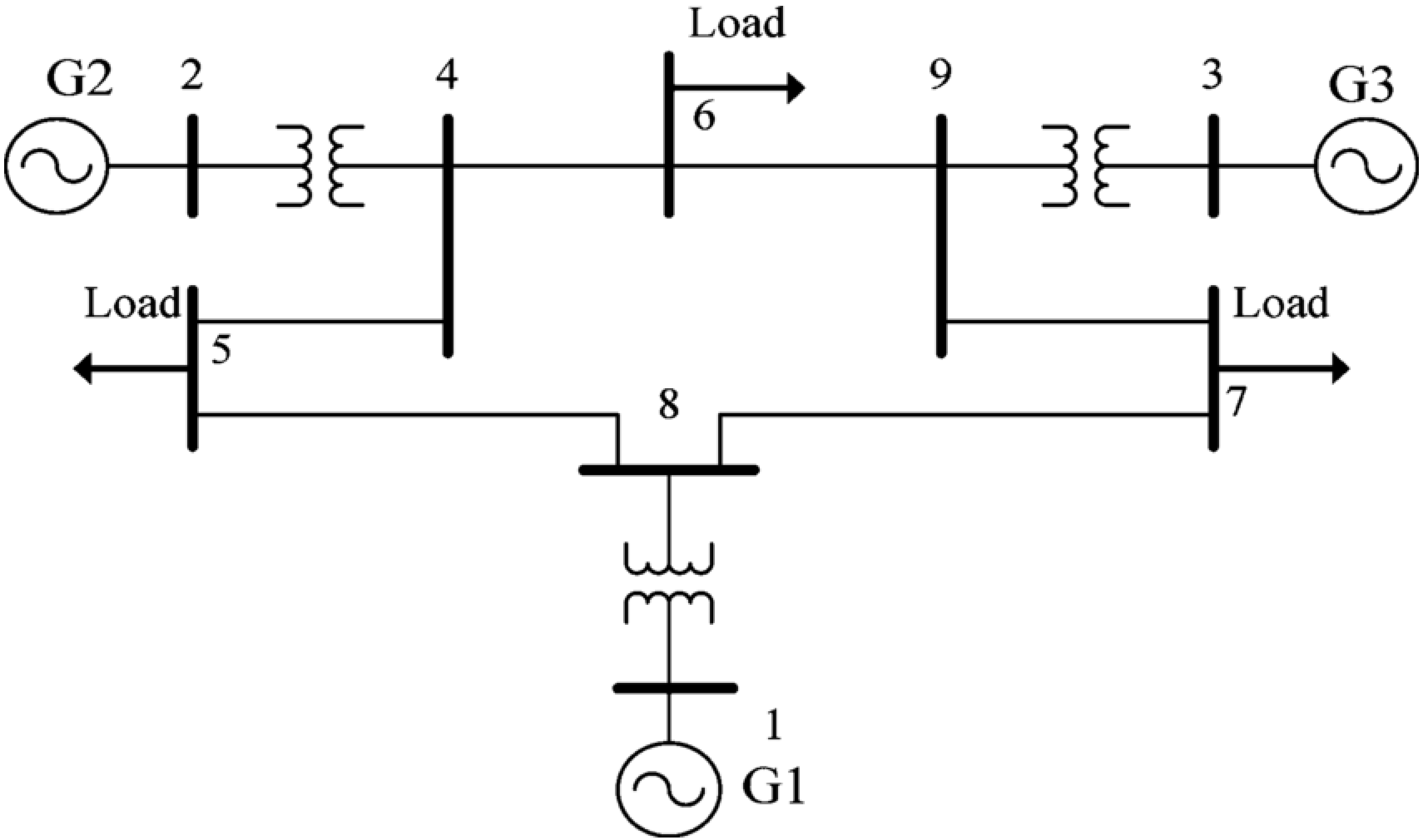
Jour 1

Structure Générale des Réseaux Eletriques

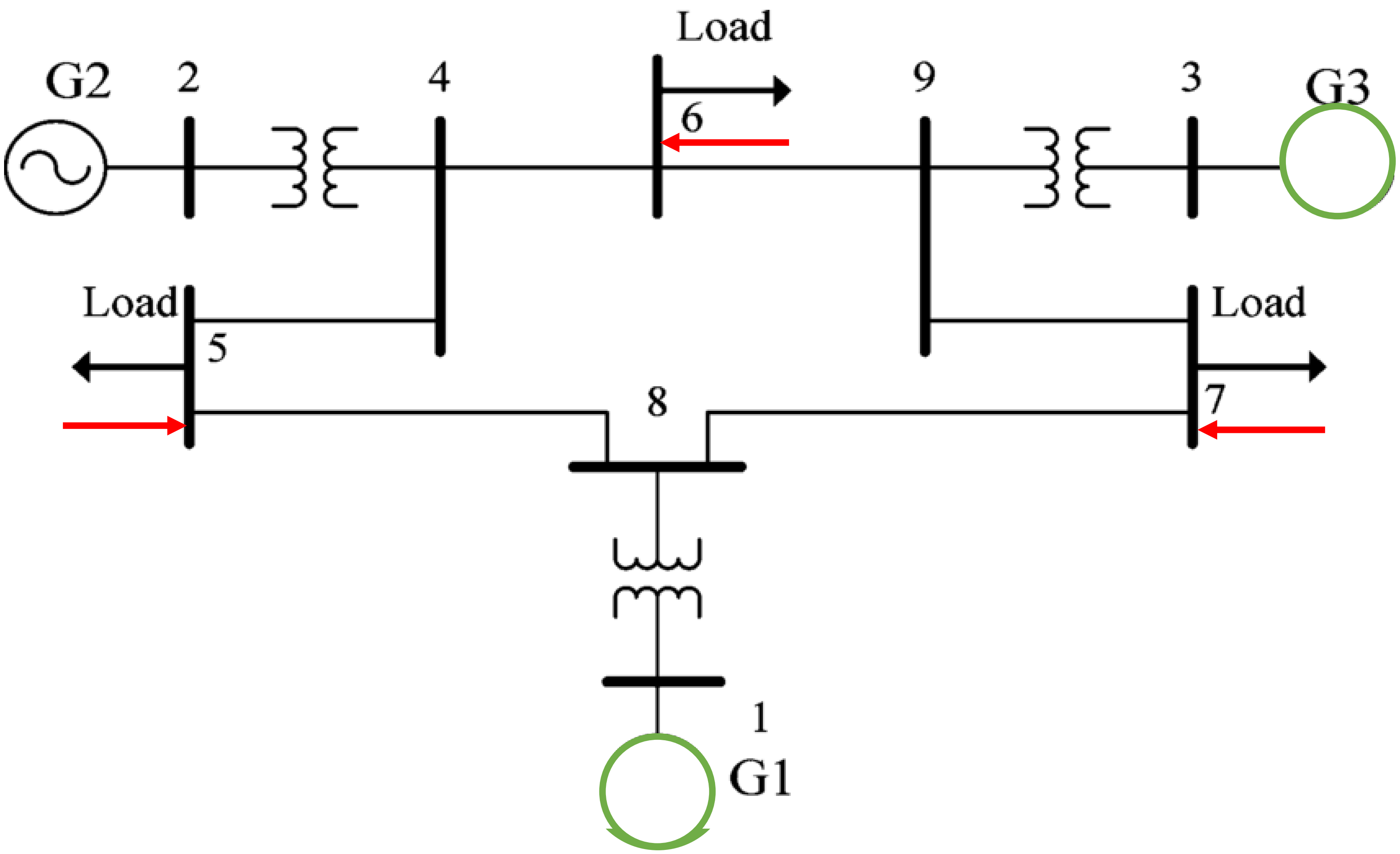
Production → Poste Elevateur de Tension → Transport → Poste Abaisseur de Tension → Distribution



Réseaux électriques de transport: Fonctions et composantes



Réseaux Electriques de Transport du Futur



Modeling Tools for Renewable Integration Planning in the Bulk Power System (BPS)

- Learning Objectives
- Potential Impacts of Renewables on BPS
- Common Renewable Integration Screening Metrics
- Integration Challenges and Modeling Requirements
- The Limitations of PSS/E Modeling

Learning Objectives

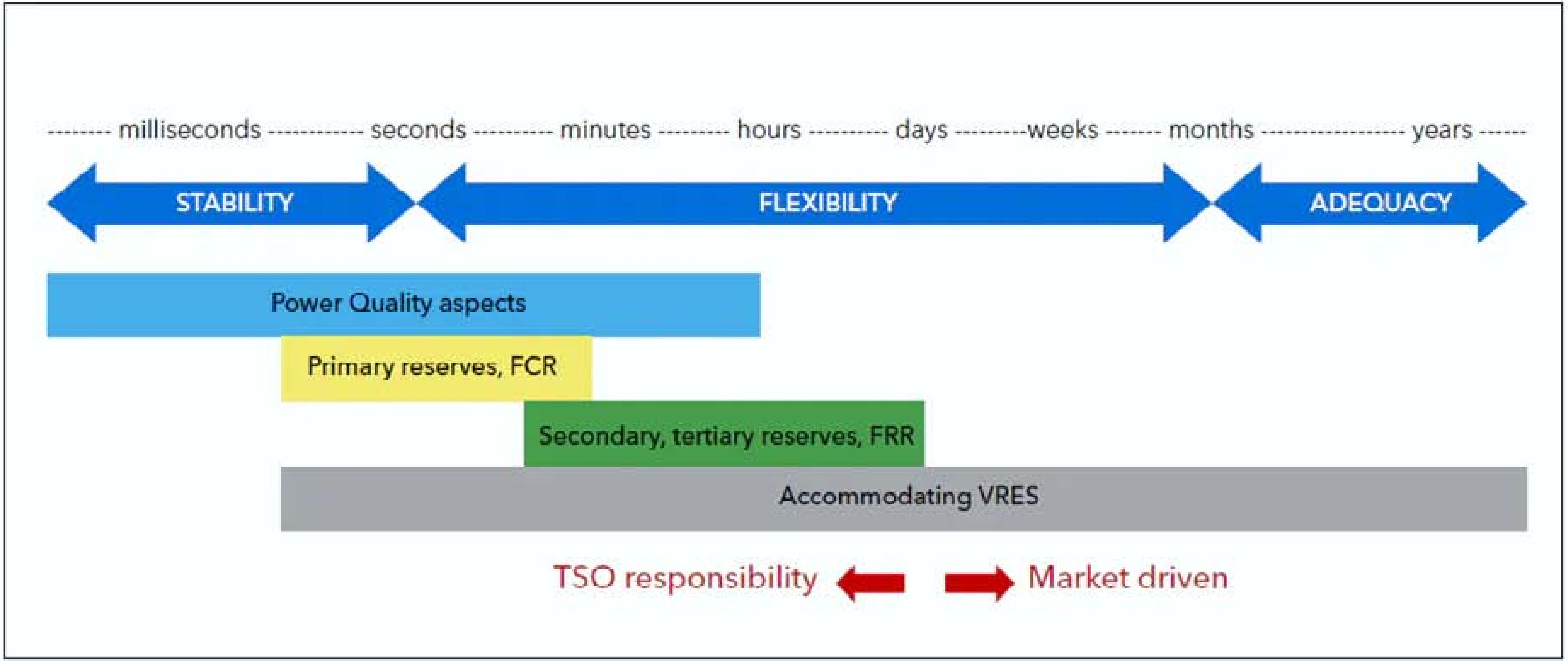
- Understanding potential impacts of renewables on the bulk power system (BPS) operation
- Identifying key integration metrics
- Choosing the right tools for integration impact assessment

Potential Impacts of Renewables on BPS

- BPS operational requirements:
  - Supply must always be balanced with demand and network losses
  - Safe, dependable, and stable operation

- Three broad categories of challenge
  - Stability
    - Power quality and fast response to load variation
  - Flexibility
    - Compensates for supply-demand imbalance
  - Adequacy
    - Ability to meet end-user demand and energy needs, at all times
    - Accounts for planned and possible outages

