International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 16, No. 3, September 2025, pp. 1658~1672
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v16.i3.pp1658-1672

Synchronous generator system identification via dynamic simulation using PSS/E: Malaysian case

Saleh Ba-swaimi[1,2], Renuga Verayiah[1], Tan Yi Xu[1], Nagaraja Rupan Panneerchelvan[1], Aidil Azwin Zainul Abidin[1], Marayati Marsadek[1], Agileswari K. Ramasamy[1], Izham Zainal Abidin[1], W. Mohd Suhaimi Wan Jaafar[3]
[1]Institute of Power Engineering, Universiti Tenaga Nasional, Selangor, Malaysia
[2]Department of Electronic and Communications Engineering, College of Engineering and Petroleum, Hadhramout University, Mukalla, Yemen
[3]TNB Repair and Maintenance Sdn. Bhd., Petaling Jaya, Kajang, Malaysia

Article Info

Article history:

Received Feb 1, 2024
Revised May 27, 2025
Accepted Jun 3, 2025

Keywords:

Dynamic tests
Electrical energy generation
Loads rejection test
Open-circuit saturation
Synchronous generator simulation

ABSTRACT

The synchronous generator (SG) plays a crucial role in power systems by serving as a stable and reliable source of electrical energy. The performance of an SG hinges on its standard parameters, which can be derived through dynamic tests. This study introduces a method for determining the standard parameters of an SG from dynamic tests conducted via power system simulation for engineering (PSS/E). The proposed method entails conducting several key tests on the generator, including a direct-load rejection test, excitation removal test, quadrature-axis load rejection test, arbitrary axis load rejection test, and open-circuit saturation test. The results obtained from these tests are then utilized to calculate the standard parameters of the SG accurately. To validate the effectiveness of the method, simulation data from the SG, as well as the designed initial data, are utilized. Statistical analysis reveals that the maximum relative error is equal to or less than 2.7% of the design values for all standard parameters, emphasizing the robustness and accuracy of the proposed method. The methodology presented in this study can complement field or site measurements, as it enables the verification of system parameters through dynamic simulations.

Corresponding Author:

Renuga Verayiah
Institute of Power Engineering, Universiti Tenaga Nasional
IKRAM-UNITEN St., Kajang 43000, Selangor, Malaysia
Email: renuga@uniten.edu.my

1. INTRODUCTION

Electric power generation involves using various types of electric generators, each with unique characteristics and applications [1]. These include linear generators, which are often used in niche applications; induction generators, typically used in wind energy systems; and permanent magnet generators, valued for their high efficiency in renewable energy systems [2]. Among these, the synchronous generator (SG) is significant, as it efficiently converts mechanical energy into electrical energy and ensures grid stability. SGs are commonly employed in large-scale power plants, such as hydroelectric, thermal, and nuclear facilities, where they play a critical role in generating and supplying electricity to the grid.

To determine the fundamental parameters of an SG, such as field winding characteristics, leakage reactions, and magnetizing and damping winding properties, it is necessary to calculate the standard parameters first. These standard parameters include direct-axis and quadrature-axis synchronous/reactance/transient/sub-transient reactances, rotor time constants, inertia constant, and saturation factors at different flux levels.

Dynamic tests offer a means to determine these standard parameters accurately. Once obtained, mathematical relationships can be utilized to derive the fundamental parameters [3].

The proposed methods for deriving SG parameters can be categorized into two main types: standstill methods [4] and online procedures [5]. Standstill methods or offline procedures are mandatory tests conducted during generator start-up, maintenance, and service operations. These tests, such as load rejection and sudden short-circuit tests, are classified into time domain and frequency domain methods [6]. On the other hand, online procedures involve testing methods performed in real-time while the generator is in operation [7], [8].

Various methods have been proposed for modeling and parameter identification of SG, including an Unscented Kalman filter (UKF) [9], a Constrained Iterated Unscented Kalman Filter. (CIUKF) [10], [11], optimization algorithms [12], [13], maximum-likelihood estimation [14], nonlinear techniques [15], [16], neural networks [17], [18], trajectory sensitivities [19], [20], adaptive model [7], [21], frequency response [22], and load rejection dynamic tests [23], [24]. Dynamic mathematical models of SG serve as essential tools for understanding their behavior and predicting performance in different operating conditions [23]. These models play a critical role in designing, analyzing, and controlling SGs in modern power systems engineering [24], [25]. Dynamic tests are conducted on operating SG to determine standard parameters such as synchronous reactance, transient reactance, and sub-transient reactance [26]. However, there are concerns about the difficulty and practicality of extracting the necessary parameters from these tests, especially in situations where precise results are needed quickly (such as during maintenance shutdowns), using readily available tools [27], [28].

This research paper investigates the determination of SG standard parameters or system identification through dynamic simulation conducted using the industrial-grade power system simulation (PSS/E) software. The PSS/E used in this project for system identification has provided a more accurate representation of the system's behavior due to the practicality of the mathematical model. The proposed methodology in this study can complement the field or site measurement as it enables the verification of the system parameters through dynamic simulations. This study aims to prove the use of dynamic tests for accurately deriving the standard parameters of SG via system identification. It provides an overview of various dynamic tests that can be employed. It presents a case study demonstrating the utilization of dynamic tests to derive the standard parameters of an SG.

The remaining sections of this article are structured as follows: Section 2 details the methodological approach employed for modeling and validating the determination of SG standard parameters. Section 3 overviews the combined cycle power plant (CCPP), encompassing generator characteristics, selected dynamic models, and network topology. Section 4 presents the results obtained from the simulation conducted in PSS/E. In Section 5, the results obtained are thoroughly discussed and compared with results from other proposed methods. Finally, Section 6 presents the conclusions derived from this study.

2. METHOD

This section describes the methodology used to conduct the direct-load rejection test, excitation removal test, quadrature-axis load rejection test, arbitrary-axis load rejection test, and open-circuit saturation test in PSS/E.

2.1. Direct axis-load rejection test

To determine the d-axis parameters, the generator must be connected to the grid, supplying the minimum possible active power, ideally at zero, and the maximum possible reactive power. The field test results indicate that the minimum active power is 5.8 MW with a reactive power of -16.5 MVAR for the steam turbine generator (STG3) and 2.3 MW with a reactive power of -16.1 MVAR for the gas turbine generator (GTG1 & GTG2). The d-axis parameters can be determined according to Figure 1 and the (1)-(3) [29]. The following steps outline how to perform the D-axis load rejection test in PSS/E:

i) Step 1: Load the .sav case file and .sld file.
ii) Step 2: Reduce the generator load to the minimum value determined from the field test.
iii) Step 3: Solve the system to check for convergence.
iv) Step 4: Prepare the converted case:
   a) Convert generators and loads: Go to Power flow > Convert Loads and Generators.
   b) Order the network for matrix operations: Go to Power flow > Solution > Order Network for Matrix Operations.
   c) Factorize the admittance matrix: Go to Power flow > Solution > Factorize Admittance Matrix.
   d) Set up the solution for switching studies: Go to Power flow > Solution > Solution for Switching Studies.
v) Step 5: Load the dynamic file (.dyr): Go to File > Open.

vi) Step 6: Define channels for the output: Go to Dynamics > Channel Setup Wizard > ETRM.
vii) Step 7: Perform the dynamic simulation:
  (a) Define the output file and initialize the simulation: Go to Dynamics > Simulation > Perform Simulation.
  (b) Simulate pre-fault conditioning: Go to Dynamics > Simulation > Perform Simulation > 20s.
  (c) Apply the fault by opening the generator circuit breaker.
  (d) Simulate the fault duration: Go to Dynamics > Simulation > Perform Simulation > 60s.
viii) Step 8: Plot the output file to analyze the results: Go to File > Open.

