THE BAHAMAS POWER SYSTEM STABILITY STUDY FOR THE IMPLEMENTATION OF A HIGHER RENEWABLE ENERGY PENETRATION LEVEL

OPERATIONS MANUAL FOR THE SIMULATION MODELS FOR ELEUTHERA AND EXUMA

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CONTENTS

1 INTRODUCTION

This document describes the dynamic model of the electric power systems of the islands of Eleuthera and Exuma developed by Energynautics in the project *The Bahamas power system stability study for the implementation of a higher renewable energy penetration level* funded by United Nations Industrial Development Organization (UNIDO).

The purposes of this first draft report are to:

- list all the different dynamic models used for synchronous generators, renewable generators and battery in ETAP,
- give an overview of the organization of the different scenarios in ETAP as described in the critical scenarios report (deliverable D2.aii),
- serve as a manual for usage and future modification of the ETAP model.

The assumptions regarding the various models are based on the Deliverable D2.aii for Eleuthera and Exuma provided earlier. Various assumptions have been made in the cases where data was not available. These are mentioned wherever necessary in this report.

2 DYNAMIC SIMULATION MODELS IN ETAP

This section provides a summary of the various dynamic models used for different generating sources in ETAP.

The referenced dynamic models for the generators (respectively their controls) are generic models from IEEE and WECC of which implementations are provided with the ETAP software package.

2.1 EXUMA GENERATORS

Exuma system has generators at the George Town Power Station (GTPS).

Table 2.1: Dynamic models for generators in Clifton Pier and their associated control mode

Generator	Scenarios	Governor	Exciter	Control Mode
Gen1-Gen4	All	GGOV1	AC8B	Voltage Control
Rental Gen	All	-	-	Q Control

Assumptions had to be made about the generator parameters, the capability curve, governor and exciter model and its parameters.

2.2 ELEUTHERA GENERATORS

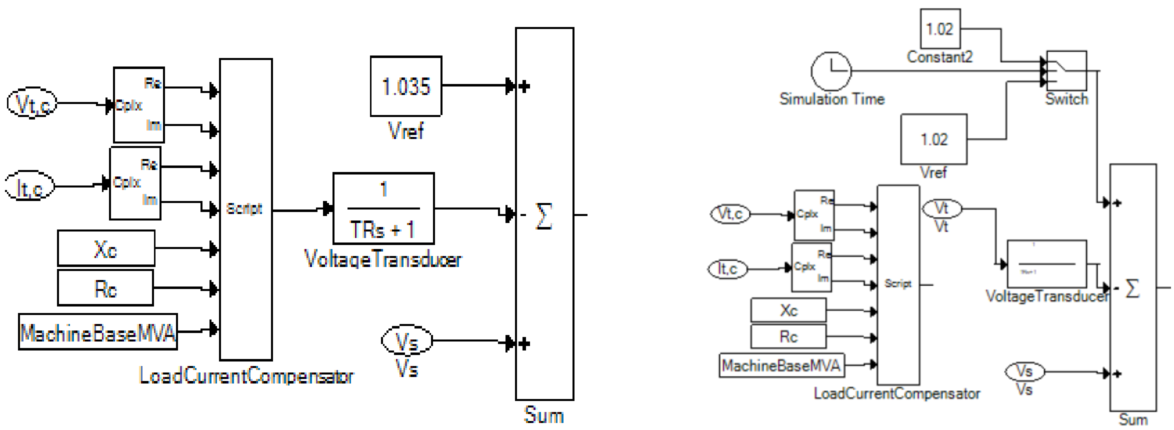
The Eleuthera system has three power stations, namely Rock Sound (RSPS), Hatchet Bay (HBPS) and Harbour Island (HIPS).

Table 2.2: Dynamic models for generators in Blue Hills and their associated control mode

Generator	Scenarios	Governor	Exciter	Control Mode
HBPS	All	GGOV1	AC8B	Voltage Control
RSPS	All	GGOV1	AC8B	Voltage Control
HIPS	All	GGOV1	AC8B	Voltage Control

Assumptions had to be made about the generator parameters, the capability curve, governor and exciter model and its parameters.

It must be noted here that the exciter and governor models in use were UDM models and not built-in models. This was because with built-in models, initialization issues resulting from interaction of PV models with exciter models were visible. These were then corrected for in the UDM model. UDM models also allow the possibility for internal signal plotting, which is not possible with built-in models. The exciter model was updated as shown in Figure 2.1. This was done in consultation with ETAP support because the Vref is a model reference parameter and was wrongly initialized at the beginning due to fluctuating PV output.



