TRANSPOWER

Grid Zone 14 EMT Model User Guide

Version: 1.0

Date: July 2025

Version	Date	Change
1.0	July 2025	Initial Issue

	Name & Position	Date
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IMPORTANT

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1. Introduction

A PSCAD model of the region covered by grid zone 14 was developed for asset owners to conduct their own Electromagnetic Transient (EMT) connection studies in this region as per Connection Study Requirements for New Generating Assets (GL-EA-0953)[1]. The model contains detailed representations for grid zone 14, while the rest of the South Island grid network is represented by equivalent voltage sources and a simplified network. The model contains synchronous generator models along with their respective automatic voltage regulators (AVR) and passive reactive power compensation devices.

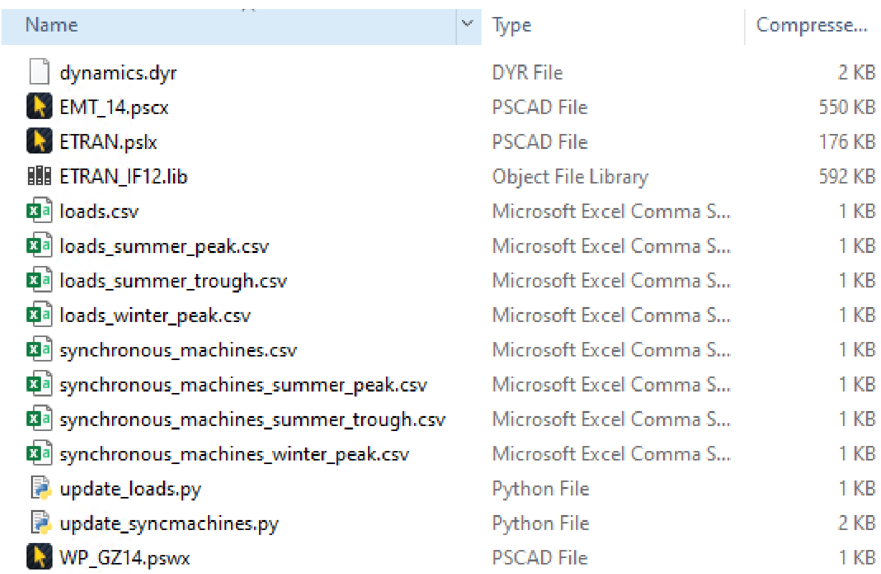
The EMT network model components were created using E-TRAN software developed by Electranix Corporation[2]. The power-flow solution and network equivalent were created using DigSILENT PowerFactory. This document provides guidance for loading the network model into PSCAD, along with brief descriptions of the models.

[1] Connecting generation | Transpower

[2] E-TRAN Runtime library for PSCAD | Electranix Corporation

2. Files Provided by the System Operator

The system operator provides the asset owner with the GZ_14_EMT_model .zip package containing the files shown in Figure 1. Table 1 includes descriptions of the files provided in the .zip package.



Name	Type	Compresse...
dynamics.dyr	DYR File	2 KB
EMT_14.pscx	PSCAD File	550 KB
ETRAN.pslx	PSCAD File	176 KB
ETRAN_IF12.lib	Object File Library	592 KB
loads.csv	Microsoft Excel Comma S...	1 KB
loads_summer_peak.csv	Microsoft Excel Comma S...	1 KB
loads_summer_trough.csv	Microsoft Excel Comma S...	1 KB
loads_winter_peak.csv	Microsoft Excel Comma S...	1 KB
synchronous_machines.csv	Microsoft Excel Comma S...	1 KB
synchronous_machines_summer_peak.csv	Microsoft Excel Comma S...	1 KB
synchronous_machines_summer_trough.csv	Microsoft Excel Comma S...	1 KB
synchronous_machines_winter_peak.csv	Microsoft Excel Comma S...	1 KB
update_loads.py	Python File	1 KB
update_syncmachines.py	Python File	2 KB
WP_GZ14.pswx	PSCAD File	1 KB

Figure 1: Files provided in the .zip file.

Table 1: Description of the files provided.

File name	Description
dynamics.dyr	Dynamic record file for generator, AVR and power system stabiliser (PSS) models. This file should be placed in the same folder as the EMT_14.pscx case.
EMT_14.pscx	A single simulation file containing South Island grid zone 14 in detail. The model has boundaries at TWZ 220 kV and NSY 220 kV buses.
ETRAN.pslx	The runtime library developed by Electranix to be used with E-TRAN-converted PSCAD files. The latest version of this library is freely available on the Electranix' website[3].
ETRAN_IF12.lib	The encrypted source code file for E-TRAN runtime library. This should be loaded as a resource file in the ETRAN.pslx library.

[3] E-TRAN Runtime library for PSCAD | Electranix Corporation

File name	Description
loads.csv (loads_summer_peak.csv, loads_summer_trough.csv, loads_winter_peak.csv)	A .csv file detailing the loads within the network model. The data is obtained from the PowerFactory power-flow solution. Three load value files are provided for summer peak, summer trough and winter peak load conditions respectively.
synchronous_machines.csv (synchronous_machines_summer_peak.csv, synchronous_machines_summer_trough.csv, synchronous_machines_winter_peak.csv)	A .csv file containing details of the synchronous machines within the network model. The data is obtained from the PowerFactory power-flow solution. Three generation dispatch files are provided for summer peak, summer trough and winter peak load conditions respectively.
update_loads.py	A python file used to update the load values provided by the **loads.csv** file.
update_syncmachines.py	A python file used to update the initial conditions of synchronous machines provided by the **synchronous_machines.csv** file.
WP_GZ14.pswx	This is a PSCAD workspace file which should load all necessary files into the PSCAD workspace to run the PSCAD case.