$$X_d = \frac{C}{I_\circ} \quad (1)$$

$$X_d' = \frac{B}{I_\circ} \quad (2)$$

$$X_d'' = \frac{A}{I_\circ} \quad (3)$$

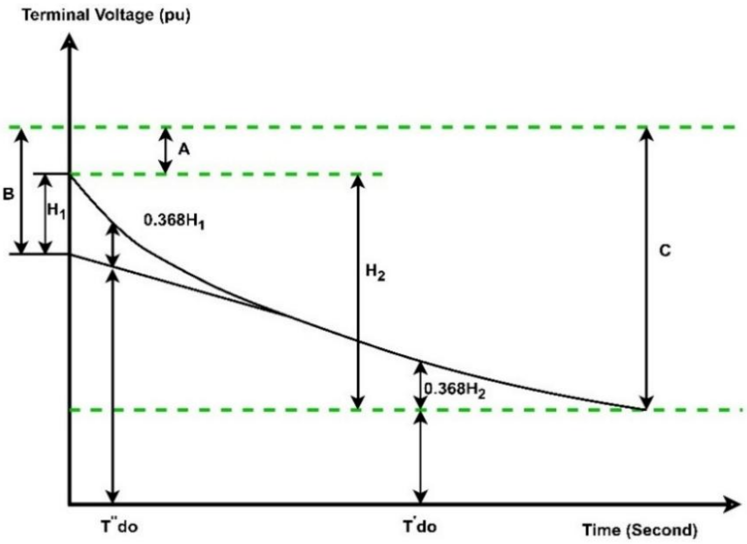

Figure 1. Typical transient response of generator terminal voltage in direct-axis test

2.2. Quadrature-axis load rejection test

To conduct the q-axis load rejection test, follow the same procedures outlined in the d-axis load rejection test, with one key modification in Step 2. Instead of adjusting the generator load to the minimum value, the load must be adjusted until the rotor angle is 90 degrees away from the reference point obtained during the direct-axis test. This ensures proper alignment for the q-axis analysis. The determination of the d-axis parameters can then be performed based on Figure 1 and (4)-(6) [29].

$$X_q = \frac{\sqrt{A^2-C^2}}{I_\circ} \quad (4)$$

$$X_q'' = \frac{\sqrt{A^2-C^2}-\sqrt{A^2-B^2}}{I_\circ} \quad (5)$$

$$X_d'' = \frac{A}{I_\circ} \quad (6)$$

Where: $I_\circ$ is the interrupted current

2.3. Arbitrary axis load rejection test

The arbitrary axis load rejection test follows the same procedures as described in the d-axis load rejection test, with two modifications. In Step 2, instead of adjusting the generator load to the minimum value, it must be reduced to 18 MW. In step 6, the output for channel setup should be the speed (SPD) rather than the terminal voltage (ETRM). The inertia time constant (H) can be determined based on Figure 2 and (7).

$$H = \frac{P_{\circ} \times F_{\circ}}{2 \times \frac{df}{dt} \times MVA_{base}} \tag{7}$$

Where: $\frac{df}{dt}$: Initial slope, $F_{\circ}$: Base frequency, $P_{\circ}$: load rejection

2.4. Open circuit saturation test

To perform the open-circuit saturation test, it follows the same procedures outlined in the d-axis load rejection test, with two modifications. In Step 2, the generator circuit breaker should be set to open instead of adjusting the generator load. In Step 7(c), instead of applying a fault, it should be set to increase the exciter current in steps of 0.1 per unit (pu) until the maximum allowable terminal voltage is reached. The d-axis parameters can be determined based on Figure 3 and (8) and (9).

$$S_{1.0} = \frac{B-C}{A-B} \tag{8}$$

$$S_{1.2} = \frac{E-F}{D-E} \tag{9}$$

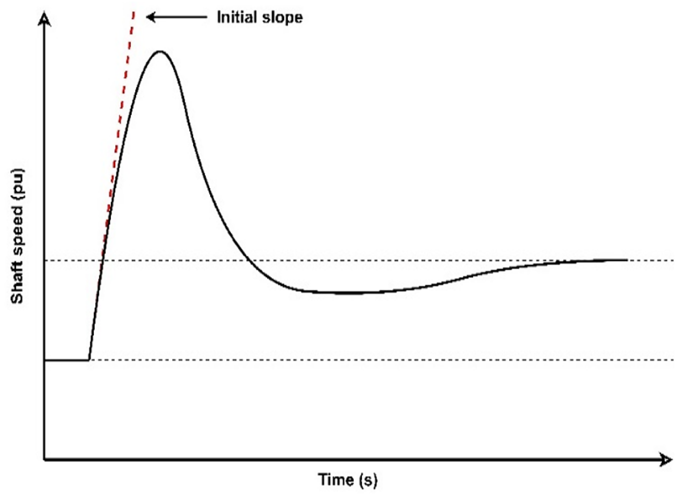

Figure 2. Derivation of the inertia time constant

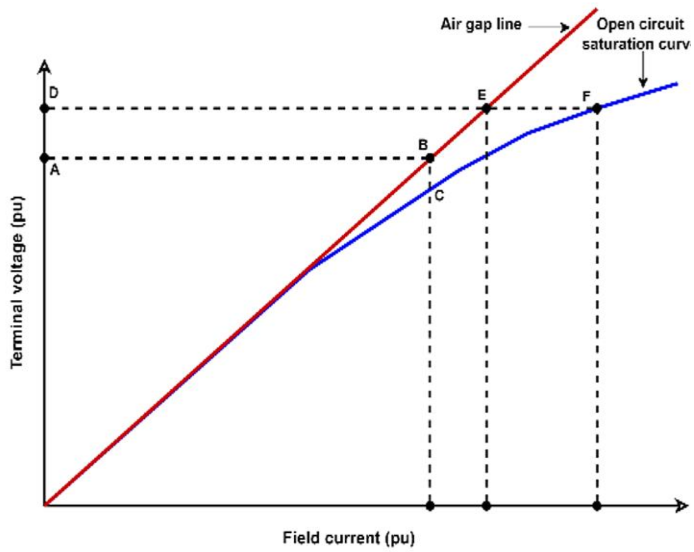

Figure 3. Typical open-circuit saturation curve

2.5. Excitation removal test
The excitation removal test follows the same procedures as the d-axis load rejection test, with two essential modifications. In Step 2, the generator circuit breaker is set to open instead of adjusting the generator load. In Step 7(c), the exciter field circuit breaker is opened rather than applying a fault or manipulating exciter currents. These adjustments allow for the proper execution of the excitation removal test.

3. CASE STUDY
The simulation results presented in this study are based on a modified CCPP in Malaysia as a representative case study. The plant configuration includes two gas turbine units (GTG1 and GTG2) and one steam turbine unit (STG3), as depicted in Figure 4. These components are interconnected to form a single power generation block within the plant. The SG generator ratings for each unit are as follows: i) The steam turbine unit (STG3) is rated at 146.25 MVA, operates at 13.8 kV, and has a power factor of 0.8. It is driven by a steam turbine with a nameplate rating of 117 MW. ii) The gas turbine units (GTG1 and GTG2) are both rated at 134.625 MVA, operate at 15 kV, and have a power factor of 0.8. They are driven by either natural gas or distillate oil-fired turbines.

The electromagnetic model of the round rotor generator (GENROU) was employed to accurately represent the gas and steam unit generators, as recommended by [30]. GENROU is a well-established mathematical model specifically designed to simulate the performance of round rotor generators, which are SGs featuring a circular rotor. By leveraging the principles of electromagnetism, this model enables the prediction of the generator's behavior across varying operating conditions, including different load and excitation levels [31]. The utilization of the GENROU model has become prevalent in the design and analysis of round rotor generators, providing valuable insights into their performance characteristics under diverse operating conditions. For a comprehensive understanding of the GENROU model, including saturation effects, the block diagram representation can be referred to in [32].