Before the modification **After the modification**

Figure 2.1: AC8B modification

2.3 RENEWABLES

The renewables have been divided into residential PV and commercial PV. Battery Energy Storage Systems (BESS) units have been considered as well. The associated models and their control model are listed in Table 2.3.

Table 2.3: Dynamic models for PV generators and their associated control mode

Generator	Scenarios	Model	Control Mode
PV Residential	2026 and 2030	PVD1	Q Control, down frequency droop
PV Commercial	All	WECC2 with REPC_A	Voltage Control, up and down frequency droop
BESS	All	WECC2 with REPC_A	Voltage Control, frequency droop

Assumptions were made regarding the size and placement of the PV and BESS units in the model. The PV implementation in ETAP is shown in Figure 2.2 for a PV generator in Gregory Town in Eleuthera system. The lumped load is used for modelling the plant controller. Each element can have more than one dynamic model associated with it. The voltage and frequency relays implemented are also visible in the figure. The data for the dynamic models also had to be completely assumed.

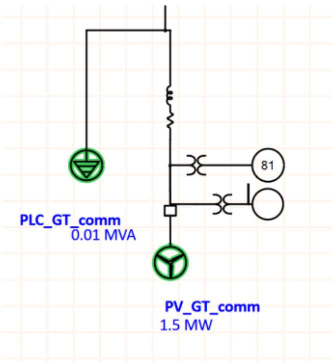


Figure 2.2: PV implementation in ETAP

The BESS model involved two different components for load flow and dynamic simulations. The static generator element was used for dynamic simulation, and a lumped load element for the load flow. This was done by changing the breaker status in the configuration manager, which therefore implied using a different configuration for load flow and dynamic simulation. Such a setup was done because the static generator element cannot be configured to consume power during load flow (to model the charging process of battery) in the component setup and thus a lumped load element was required during load flow. This is not a problem in dynamic simulations as the behavior of the element can be changed by adjusting the dynamic model set-points. The dynamic simulations also involved a lumped load element for modelling the plant controller (PLC). The BESS setup along with the PLC and protective relays in ETAP is shown in Figure 2.3. The model is from a BESS assumed located at Hatchet Bay in Eleuthera system.

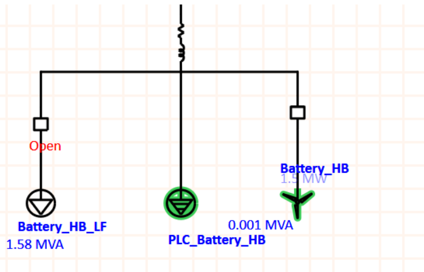


Figure 2.3: BESS setup in the model

The list of PV and BESS installation sites and their rating has been covered as a part of the deliverable D2.aii.

3 MODEL ORGANISATION IN ETAP

The model has been organized as a base case (representing the year 2023) on which various revisions are added depending on the year and study case under consideration. These revisions are further subdivided into study cases representing peak load, high PV and light load conditions as described in Deliverable D2.aii. The description of these cases are provided in this section.

3.1 ETAP REVISION MANAGER

ETAP Revision manager allows modifications in the base case depending on the future grid infrastructure considerations. Revisions also need to be used to replace the dynamic model in use for a device. The revisions along with the incorporated changes are listed below:

- Base Case: The case represents the power system as in 2023.
    - 2023_PL Case: This revision has been defined to keep the BESS in discharging state for the peak load (PL) case.
    - 2023_LL Case: This revision has been defined to keep the BESS in connected state (with 0 power output pre-fault) for the light load (LL) condition. The PVs are not activated in this case.
    - 2023_PV Case: The revision has been defined to keep the BESS in charging state for the High PV case. The PVs are activated in this case.
- 2026 Revisions: The changes are mostly related to the tap settings of transformers, expansion of renewable facilities (to include residential PVs) and their associated transformers.
    - 2026_PL Case: This revision has been defined to keep the BESS in discharging state for the peak load (PL) case.
    - 2026_LL Case: This revision has been defined to keep the BESS in connected state (with 0 power output pre-fault) for the light load (LL) condition. The PVs are not activated in this case.
    - 2026_PV Case: The revision has been defined to keep the BESS in charging state for the High PV case. The PVs are activated in this case.
- 2030 Revisions: The changes are mostly related to the tap settings of transformers, expansion of renewable facilities (to include residential PVs) and their associated transformers.
    - 2030_PL Case: This revision has been defined to keep the BESS in discharging state for the peak load (PL) case.
    - 2030_LL Case: This revision has been defined to keep the BESS in connected state (with 0 power output pre-fault) for the light load (LL) condition. The PVs are not activated in this case.
    - 2030_PV Case: The revision has been defined to keep the BESS in charging state for the High PV case. The PVs are activated in this case.