Potential Impacts of Renewables on BPS



Source: DNVGL

Potential Impacts of Renewables on BPS

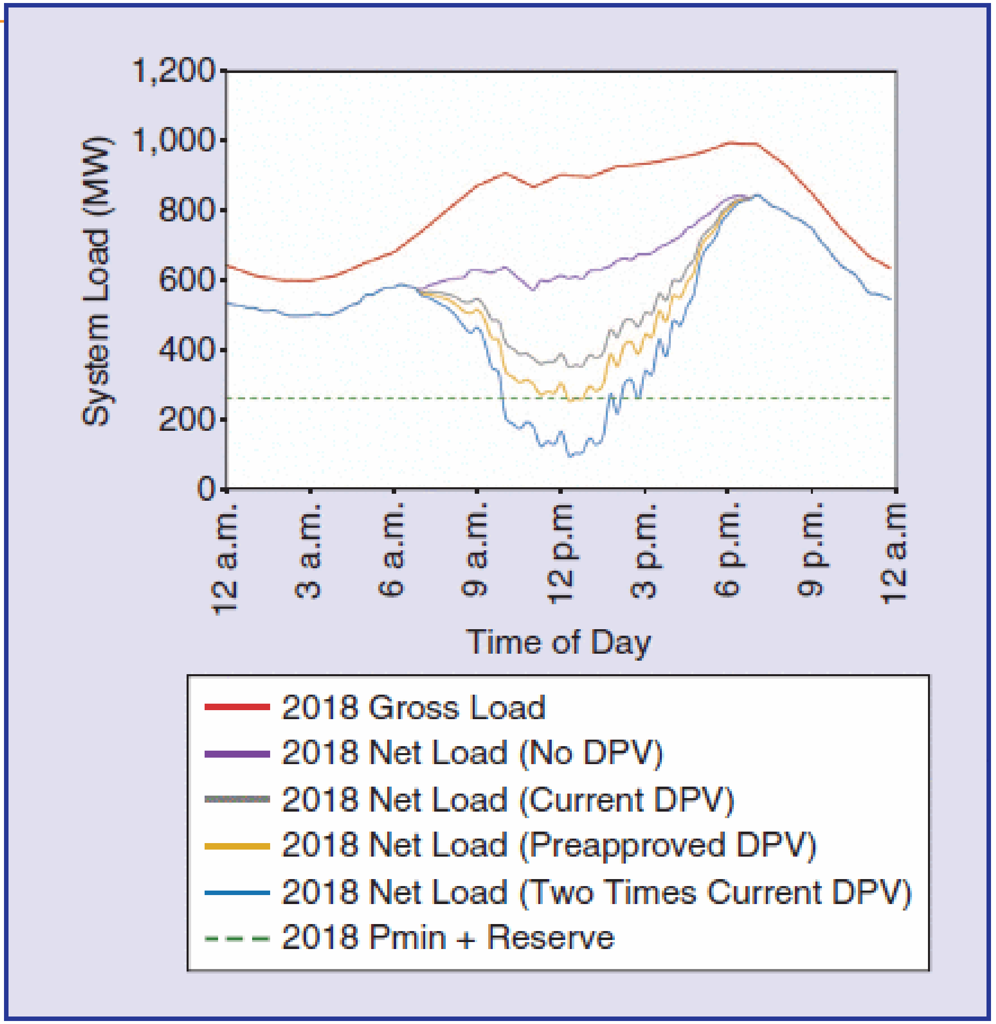
STABILITY

- Renewables are mostly coupled to the grid via electronic converters
- Inverter-based resources (IBR) are susceptible to create weak grid conditions
  - Little or no inertia for synchronizing power
  - Power output depends on high frequency electronic controls
  - Controls themselves depend on stable reference voltage
  - Voltage reference becomes less stable in weak grid conditions
  - As more conventional generation is replaced IBRs, grid stiffness reduces
  - Primary frequency response needs will increase
- Underfrequency load shedding may prove ineffective

Potential Impacts of Renewables on BPS

FLEXIBILITY / ADEQUACY

- Increased balancing issues
  - Steep demand ramp
  - Less predictable variability
- Operating reliability
  - Ability to withstand unanticipated component losses or disturbances



HECO's "duck curve," showing increased impacts of DPV on system load for the worst day of the year [D. Lew *et al.*]

Common Renewable Integration Screening Metrics

- Grid strength
  - the sensitivity of the resource's terminal voltage to variations of current injections
  - how "stiff" the grid is in response to small perturbations such as changes in load or switching of equipment
  - Weak grids can pose challenges for connecting new resources and particularly for connecting inverter- based resources
- Grid strength-based metrics
  - SCR, WSCR, CSCR, SCRIF, SDSCR

Common Renewable Integration Screening Metrics

Metric	Formula	
Short-Circuit Ratio (SCR)	$SCR_i = \dfrac{SCMVA_i}{P_{DPV_i}}$	$SCMVA_i$: Short-circuit capacity in MVA at node i P_{DPV_i}: Power injection of the DPV at node i $CSCMVA$: Composite short-circuit capacity of all DPV units ΔV_i: Voltage variation at node i V_i: Voltage of node i $Z_{DPV_{ij}}$: Element in row i, column j of the Thevenin equivalent impedance matrix of the set of DPVs $\theta_{Z_{ij}}$: Angle of $Z_{DPV_{ij}}$ θ_{V_i}: Angle of V_i
Weighted Short-Circuit Ratio (WSCR)	$WSCR = \dfrac{\sum_i^N SCMVA_i P_{DPV_i}}{(\sum_i^N P_{DPV_i})^2}$	
Composite Short-Circuit Ratio (CSCR)	$CSCR = \dfrac{CSCMVA}{\sum_i^N P_{DPV_i}}$	
Short-Circuit Ratio with Interaction Factors (SCRIF)	$SCRIF = \dfrac{SCMVA_i}{P_{DPV_i} + \sum_{j \neq i}^N \frac{\Delta V_i}{\Delta V_j} P_{DPV_j}}$	
Site Dependent Short-Circuit Ratio (SDCSR)	$SDSCR_i = \dfrac{\lvert V_i \rvert^2 / \lvert Z_{DPV_{ii}} \rvert}{(P_{DPV_i} + \sum_{j \neq i}^N P_{DPV_j} \frac{\lvert Z_{DPV_{ij}} \rvert}{\lvert Z_{DPV_{ii}} \rvert} \frac{\lvert V_i \rvert}{\lvert V_j \rvert} \cos(\theta_{Z_{ii}} - \theta_{Z_{ij}} + \theta_{V_i} - \theta_{V_j}))}$	

Common Renewable Integration Screening Metrics

Metric		Simple calculation using short circuit program	Accounts for nearby inverter based equipment	Provides common metric across a larger group of VER	Accounts for weak electrical coupling between plants within larger group	Considers non-active power inverter capacity*	Able to consider individual sub-plants within larger group
SCR	Short Circuit Ratio	★★	X	X	X	X	X
CSCR	Composite SCR	★	★★	★★	X	X	X
WSCR-MW	Weighted SCR using MW	★	★★	★★	★	X	X
WSCR-MVA	Weighted SCR using MVA	★	★★	★★	★	★★	X
SCRIF	Multi-Infeed SCR	X	★★	X	★★	★★	★★

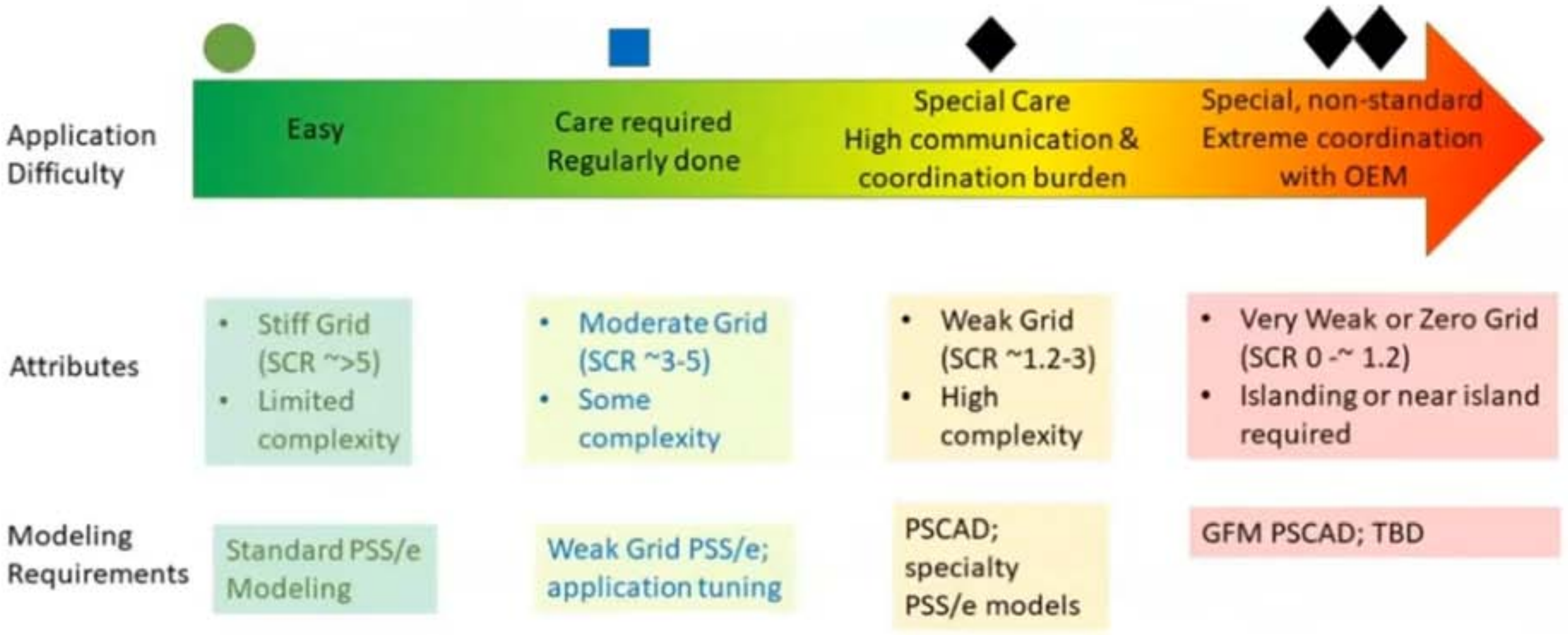
* e.g., STATCOMs or partial power inverter-based resources

X The metric cannot be applied for the described purpose
★ The metric can be applied to a limited extent or with some additional effort or processing
★★ The metric is easily or directly applied for the described purpose

Source: NERC 2017

Integration Challenges and Modeling Requirements

Modeling requirements vary with system strength



[Source: N. Miller]

Integration Challenges and Modeling Requirements

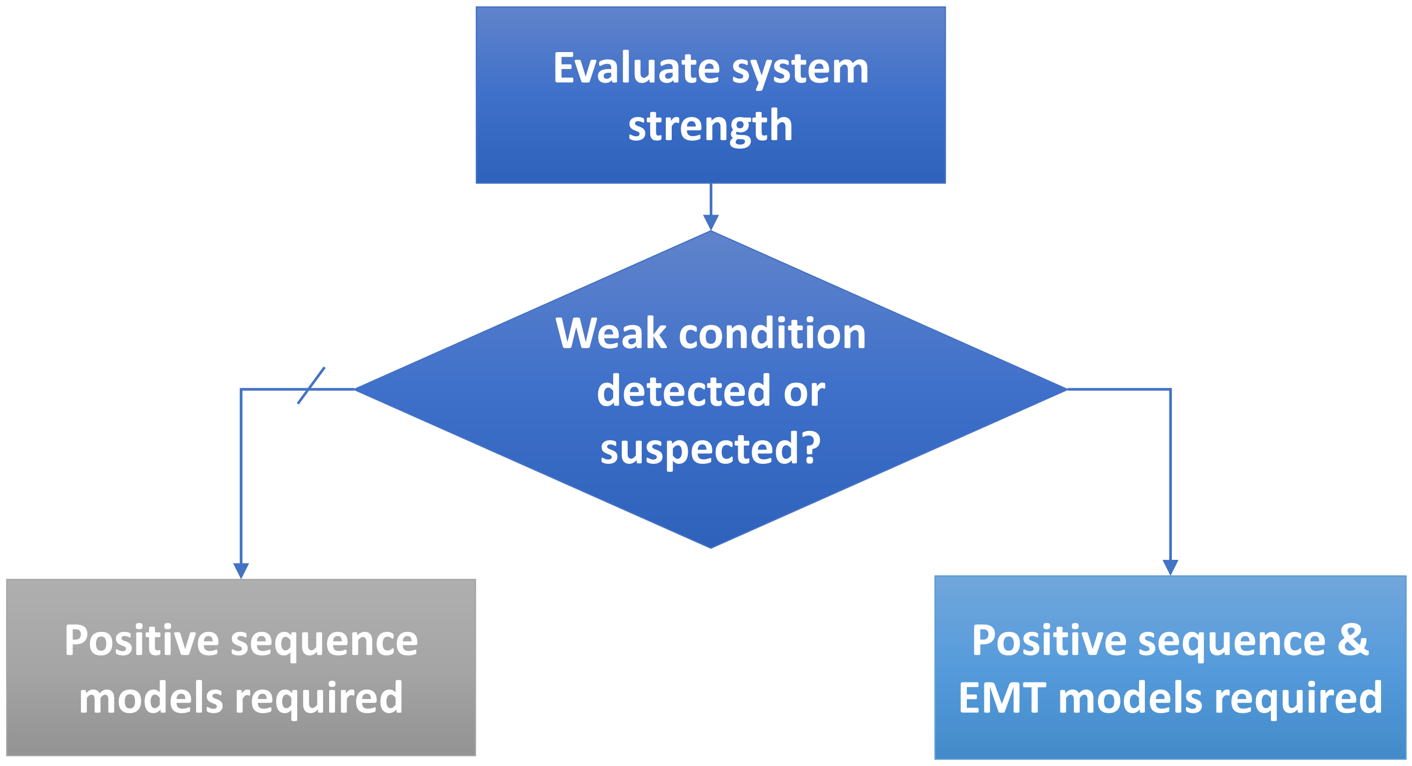
- Generic Positive Sequence Stability Model
  - Used for interconnection-wide modeling
  - Required for every resource seeking interconnection to the BES
  - Expected to accurately represent the general dynamic behavior of the IBR
- Detailed Positive Sequence Stability Model
  - Required for interconnection stability studies
  - Uses the most detailed model available for the study(e.g., positive sequence transient stability analyses)
  - Detailed models from the IBR manufacturer
- Electromagnetic Transient (EMT) Model
  - Required if a weak grid condition has been identified or suspected

The Limitations of PSS/E Modeling

- PSS/E is a positive sequence phasor domain modeling tool
- Can lead to inaccurate stability results in weak grid conditions
- Positive-sequence modeling tools cannot fully capture transients in weak grid conditions
- Electromagnetic transient modeling is required
- Positive sequence phasor domain modeling software (e.g., PSS/E)
  - Iteratively solve a system of equations to satisfy a set of constraints in the phase domain.
- EMT software (e.g., PSCAD)
  - Solves systems of differential equations which describe the three-phase electrical network in the time domain
  - Allows unbalanced faults, harmonics, and fast transients

Lessons Learned from BPS-level Integration Studies

- System strength metrics are solely for screening purpose and are considered as indicators
- The increase of IBR share of the generation mix is likely to induce reduction in system strength
- Interconnection studies will require more and more EMT modeling



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Jour 2: Modélisation et étude des réseaux de transport a l’aide du logiciel PSS/E

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  - Introduction aux études des stabilité dynamique des réseaux de transport

Day 2: Modélisation et étude des réseaux de transport a l’aide du logiciel PSS/E

- *Creation d’un modèle PSS/E*
- *Ecoulement de puissance*
- *PV Analysis*
- *QV Analysis*

Small Test Case

Consider the PJM 5-bus system shown in Figure 2. Line data are listed in Table 4. Generator and load data are listed in Table 5. Assume that bus A is the reference bus.