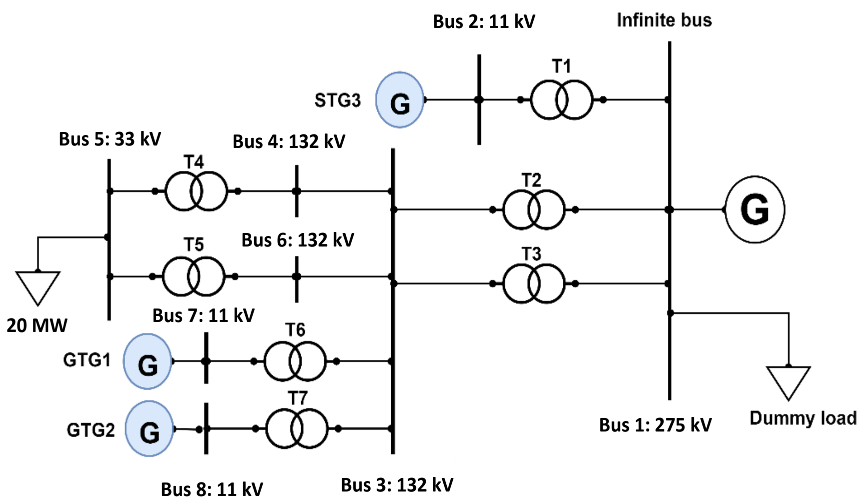

Figure 4. CCPP single-line diagram

4. RESULTS AND DISCUSSIONS
4.1. RESULT
The results of GTG1 and GTG2 are presented as one group because they share the same system design. However, the STG3 is presented separately due to its distinct design and operational conditions, which differ from those of GTG1 and GTG2. This separation allows for a comprehensive analysis of the performance and characteristics of each turbine type, considering their specific attributes and requirements. The amplification of plots is employed in the PSS/E environment to enhance the accuracy of readings and observations. By amplifying the plots, finer details and subtle variations in the data can be magnified and analyzed with greater precision.

4.1.1. Excitation removal test
The excitation removal test is conducted to validate the generator's direct-axis transient open-circuit time constant (T'_{do}) used in the simulation. In this test, the generator operates at full speed with no load, and

the unit circuit breaker is open. The exciter field circuit breaker is then opened, and the resulting generator terminal voltage is recorded. Based on Figures 5 and 6, (GTG1 and GTG2), which present the generator terminal voltage during the excitation removal test, the value of T_do^' for STG3 and the gas units is calculated as follows:

$$H_2 = 1.05, 0.368H_2 = 0.3864, T_{do}^{'} = 11.9 \text{ second (GTG3)}$$

$$H_2 = 1.05, 0.368H_2 = 0.3864, T_{d}^{'} = 9 \text{ Second (GTG1 and GTG2)}$$

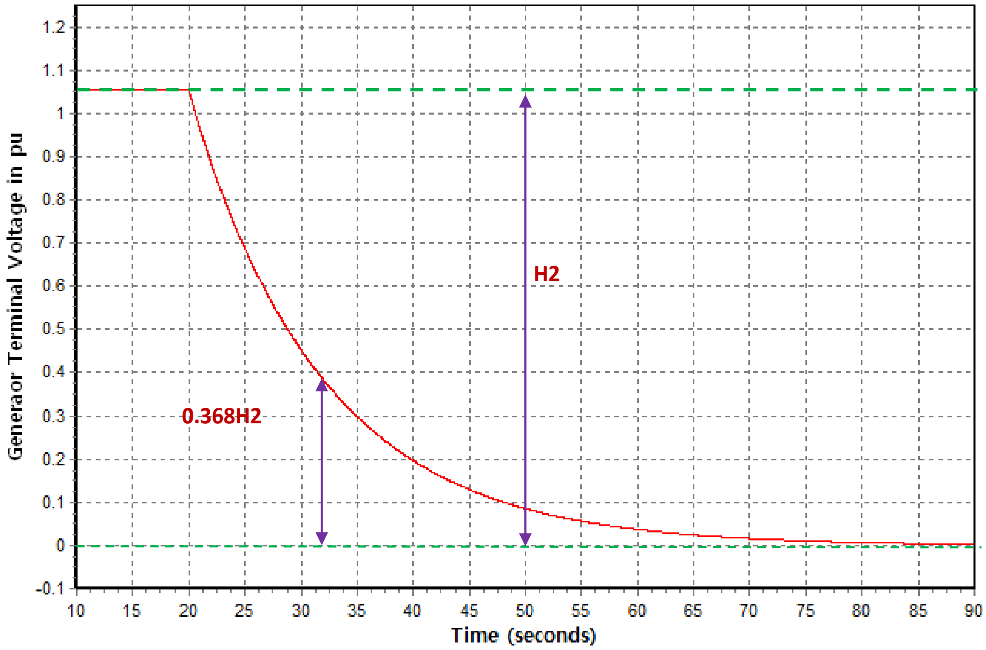

Figure 5. Generator terminal voltage in excitation removal test for STG3

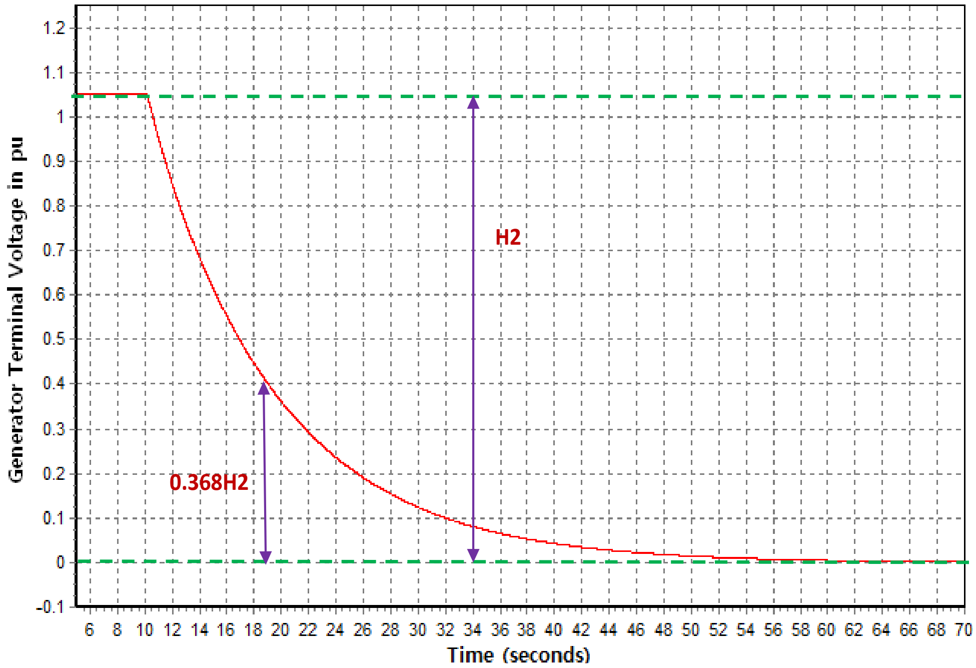

Figure 6. Generator terminal voltage in excitation removal test for GTG1 and GTG2

4.1.2. Direct-axis parameters test

The objective of the d-axis test is to validate the generator's direct-axis parameters used in the simulation, which include the synchronous, transient, and sub-transient reactances ($X_d, X_d^{'}, X_d^{''}$), as well as the transient and sub-transient time constants ($T_{do}^{'}, T_{do}^{''}$). In this test, the generator's load was reduced to the minimum possible value based on the field test results. The circuit breaker was opened, and terminal voltage values were recorded to validate the model. During the test, the generator operated at a load of 5.8 MW/-16.5 MVAR for STG3 and 2.3 MW/-16.1 MVAR for GTG1 & GTG2. The direct-axis parameters for steam and gas units can be calculated based on the generator terminal voltage depicted in Figures 7 and 8, along with (1)-(3), as :

$$A = 0.026, B = 0.03, C = 0.195, H_1 = 0.01, H_2 = 0.114, 0.368H_1 = 0.004$$

$$0.368H_2 = 0.042, T_d^{"} = 0.04\text{Second}, I_{\circ} = 0.12\text{pu}$$

$$X_d = 1.625\text{pu},\ X_d^{'} = 0.25\text{pu}, X_d^{"} = 0.216\text{pu} \quad \text{(STG3)}$$

$$A = 0.0125, B = 0.017, C = 0.133, H_1 = 0.01, H_2 = 0.132$$

$$0.368H_1 = 0.004, 0.368H_2 = 0.05, T_d^{"} = 0.05 \text{ second}, I_{\circ} = 0.076$$

$$X_d = 2.1\text{pu},\ X_d^{'} = 0.22\text{pu}, X_d^{"} = 0.1644\text{pu} \quad \text{(GTG1 and GTG2)}$$