3. Setting up the Study Case

The package is created using PSCAD V5.0.2 with Intel Fortran Classic 2021.12.0 compiler and Visual Studio 2022 installed. Loading the package into older PSCAD versions and/or with an older Intel Fortran compiler and Visual studio version may cause the study case to fail. This section explains the steps that are required to load the study case.

3.1 Loading the Case File and General Setup

Once the provided .zip file is extracted, the user can open the WP_GZ14.pswx workspace file. This should load all necessary files and resources into the PSCAD environment. If the workspace fails to load correctly, the user can follow the sequence to load all the files manually.

Use the File -> Open command from PSCAD to load both files below.

1. ETRAN.pslx
2. EMT_14.pscx

Once these two files are loaded, expand the ETRAN.pslx library by clicking the + sign beside the file name in the workspace. Right-click on the Resources subfolder and navigate to the Add -> Binary (*.o, *.obj, *.lib) submenu.

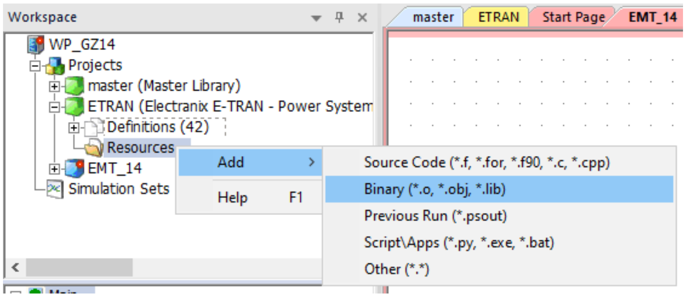


Figure 2: Adding .lib files to the project

Then add the ETRAN_IF12.lib file as shown Figure 3.

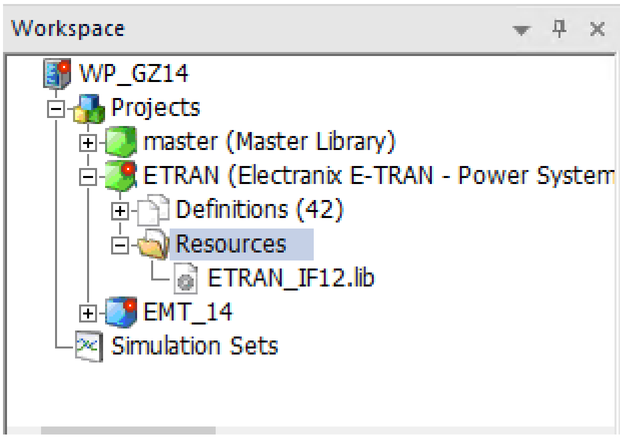


Figure 3: All the .lib files loaded in correct order.

The following figure shows a snapshot of the PSCAD workspace after the workspace WP_GZ14.pswx is correctly loaded.

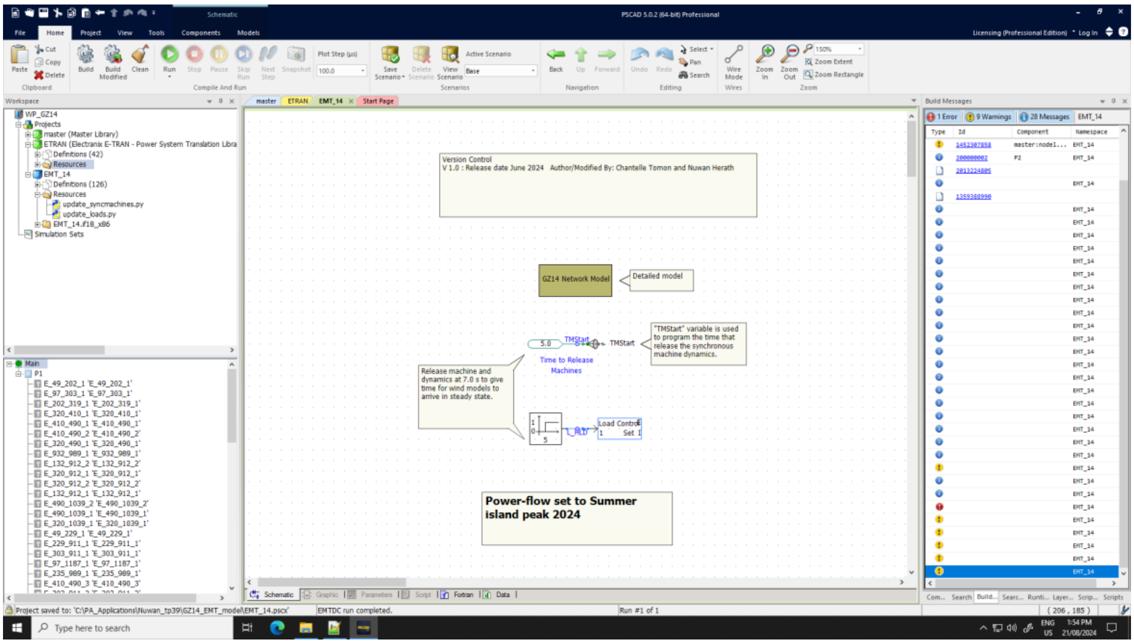


Figure 4: Screenshot of the correctly loaded PSCAD workspace and canvas.

