TRANSPOWER

Grid Zone 11, 13 EMT Model User Guide

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Contents

1.0 Introduction

A PSCAD model of the region covered by grid zones 11 and 13, including the HVDC bipole, 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 of grid zones 11 and 13, while the rest of the South Island grid network is represented by equivalent voltage sources and a simplified network. The model includes a simplified HVDC link with inverter stations connected to an equivalent network representing the Haywards 220 kV bus. The model contains synchronous generator models along with their respective automatic voltage regulators (AVR) and reactive power compensation devices modelled using simplified generic models.

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

2.0 Files Provided by the System Operator

The system operator provides the asset owner with the GZ_11_13_EMT_model .zip package containing files shown in Figure 1. Table 1 includes descriptions of the files provided in the .zip package.

Name	Type	Compressed size
dynamics.dyr	DYR File	3 KB
EMT_11_13.pscx	PSCAD File	583 KB
ETRAN.pslx	PSCAD File	177 KB
ETRAN_IF12.lib	Object File Library	592 KB
loads.csv	Microsoft Excel Comma S...	1 KB
synchronous_machines.csv	Microsoft Excel Comma S...	1 KB
update_loads.py	Python File	1 KB
update_syncmachines.py	Python File	2 KB
WP_11_13.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 and AVR/exciter models. This file should be placed in the same folder as the EMT_11_13.pscx case.
EMT_11_13.pscx	A simulation file containing South Island grid zones 11 and 13, including a simple model of the HVDC bipole link connected to an equivalent source at Haywards. The South Island model has boundaries at Clyde 220 kV, Livingstone 220 kV, Islington 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.
loads.csv	A .csv file containing details of the loads within the network model. The data is obtained by the PowerFactory power-flow solution.
synchronous_machines.csv	A .csv file containing details of the synchronous machines within the network model. The data is obtained by the PowerFactory power-flow solution.

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

File name	Description
update_loads.py	A python file used to update the load values based on the power-flow details provided by the **loads.csv** file.
update_syncmachines.py	A python file used to update the initial conditions of synchronous machines based on the power-flow details provided by the **synchronous_machines.csv** file.
WP_11_13.pswx	This is a PSCAD workspace file which should load all necessary files into the PSCAD workspace to run the PSCAD case.

3.0 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 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_11_13.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_11_13.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 **Add -> Binary (*.o, *.obj, *.lib)** submenu.

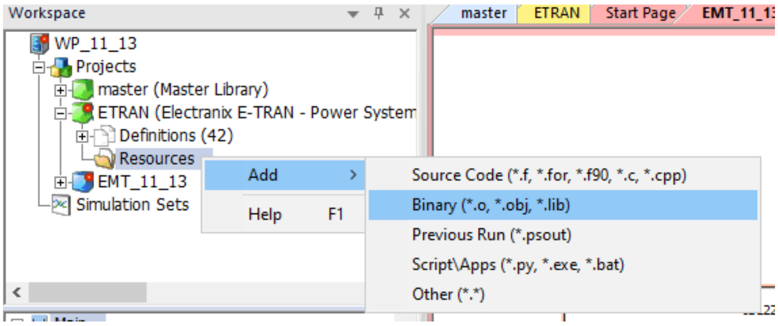

Figure 2: Adding .lib files to the project.

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

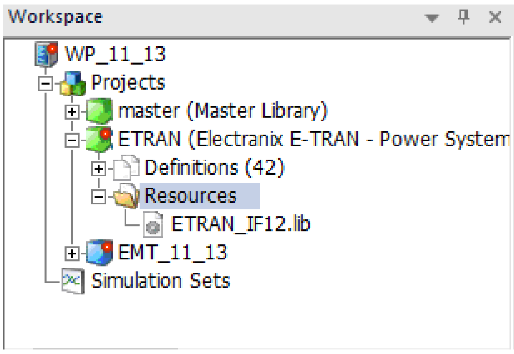

Figure 3: All the .lib files loaded in correct order.

The following figure shows a snapshot of the PSCAD workspace after the workspace **WP_11_13.pswx** is correctly loaded.

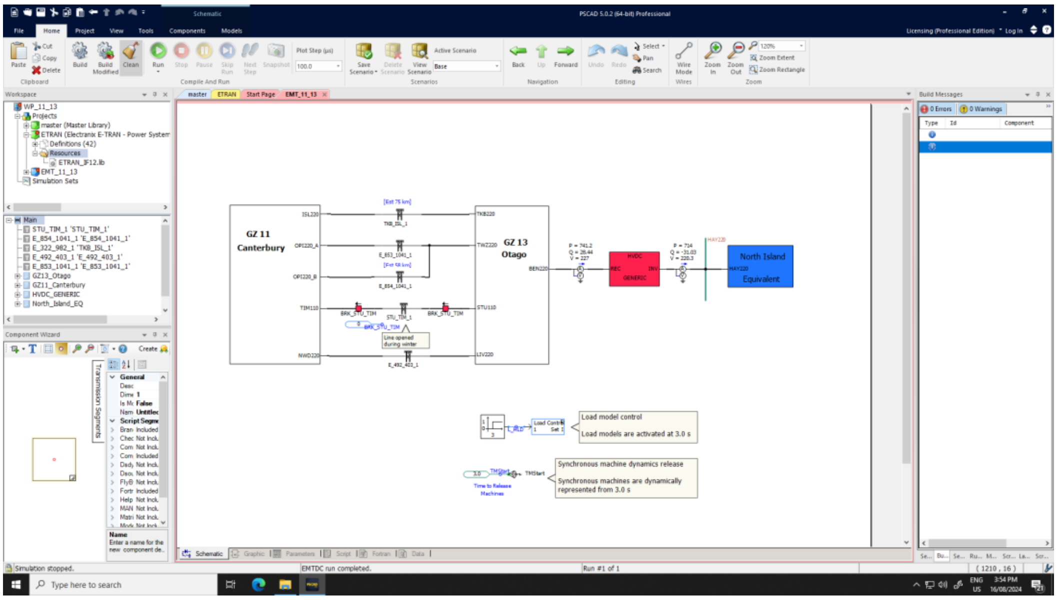

Figure 4: Screenshot of the correctly loaded PSCAD workspace and canvas.