4.1.3. Arbitrary axis load rejection test

The objective of the partial load rejection test is to validate the generator's inertia time constant by observing the initial increase in generator speed during load rejection. In this test, the generator operated at a partial load of 18 MW for GTG1 and GTG2 and 39.2 MW for STG3 when the test was conducted. The D-axis parameters for both the steam and gas units can be calculated based on the generator terminal voltage, shown in Figures 9 and 10. These calculations are performed using (7) as i) $H = 6.686$, where: $F_{\circ} = 50\ Hz, P_{\circ} = 18\ MW, MVA_{base} = 134.60\ MVA, \frac{df}{dt} = 0.5$ (GTG1 and GTG2); and ii) $H = 4.497$, where: $F_{\circ} = 50\ Hz, P_{\circ} = 39.2\ MW,\ MVA_{base} = 146.25\ MVA, \frac{df}{dt} = 1.49$ (STG3).

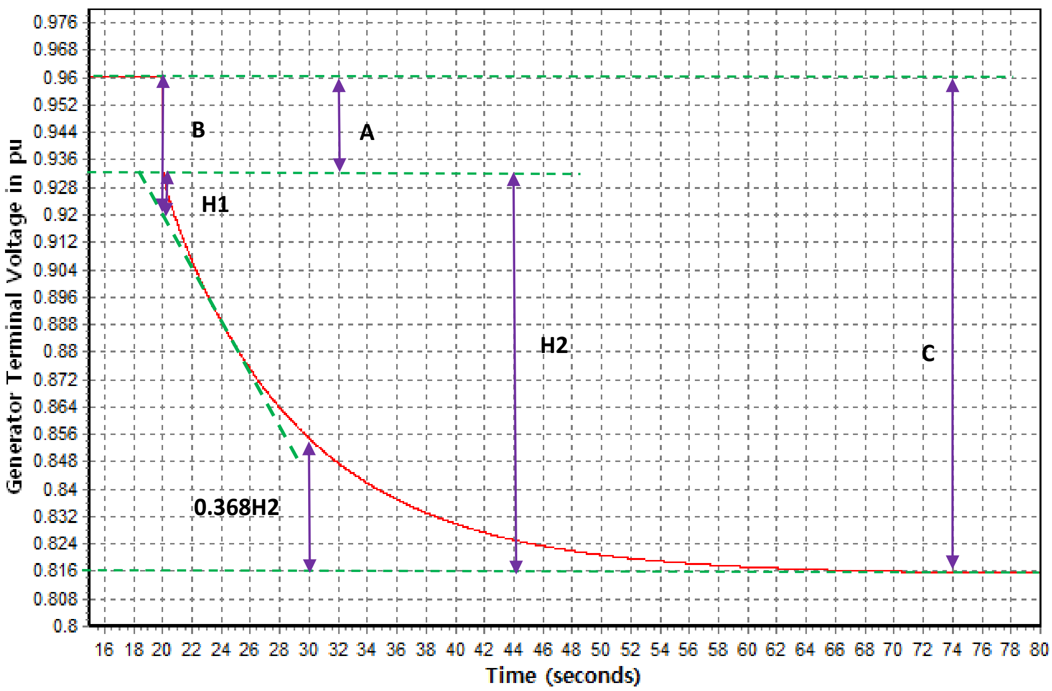

Figure 7. Generator terminal voltage in direct-axis test for STG3

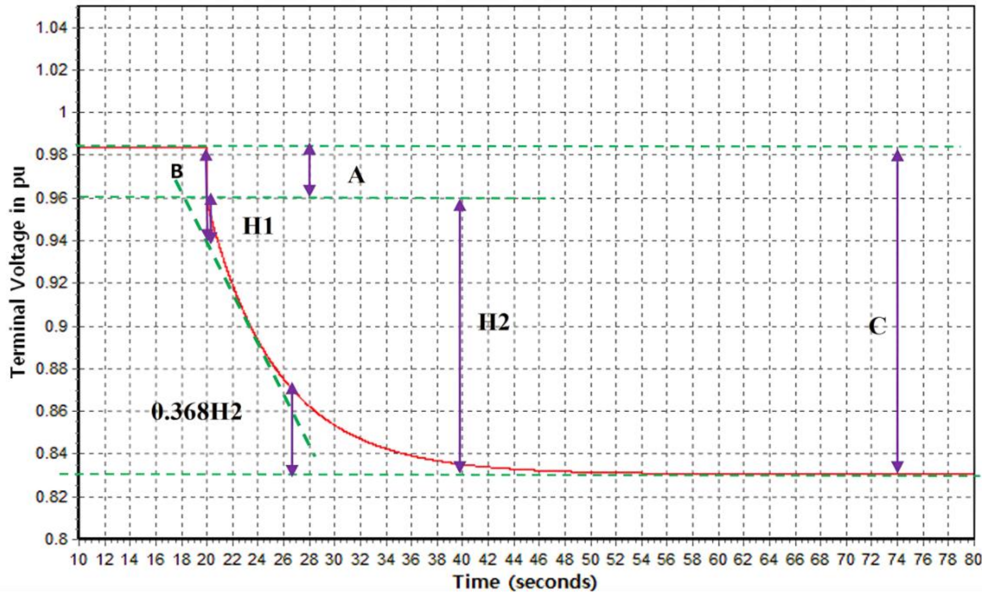

Figure 8. Generator terminal voltage in direct-axis test for GTG1 and GTG2

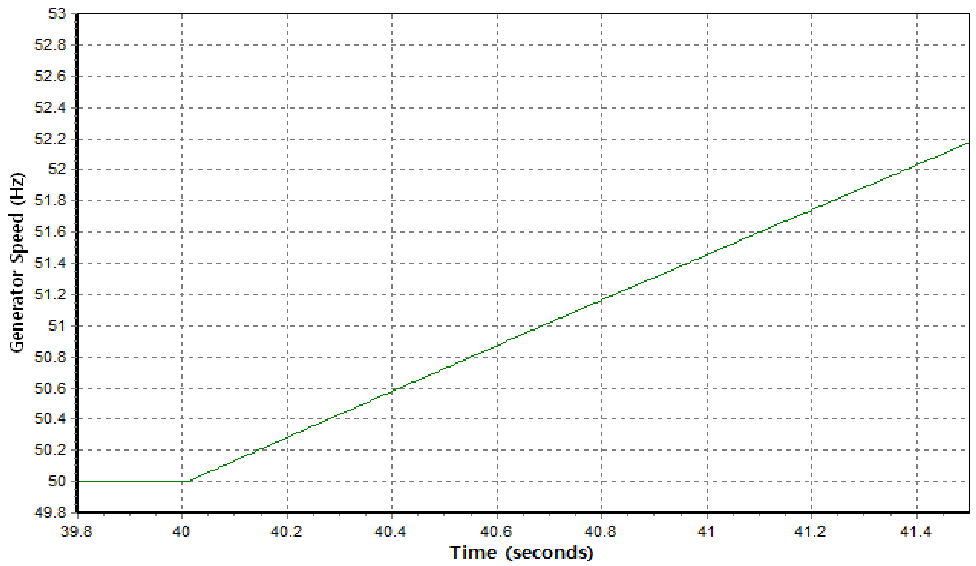

Figure 9. Generator initial speed increase in 39.2 MW load rejection test for STG3