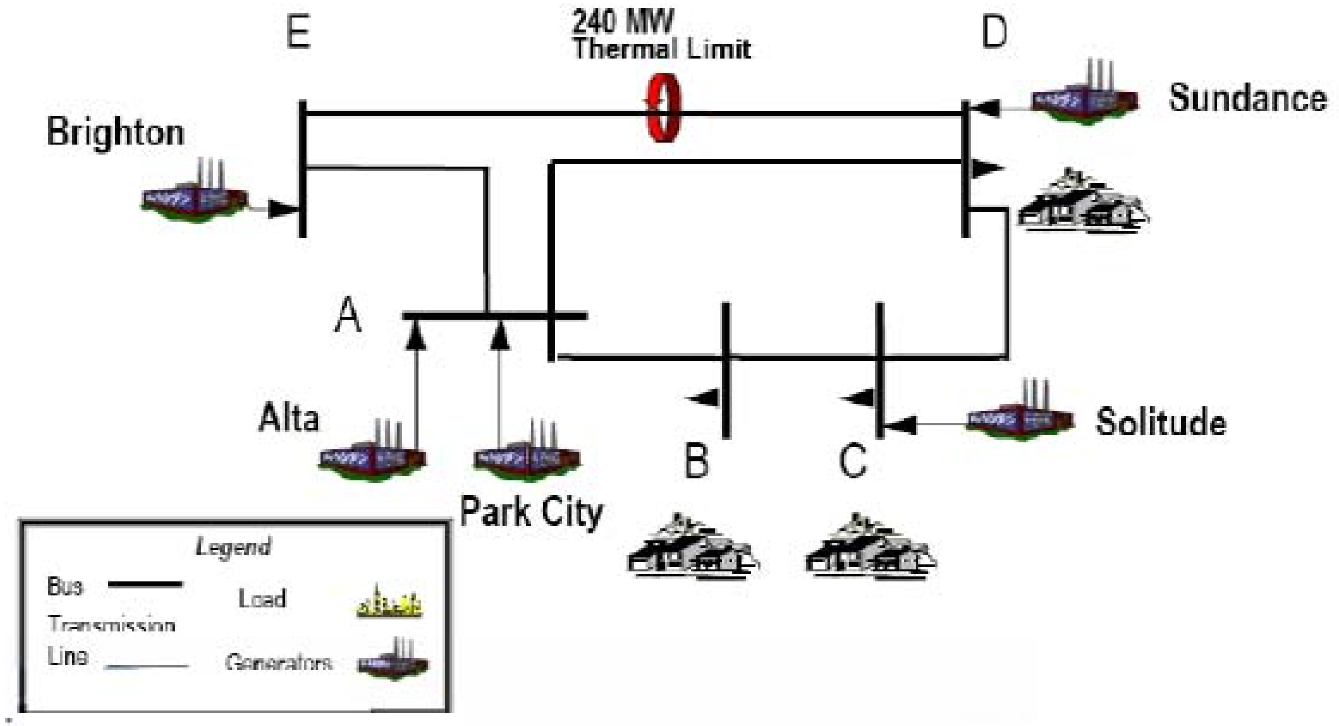


Figure 2. One-line diagram of the PJM 5-bus system

Table 4. Line Data

Line	From Bus	To Bus	Reactance (p.u.)	Flow Limit (MW)
A->B	A	B	0.0291	1000
A->D	A	D	0.0304	1000
B->C	B	C	0.0108	1000
C->D	C	D	0.0297	1000
D->E	D	E	0.0297	240
E->A	E	A	0.0064	1000

Table 5. Generator and Load Data

Participant Name	Participant Type	Location	Min MW	Max MW	Price ($/MWh)
Alta	Generator	Bus A	0	110	14
Park City	Generator	Bus A	0	100	15
Solitude	Generator	Bus C	0	520	30
Sundance	Generator	Bus D	0	200	29
Brighton	Generator	Bus E	0	600	10

Participant Name	Participant Type	Location	MW
LSE B	Load	Bus B	300
LSE C	Load	Bus C	300
LSE D	Load	Bus D	300

Small Test Case

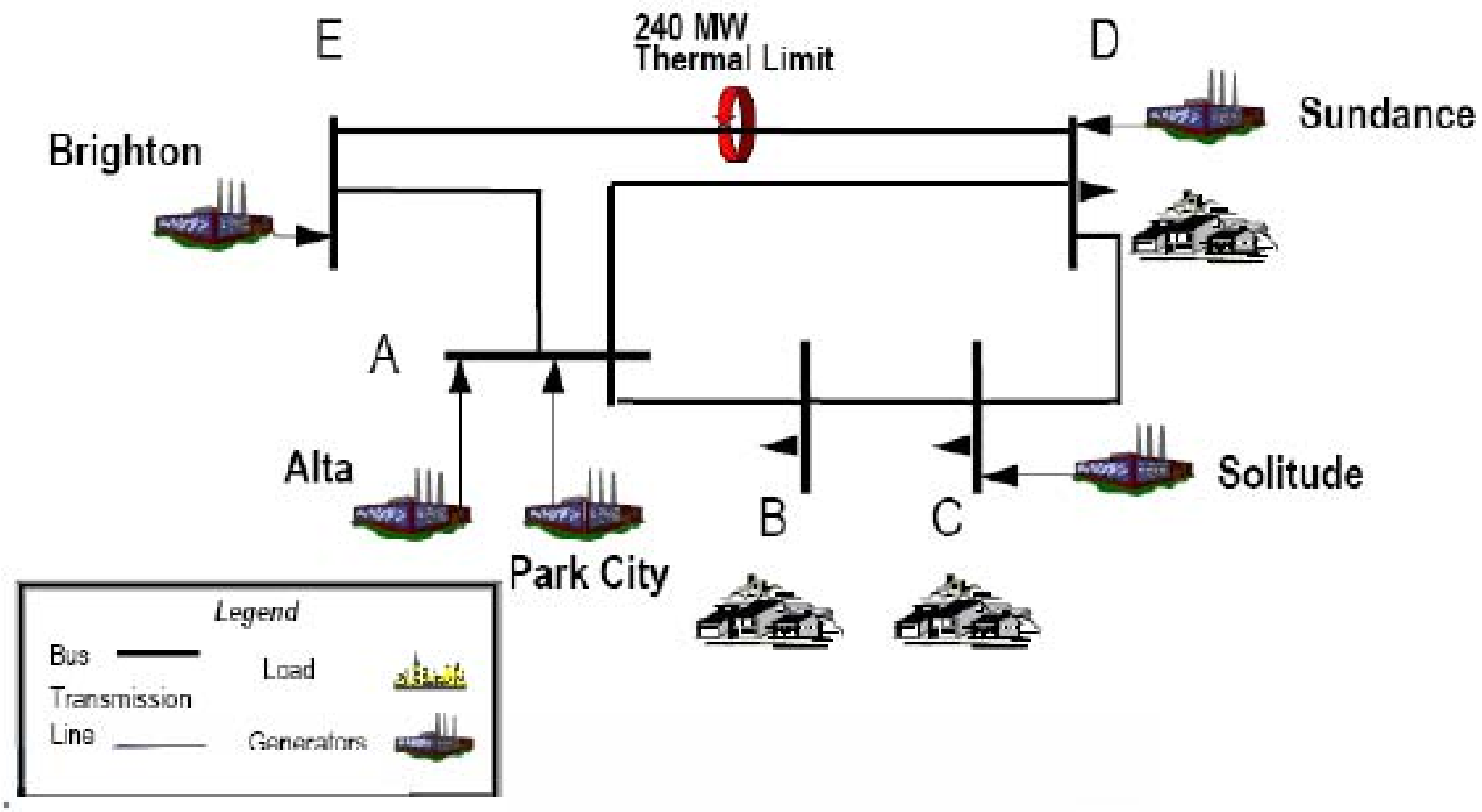


Figure 2. One-line diagram of the PJM 5-bus system

Creating a simple PSS/E project from scratch

- Simple system
  1. Start PSS/E
  2. Create a new file:
     a. Click – File/New. A small dialog box with five option buttons will be opened.
     b. Select the option “Network Case” and click OK. This will open a “Build New Case” dialog box.
     c. Set the “Base MVA” as “100.00”. Then there will be two blank spaces corresponding to “heading line 1” and “heading line 2” to be filled out.
     d. A spreadsheet interface will appear, where you will build your new case.

Creating a simple PSS/E project from scratch

- Simple system
  3. Needed data
     a. Bus Data:
        – Base KV for each bus
        – Bus type: Swing, PV, PQ
     b. Branch Data (Transmission lines):
        – "From" bus and "To" bus numbers
        – R, X, and Line charging values in per unit
     c. Load Data:
        – The "Bus number" to which the load is connected
        – P (in MW) and Q (MVAR) of the load
     d. Generator Data:
        – "Bus number" of the bus to which the generator is connected
        – Real power rating (in MW). Maximum and minimum limits for reactive power (in MVAr)
     e. Transformer Data:
        – "From" bus and "To" bus numbers

Creating a simple PSS/E project from scratch

- Simple system

  4. Save the case

     a. Click **File→Save Case As** from the File menu. This will open a "Save / Show network data" dialog box

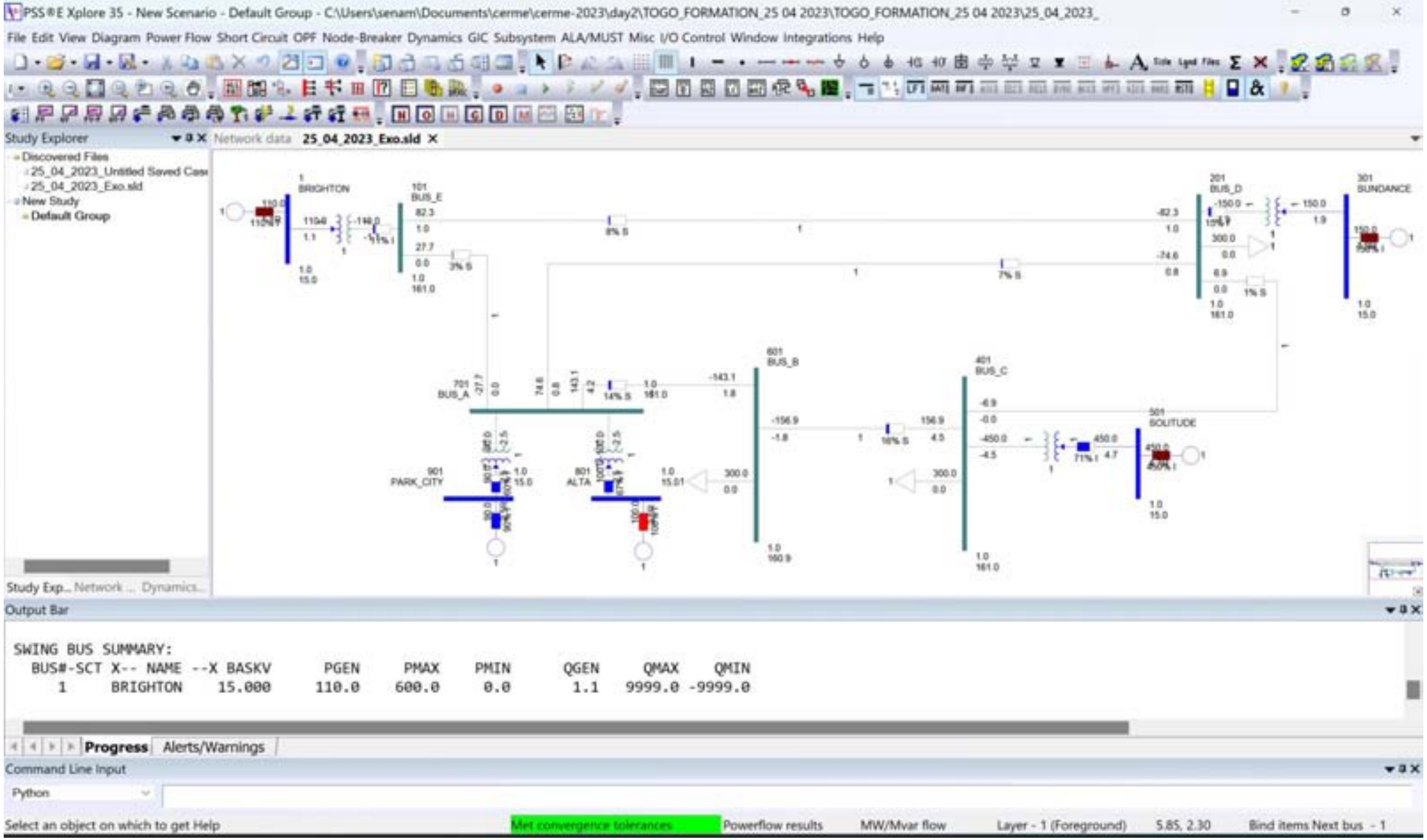
     b. Select the "**Case Data**" tab

     c. In the "destination" frame, click on the button with 3 dots to select your destination. The file path should appear in the destination text box (on the left of the button)

     d. Click OK and Close.