3.2 Case File Arrangement

The network model is available within the **GZ14 Network Model** subpage in the canvas. Figure 5 shows the layout of the network model.

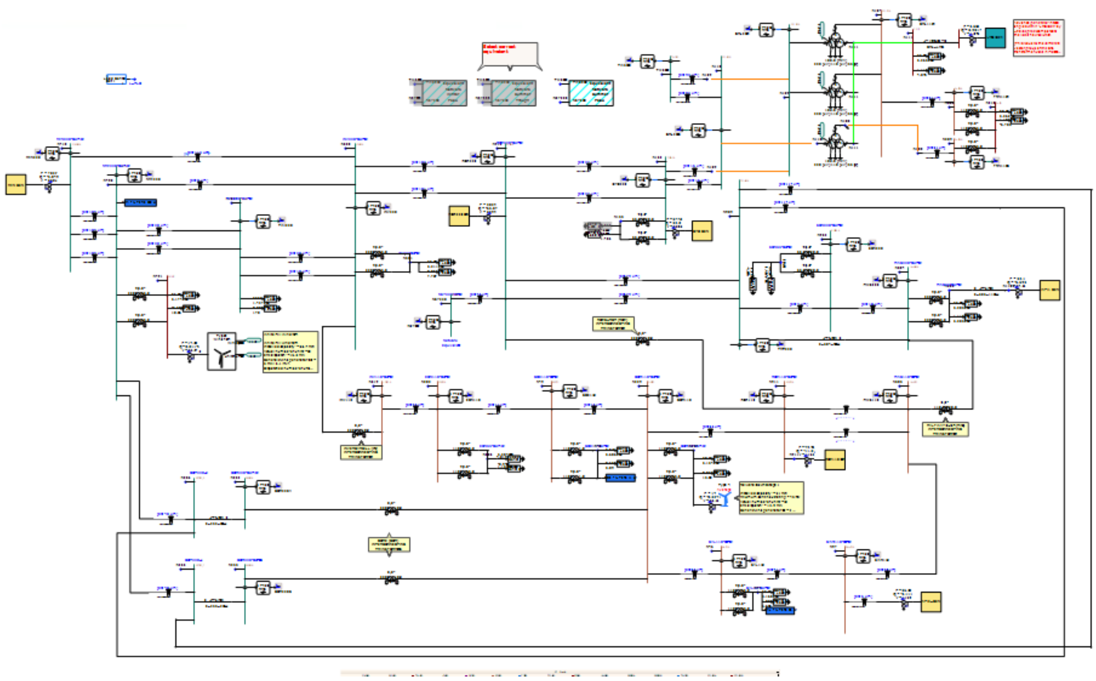


Figure 5. Layout of the network model.

3.3 Setting Up the Compiler

An Intel® Fortran Compiler is required to run the simulation case. The simulation cases were developed using **Intel® Fortran Compiler Classic 2021.12.0** compiler. The user must make sure a correct version of Intel Fortran compiler is installed on the computer[4]. The compiler can be selected by navigating to **File -> Application Options -> Dependencies** and selecting the correct Fortran compiler. Figure 6 shows the window to configure the Fortran compiler.

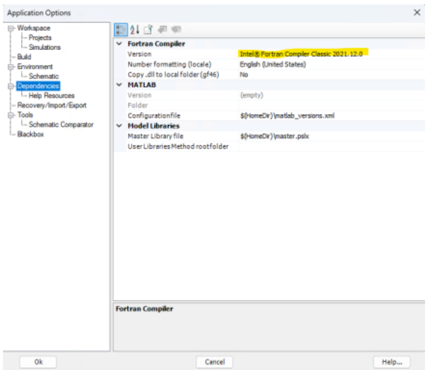


Figure 6: Setting up the compiler

3.4 Setting Up the Project Simulation Time Step

Setting up the correct simulation time step is crucial for accurate results. It is essential to run the simulation at a time step (solution time step) at 20 µs or below due to the modelling requirements. Users can use a slightly larger channel plot step to reduce the memory usage from the simulation. In this configuration, a 100 µs channel plot step is recommended. All these parameters can be changed in the **Project Settings** by right-clicking anywhere on the canvas as shown in Figure 7.

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[4] Compatibility of compilers and Visual studio versions with PSCAD versions can be found at https://www.pscad.com/knowledge-base/article/102

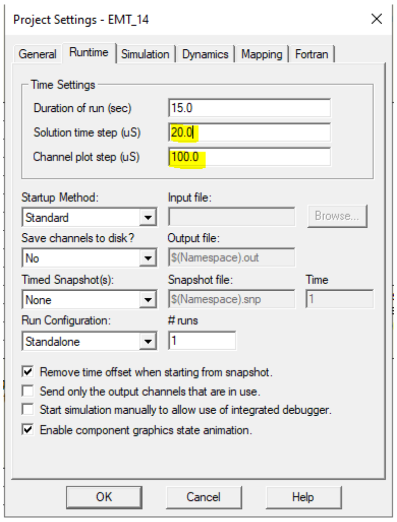


Figure 7: Setting up the solution time step.