4.1.4. Quadrature-axis parameters test

The objective of the partial load rejection test is to validate the generator's quadrature-axis parameters used in the simulation, which include the synchronous and transient reactances ($X_q, X_q^{''}$), as well as the transient and sub-transient time constants ($T_{qo}^{'}, T_{qo}^{''}$). During this test, the generator load is adjusted until the rotor angle is 90 degrees away from the reference point obtained during the direct-axis test. The circuit breaker is opened, and terminal voltage values are recorded to validate the model. The rotor angle for the turbine was 90 degrees away from the reference point taken at the direct axis when the test was conducted, and the generator terminal voltage for the steam unit is shown in Figure 11 and for gas units in Figure 12. Using (4)-(6), the turbine Q-axis parameters are calculated as follows:

$A = 0.97875, B = 0.96675, C = 0.92, T_q' = 3$ sec., $T_q'' = 0.15$ sec., $I_o = 0.22$ pu
$X_q'' = 0.91$pu(STG3)
$A = 1.027, B = 0.9954, C = 0.965, T_q'$, 1.3second, $T_q'' = 0.075$second, $I_o = 0.22$ pu
$X_q'' = 0.448$ pu (GTG1 and GTG2)

4.1.5. Open-circuit saturation test

The open-circuit saturation test aims to validate the generator's saturation factors used in the simulation. The generator operates at full speed with no load during this test, and the unit circuit breaker is open. The exciter current varies in steps until the possible maximum terminal voltage value is recorded. This test can verify the accuracy and reliability of the saturation factors used in the simulation. By utilizing the results of the open-circuit saturation test, it becomes possible to calculate the generator saturation factors. Figures 13 and 14 depict the data points required to determine the $S_{1.0}$ and $S_{1.2}$ values specifically for the steam and gas turbine generating units, represented by small circles. Using (8) and (9), the saturation factors for STG3 and gas units (GTG1 and GTG3) can be determined as follows:

$$C = 1.375, B = 1.26, A = 0, D = 0, F = 1.9, E = 1.50$$

$$S_{1.0} = 0.09, S_{1.2} = 0.266 \text{ (STG3)}$$

$$C = 1.136, B = 0.976, A = 0, D = 0, F = 1.696, E = 1.2$$

$$S_{1.0} = 0.17$$

$$S_{1.2} = 0.4 \text{ (GTG1 and GTG2)}$$

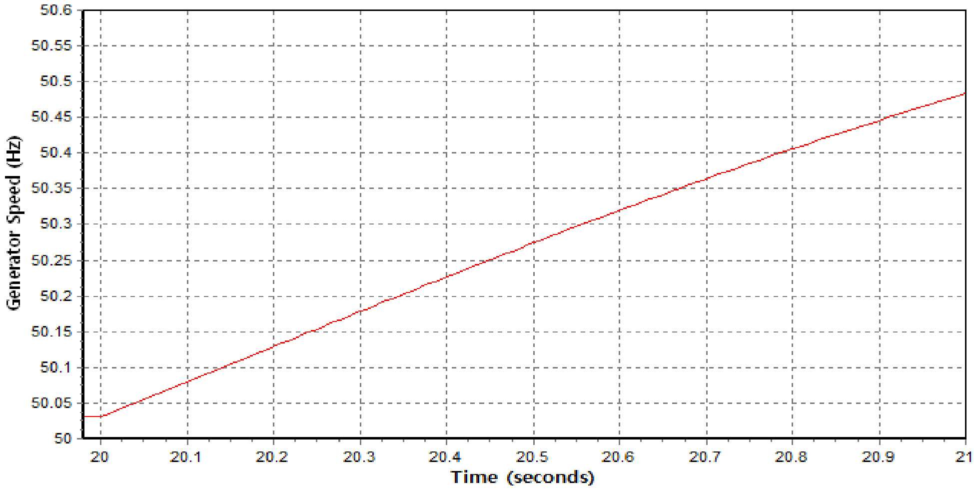

Figure 10. Generator initial speed increase in the 18 MW load rejection test for GTG1 and GTG2

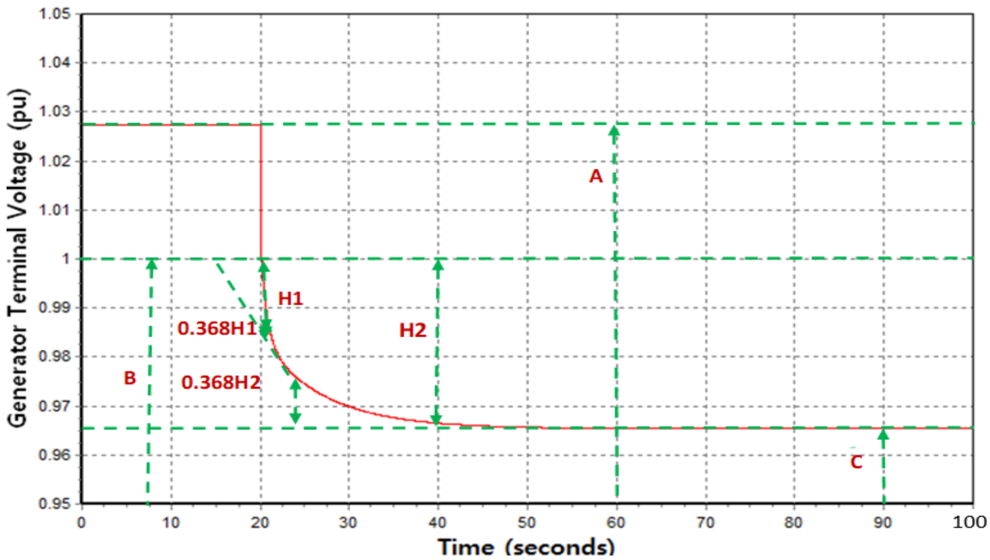

Figure 11. Generator terminal voltage in q-axis test for STG3

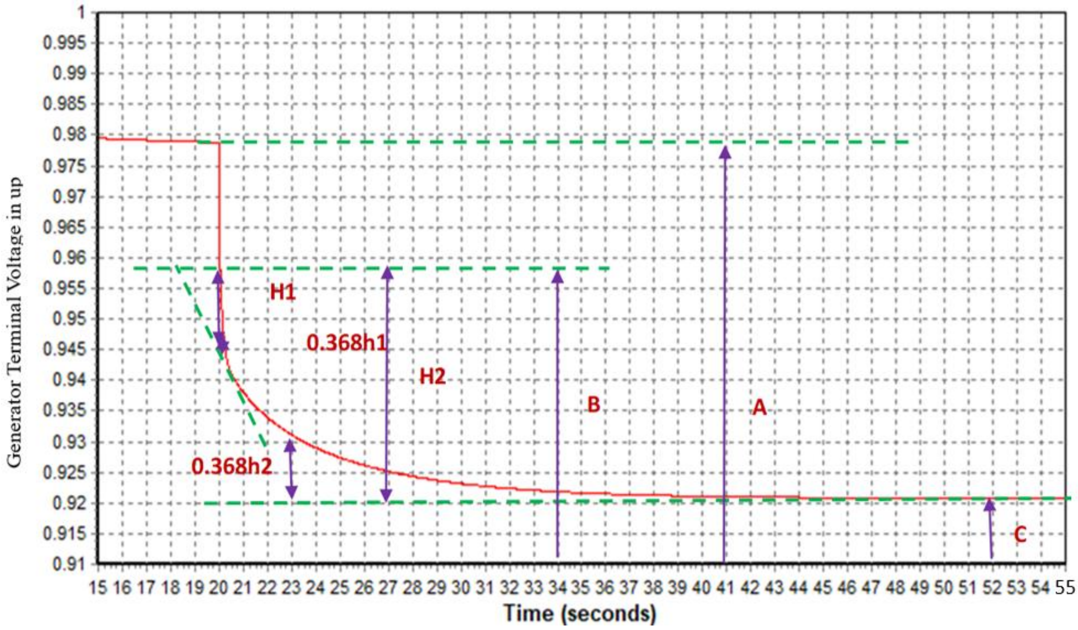

Figure 12. Generator terminal voltage in q-axis test for STG3

4.2. Discussion

The obtained results, as shown in Table 1, demonstrate the effectiveness of the proposed method for deriving standard parameters of an SG using dynamic measurements. The dynamic tests conducted in PSS/E for this study showed that the proposed method resulted in more accurate standard parameter values than the other methods. The maximum error obtained using the proposed method was 2.7%, while the maximum error obtained using other simulation software or other methods was 5% [29], 5% [26], 5.8% [33], 4.15% [12], 7.25% [7], and 4.8% [19]. This indicates that the proposed method has the potential to significantly improve the accuracy of SG standard parameter derivation.