3.2 Case File Arrangement

The network model is divided into four main subpages:

1. North Island Equivalent subpage
2. HVDC Generic subpage
3. GZ 13 Otago subpage
4. GZ 11 Canterbury subpage

The subpages are distributed in the canvas as shown in Figure 5.

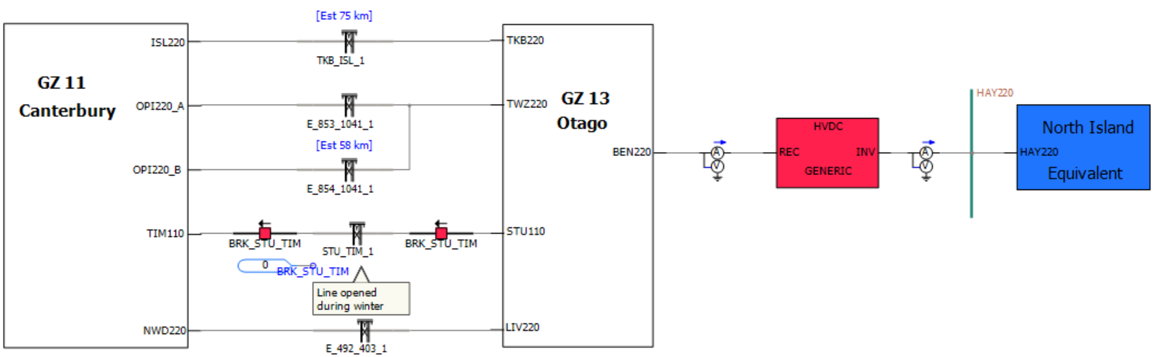

Figure 5: Main page of PSCAD workspace.

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.

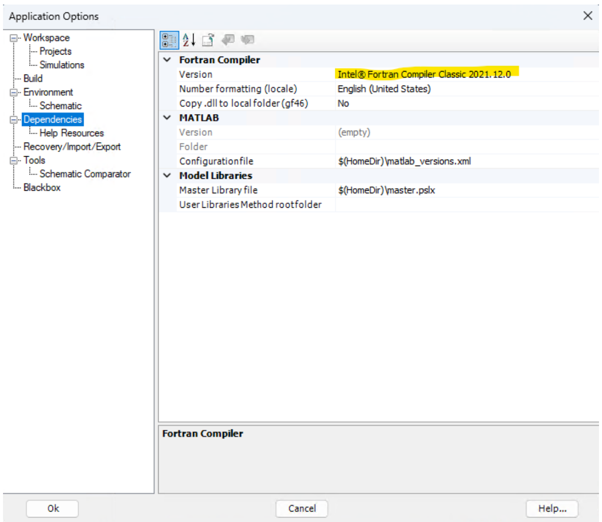

Figure 6: Setting up the compiler.

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.

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

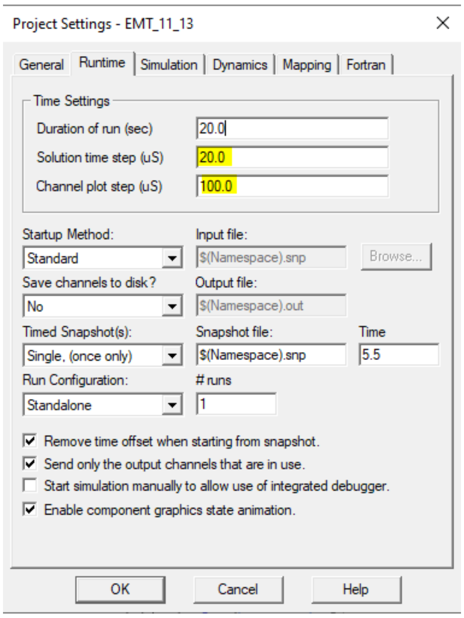

Figure 7: Setting up the solution time step.

4.0 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 simulation model contains only regions associated with grid zones 11 and 13, including the HVDC system. The rest of the network is represented by equivalent voltage sources and a network to simplify the EMT simulation. Since the EMI case is built separately for the two islands, the equivalents should be carefully calculated.

The EMT model is made considering 700 MW flow in HVDC link at Haywards 220 kV bus. The HVDC link has a loss of around 20 MW at this operating point. Considering this, the EMI PowerFactory case needs be reconfigured to have constant HVDC export of 720 MW (remove the slack control at HVDC). For the North Island, the network reduction will only include the Haywards station. The slack generator was set to HVDC static generator in the EMI case with the voltage angle of Haywards 220 kV bus at 0°. The network was reduced based on the following selected boundary of the EMI PowerFactory case.

	Boundary Cubicle StaCubic	Head Folder	Busbar	Branch	Orientation
1	HAY-JFT-2	HAY220	HAY220B	HAY-JFD-2	--> Busbar
2	Cub_1	HAY220	HAY220B	HAY-PRT-2	--> Busbar
3	HAY-JFT-1	HAY220	HAY220B	HAY-JFD-1	--> Busbar
4	Cub_1	HAY220	HAY220C	HAY-PRT-1	--> Busbar
5	Cub_GFD-HAY-1	HAY110	HAY110A...	GFD-HAY-1	--> Busbar
6	Cub_GFD-HAY-2	HAY110	HAY110B4	GFD-HAY-2	--> Busbar
7	Cub_HAY-MLG-1	HAY110	HAY110A...	HAY-MLG-1	--> Busbar
8	Cub_HAY-MLG-2	HAY110	HAYB110B3	HAY-MLG-2	--> Busbar
9	Cub_HAY-TKR-1	HAY110	HAY110A...	HAY-TKR-1	--> Busbar
10	Cub_HAY-TKR-2	HAY110	HAY110B1	HAY-TKR-2	--> Busbar
11	Cub_HAY-UHT-1	HAY110	HAY110A...	HAY-UHT-1	--> Busbar
12	Cub_HAY-UHT-2	HAY110	HAYB110B3	HAY-UHT-2	--> Busbar

Figure 8: EMI PowerFactory boundary for reducing North Island Power Grid.