4. Simulation Case Details

The simulation case was developed based on the EMI PowerFactory study case for 202311, available on the Electricity Authority's website[5]. The summer 2024 variation has been considered to obtain the minimum strength in the system.

Users may replicate the power flow conditions by creating equivalents for other load condition variations or by updating the case using the latest version of the EMI study. For further assistance, please contact the system operator.

4.1 Network Equivalents

The network model contains network components associated with grid zone 14. The rest of the network is represented by equivalent voltage sources and a reduced network model to simplify the EMT simulation.

The slack generator was set to Manapouri G1 with voltage angle of Manapouri 220 kV bus to be at 0°. The network was reduced in PowerFactory based on the following selected boundary of the EMI PowerFactory case.

	Boundary Cubicle StaCubic	Head Folder	Busbar ElmTerm	Branch Elm*,RelFuse,StaSua*	Orientation
1	Cub_CML-TWZ-2	TWZ220	N_ES2439...	CML-TWZ-2	--> Busbar
2	Cub_CML-TWZ-1	TWZ220	N_ES2469...	CML-TWZ-1	--> Busbar
3	Cub_NSY-ROX-1	NSY220	N_206_ES...	NSY-ROX-1	--> Busbar

Figure 8: EMI PowerFactory boundary for reducing rest of the South Island power grid.

Once the network boundary is created in PowerFactory (named **Boundary-GZ14** in this example), part of the network exterior to the boundary can be reduced via **CALCULATION -> Additional Functions -> Network Reduction** in PowerFactory. This will open the **Network Reduction** window. In this window, parameters should be set as follows to create an Extended Ward Reduction. Leave other settings as default. Once the settings are configured, press **Execute**[6].

[5] Electricity Authority - EMI (market statistics and tools) (ea.govt.nz)

[6] Additional information regarding Network Reduction is available at PowerFactory user manual.

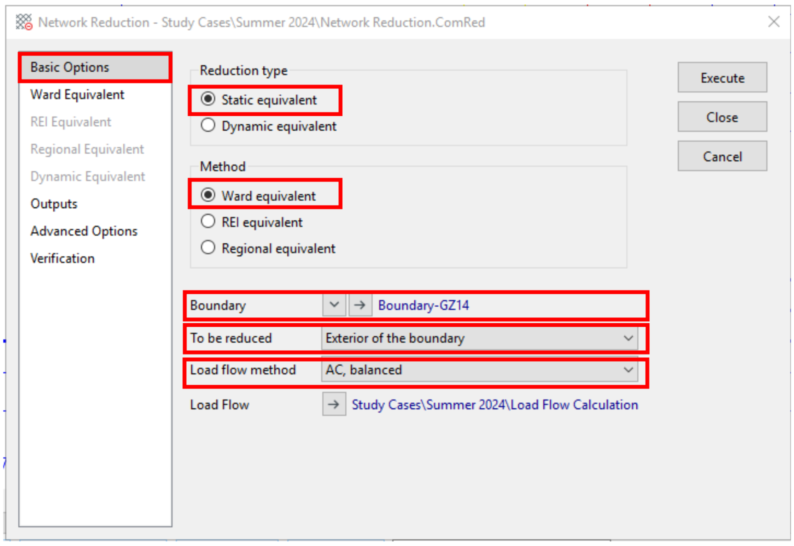


Figure 9: Network Reduction window: Basic Options.

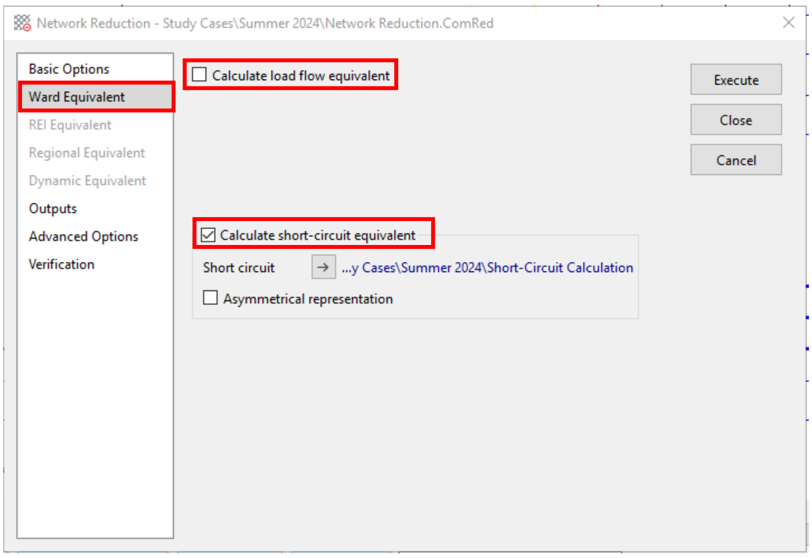


Figure 10. Network Reduction window: Ward Equivalent.

Once the network is reduced, AC voltage sources and Common Impedances appear in the PowerFactory network data. The magnitude, angle, initial active and reactive powers of the equivalent network AC voltage sources, as well as network impedances between equivalent AC voltage sources in the EMT model were set based on the power-flow solution of the reduced PowerFactory case.