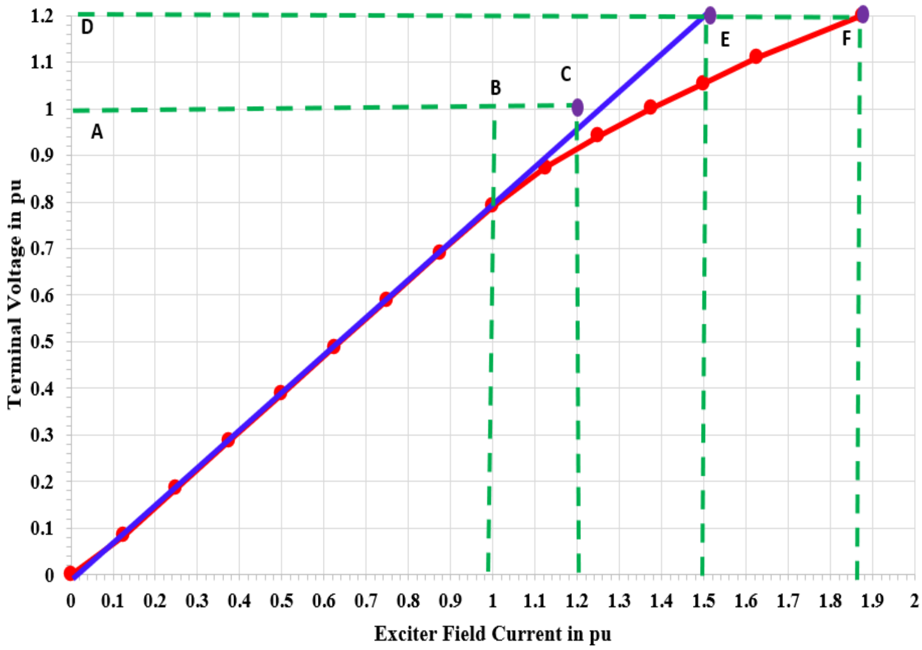

Figure 13. Open-circuit characteristic (OCC) test plot for STG3

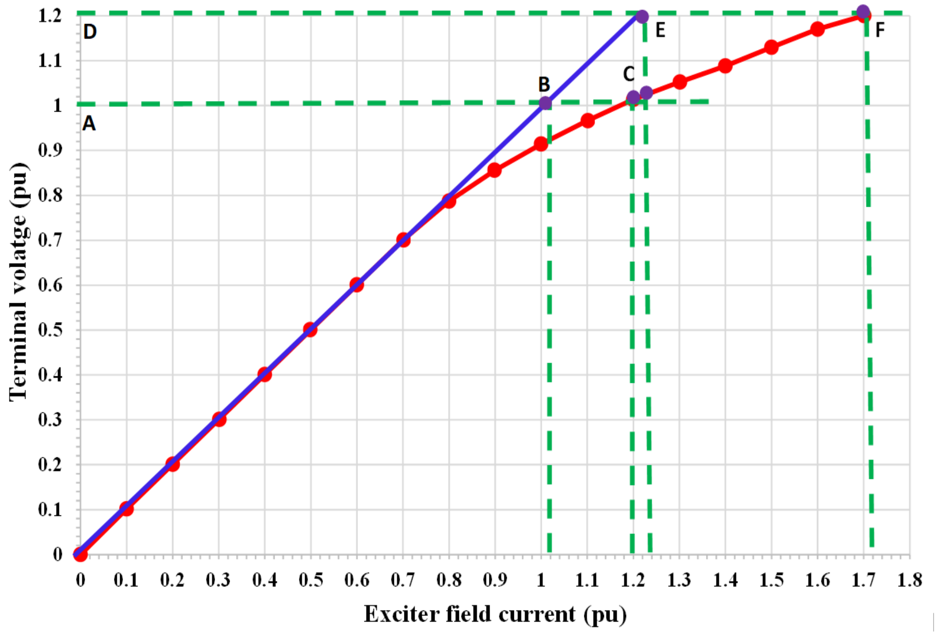

Figure 14. Open-circuit characteristic (OCC) test plot for GTG1 and GTG3

Table 1. Obtained values versus designed values of synchronous generator standard parameters

Unit	Gas units			Steam unit		
Variable	Obtained values	Original values	Relative error	Obtained values	Original values	Relative error
X_d	2.1	2.1	0.00%	1.625	1.63	0.50%
X'_d	0.22	0.218	0.90%	0.25	0.251	0.10%
X''_d	0.1644	0.162	1.50%	0.216	0.215	0.10%
T'_d	9	9	0.00%	11.9	11.9	0.00%
T''_d	0.05	0.05	0.00%	0.04	0.04	0.00%
X_q	1.5	1.5	0.00%	1.59	1.6175	2.70%
X''_q	0.91	0.9	1.10%	0.448	0.4503	0.20%
T'_q	3	3	0.00%	1.3	1.32	2.00%
T''_q	0.15	0.15	0.00%	0.075	0.077	0.20%
H	6.686	6.77	1.20%	4.497	4.5	0.30%
$S_{1.0}$	0.17	0.17	0.00%	0.09	0.09	0.00%
$S_{1.2}$	0.4	0.4	0.00%	0.266	0.27	0.40%

5. CONCLUSION

The study introduced a method for deriving the standard parameters of an SG, including steam and gas units, through dynamic tests conducted using PSS/E. The standard parameters include inludes X_d, X'_d, X''_d, T'_d, T''_d, X_q, X''_q, T'_q, T''_q, H, $S_{1.0}$ and $S_{1.2}$ are determined through various dynamic tests, including direct-load rejection, excitation removal, quadrature-axis load rejection, arbitrary-axis load rejection, and open-circuit saturation tests. Data collected from the field are utilized to verify the results obtained from these dynamic tests. Statistical analysis reveals that the maximum error relative to the true values is 2.7% or less of the design values for all standard parameters, indicating a high level of accuracy that reinforces the reliability and practicality of the proposed method. Furthermore, the strong agreement between simulation outcomes and design parameters suggests that simulation results can serve as a valuable reference for conducting dynamic tests in real-world scenarios. Future work will incorporate exciters, governors, and stabilizers into the model to assess the system's stability through dynamic tests.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation for the financial support that was provided by the Bold Grant 2022 (Project Code J510050002/2022003, 202205001ETG), UNITEN-ITPLN International Community Grant 2023 (Project Code 20230002ITPLN), and REMACO for supporting the research facilities, which made this research project a success. The authors would like to acknowledge Dr. Tasdik

Darmana and Dr. Rizki Pratama Putra for their facilitation and collaboration in achieving the UNITEN–ITPLN International Community Grant 2023.