Once the network boundary is created in PowerFactory (named **Boundary-HAYWARDS** in this example), part of the network exterior to the boundary can be reduced via **CALCULATION -> Network Reduction** in PowerFactory. This will open the **Network Reduction** window. In this window,

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

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].

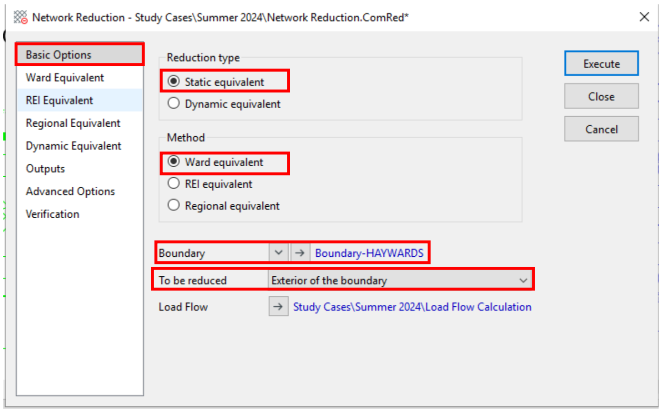

Figure 9: Network Reduction window: Basic Options.

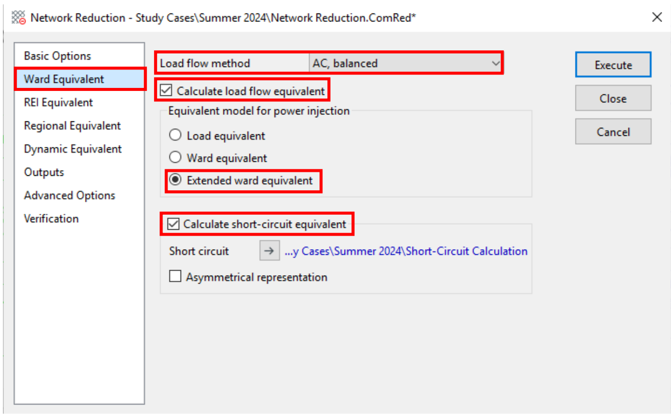

Figure 10: Network Reduction window: Ward Equivalent.

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.

Similarly, the South Island power grid slack generator was changed to BEN G1 with Benmore 220 kV bus voltage angle defined at 0°. The network was reduced based on the following selected boundary of the EMI PowerFactory case.

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

	Boundary Cubicle StaCubic	Head Folder	Busbar	Branch	Orientation
1	Cub_BRY-ISL-1	ISL220	ISL220D	BRY-ISL-1	--> Branch
2	Cub_ASB-ISL-1	ISL220	ISL220C	ASB-ISL-1	--> Branch
3	Cub_ISL-LIV-1	ISL220	ISL220B	ISL-NWD-1	--> Branch
4	Cub_ISL-TKB-1	ISL220	ISL220A	ISL-TKB-1	--> Branch
5	Cub_CYD-ROX-1	CYD220	CYD220B	CYD-ROX-1	--> Busbar
6	Cub_CYD-ROX-2	CYD220	CYD220A	CYD-ROX-2	--> Busbar
7	Cub_LIV-NSY-1	LIV220	LIV220	LIV-NSY-1	--> Busbar

Figure 11: EMI PowerFactory boundary for reducing South Island power grid.

Once the network is reduced[7], AC voltage sources and Common Impedances appear in the PowerFactory network data. The magnitude, angle, initial active and reactive powers of the equivalent network impedances and equivalent network AC voltage sources in the EMT model were set based on the power-flow solution of the reduced PowerFactory case.

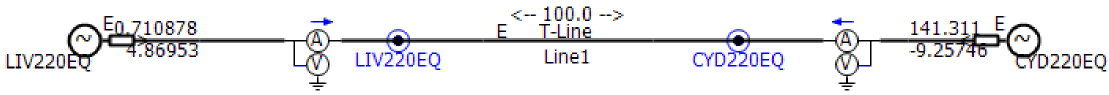

Figure 12: Network equivalent in GZ 13 Otago subpage.

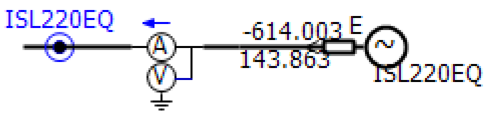

Figure 13: Network equivalent in GZ 11 Canterbury subpage.

4.2 HVDC Model

A generic bipole HVDC model available in the PSCAD Knowledge Base[8] was used for the HVDC link. Only converter controls are implemented without bipole controls. Figure 14 shows a schematic of the HVDC model.

[7] Ward reduction available in PowerFactory 2021 was used to reduce the network.
[8] https://www.pscad.com/knowledge-base/article/190