  Your case is ready!

Creating a simple PSS/E project from scratch



Load flow analysis

- Purpose
  - Given the demand at all buses and the power production of each power plant, find the power flow in each branch of the network.
- Technical background
  - Solve the power system network defined by:
    - $I_n = Y_{nn} V_n$
- Input:
  - Transmission lines: impedances and charging admittances
  - Transformers: impedances and tap ratios
  - Shunt-connected devices (static capacitors and reactors): admittances
  - Loads: power consumption
  - Generators: real power output, voltage magnitude **or** reactive power output, maximum and minimum reactive power output capability

Load flow analysis

- Output:
  - Voltage magnitude, where unknown
  - Voltage angle at every bus
  - Reactive power output of generators, where unknown
  - Real and reactive power, and current flow in each transmission line and transformer
- Solve power flow
  - Go to the 4^{th} toolbar and click on the Solve Load Flow icon
    - The “Load Flow Solutions” dialog box opens
    - Click on either the Newton or Gauss tab
    - Select the solution method you would like to use
    - Set the remaining parameters
  - Click Solve
  - Use the power flow reports feature to check results

PV Analysis

- Purpose
  - Evaluate how system voltages change as a result of increasing real power transfers.
- Technical background
  - The voltage at a given bus compared to the amount of transfer is non-linear and could become unstable when a small amount of power transfer results in a very large voltage decrease.

PV Analysis

- Purpose
  - Evaluate how system voltages change as a result of increasing real power transfers.
- Technical background
  - The voltage at a given bus compared to the amount of transfer is non-linear and could become unstable when a small amount of power transfer results in a very large voltage decrease.

PV Analysis

Analysis

- Launch PSS/E
- Open a case on which to run the analysis
- Open the corresponding slider diagram
- Decide of a source subsystem and of a sink subsystem
- Save both files in a directory dedicated for the PV analysis
- Create 3 new text files with extensions ".sub", ".mon", and ".con"
  - If :
    - the system considered is the example case sample.sav,
    - the source subsystem made of buses 101 and 102,
    - the sink subsystem made of "Area 1"
  - The content of these 3 files can be as shown in the next slide

PV Analysis

pv_analysis.sub - Notepad

File Edit Format View Help

```
SUBSYSTEM SOURCE
   BUS 101
   BUS 102
END

SUBSYSTEM SINK
   AREA 1
END

SUBSYSTEM CON
   AREA 1
END

SUBSYSTEM MON
   AREA 1
END
END
```

pv_analysis.mon - Notepad

File Edit Format View Help

```
MONITOR VOLTAGE RANGE SUBSYSTEM MON 0.950 1.050
MONITOR BRANCHES IN SUBSYSTEM MON
MONITOR TIES FROM SUBSYSTEM MON
END
```

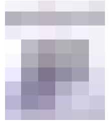
pv_analysis.con - Notepad

File Edit Format View Help

```
SINGLE LINE IN SUBSYSTEM CON
SINGLE TIE FROM SUBSYSTEM CON
END
```

PV Analysis

Analysis

- Run PV analysis
  - Go to Power Flow →Contingency, Reliability, PV/QV analysis →PV analysis
  - Or click on the PV analysis icon on the 4th toolbar 
  - The “PV Analysis” dialog box opens
  - Next, build the distribution factor data file (“*.dfx”)
    - Click the “DFAX” button
      - The “Build Distribution Factor Data File” dialog box appears
      - Fill in the file request boxes the appropriate file paths for **sub**system file, **mon**itored element file, and **con**tingency file
      - Name the “*.dfx” file in the “Distribution Factor file” box and click OK
  - In the “PV Analysis” dialog box, name the PV results output file and click OK

PV Analysis

Exporting reports

- Go to **Power Flow → Reports →Export ACCC, PV/QV** results to excel
- Fill in any relevant box

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  - Introduction aux études des stabilité dynamique des réseaux de transport

Jour 3: Analyse de l’impact des énergies renouvelables sur les réseaux électriques de transport

- *QV Analysis*
- *Fault Analysis*
- Modélisation des énergies renouvelables dans l’environnement PSS/E
- Etude de l’impact des énergies renouvelables sur le réseau de transport – Ecoulement de puissances

PV Analysis

Exporting reports

- Go to **Power Flow → Reports →Export ACCC, PV/QV** results to excel
- Fill in any relevant box

QV Analysis

- Purpose

QV analysis studies how variations in reactive power injection at a bus affect the voltage at that same bus.

QV Analysis

Analysis

- Launch PSS/E
- Open a case on which to run the analysis
- Open the corresponding slider diagram
- Decide of a source subsystem and of a sink subsystem
- Save both files in a directory dedicated for the QV analysis
- Create 3 new text files with extensions “.sub”, “.mon”, and “.con”
  - If :
    - the system considered is the example case sample.sav,
    - the bus considered for analysis is 154
  - The content of these 3 files can be as shown in the next slide

QV Analysis

qv_analysis.sub - Notepad

File Edit Format View Help

```
SUBSYSTEM CON
  BUS 154
END

SUBSYSTEM MON
  BUS 154
END
END
```

qv_analysis.mon - Notepad

File Edit Format View Help

```
MONITOR VOLTAGE RANGE SUBSYSTEM MON 0.950 1.050
END
```

qv_analysis.con - Notepad

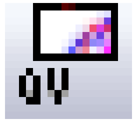
File Edit Format View Help

```
SINGLE LINE IN SUBSYSTEM CON
SINGLE TIE FROM SUBSYSTEM CON
END
```

QV Analysis

Analysis

- Run QV analysis
  - Go to Power Flow →Contingency, Reliability, PV/QV analysis →QV analysis
  - Or click on the QV analysis icon on the 4th toolbar



  - The "QV Analysis" dialog box opens
  - Next, build the distribution factor data file ("*.dfx")
    - Click the "DFAX" button
      - The "Build Distribution Factor Data File" dialog box appears
      - Fill in the file request boxes the appropriate file paths for **sub**system file, **mon**itored element file, and **con**tingency file
      - Name the "*.dfx" file in the "Distribution Factor file" box and click OK
  - In the "QV Analysis" dialog box, name the QV results output file and click OK

QV Analysis

Exporting reports

- Go to **Power Flow → Reports →Export ACCC, PV/QV** results to excel
- Fill in any relevant box

Fault Analysis

Short Circuit Analysis

Fault analysis data requirements

- **Bus Data**
  - Base KV,
  - G-Shunt (MW) (positive, negative, and zero sequence)
  - B-Shunt (MVAR) (positive, negative, and zero sequence)
  - Bus type
    - Swing Bus (the generator bus used to balance flows)
    - PV bus (a voltage control bus, and generally, a generator bus)
    - PQ bus (a non-voltage control bus, generally non generator bus).

- **Branch Data (Transmission lines)**
  - “From” bus and “To” bus numbers
  - R, X, and Line charging (positive and zero sequence) values in per unit.

- **Load Data**
  - The “Bus number” of the bus to which it is connected.
  - P (in MW) and Q (MVAR) of the load.

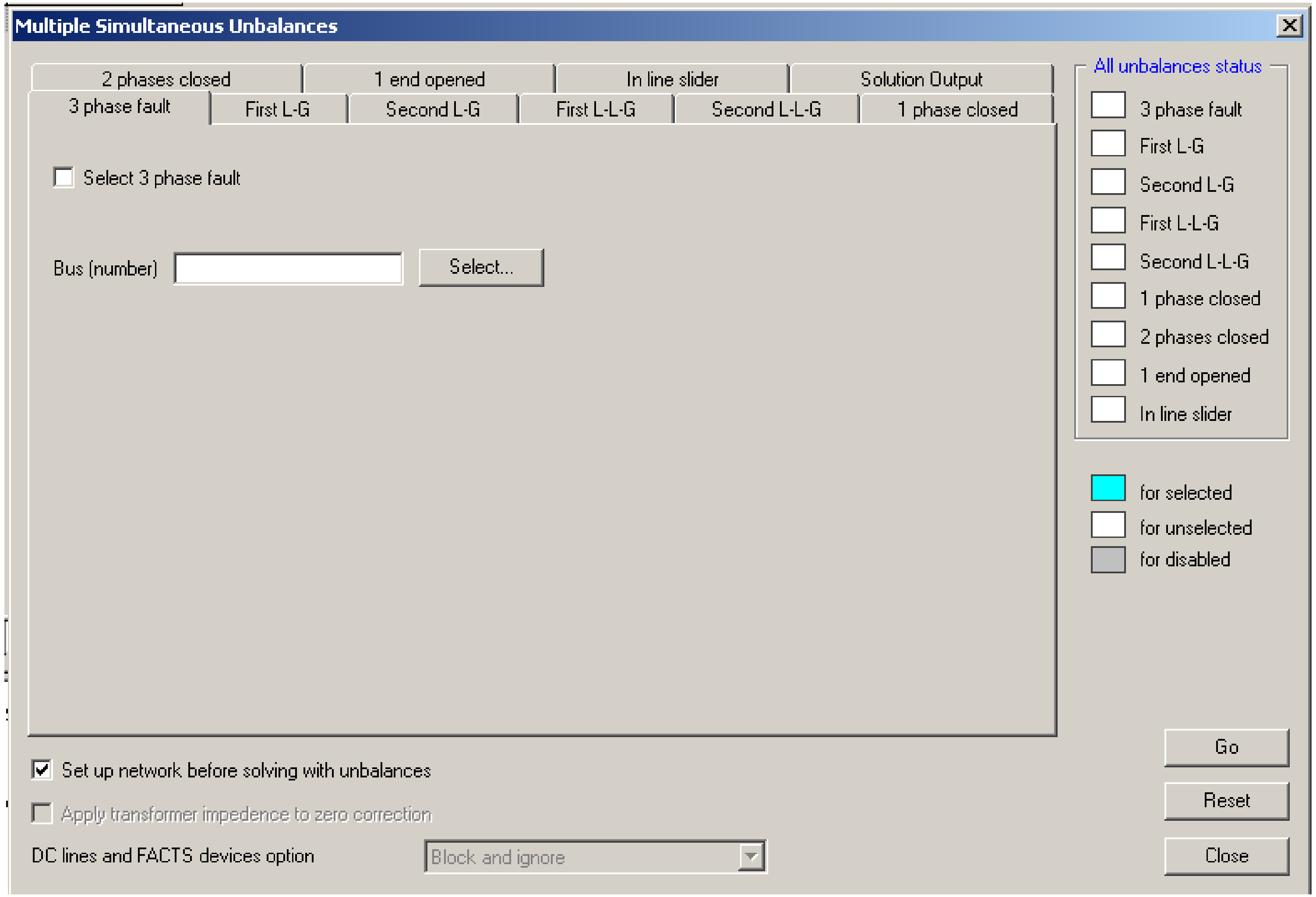
- **Generator or Machine Data**
  - The “Bus number” to which it is connected.
  - Generator Real Power Rating (in MW). Maximum and minimum limits for reactive power (in MVAr)
  - Generator R, X to ground for all the sequences in per unit.

- **Transformer Data**
  - “From” bus and “To” bus numbers
  - Transformer R, X (for positive and zero sequences) in per unit
  - Transformer R, X to ground in per unit. Note: This parameter will obviously depend on if your transformer’s connection is grounded or not
  - The Transformer’s Connection (i.e., Δ-Y, Ygrounded-Y, Δ-Δ, etc.)