FUNDING INFORMATION

This research was funded through the Bold Grant 2022 under Project Code J510050002/2022003, 202205001ETG. The grant provided financial support in the form of a Graduate Research Assistantship (GRA) to carry out this study.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Saleh Ba-swaimi	✓	✓	✓	✓	✓	✓		✓	✓				✓	
Renuga Verayiah		✓				✓	✓	✓	✓		✓	✓		
Tan Yi Xu	✓		✓	✓					✓		✓		✓	
Nagaraja Rupan Panneerchelvan		✓	✓							✓				
Aidil Azwin Zainul Abidin	✓						✓			✓		✓		✓
Marayati Marsadek		✓			✓					✓		✓		
Agileswari K. Ramasamy		✓			✓					✓		✓		
Izham Zainal Abidin	✓						✓			✓			✓	
W. Mohd Suhaimi Wan Jaafar		✓					✓	✓		✓				✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [RV]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

REFERENCES

[1] A. K. Alahmad, R. Verayiah, S. Ba-swaimi, H. Shareef, A. Ramasam, and A. Abu-rayash, "Optimized two-stage planning model for integrating compressed air energy storage with uncertain correlated wind farms in power systems," *Energy Conversion and Management: X*, vol. 25, no. October 2024, p. 100838, 2025, doi: 10.1016/j.ecmx.2024.100838.

[2] L. Aththanayake, N. Hosseinzadeh, A. Gargoom, and H. Haes, "Power system reduction techniques for planning and stability studies: A review," *Electric Power Systems Research*, vol. 227, no. PA, p. 109917, 2024, doi: 10.1016/j.epsr.2023.109917.

[3] K. Subramanya and T. Raj, "Capability of synchronous and asynchronous hydropower generating systems: A comprehensive study," *Renewable and Sustainable Energy Reviews*, vol. 188, no. October, p. 113863, 2023, doi: 10.1016/j.rser.2023.113863.

[4] C. Hernandez, M. A. Arjona, and S. Member, "Parameter estimation of a synchronous-generator two-axis model based on the standstill chirp test," *IEEE Transactions on Energy Conversion*, vol. 28, no. 1, pp. 44–51, 2013.

[5] J. K. Hwang, S. Yoon, and K. Lee, "Comparison of the accuracy of generator dynamic state estimation based on the treatment of the governor-turbine mechanical power," *IEEE Access*, vol. 12, no. July, pp. 105187–105200, 2024, doi: 10.1109/ACCESS.2024.3435354.

[6] A. Arastou, W. Original, M. Karrari, W. Review, and B. Zaker, "New method for synchronous generator parameters estimation using load rejection tests data considering operational limitations," *Electric Power Systems Research*, vol. 192, no. October 2020, p. 106999, 2021, doi: 10.1016/j.epsr.2020.106999.

[7] M. Senyuk, S. Beryozkina, A. Berdin, A. Moiseichenkov, M. Safaraliev, and I. Zicmane, “Testing of an adaptive algorithm for estimating the parameters of a synchronous generator based on the approximation of electrical state time series,” *Mathematics*, vol. 10, no. 22, pp. 1-18, 2022, doi: 10.3390/math10224187.

[8] S. Ba-swaimi, R. Verayiah, V. K. Ramachandaramurthy, A. K. AL Ahmad, and S. Padmanaban, “Two-stage strategic optimal planning of distributed generators and energy storage systems considering demand response program and network reconfiguration,” *Energy Conversion and Management: X*, vol. 24, no. October, p. 100766, 2024, doi: 10.1016/j.ecmx.2024.100766.

[9] U. K. Filtering and R. S. Blum, “Data-driven dynamic state estimation of synchronous generators via sparsity promoting,” *2024 12th International Conference on Smart Grid (icSmartGrid)*, pp. 558–563, 2024, doi: 10.1109/icSmartGrid61824.2024.10578250.

[10] A. Rouhani, I. S. Member, and A. Abur, “Constrained iterated unscented Kalman filter for dynamic state and parameter estimation,” *IEEE Transactions on Power Systems*, vol. 8950, no. c, pp. 1–11, 2017, doi: 10.1109/TPWRS.2017.2764005.

[11] K. K. Challa and G. Gurrala, “Dynamic state and parameter estimation of synchronous generator from digital relay records,” *Electric Power Systems Research*, vol. 189, no. October 2019, p. 106743, 2020, doi: 10.1016/j.epsr.2020.106743.

[12] B. Zaker, G. B. Gharehpetian, M. Karrari, and N. Moaddabi, “Simultaneous parameter identification of synchronous generator and excitation system using online measurements,” *IEEE Transactions on Smart Grid*, vol 7, no 3, pp. 1230-1238, 2015, doi: 10.1109/TSG.2015.2478971.

[13] P. V. V Silva, E. C. Bortoni, and E. J. J. Rocha, “Identification of synchronous machines parameters using genetic algorithm and load rejection test,” *IEEE Power & Energy Society General Meeting*, 2017, doi: 10.1109/PESGM.2017.8274095.

[14] R.Wamkeue, I. Kamwa, X. Dai-Do, andA. Keyhani, “Iteratively reweighted least squares for maximum likelihood identification of synchronous machine parameters from on-line tests,” *IEEE Transactions on Energy Conversion*, vol. 14, no. 2, pp. 159–166, 1999.

[15] R. D. Fard, M. Karrari, O. P. Malik, and L. Fellow, “Synchronous generator model identification for control application using volterra series,” *IEEE Transactions on Energy Conversion*, vol. 20, no. 4, pp. 852–858, 2005, doi: 0.1109/TEC.2005.847997.

[16] M. Dehghani and S. K. Y. Nikravesh, “Nonlinear state space model identification of synchronous generators,” *Electric Power Systems Research*, vol. 78, pp. 926–940, 2008, doi: 10.1016/j.epsr.2007.07.001.

[17] Y. L. Mohammad and A. Abido, “On-line identification of synchronous machines using radial basis function neural networks,” *IEEE Transactions on Power Systems*, vol. 12, no. 4, pp. 1500–1506, 1997, doi: 10.1109/59.627848.

[18] P. Shamsollahi and P. Malik, “On-line identification of synchronous generator using neural networks,” *Proceedings of 1996 Canadian Conference on Electrical and Computer Engineering*, 1996, pp. 595–598, doi: 10.1109/CCECE.1996.548223.

[19] E. Pablo, T. Cari, and C. Alberto, “Parameter estimation of synchronous generators from different types of disturbances,” *IEEE Power and Energy Society General Meeting*, no. 1, pp. 1–7, 2011, doi: 10.1109/PES.2011.6039592.

[20] E. L. Geraldi, T. C. C. Fernandes, A. B. Piardi, A. P. Grilo, and R. A. Ramos, “Parameter estimation of a synchronous generator model under unbalanced operating conditions,” *Electric Power Systems Research*, vol. 187, 2020, doi: 10.1016/j.epsr.2020.106487.

[21] A. N. Moiseichenkov, P. Y. Kovalenko, M. D. Senyuk, and V. I. Mukhin, “Synchronous machine adaptive model for power system emergency control and technical state diagnostic,” *Ural Smart Energy Conference (USEC)*, 2020, doi: 10.1109/USEC50097.2020.9281185.

[22] S. Bogarra, A. Garcia, M. Moreno-eguilaz, and J. Riba, “Detailed off-line parameter identification of Synchronous generator based on frequency response tests,” *2018 IEEE 18th International Power Electronics and Motion Control Conference (PEMC)*, pp. 906–911, 2018.

[23] C. Bortoni and J.A. Jardini, “Identification of synchronous machine parameters using load rejection test data,” I*EEE Transactions on Energy Conversion*, vol. 17, no. 2, pp. 242–247, 2002, doi: 10.1109/TEC.2002.1009475.

[24] G. Valverde *et al.*, “Nonlinear estimation of synchronous machine parameters using operating data,” *IEEE Transactions on Energy Conversion*, vol. 26, no. 3, pp. 831–839, 2011, doi: 10.1109/TEC.2011.2141136.

[25] S. Ba-swaimi, R. Verayiah, V. K. Ramachandaramurthy, and A. K. ALAhmad, “Long-term optimal planning of distributed generations and battery energy storage systems towards high integration of green energy considering uncertainty and demand response program,” *Journal of Energy Storage*, vol. 100, p. 113562, Oct. 2024, doi: 10.1016/j.est.2024.113562.