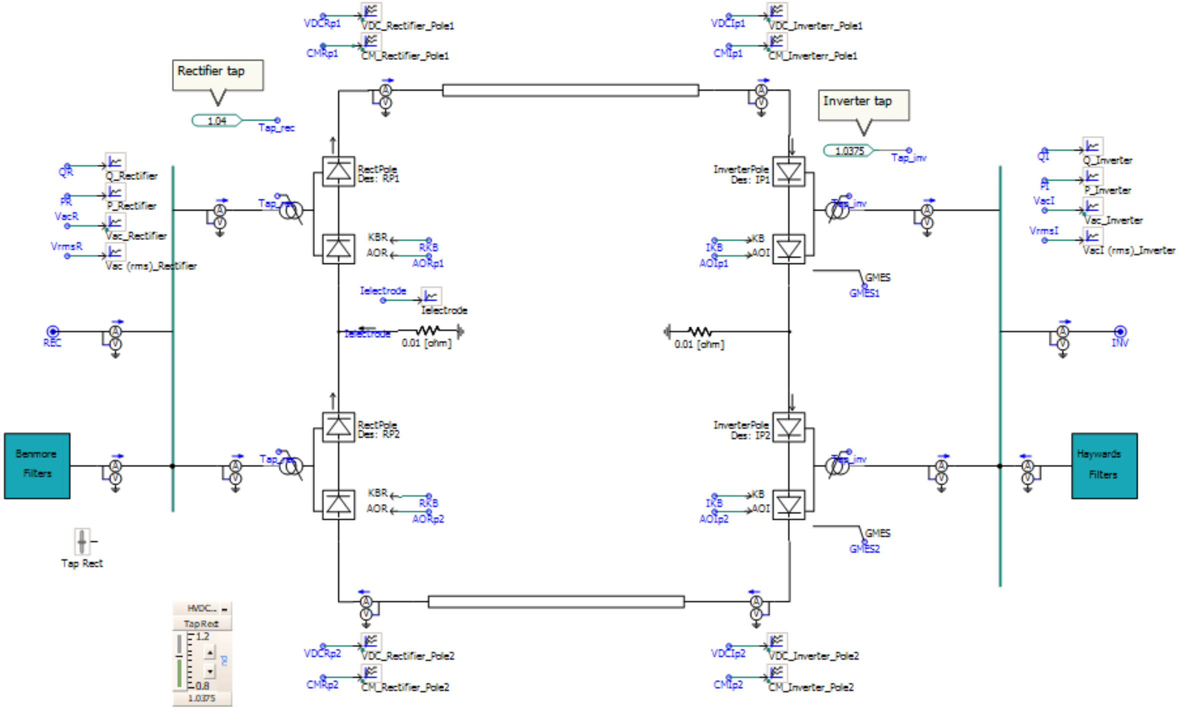

Figure 14: Generic HVDC model.

When conducting power-flow analysis in the EMI case, the converter transformer tap positions need to be manually adjusted to match the reactive power-flow into the converter stations. The simulation model is set to send power from the South Island to North Island. The active power setpoint at Haywards 220 kV can be set by adjusting the **Bipole Power Order [MW]** slider on the **HVDC Generic** subpage.

The filters at Haywards and Benmore need to be adjusted based on the active power setpoint. Figure 15 and Figure 16 show the filter bank construction.

A STATCOM is available at Haywards 220 kV bus; this is modelled as a generic STATCOM model. The reactive power response of the STATCOM heavily affects the voltage recovery following faults closer to Haywards station.

Note: No reactive power controller (RPC) is implemented in the generic HVDC model.

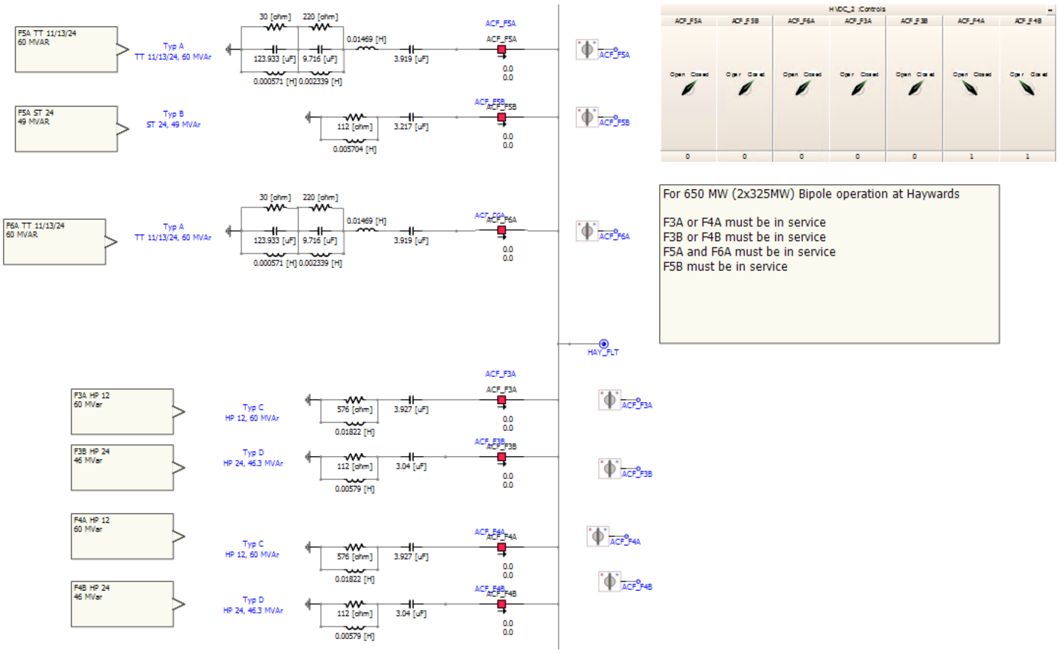

Figure 15: Filter bank at Haywards.