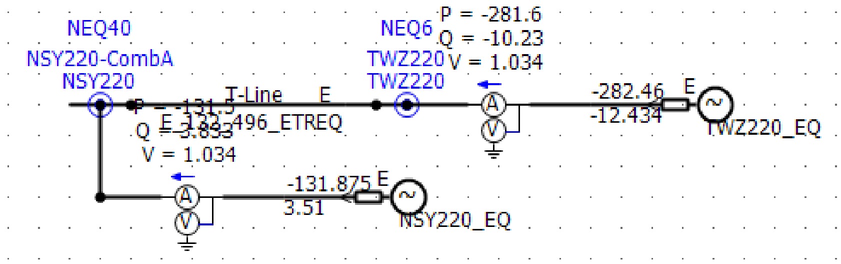


Figure 11: Network equivalent for Summer Peak network condition in EMT_14.pscx.

The common impedances between buses could be between different voltages.

Depending on the network conditions (dispatch, load conditions, reactive power compensation) the equivalent network impedance can change.

4.2 Network Model

The network model consists of lower South Island generation, including hydro generation at Manapouri, Clyde and Roxburgh, as well as wind farms at Kaiwera Downs, Whitehill and Mahinerangi.

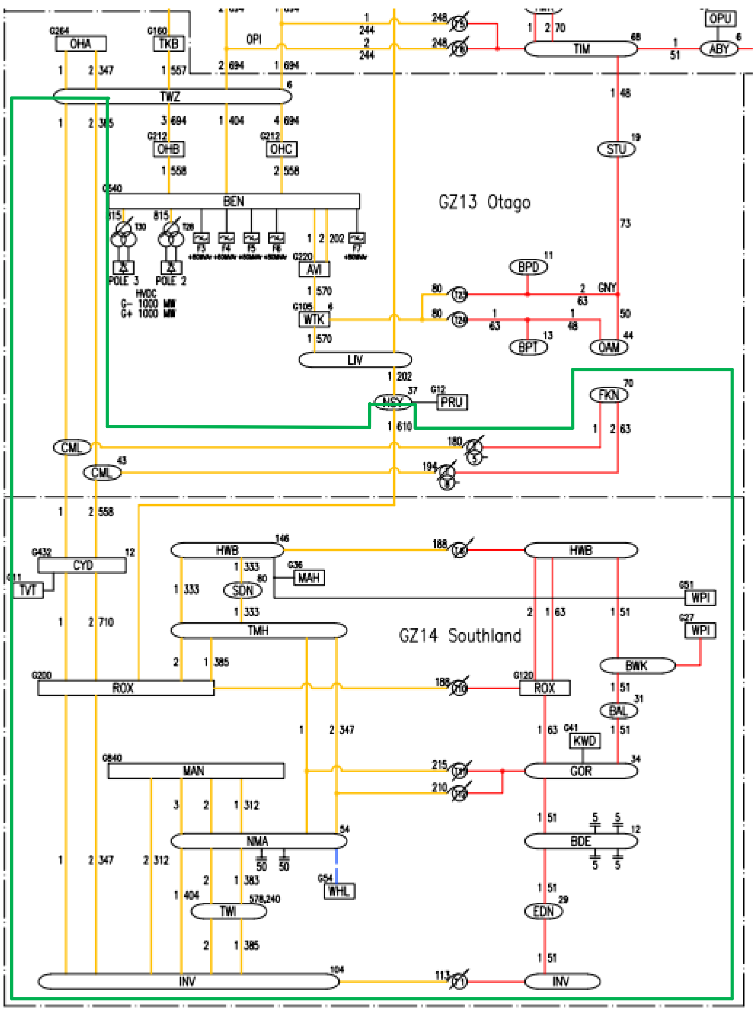


Figure 12: Region represented in detail in EMT in the network model.

4.3 Generation within the Region

Name of the Generator	Capacity (MVA)	Dispatch (MW)	Energy Source	Model
Manapouri (MAN)	135.0 135.0 135.0 135.0 135.0 135.0 135.0	100.0 100.0 100.0 100.0 100.0 100.0 100.0	Hydro	GENSAE
Roxburgh (ROX)	44.4 44.4 44.4 44.4 44.4 44.4 44.4 44.4	42.0 40.0 40.0 40.0 40.0 40.0 8.5 OOS[7]	Hydro	GENSAL
Clyde (CYD)	120.0 120.0 120.0 120.0	108.0 108.0 108.0 54.0	Hydro	GENSAE
Waipori 1 & 2 (WPI)	12.9 23.0 26.1 26.1 8.0 9.0	6.4 18.0 18.0 12.4 OOS OOS	Hydro	GENSAE
Roaring Meg (UMG and LMG)	2.5 1.0 0.5 0.9	1.5 0.8 0.4 0.7	Hydro	GENSAE
White Hill wind farm (WHL)	66.4	16.5	Wind	Type 2
Kaiwera Downs Stage 1 (KWD)	51	12.9	Wind	Type 4

[7] OOS-Out of service

Mahinerangi Wind farm (MAH)	37	10.8	Wind	Type 2

4.4 Generator Models

Due to the sensitivity of the information regarding models of generators, generic models have been used to model the generators. Synchronous machines are modelled using GENSAE and GENSAL models, with their automatic voltage regulators using respective IEEE generic models. Wind farms are modelled with generic wind farm models available in PSCAD knowledge base. Table 2 provides reference URLs for each resource.

Table 2. Resource links for wind farm models.

Wind Farm Type	URL
Type 2	[Type 2 Wind Turbine Generators | PSCAD]()
Type 4	[Type 4 Wind Turbine Generators | PSCAD]()

4.5 Load Model

The active and reactive power components of the loads at grid exit points (GXPs) are modelled as constant current sources and constant impedance models respectively to align with the widely accepted load dynamic characteristics[8].