Short Circuit Analysis

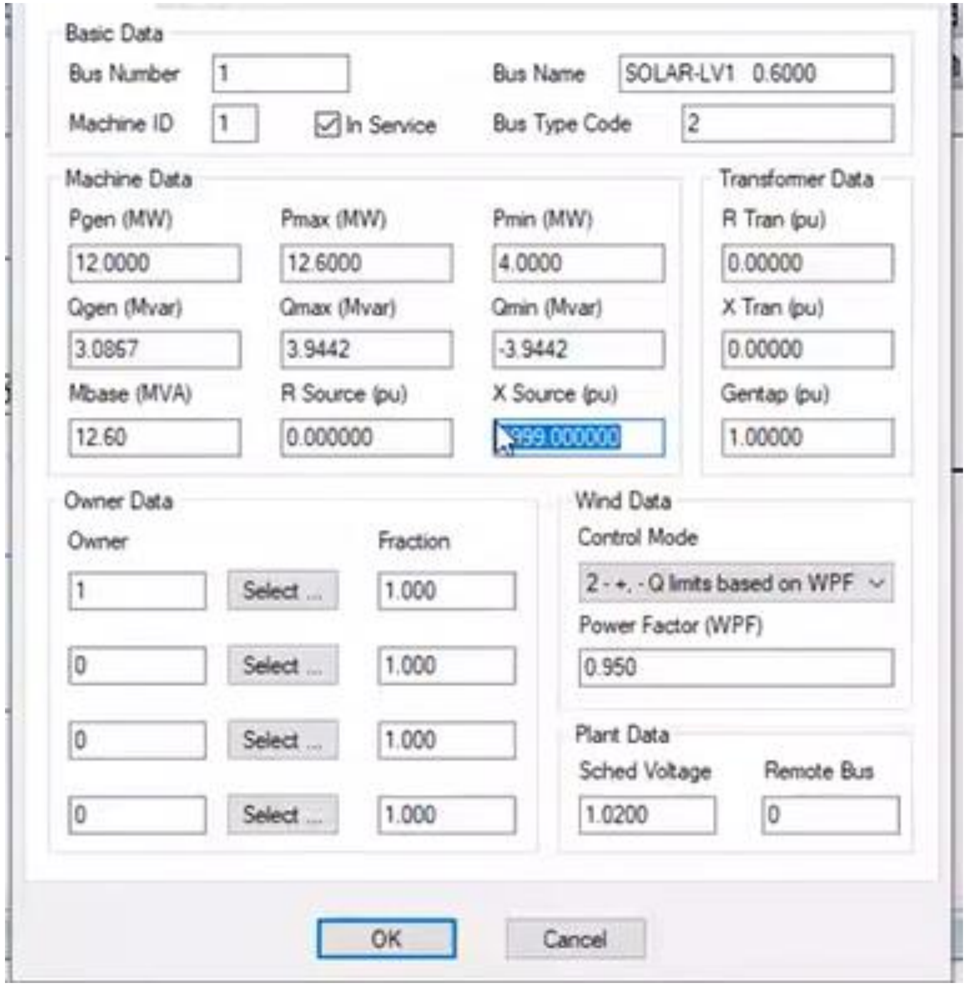
Performing fault analysis

- Go to **Short Circuit → Solve and report network with unbalances (SCMU/SCOP)**
  - The fault analysis dialog box opens
  - Check the **“Set up network before solving with unbalances”** box
  - Select the fault type to be performed
  - Select the bus (number) where the fault is to be applied and its characteristics when appropriate
  - Press Go to run the simulation



Modeling Renewable Energy Systems in PSS/E

- Wind
  - Generally modeled as Type 3 or Type 4 machine
  - PSSE control mode 2 or 3
  - Qmin = -Qmax
- Solar
  - PSSE control mode 2
  - High X source (9999)
  - Qmin = -Qmax
- Energy storage
  - PSSE control mode 2
  - High X source (9999)
  - Pmin = -Pmax; Qmin = -Qmax



Modeling Renewable Energy Systems in PSS/E

- Creating the dynamic models
  - In your project directory, create a text file with extension "*.dyr"
  - Start PSS/E, open the project, open the empty "*.dyr" file
  - The dynamic data spreadsheet will open
    - Fill in all required dynamic data for all equipment
    - Save the project

Etudes d’Intégration des Energies Renewables dans les Reseaux Electriques de Transport

Jour 4: Analyse de l’impact des énergies renouvelables sur les réseaux électriques de transport

Kwami Senam Sedzro, PhD

Curriculum

- **Jour 1: Réseaux Electriques de Transport et PSS/E**
  - Réseaux électriques de transport: Fonctions et composantes
  - Réseaux électriques de transport du futur
  - Intégration des énergies renouvelables
  - Le logiciel PSS/E
- **Jour 2: Modélisation et étude des réseaux de transport a l'aide du logiciel PSS/E**
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  - Etude de l'impact des énergies renouvelables sur le réseau de transport – Analyse des puissances de court-circuit
- **Jour 5: Introduction aux études des stabilité dynamique des réseaux de transport**
  - Introduction aux études des stabilité dynamique des réseaux de transport

Jour 4: Analyse de l’impact des énergies renouvelables sur les réseaux électriques de transport

- *Etude de l’impact des énergies renouvelables sur le réseau de transport – Analyse des contingences*
- *Etude de l’impact des énergies renouvelables sur le réseau de transport – Analyse des puissances de court-circuit*

Contingency Analysis

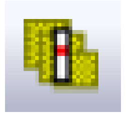
Contingency Analysis

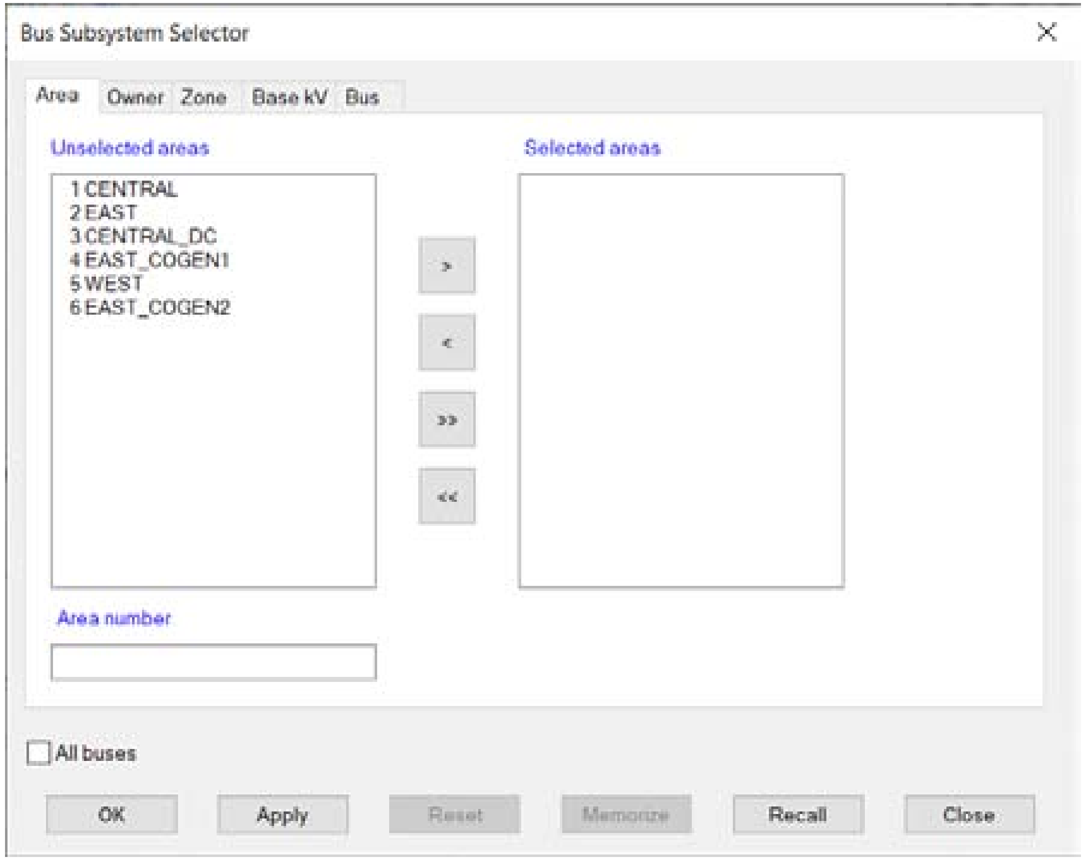
The AC Contingency Calculation (ACCC) uses 3 files:

- subsystem file ("*.sub")
  - The subsystem file informs the simulator to only look at a given section, or zone of the network.
- monitor file ("*.mon")
  - The monitor file tells the simulator which branches to supervise during the contingency analysis
- contingency file ("*.con")
  - The contingency file is programmed to remove equipment from service to mimic potential outage conditions. When a single line is taken out of service, the case is referred to as an (N-1) contingency.

Contingency Analysis

How to generate these files?

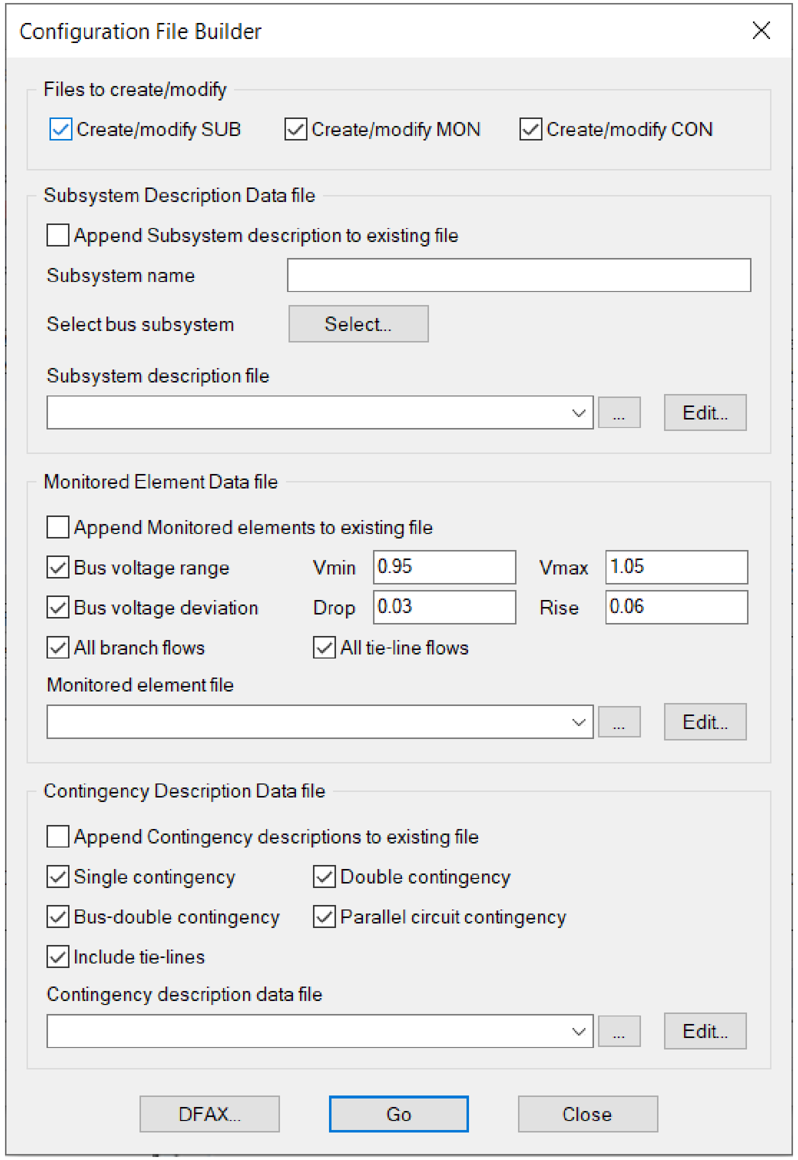
- Start PSS/E
- Open a saved case (.sav and .sld files) 
- Click on **Create/Modify Config Files**
  - **(can also be obtained from the Power Flow menu) →**
  - The Configuration File Builder dialog box opens
  - Uncheck the “Append subsystem description to the existing file” box
  - Give a subsystem name
  - Click select from the “Select bus subsystem”
    - The “Bus subsystem selector” dialog box opens
    - Select an area from the “Unselected areas” box, click on the “>” button to add it to the “Selected areas” box
    - Click “Apply” and “OK” to close the dialog box



Contingency Analysis

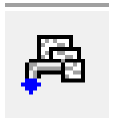
How to generate these files? (cnt'd)

- Click on the 3-dot button next to the "Subsystem description file" box
  - Name your subsystem file, then save it.
- Click on the 3-dot button next to the "Monitored element file" box
  - Name your monitored element file, then save it.
- Click on the 3-dot button next to the "Contingency description data file" box
  - Name your contingency description file, then save it.
- Click Go, then DFAX
  - Navigate to the directory where you would like to create your distribution factor output file. It is a text file with extension ".dfx". Name it, select it, and press OK on the "Build Distribution Factor Data File" dialog box
- Congratulations! The "*.con", "*.mon", and "*.sub" files have now been created



Contingency Analysis

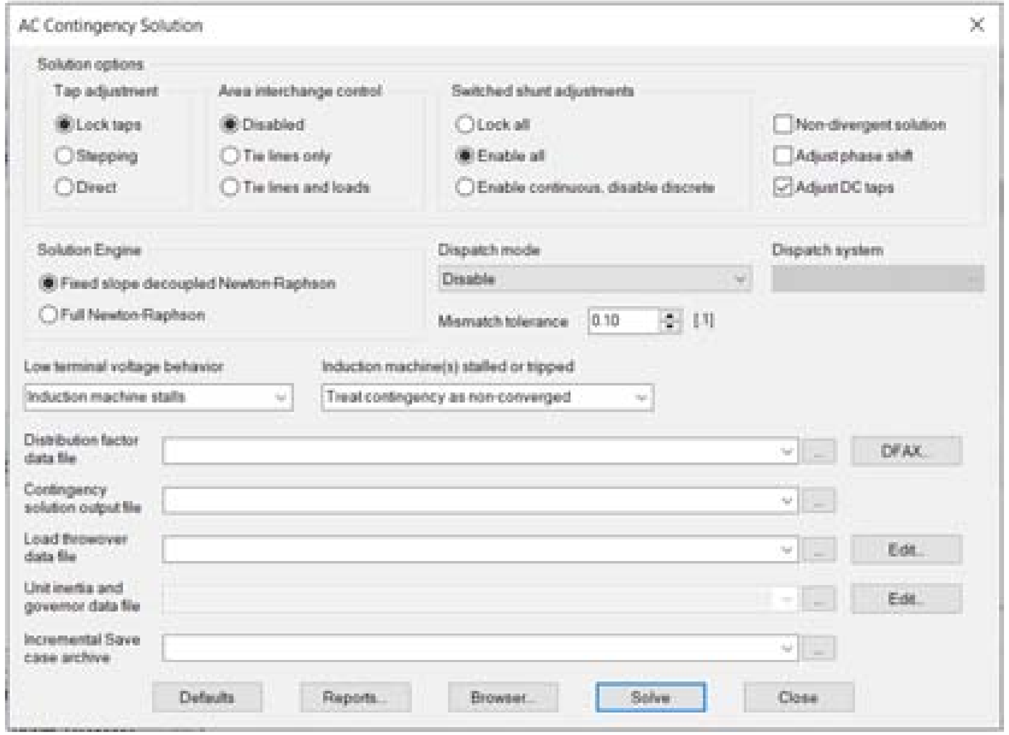
Run the contingency analysis



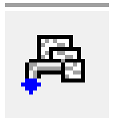
- Click on the AC contingency calculation (ACCC) button on the 4th toolbar