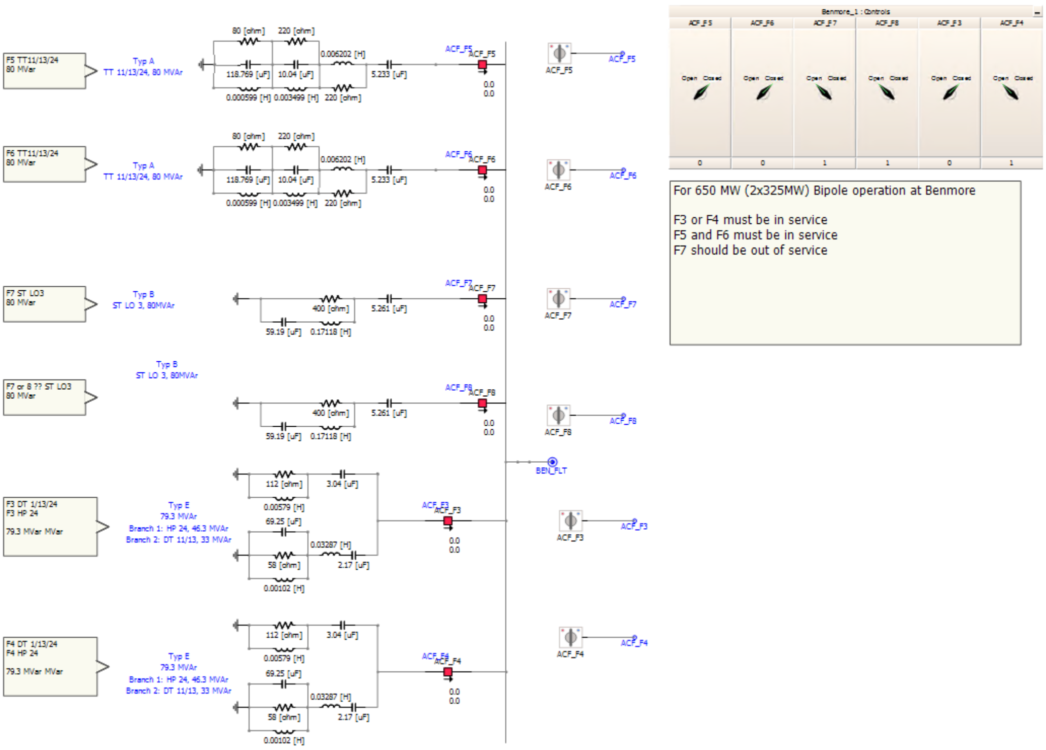

Figure 16: Filter bank at Benmore.

The filters are selected based on the bipole/monopole operation and the DC power transfer. Table 2 to Table 5 present how the filters are switched on/off at Benmore and at Haywards based on the power setpoint and bipole/monopole operation. The available DC power transfer shown for performance will be used to switch in the next filter.

Table 2: Filter selection for Haywards bipole operation.

In Service Combination				Performance (MW)	DC link rating (MW)
F3A/ F4A	F3B/ F4B	F5A/F6A	F5B		
0	0	1	1	0	70
0	1	1	1	140	140
0	1	2	1	490	490
1	1	2	1	1000	1200
2	1	2	1	1200	1200
2	2	2	1	1400	1400

Table 3: Filter selection for Haywards monopole operation.

In Service Combination				Performance (MW)	DC link rating (MW)
F3A/ F4A	F3B/ F4B	F5A/F6A	F5B		
0	0	1	0	0	70
0	0	1	1	210	350
0	1	1	1	245	350
0	1	2	1	700	1000
1	1	2	1	1000	1000
1	2	2	1	1000	1000
2	2	2	1	1000	1000

Table 4: Filter selection for Benmore bipole operation.

In Service Combination			Performance (MW)	DC link rating (MW)
F3/F4	F5/F6	F7		
1	0	0	0	140
0	1	0	0	140
1	1	0	350	350
1	2	0	560	1200
1	2	1	1200	1200
2	2	1	1400	1400

Table 5:Filter selection for Benmore monopole operation.

In Service Combination			Performance (MW)	DC link rating (MW)
F3/F4	F5/F6	F7		
0	1	0	280	350
1	1	0	420	700
1	1	1	700	1000
1	2	1	1000	1000
2	2	1	1000	1000

4.2.1 North Island Equivalent Subpage

This subpage represents the Haywards 220 kV and 110 kV bus bars with interconnecting transformers, synchronous condensers and Haywards STATCOM (a generic STATCOM model is used). The rest of the North Island is represented by two equivalent voltage sources connected at Haywards 220 kV and 110 kV buses and a fictitious interconnecting transformer connected between the two buses.

Figure 17 provides an overview of the North Island Equivalent subpage.

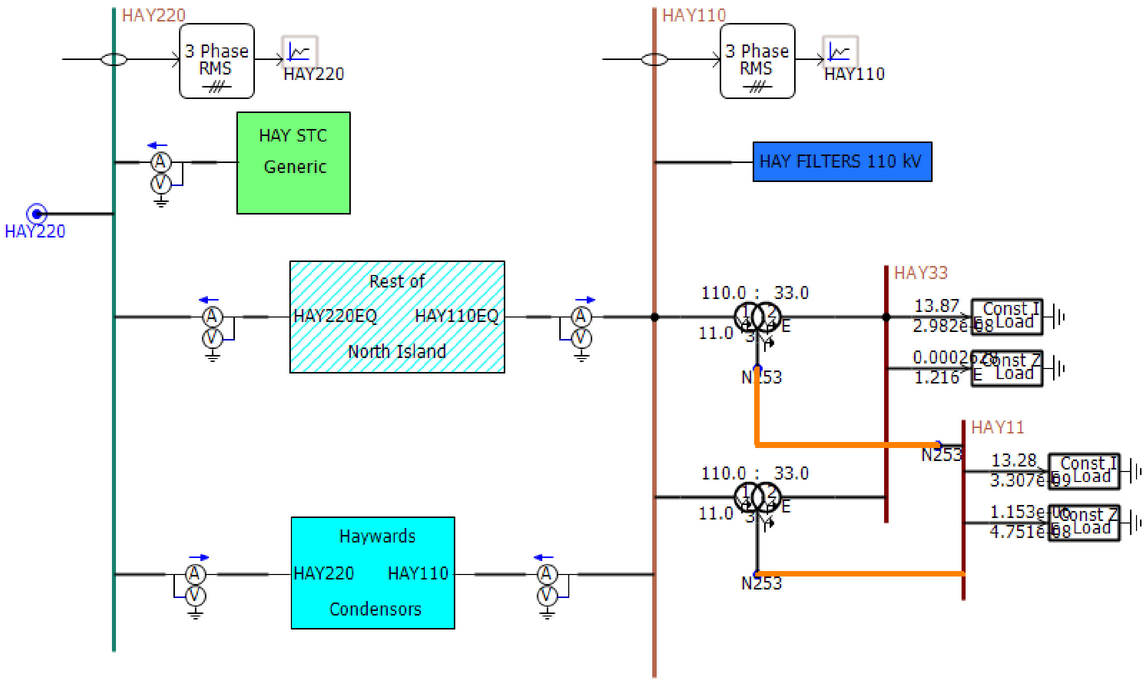

Figure 17: Haywards equivalent subpage overview.