3.2 ETAP STUDY CASE MANAGER

The revisions have their own study cases associated with them. The study cases are used for choosing the generation and loading categories, creating the events for contingencies and for choosing the devices to be plotted.

The following categories have been defined and are in use for the project:

i) **Peak load**: Representing the peak load study case

ii) **High PV**: Representing the High PV study case.

iii) **Light load**: Representing the light load study case

It must however be noted that these categories are only changed for the generation category and not the loading category as seen in Figure 3.1. The loading category is always set to design mode irrespective of the case and the yearly scenario. This is because the loading for the system in different cases and yearly scenarios is adjusted by changing the "Const. Z" scaling factor for the loads as also marked in Figure 3.1.

Figure 3.2 provide a representation of how the categories are chosen and defined within the unit parameter editor in ETAP.

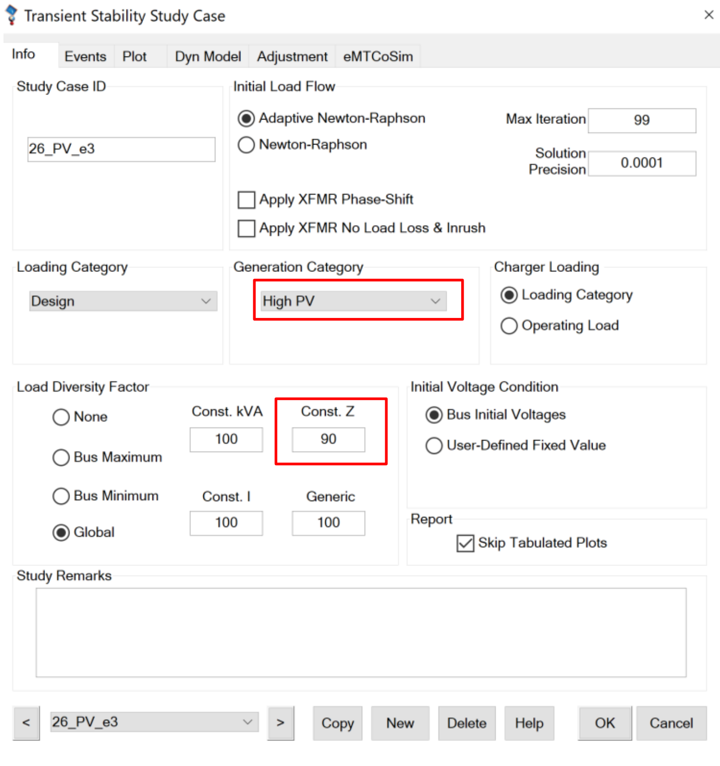


Figure 3.1: Transient stability study case manager with created generation categories

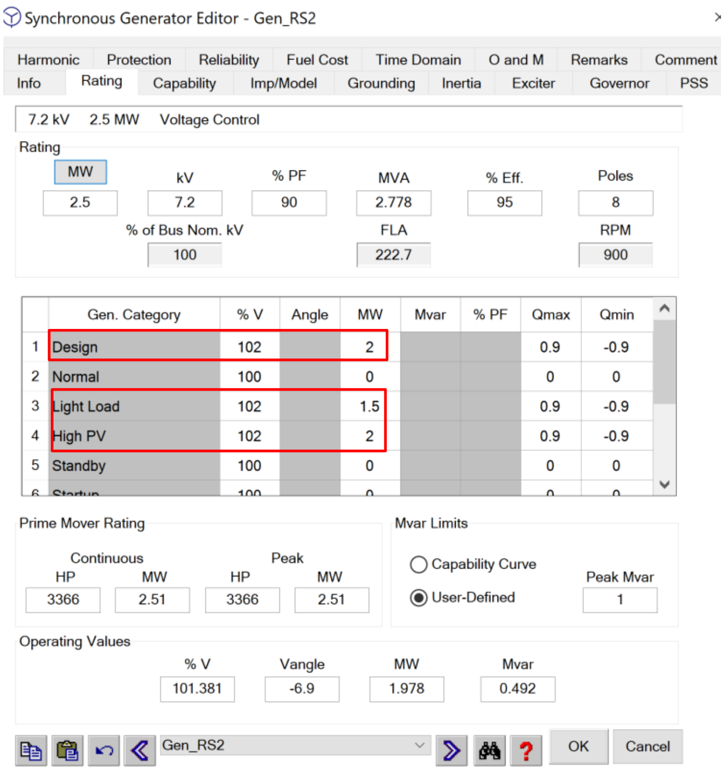


Figure 3.2: Generation categories in ETAP

The study case manager also has tabs for creating the events for different contingencies. An example setup for the event concerning loss of generator at HBPS is shown in Figure 3.3.