  (or go to **Power Flow → Contingency, Reliability, PV/QV analysis → AC contingency solution (ACCC)…**)

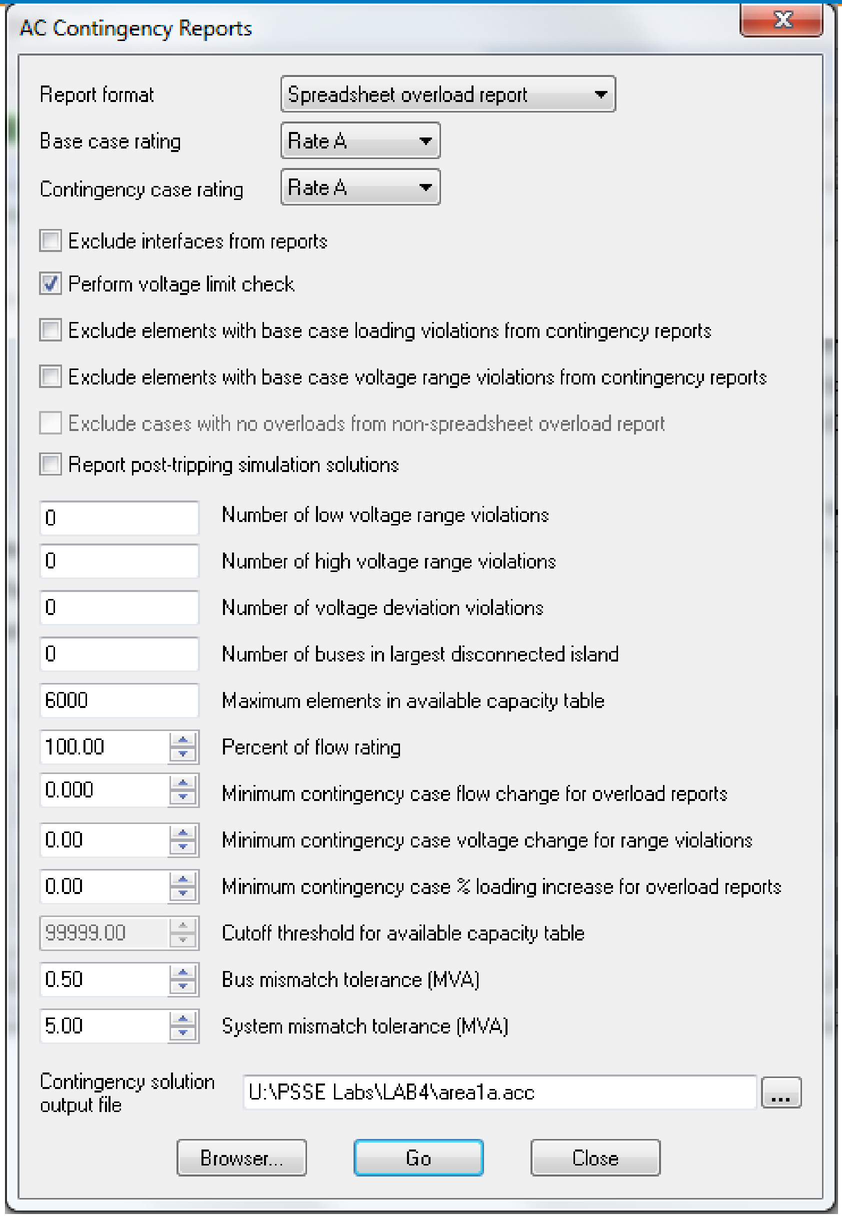
  - The "AC Contingency Solution" dialog box opens.
- Click on the 3-dot button next to the "Distribution factor data file" box
  - Navigate to the ".dfx" file you created, select it, and click "save".
- Click on the 3-dot button next to the "Contingency solution output file" box
  - Navigate to the directory where you would like to write the contingency results.
  - Give a file name and click "save"
- Click on Solve



Contingency Analysis

Reporting ACCC results 

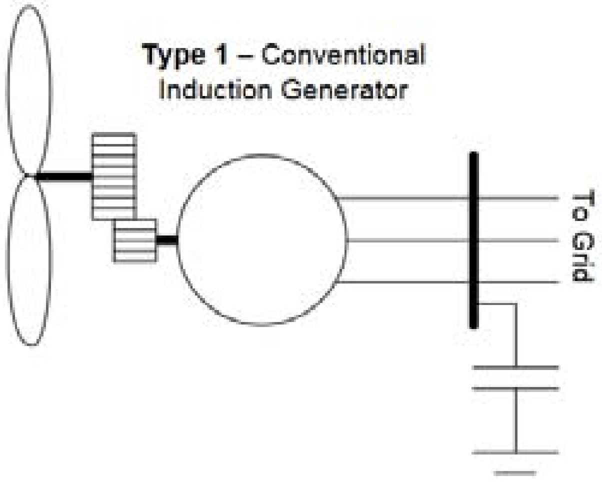
- Click on Reports...
  - The “AC Contingency Report” dialog box opens
- Make sure the correct ACCC results file is pointed to in the “Contingency solution output file” box.
- Click on Go to run the report
  - Check the list of files created, in the report tab.

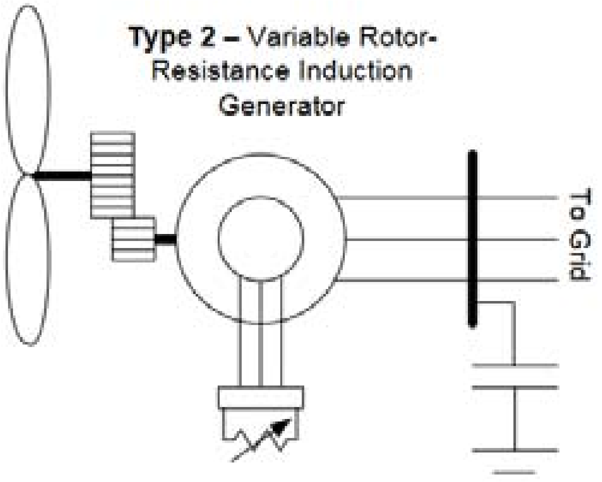


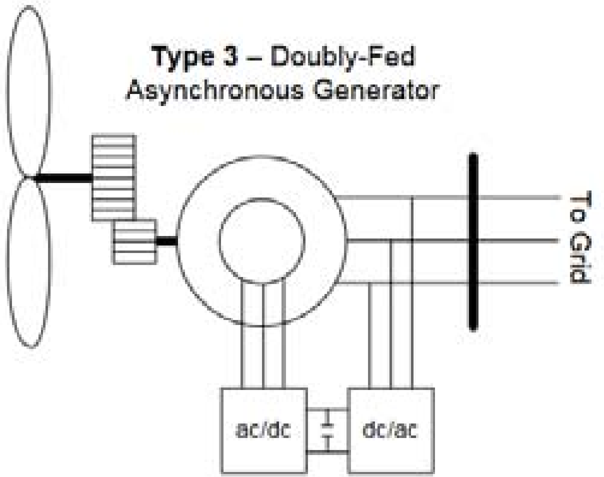
Modeling Renewable Energy Systems in PSS/E

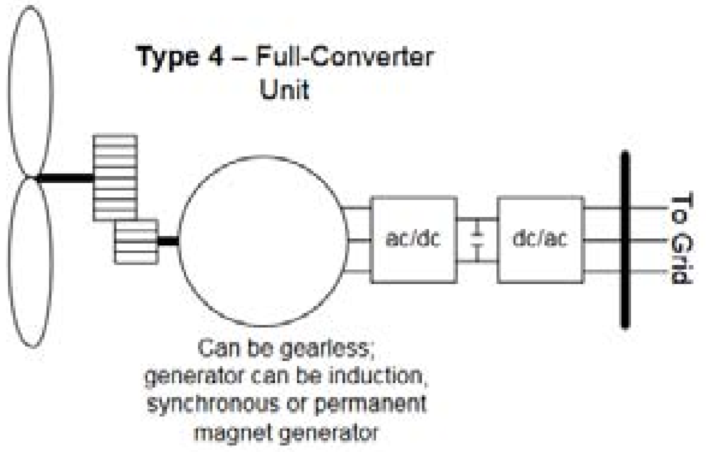
Modeling Renewable Energy Systems in PSS/E

- Generic dynamic model
  - Plant control model
  - Generator/Converter
  - Electrical control mod
- Wind
- Solar
- Energy storage