4.3 GZ 13 Otago Subpage

This subpage consists of a detailed model of the Otago region, including major hydro generators within the region. The region of the South Island network within the green line in Figure 18 is covered in the **GZ 13 Otago** subpage.

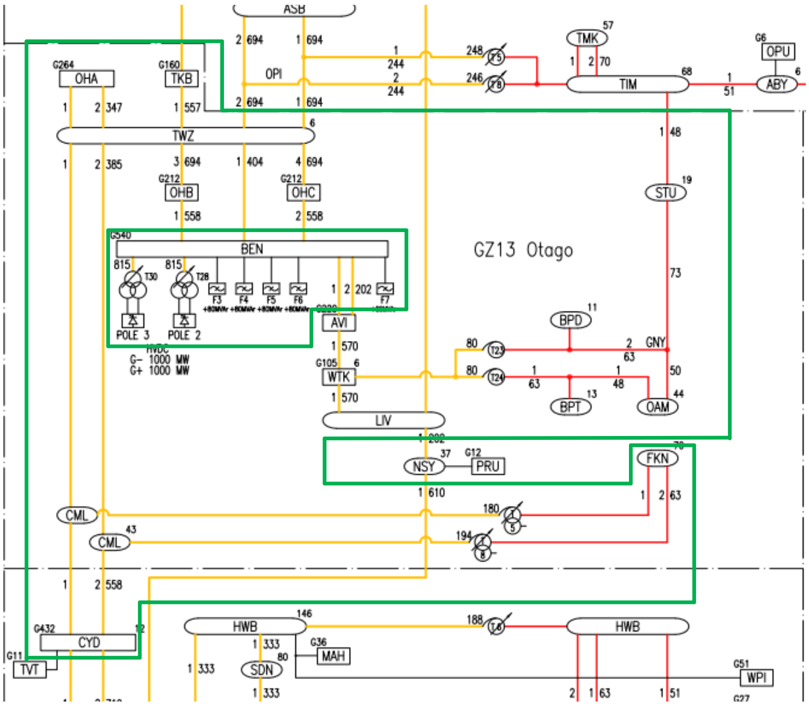

Figure 18: Region represented on the GZ 13 Otago subpage.

4.3.1 Generation Within the Region

Name of the Generator	Capacity (MVA)	Dispatch (MW)	Energy Source	Model
Waitaki (WTK)	16.67 16.67 16.67 16.67 16.67 16.67 16.67	15.0 15.0 15.0 15.0 15.0 1.77 OOS	Hydro	GENSAE
Aviemore (AVI)	61.0 61.0 61.0 61.0	58.0 58.0 57.3 OOS	Hydro	PSCAD master library Synchronous machine model (Saturation curve by table)
Benmore (BEN)	112.5 112.5 112.5 112.5	83.6 90.0 90.0 90.0	Hydro	PSCAD master library Synchronous machine model

Name of the Generator	Capacity (MVA)	Dispatch (MW)	Energy Source	Model
	112.5 112.5	90.0 95.0		(Saturation curve by table)
Ohau A (OHA)	73.33 73.33 73.33 73.33	66.0 66.0 48.0 20.5	Hydro	GENSAE
Ohau B (OHB)	58.889 58.889 58.889 58.889	53.0 53.0 53.0 30.0	Hydro	GENSAE
Ohau C (OHC)	58.889 58.889 58.889 58.889	52.0 53.0 53.0 29.0	Hydro	GENSAE
Tekapo B (TKB)	88.9 88.9	78.0 65.0	Hydro	GENSAE
Clyde (CYD)	120.0 120.0 120.0 120.0	OOS 94.5 94.5 94.5	Hydro	GENSAE
Roaring Meg (RMG) (LMG and UMG)	2.5 1.0 0.54 0.86	1.5 0.8 0.4 0.7	Hydro	GENSAE

4.4 GZ 11 Canterbury Subpage

The subpage consists of a detailed model of the Canterbury region, including major hydro generators within the region. The region of the South Island network within the green line in Figure 19 is covered on the **GZ 11 Canterbury** subpage.

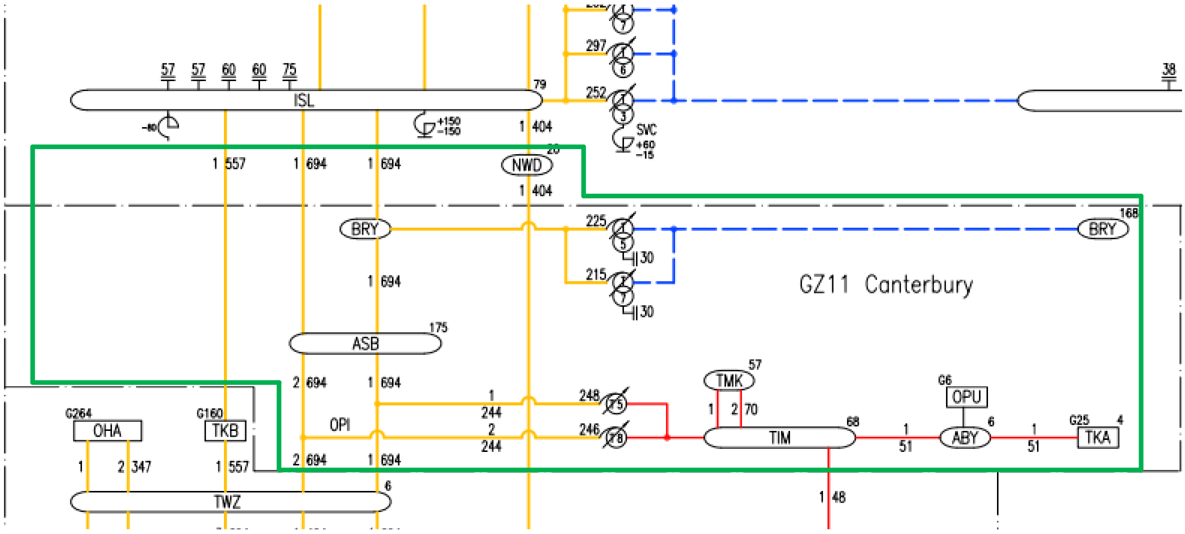

Figure 19: Region represented on the GZ 11 Canterbury subpage.