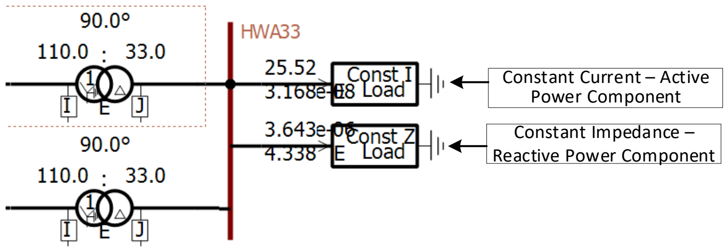


Figure 13: Example load representation.

[8] Kundur, Prabha S., and Om P. Malik. 2022. Power System Stability and Control. 2nd ed. New York: McGraw Hill.

5. Update Initial Conditions using Power-flow Data

The **update_syncmachines.py** and **update_loads.py** scripts can be used along with **synchronous_machines.csv** and **loads.csv** to rapidly update the initial conditions of the synchronous machines and load values based on the power-flow solution.

5.1 Update Synchronous Machines

Step 1

First, the **synchronous_machines.csv** needs to be updated based on the power-flow solution. Figure 14 gives an overview of the .csv file data format opened in Excel.

Note: the user must not change the data order or format.

	A	B	C	D	E	F	G	H
1	Generator	PSCAD Bus	PSCAD cir	Out of ser	PF Voltage (pu)	PF angle (deg)	PF Pgen (MW)	PF Qgen (MW)
2	CYD-G1			0	1.065	-32.1	108	20.5
3	CYD-G2			0	1.065	-32.1	108	20.5
4	CYD-G3			0	1.065	-32.1	108	20.5
5	CYD-G4			0	0.972	-34.5	54	20.5
6	DSM-G1			0	1.026	-54.2	1.5	-0.4
7	DSM-G2			0	1.026	-54.2	1.5	-0.4
8	FLD-G1			1				
9	HBK-G1			1				

Figure 14: Data format of the synchronous_machines.csv file.

The same generator name used in the EMI case is used in the first column. Columns B and C can be left null or populated. Columns D to H need to be updated based on the PowerFactory power-flow solution. Once the .csv file is updated, save it in the same folder where the PSCAD case is saved.

Step 2

Add **update_syncmachines.py** as a resource to the PSCAD case. Figure 15 gives a snapshot of adding the python file to **EMT_14.pscx**

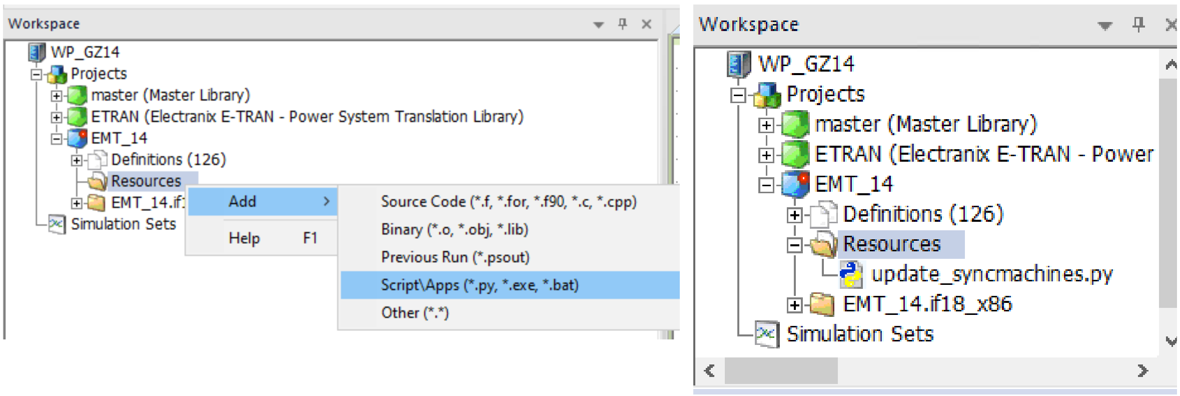


Figure 15: Addition of update_syncmachines.py script.

Step 3

Double-click the added **update_syncmachines.py** file. This will open a scripts pane in the PSCAD environment.