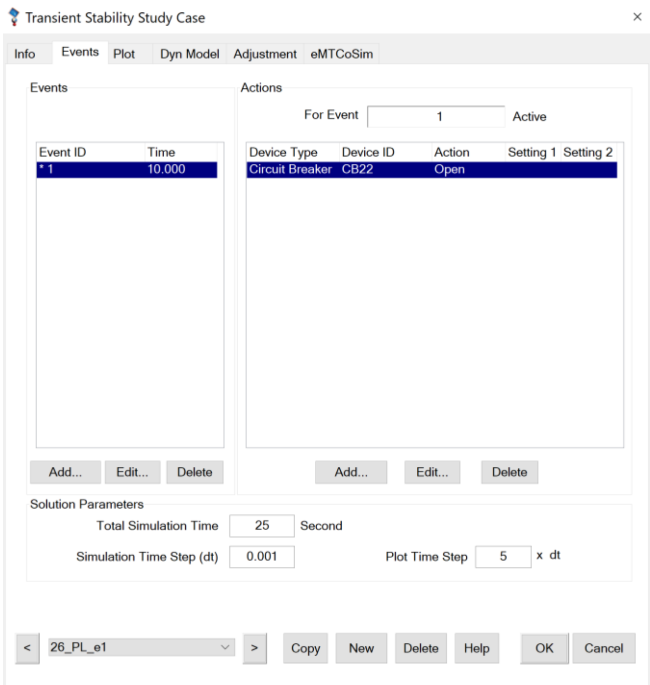


Figure 3.3: Event setup in ETAP

The study cases are defined for each contingency under consideration and for each loading case under the given yearly scenario. The naming pattern followed for transient stability study cases is: (Year)_(loading)_(event). The years are represented as 23, 26 and 30 representing the years 2023, 2026 and 2030. The loading cases are represented by abbreviations PL, LL and PV representing Peak Load, Light Load and High PV cases. The events are shown in Table 3.1.

Table 3.1: Event created in the model

Event	Description
e1	Outage of the synchronous generator with largest dispatch
e2	Outage of BESS
e3	Fault (in middle) of line and automatic clearance after 150 ms
e4	Fault (in middle) of line and clearance by disconnection of line after 150 ms

So event 1 for 2030 scenario under high PV case is named as 30_PV_e1

3.3 ETAP CONFIGURATION MANAGER

The ETAP configuration manager is used for changing the control mode of the generators (voltage control, Q control, swing) and the status of the high voltage circuit breakers. The connection status of the generators as per the dispatch between the different study cases is changed using this manager in the developed model. Each study case therefore has a unique configuration associated with it. The configurations corresponding to various revisions are listed below:

- Base case: 23_PL, 23_LL, 23_LF_PV, 23_TS_PV
- 2026: 26_PL, 26_LL, 26_LF_PV, 26_TS_PV
- 2030: 30_PL, 30_LL, 30_LF_PV, 30_TS_PV

Two separate configurations can be seen for PV cases. The second configuration (i.e. with LF_PV) has been made only for the purpose of load flow as was described in Chapter 2.3.

4 ETAP WIZARDS AND BATCH RUNNING SIMULATIONS

The section describes the usage of the wizard manager for simplifying the run process of various study cases.

4.1 SCENARIO WIZARD

The scenarios with their revisions, study cases and configuration settings are setup in the scenario wizard. The scenario wizard with the revision, configuration and study case is shown in Figure 4.1. The setup cases and plots can be recreated by running the relevant scenario as shown in Figure 4.2 in the scenario wizard.