4.4.1 Generation Within the Region

Name of the Generator	Capacity (MVA)	Dispatch (MW)	Energy Source	Model
Tekapo A (TKA)	35.0	20.0	Hydro	GENSAE

4.5 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 PSCAD library synchronous machine models with their automatic voltage regulators using respective IEEE generic models.

4.6 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[9].

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

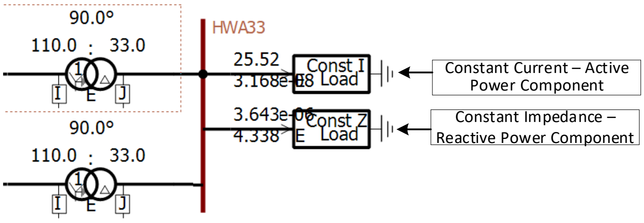

Figure 20: Example load representation.

4.7 Enable Additional Plot Channels

The simulation model consists of signals set up for plotting for observation and troubleshooting of the characteristics within the simulation model. Reducing the number of plotted signals helps to reduce usage of computer memory and increase simulation speed. These non-essential signal plots are included in a layer named **Additional_plot_channels**. This layer can be enabled/disabled from the **Layers** pane (**View** Tab -> **Panes** -> **Layers**) to plot these additional signals.

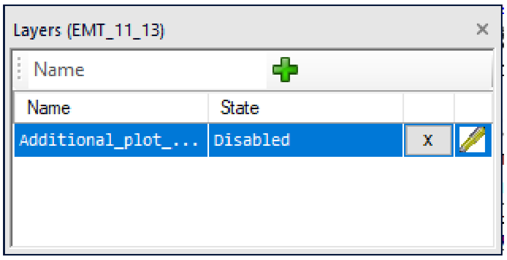

Figure 21: Enable/disable plotting of non-essential signals.

5.0 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 22 gives an overview of the .csv file data format opened in Excel.

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

	A	B	C	D	E	F	G	H
1	Generator	PSCAD Bu:	PSCAD cir	Out of service	PF Voltage (pu)	PF angle (deg)	PF Pgen (MW)	PF Qgen (MW)
2	HAY-C1			0	0.9926551	30.55796	2.75E-05	-17.49068121
3	HAY-C10			0	0.9790512	-92.61712	-2.64E-07	-18.94820372
4	HAY-C2			0	0.9926551	30.55796	2.75E-05	-17.49068121
5	HAY-C3			0	0.9954394	30.55786	1.34E-05	-8.745294036
6	HAY-C4			0	0.9954394	30.55786	1.34E-05	-8.745294036
7	HAY-C7			0	0.9791575	-92.61712	1.48E-05	-18.948319
8	HAY-C8			0	0.9791432	-92.61712	1.48E-05	-18.94831971
9	HAY-C9			0	0.9791575	-92.61712	1.48E-05	-18.948319
10	ALD-G1			1				
11	ALD-G2			1				
12	AMS-G1			1				
13	ARG-G1			1				
14	AVI-G1			0	1.020483105	-23.92219	58	-4.30076286
15	AVI-G2			0	1.020286589	-23.88726	58	-4.30076286
16	AVI-G3			0	1.020334775	-23.9444	5.73E+01	-4.30076286
17	AVI-G4			1				

Figure 22: 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 23 gives a snapshot of adding the python file to **EMT_11_13.pscx**.

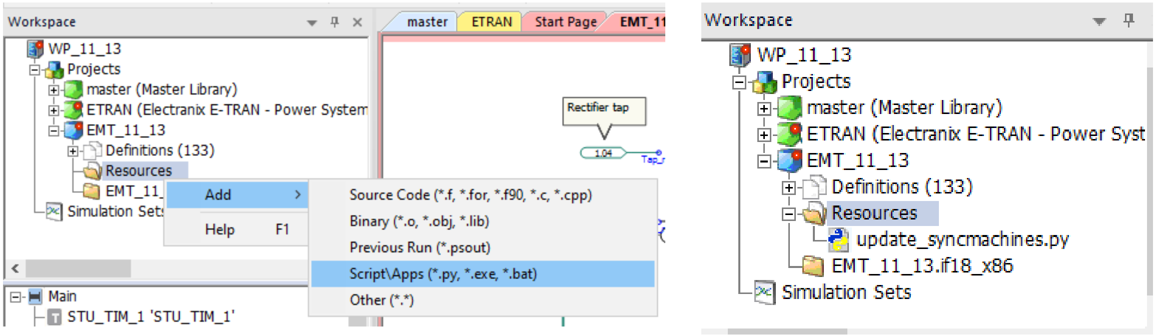

Figure 23: Addition of update_syncmachines.py script.

Step 3

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

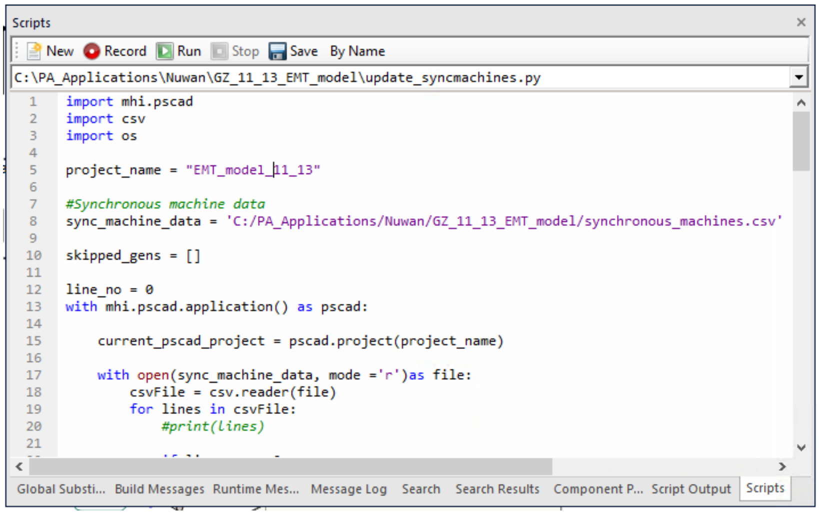

Figure 24: Scripts pane with the loaded script.