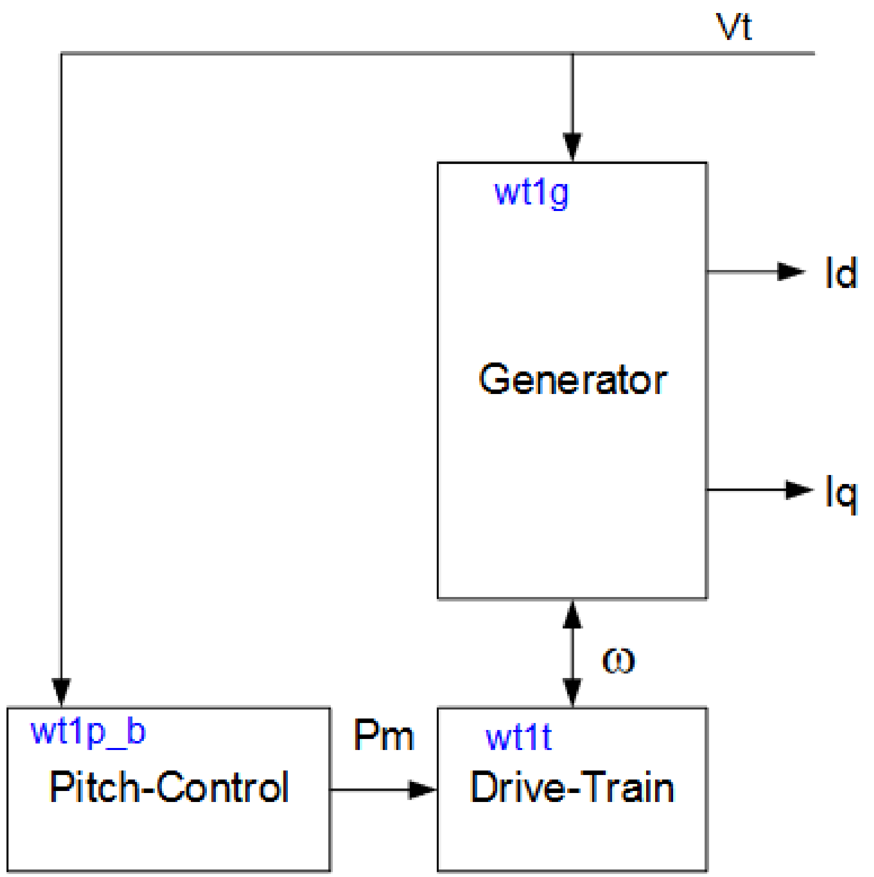




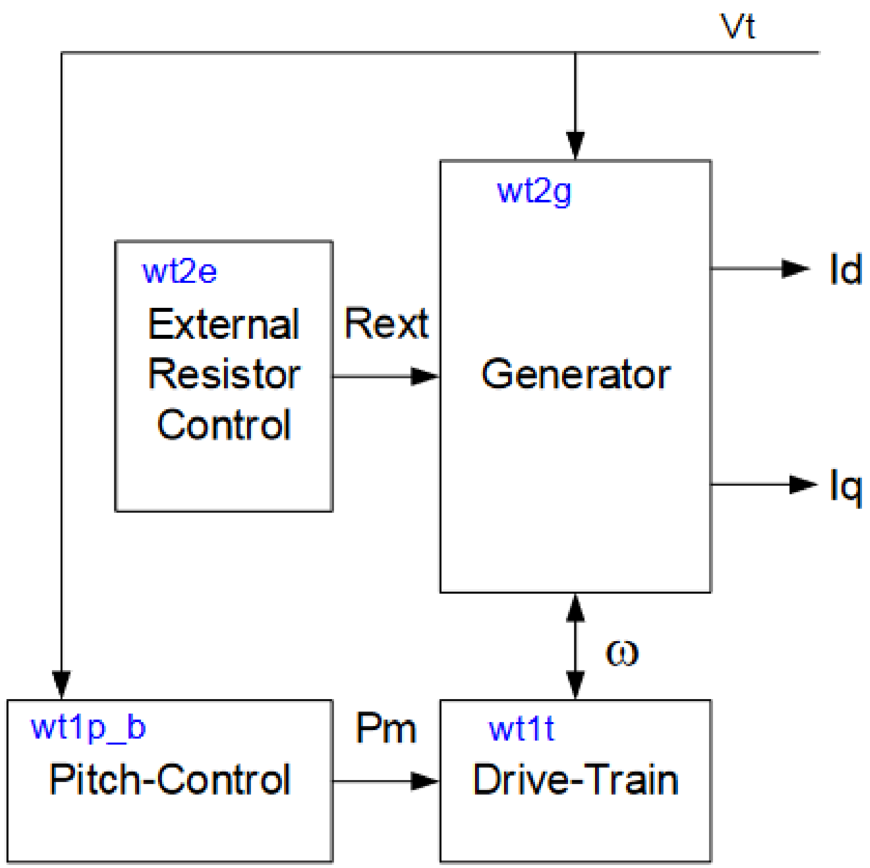




Modeling Renewable Energy Systems in PSS/E

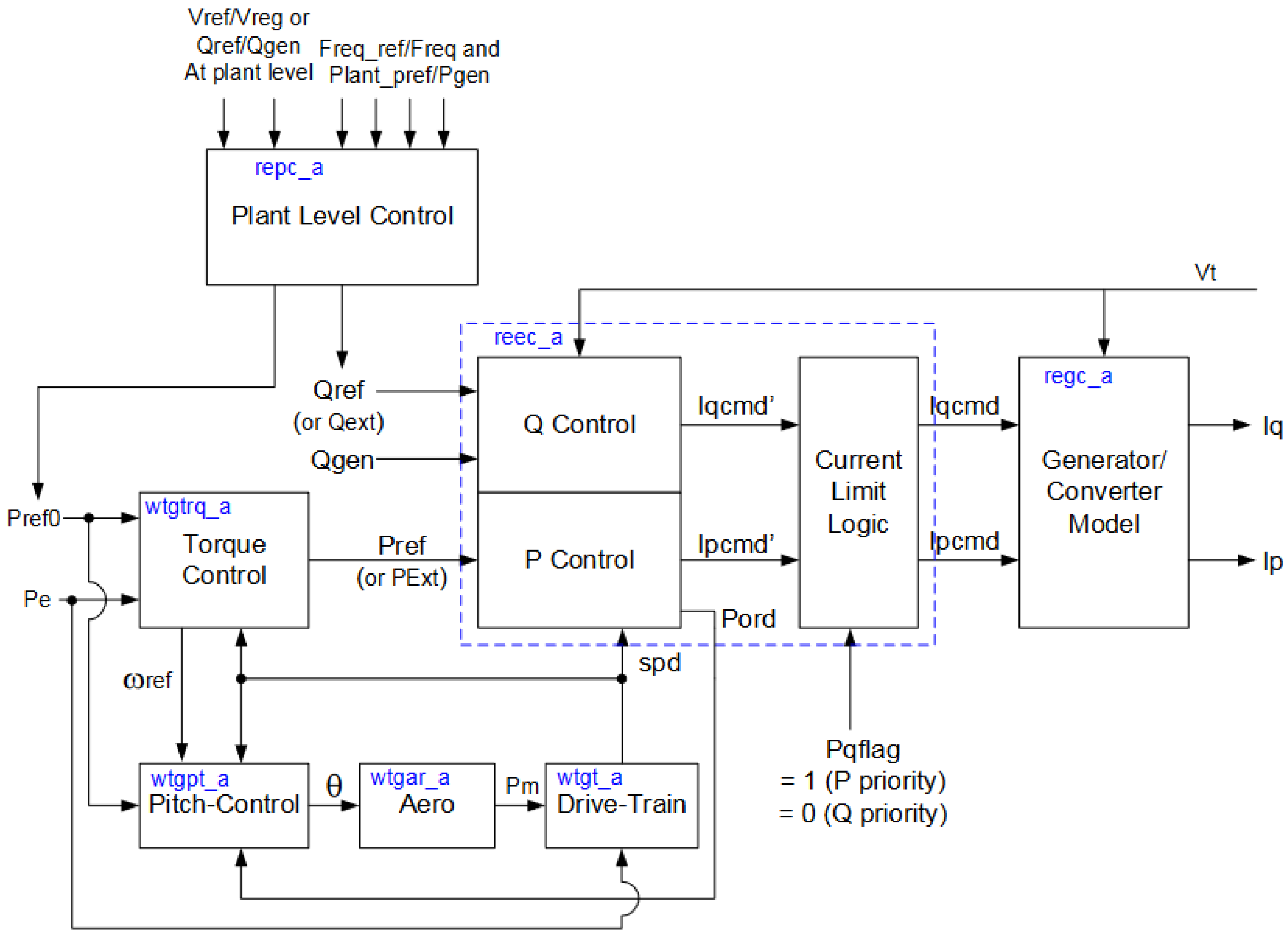


Type 1 WTG



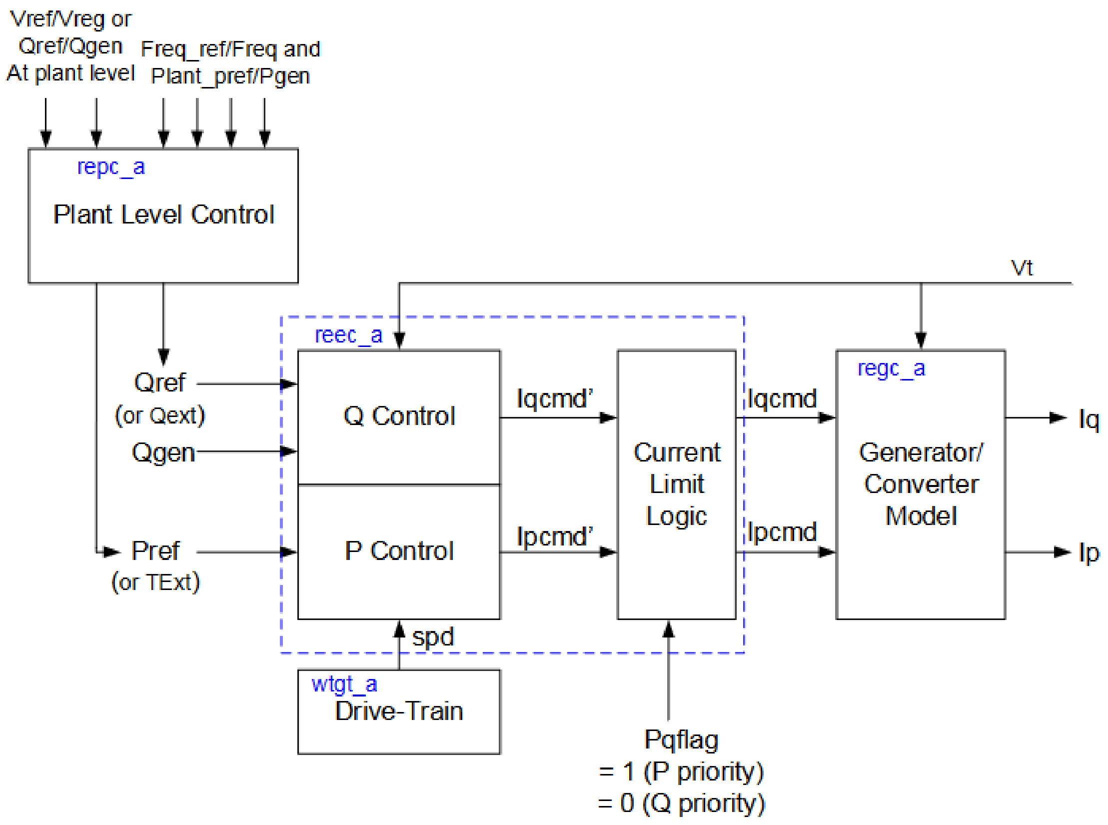
Type 2 WTG

Modeling Renewable Energy Systems in PSS/E

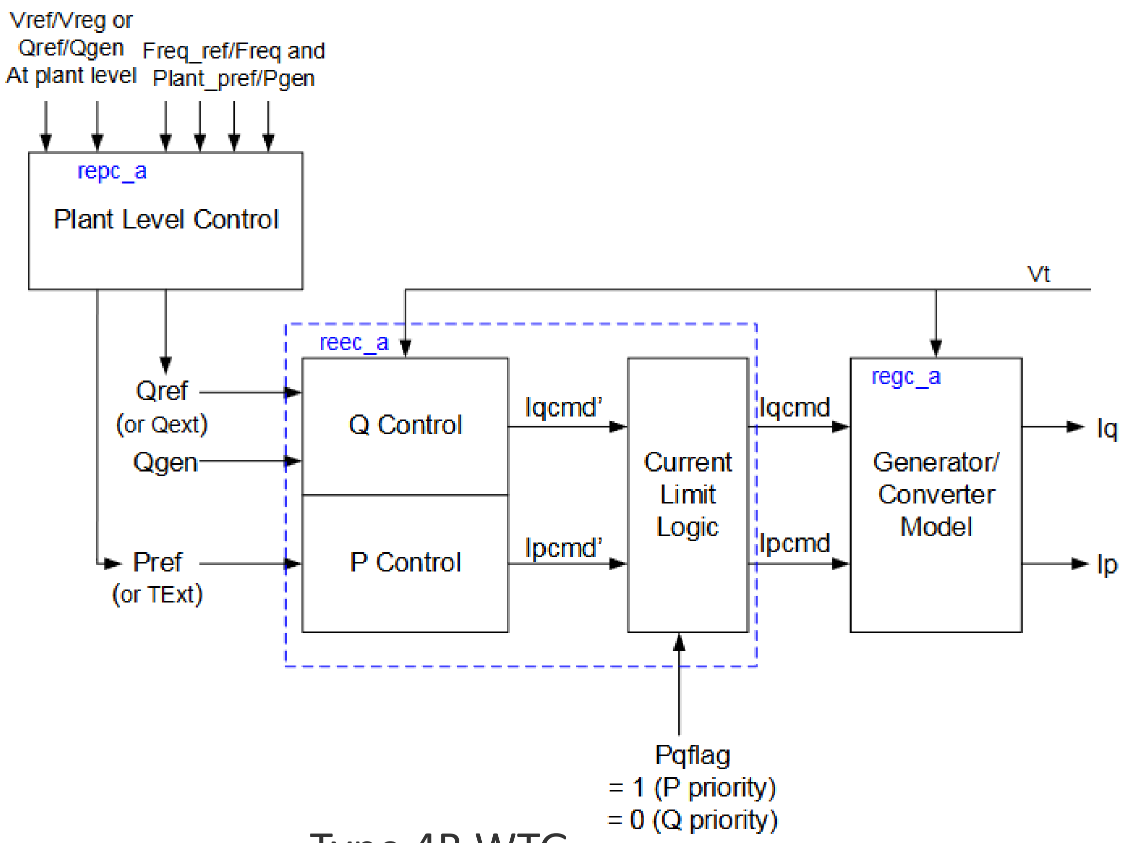


Type 3 WTG

Modeling Renewable Energy Systems in PSS/E

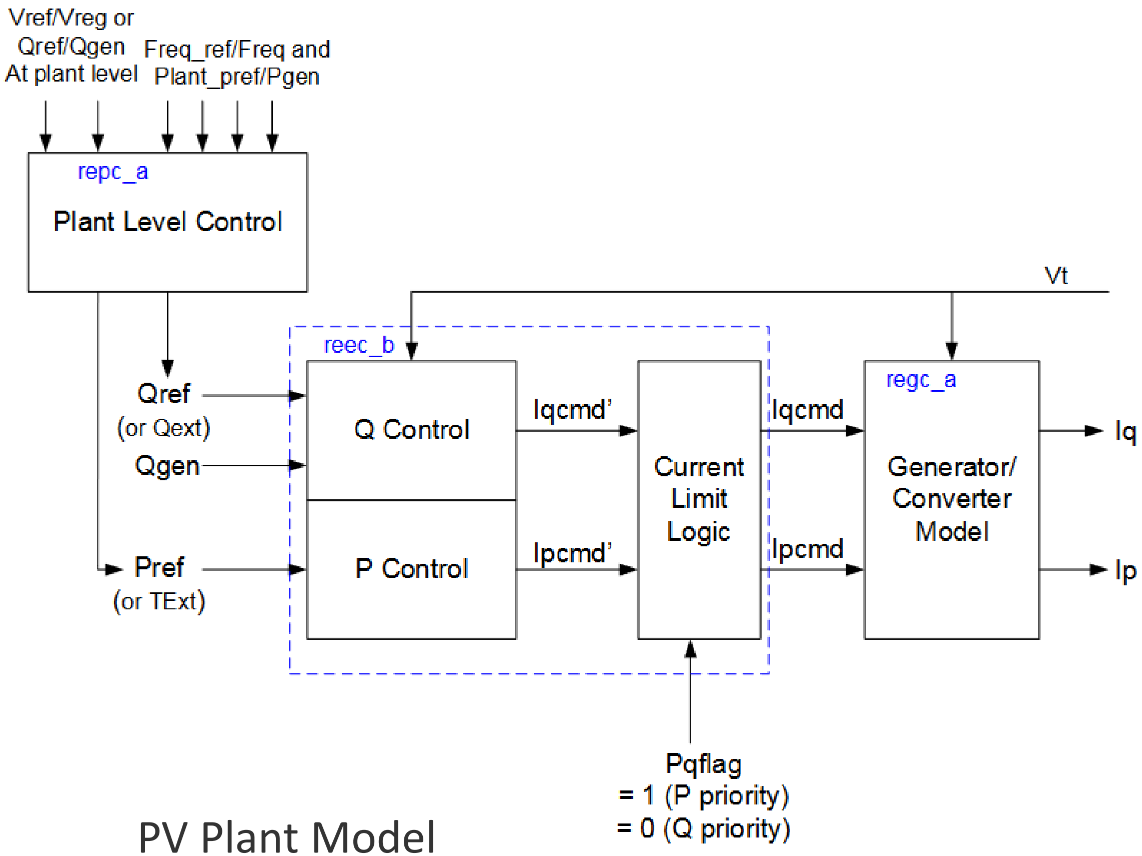


Type 4A WTG

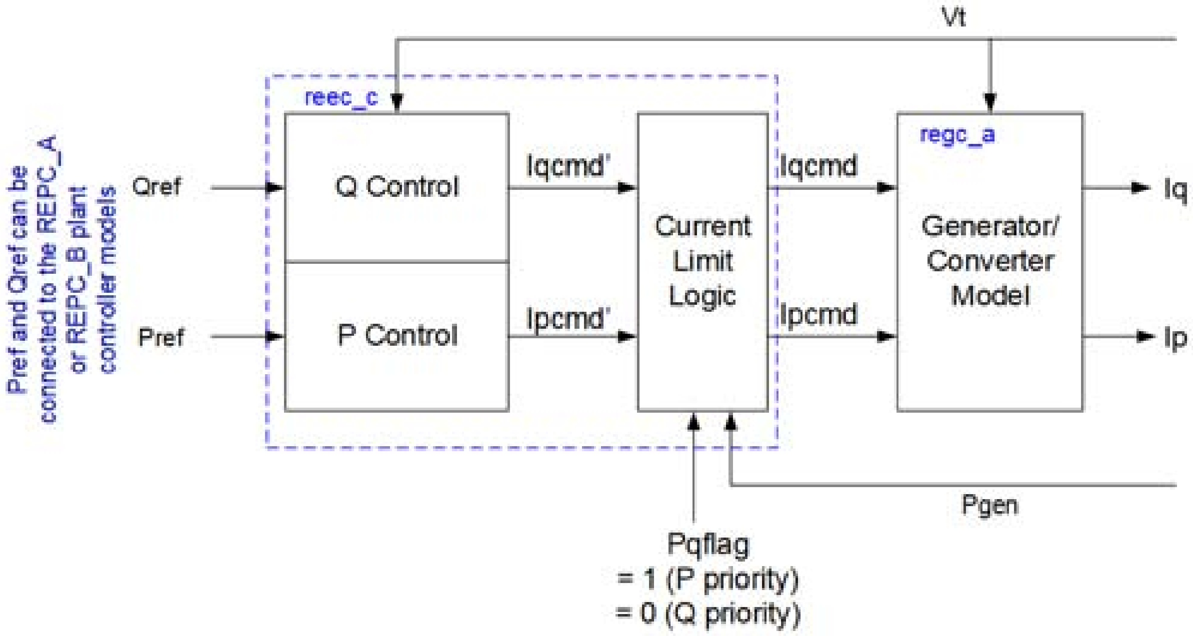


Type 4B WTG

Modeling Renewable Energy Systems in PSS/E



PV Plant Model



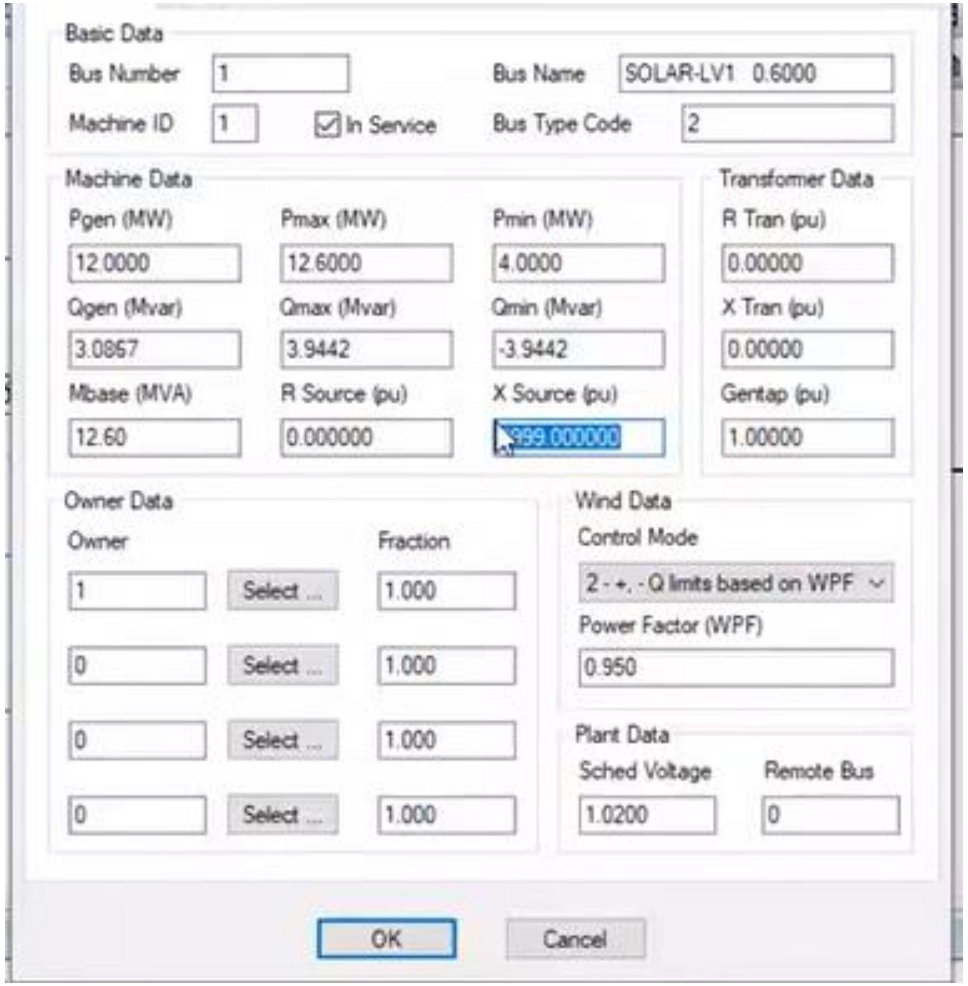
BESS Model

Modeling Renewable Energy Systems in PSS/E

Model Name in the Model Specification Document	Model Name in GE PSLF™	Model Name in Siemens PTI PSS®E
New Models (developed 2011 - 2014)		
REGC_A	regc_a	REGCAU1 (V33); REGCA1 (V34)
REEC_A	reec_a	REECAU1 (V33); REECA1 (V34)
REEC_B	reec_b	REECBU1 (V33); REECB1 (V34)
REEC_C	reec_c	REECCU1 (V33 & V34)
REPC_A	repc_a	REPCTAU1 & REPCAU1 (V33); REPCTA1 & REPCA1 (V34)
WTGT_A	wtgt_a	WTDTAU1 (V33); WTDTA1 (V34)
WTGAR_A	wtga_a	WTARAU1 (V33); WTARA1 (V34)
WTGPT_A	wtgp_a	WTPTAU1 (V33); WTPTA1 (V34)
WTGTRQ_A	wtgq_a	WTTQAU1 (V33); WTTQA1 (V34)
WT1P_B	wt1p_b	not yet part of the standard model library
Existing Models (developed prior to 2009)		
WT1G	wt1g	WT1G1
WT2G	wt2g	WT2G1
WT2E	wt2e	WT2E1
LHVRT	lhvrt	VTGTPAT
LHFRT	lhfrt	FRQTPAT

Modeling Renewable Energy Systems in PSS/E

- Wind
  - Generally modeled as Type 3 or Type 4 machine
  - PSSE control mode 2 or 3
  - Qmin = -Qmax
- Solar
  - PSSE control mode 2
  - High X source (9999)
  - Qmin = -Qmax
- Energy storage
  - PSSE control mode 2
  - High X source (9999)
  - Pmin = -Pmax; Qmin = -Qmax



Modeling Renewable Energy Systems in PSS/E

- Creating the dynamic models
  - In your project directory, create a text file with extension "*.dyr"
  - Start PSS/E, open the project, open the empty "*.dyr" file
  - The dynamic data spreadsheet will open
    - Fill in all required dynamic data for all equipment
    - Save the project

Etudes d'Intégration des Energies Renewables dans les Reseaux Electriques de Transport

Jour 5: Modélisation et étude des réseaux de transport a l'aide du logiciel PSS/E

Kwami Senam Sedzro, PhD

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  - Introduction aux études des stabilité dynamique des réseaux de transport

Jour 5: Introduction aux études des stabilité dynamique des réseaux de transport

- *Introduction aux études des stabilité dynamique des réseaux de transport*

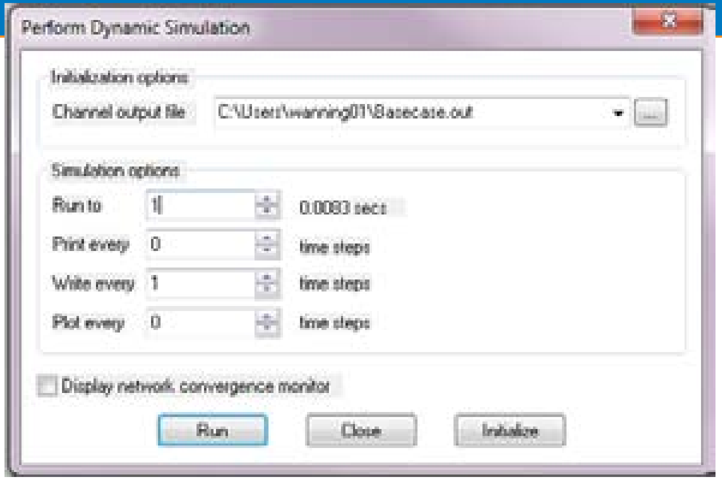
Preparing for a dynamic stability simulation

Preparing for a dynamic stability simulation

1. Open a saved case
2. With the file open, click on the **Machines** tab
   - Under the column labeled **X Source** (pu) input the Xd' value for each generator
   - Input the negative and zero sequence values
3. Convert the generators to Norton equivalents (constant current injections) and assign load characteristics to the loads.
   - Go to **Powerflow>Convert Loads and Generators**
4. Reorder the buses for sparsity (required because we converted the swing bus to a type PV bus)
   - Perform ORDR: Go to **Powerflow>Solution>Order Network for Matrix Operations**
5. Factorize the admittance matrix
   - Perform FACT: Go to **Powerflow>Solution>Factorize Admittance Matrix**
6. Solve the converted case
   - Perform TYSL: Go to **Powerflow>Solution>Solution for Switching Studies**
7. Save the converted case