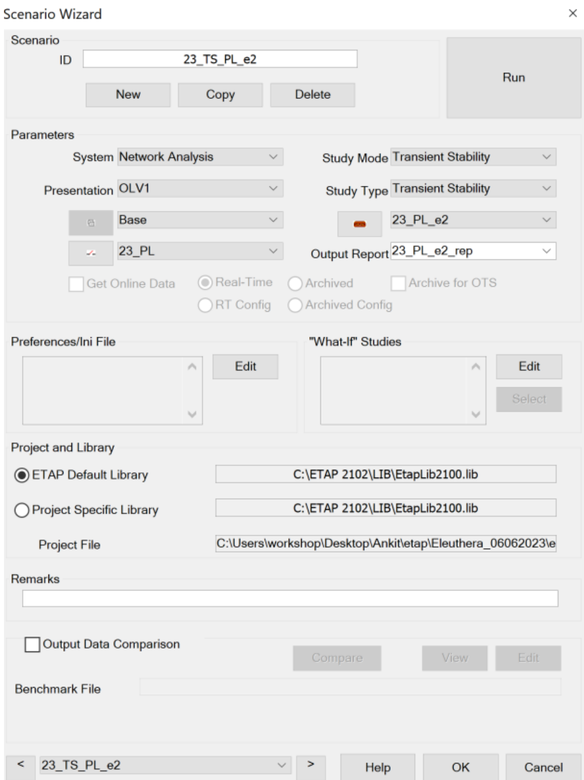


Figure 4.1: Scenario wizard in ETAP

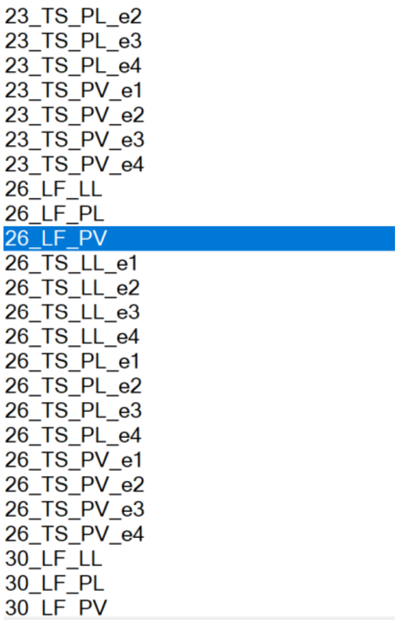


Figure 4.2: Accessible scenarios in the scenario wizard (LF: Load Flow, TS: Transient Stability)

4.2 STUDY WIZARD

The study wizard can then be used for grouping the study cases together. The load flow and transient stability study cases were grouped under the corresponding yearly cases as shown in Figure 4.3. The study macro runs all the study cases defined in it.

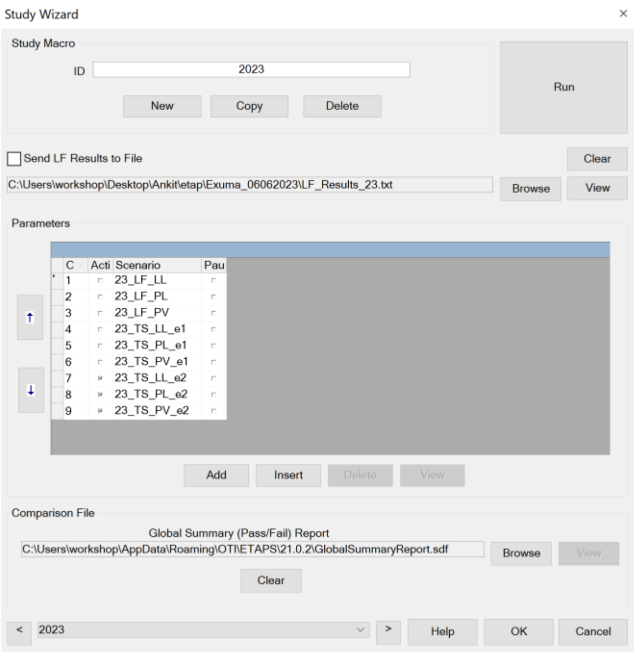


Figure 4.3: Study wizard in ETAP

ETAP also allows defining a project wizard for combining the various studies in the study wizard. This feature hasn’t been covered in this report.

The results can be viewed via the transient stability plot manager inside ETAP or by reading the SQLite database file (via Python) generated for every study case. It is also to be noted that the dynamic simulations can take upto two minutes to start depending on the amount of PVs present in the system.

5 MODEL SUMMARY

This report serves as a guideline for usage of the model. It summarizes the various dynamic models in use for the project. It also covers the organization of the different scenarios and study cases in ETAP.

The dynamic models associated with the elements are linked to the activated revision. The revision, study case and configuration setting are automatically updated once the relevant scenario is loaded in the scenario wizard. The model setup has been done to keep things as simplified as possible.

Any queries on the model can be directed back to the authors.

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