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.

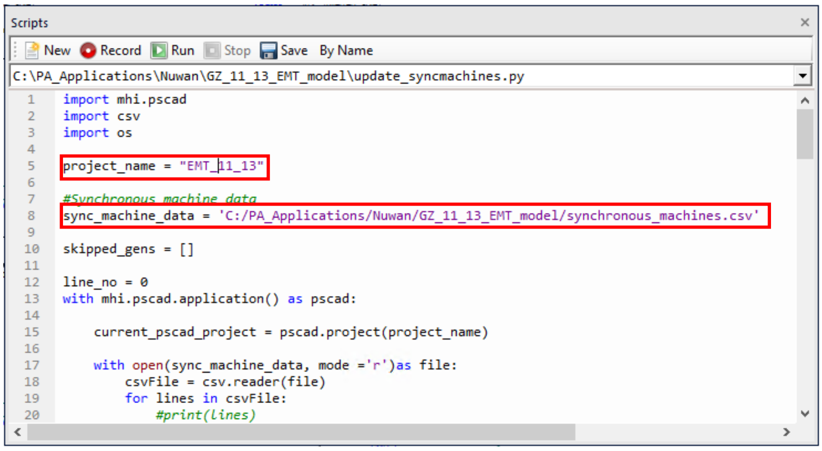

Figure 25: Update the project name and sync_machine_data variables.

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 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 26 gives an overview of the .csv file data format opened in Excel.

Note: The user must not change the load names, 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	HAY-11		0	0.975777469	13.6	5.03E-08
3	HAY-33		0	0.976695638	14.2	1.273911495
4	ABY		0	1.021754957	-2	-0.77780747
5	ASB-66		0	0.987116647	150.5	31.33908844
6	BPD		0	0.991003659	12	2.95E+00
7	BPT		0	0.996590473	10.6	4.483564854
8	BRY-66		0	1.028729827	60.799999	-16.7705975
9	CML		0	1.019318798	35.200001	3.87E+00
10	CYD		0	1.012203985	3.3	1.36568737

Figure 26: 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.

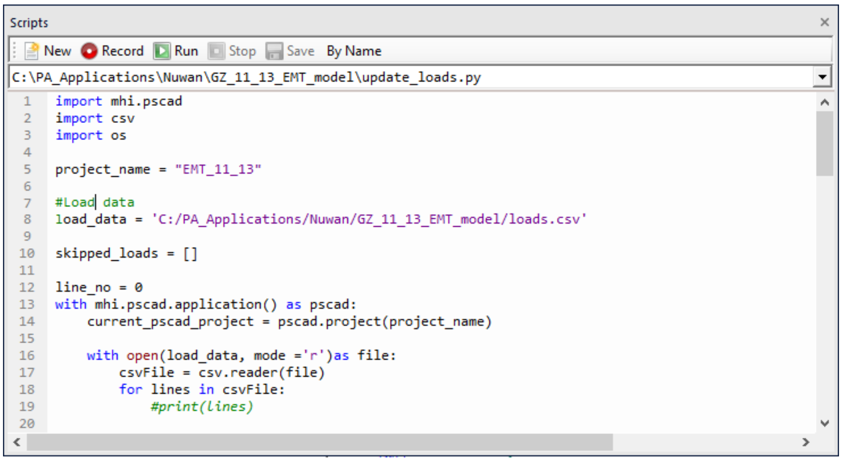

Figure 27: Scripts pane with the loaded script.

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.

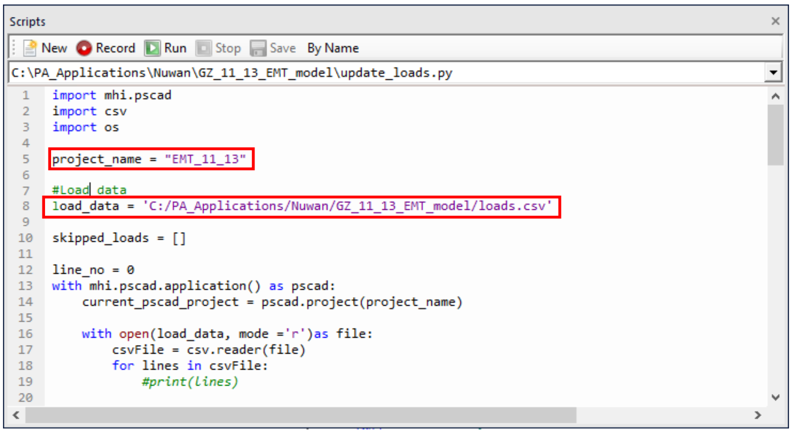

Figure 28. Update the project name and load_data variables.

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.

6.0 Assumptions and Limitations of the Model

The **EMT_11_13.pscx** PSCAD network model is provided with the following assumptions and limitations.

- It contains Grid Zone 11 and 13 transmission networks modelled in detail, including all the associated voltage control system model for generators. The HVDC link is presented with a simple generic model. The rest of the North Island and South Island networks are 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 provided python scripts.
- 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 error when performing the simulation.
- The simulation model used simplifies generic models for HVDC links and STATCOMs 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, filter configurations, static capacitors and inductors within the system are **NOT** updated automatically. It is highly recommended that users verify all parameters and dispatch against the EMI PowerFactory case.
- The generator internal angles of Roaring Meg (within the LMG GEN subpage) is different to that of the PowerFactory power-flow solution. The Cromwell GXP transformer phase shift cannot be correctly modelled in PSCAD transformers. With the implemented transformers, the Roaring Meg generator internal angles need to be advanced by +90° (E.g. if PowerFactory angle is -100°, use -10° in PSCAD).
- Studholme (STU) is supplied from Timaru (TIM) in summer and Waitaki (WTK) in winter. This requires lines to be taken on outage depending on the season of study.

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