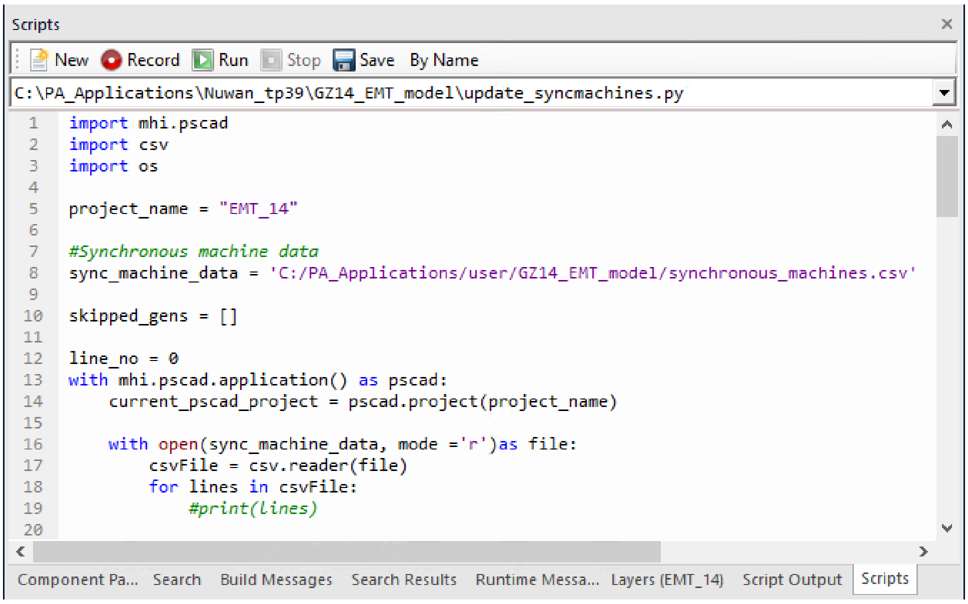


Figure 16: Scripts pane with the loaded script.

Step 4

Update the **project_name** variable with the current PSCAD case that needs to be edited.

Update the **sync_machine_data** variable with the absolute file location of the **synchronous_machines.csv** file.

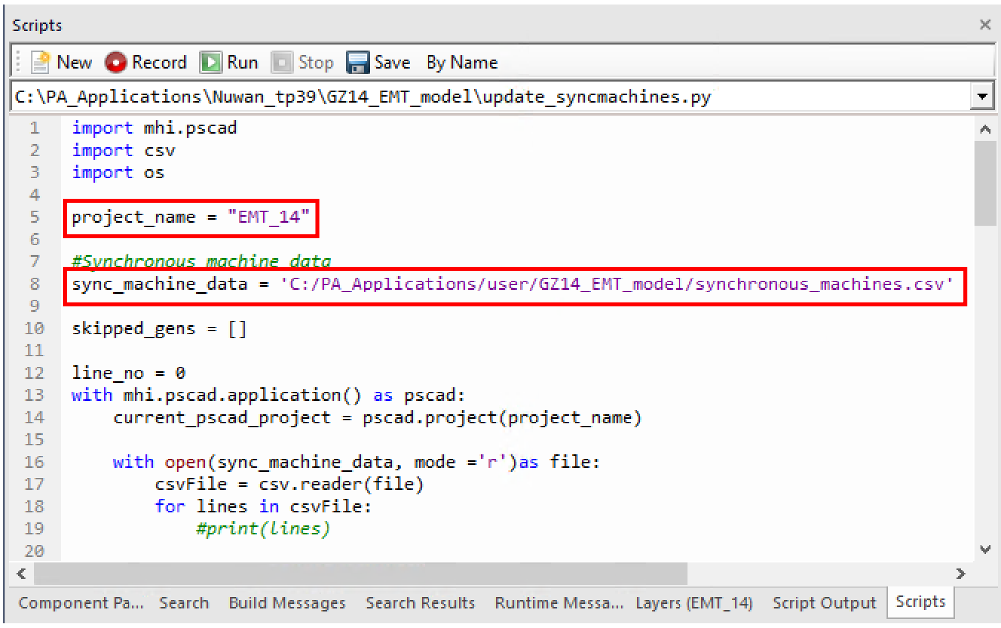


Figure 17: Update the project name and sync_machine_data variables.

Step 5

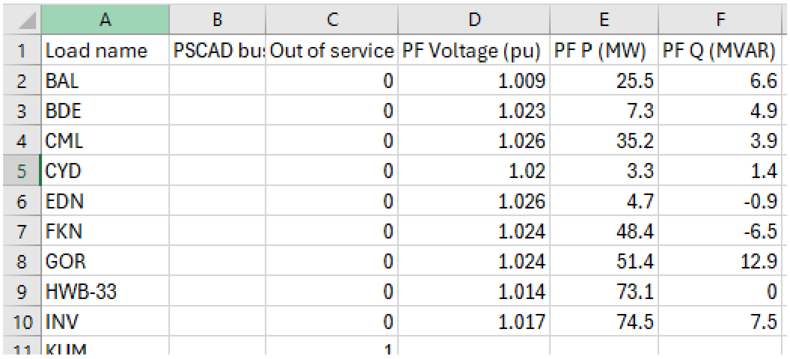
Press the **Run** button available in the Scripts pane. This should update the synchronous machines within the PSCAD case with the data provided in the **synchronous_machines.csv** file. The **Script Output** will be populated with generators that are being updated.

5.2 Update Loads

Step 1

Update the **loads.csv** based on the power-flow solution. Figure 18 gives an overview of the .csv file data format opened in Excel.

Note: The user must not change the data order or format.



	A	B	C	D	E	F
1	Load name	PSCAD bu	Out of service	PF Voltage (pu)	PF P (MW)	PF Q (MVAR)
2	BAL		0	1.009	25.5	6.6
3	BDE		0	1.023	7.3	4.9
4	CML		0	1.026	35.2	3.9
5	CYD		0	1.02	3.3	1.4
6	EDN		0	1.026	4.7	-0.9
7	FKN		0	1.024	48.4	-6.5
8	GOR		0	1.024	51.4	12.9
9	HWB-33		0	1.014	73.1	0
10	INV		0	1.017	74.5	7.5
11	KUM		1			

Figure 18: Data format of the loads.csv file.

The same load name used in the EMI case is used in the first column. Column B can be left null or populated. Columns C to F need to be updated based on the PowerFactory power-flow solution. Once the .csv file is updated, save it in the same folder where the PSCAD case is saved.