   - Perform Save/Show on your converted case. Give this converted case a different name than the saved case used

Running a base case stability simulation

Running a base case stability simulation



1. Open the case via **File>Open>(your case.sav)**.
2. Read in the dynamic data sheet: **File>Open>(your dyr file)**
3. Specify which data to record
   - Under **Dynamics**, Click **Channel setup wizard** menu button
     - Select quantities to output
     - Select buses
4. Run base case
   - Under **Dynamics**, choose **Simulation** tab, Click the **Perform Simulation** (STRT/RUN).
     - The Perform Dynamic Simulation dialog box opens.
     - Fill out the "Channel output file" text box a filename with a **".out"** extension.
     - Specify the following **Simulation options**
       - Run to: 1 (run the simulation from 0 to 1 second)
       - Print Every: 0 (write nothing to screen)
       - Write Every: 1 (write every time step to the plotting file)
       - Plot Every: 0 (do not update the plot book)
     - Click Initialize at the bottom, then Press Run. This is now your base case simulation.
     - Press Close to exit.

Performing a stability simulation

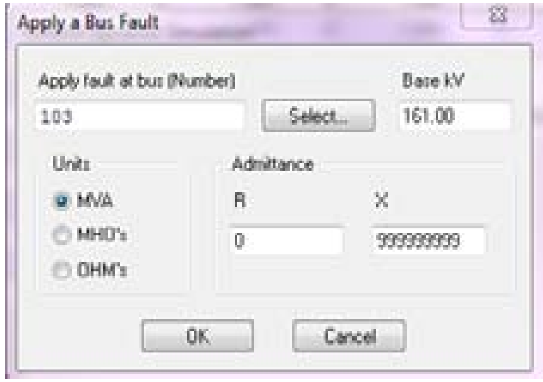
Performing a stability simulation

Key steps:

a) Initialize
b) Apply a fault
c) Run the simulation from time = 0 until t = breakers open
d) Clear the fault and remove a line
e) Run the simulation from t = breakers open until t = 10 seconds

Performing a stability simulation

1. Initialize (previous stage – base case stability)
2. Apply the fault
   - In the top menu bar, click “Disturbance” and choose “Bus fault”
   - In the “Apply a But Fault” window, Click Select option and choose the bus where to apply the fault then press OK.
   - Specify the admittance parameters of the fault and press OK
     - Example: For a short-circuit, enter “9999” in admittance X. This puts a fault with a very large susceptance at the bus – remember to select the appropriate unit



Performing a stability simulation

3. Run the simulation up to the clearing time
   - Under Dynamics, choose Simulation tab, Click the Perform Simulation (STRT/RUN)
   - In the “Channel output file” dialog box, enter the same “.out” as in the initialization step
   - Enter values for Simulation options: Run to, Print Every, Write Every, Plot Every.
     - Example:
       - Run to: 0.1 (clearing time = 0.1 sec)
       - Print Every: 0
       - Write Every: 1
       - Plot Every: 0
   - Press Run

Performing a stability simulation

4. Clear the fault
   - Go to Disturbance → Clear fault
   - In the “Clear Fault” dialog box, choose existing fault and press Go
   - Trip any relevant branch
     - Go to Disturbance → Trip a line

Performing a stability simulation

5. Run the simulation
   - Go to Dynamics → Simulation → Perform Simulation (STRT/RUN)
   - In the "Channel output file" dialog box,
     - enter the same output filename as at the initialization stage
     - Enter values for Simulation options: Print Every, Write Every, Plot Every.
     - Example:
       - Run to: 10
       - Print Every: 0
       - Write Every: 1
       - Plot Every: 0
     - Click "Run", then click "Close"

Performing a stability simulation

6. Plot results
   - Create a PlotBook
     - Go to File → New → Plot Book
   - Access recorded results
     - Go to View → Plot Tree
     - In the Plot Tree explorer window on the left, navigate to the saved ".out" (channel output) file
     - Drag and drop any desired channel to the Channel Plot book on the right to view it

System Impact Analysis Framework