Step 2

Add **update_loads.py** as a resource to the PSCAD case like in section 5.1.

Step 3

Double-click the added **update_loads.py** file. This will open a scripts pane in the PSCAD environment.

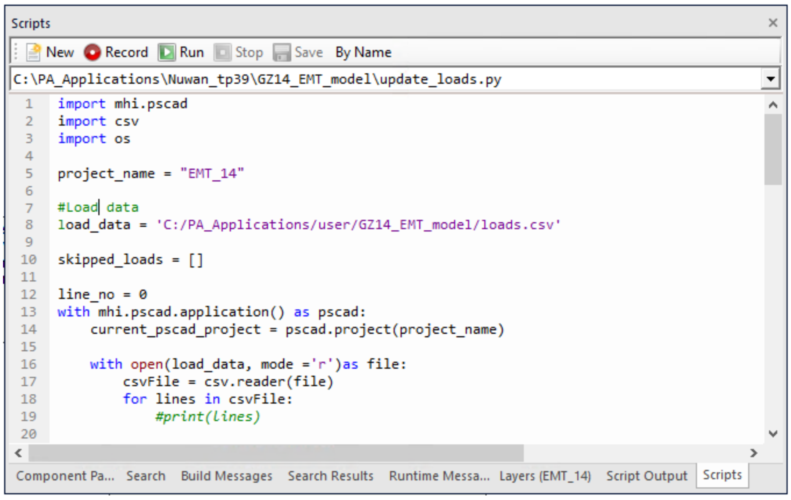


Figure 19: Scripts pane with the loaded script.

Step 4

Update the **project_name** variable with the current PSCAD case that needs to be edited.

Update the **load_data** variable with the absolute file location of the **loads.csv** file.

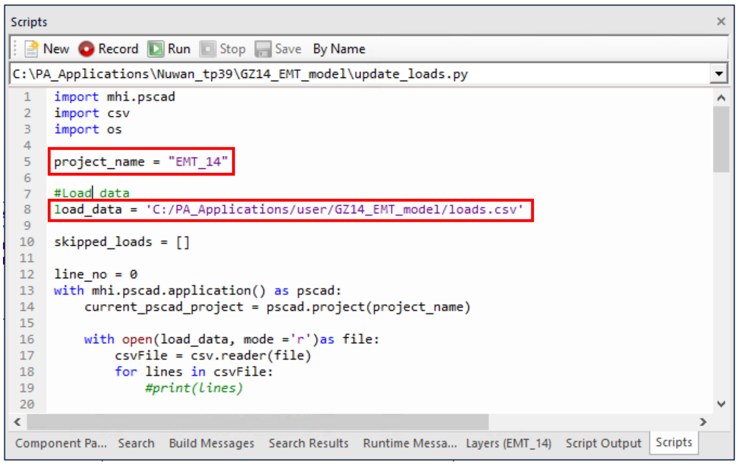


Figure 20: Update the project name and load_data variables.

Step 5

Press the **Run** button available in Scripts pane. This should update the synchronous machines within the PSCAD case with the data provided in **loads.csv** file. The **Script Output** will be populated with loads that are being updated.

6. Assumptions and Limitations of the Model

The **GZ14_EMT_model.pscx** PSCAD network model is provided with the following assumptions and limitations:

- It contains the Grid Zone 14 transmission network modelled in detail, including all the associated voltage control system models for generators. The rest of the South Island network is modelled as equivalent networks with equivalent generators modelled as a constant frequency AC voltage source. This PSCAD network model is suitable for fault ride through and other voltage-related system studies.
- The simulation model requires an Intel® Fortran Compiler Classic 2021.12.0 to compile the simulation case.
- The simulation case was built using PSCAD version 5.0.2.0.
- The simulation case was developed with Visual Studio 2022.
- The EMT model has been created for a specific operating point of the power system (2024 Summer loading in EMI case). Users can modify the system for different study scenarios using the python scripts provided.
- The dynamics of machines are released at 3.0 s of the simulation run. Thus, it is recommended to run the simulation further about 3-5 s to ensure the system is in steady state. Verify the system is in steady state prior to conducting the studies.
- The EMT model was converted from the power-flow file using a 20 µs simulation time step. Users could reduce the time step further if required, but increasing the simulation time step would likely result in errors when performing simulation.
- The simulation model used simplifies generic models for wind farms due to the restrictions of using detailed models. The response of the generic models may not fully represent the behaviour of the actual asset(s).
- The python scripts provided with the model only update the initial condition of generators and load values. The transformer tap positions, equivalent network initial conditions and equivalent network impedances, wind farm power outputs, filter configurations, and static capacitors and inductors within the system are **NOT** updated automatically. It is highly recommended that users verify all parameters and dispatch against the PowerFactory case.
- The generator internal angles of Lower and Upper Roaring Meg (LMG and UMG) are different to that of the PowerFactory power-flow solution. The Cromwell GXP transformer phase shifts cannot be correctly modelled in PSCAD transformers. This requires the generator internal angle to be advanced +90° (E.g. if PowerFactory angle is -100°, use -10° in PSCAD).
- The model is provided with three network equivalents for three different grid configurations. The provided **EMT_14.pscx** is configured for summer peak load condition and if the network equivalent is swapped, grid zone 14 must be appropriately updated: synchronous generators, loads, reactive power compensation devices, transformer taps.

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