[26] J. C. P. Suni, E. Ruppert, and F. Fajoni, “On the synchronous generator parameters determination using dynamic simulations based on IEEE standards,” *The XIX International Conference on Electrical Machines - ICEM 2010*, 2010, doi: 10.1109/ICIT.2010.5472769.

[27] D. Tiomo, E. Y. Kenfack, and R. Wamkeue, “Dynamic study and analysis of synchronous generator under sudden short circuit and load rejection tests,” *2019 IEEE/IAS 55th Industrial and Commercial Power Systems Technical Conference (I&CPS)*, pp. 1–5, 2019.

[28] A. K. AL Ahmad, R. Verayiah, H. Shareef, A. Ramasamy, and S. Ba-swaimi, “Optimizing renewable energy and green technologies in distribution systems through stochastic planning of distributed energy resources,” *Energy Conversion and Management: X*, vol. 25, no. September 2024, p. 100834, 2025, doi: 10.1016/j.ecmx.2024.100834.

[29] F. P. De Mello and J.R. Ribeiro, “Derivation of synchronous machine parameters from tests,” IEEE Transactions on Power Apparatus and Systems, 1976, doi: 10.1109/T-PAS.1977.32443

[30] T. Xu, A. B. Birchfield, S. Member, and T. J. Overbye, “Modeling, tuning, and validating system dynamics in synthetic electric grids,” *IEEE Transactions on Power Systems*, vol. 33, no. 6, pp. 6501–6509, 2018, doi: 10.1109/TPWRS.2018.2823702.

[31] S. Talpur, “Testing and model validation of round rotor synchronous generator,” *Renewable and Sustainable Energy Reviews*, vol. 80, no. April, pp. 880–887, 2017, doi: 10.1016/j.rser.2017.05.244.

[32] T. Xu, A. B. Birchfield, K. S. Shetye, and T. J. Overbye, “Creation of synthetic electric grid models for transient stability studies,” *The 10th Bulk Power Systems Dynamics and Control Symposium (IREP 2017)*, no. Irep, pp. 1–6, 2017.

[33] G. G. Rodríguez, A. Silveira, and N. Zeni, “Identification of synchronous machine parameters from field flashing and load rejection tests with field voltage variations,” *Electric Power Systems Research*, 2016, doi: 10.1016/j.epsr.2016.08.025.

BIOGRAPHIES OF AUTHORS

Saleh Ba-swaimi was born in Hadhramout, Yemen, in 1991. He received his B.Sc. degree in Electronic and Communication Engineering from Hadhramout University, College of Engineering, Yemen, in 2015, and completed his M.Sc. in Electrical Engineering (Power Systems) at Universiti Tenaga Nasional (UNITEN), Selangor, Malaysia, in 2021. He is currently a Ph.D. candidate in Electrical Engineering (Power Systems) at UNITEN. His research focuses on power quality, as well as the optimal planning and operation of renewable energy systems (RES). He can be contacted at email: stb.eng.20@gmail.com.

Renuga Verayiah received her Bachelor of Electrical and Electronics Engineering Degree in 2002 and her Master of Electrical Engineering in 2007 from the University Tenaga Nasional, Malaysia. She obtained her Ph.D. degree in Electrical, Electronics, and Systems Engineering in 2017 from Universiti Kebangsaan Malaysia, Malaysia. She is currently serving as a senior lecturer at the Department of Electrical & Electronics Engineering, UNITEN, and as a Program Coordinator for the Master of Electrical Engineering Program at the College of Graduate Studies, UNITEN. She is a member of the Institute of Engineering and Technology (MIET), United Kingdom, and the Institution of Engineers Malaysia (IEM). She is also a Certified Energy Manager, Certified Professional in Measurement and Verification, and a technical working committee member for the country's National GHG inventory and International Consultation and Analysis (ICA) (BUR2) Malaysia. Her research interests include power system steady-state analysis, power system dynamic analysis, and power system optimization. She can be contacted at email: renuga@uniten.edu.my.

Tan Yi Xu received his bachelor's degree in electrical power engineering from UNITEN in 2022 and joined UNITEN R&D as a research engineer temporarily for a consultancy project. Currently, he works in TNB Distribution Network Division as a maintenance planner, where he analyses breakdown trends and monitors asset maintenance plans based on internal guidelines. He can be contacted at email: aarontan8551@gmail.com.

Nagaraja Rupan Panneerchelvan received the B.Eng. degree in electrical power engineering from Universiti Tenaga Nasional, Malaysia, in 2019. Currently, he is an electrical engineer in a manufacturing plant. His research interests include renewable energy, energy storage systems, power quality, power generation, power grids, power transmission system stability, and reliability. He can be contacted at email: nagarajarupan@gmail.com.

Aidil Azwin Zainul Abidin received a B.Sc. in electrical engineering from Purdue University and Indiana University Indianapolis (IUPUI), United States, in 1999, a master's in electrical engineering in power (MEP), and a Ph.D. in engineering from Universiti Tenaga Nasional (UNITEN) in 2005 and 2012, respectively. He is a senior lecturer in the Electrical and Electronics Department at Universiti Tenaga Nasional (UNITEN). His research interests include power system protection, control systems, physical systems, and real-time simulations. He can be contacted at email: aidilazwin@uniten.edu.my.

Marayati Marsadek received a bachelor's of electric power and a master's degree in electrical engineering from National Energy University, Putrajaya, Malaysia, in 2002 and 2006, respectively. She received the Ph.D. degree in electrical, electronics, and systems engineering from the National University of Malaysia in 2011. She is the Director of the Institute of Power Engineering and Senior Lecturer with the Department of Electric Power at the National Energy University. Her research interest includes power system stability, active network management, and risk assessment. She has written more than ten guidelines and manuals used by engineers in Tenaga Nasional Berhad (TNB), Malaysia. She has been actively involved in research and consultancy work related to energy, demand side response, power system stability, and renewable energy. She can be contacted at email: marayati@uniten.edu.my.

Agileswari K. Ramasamy was born in Taiping and was brought up in Batu Gajah where her father K. Ramasamy served as railway station master. She received both her primary and secondary education at St. Bernadette's Convent, Batu Gajah. Later, she continued her higher secondary education at Batu Gajah Government English School, Batu Gajah, Malaysia. She is the recipient of the Tenaga Nasional Scholarship, where she pursued her Electrical Engineering degree via a twining program between IKATAN (now UNITEN) and Purdue University, United States. She joined NITEN as a tutor in 1999 after graduating from Purdue University, West Lafayette 1999. She pursued her master's in control systems at Imperial College London in 2000 and became a lecturer at UNITEN in 2001. She completed her Ph.D. (Engineering) from UNITEN in 2008. Currently, she is a Professor and the Dean of the College of Graduate Studies at UNITEN. She is active in research and consultancy in the area of renewable energy, energy harvesting, second-life batteries, and control system applications. She has authored several high-impact journals, teaching modules, and technical guidelines for Malaysia. She is a Professional Engineer as well as a Registered Energy Manager. She can be contacted at email: agileswari@uniten.edu.my.

Izham Zainal Abidin received his B.Sc. degree in Electrical Engineering from the University of Southampton, United Kingdom, in 1997, and his Ph.D. degree in Electrical Engineering from the University of Strathclyde, United Kingdom, in 2002. He is currently a Professor with the Department of Electrical Power Engineering and the Deputy Vice-Chancellor (academic and international), Universiti Tenaga Nasional, Selangor, Malaysia. His research interest includes power system analysis, artificial intelligence, and smart grid. He can be contacted at email: izham@uniten.edu.my.

W. Mohd Suhaimi Wan Jaafar is a Project Director at TNB Remaco, a subsidiary of TNB Power Generation, which specializes in the operation and maintenance of energy-related industries, particularly power plants. He possesses strong technical competencies in the control and instrumentation field and is well-regarded among his peers in the TNB power sector. As a Project Director, he likely oversees and manages some of these complex projects, ensuring they are completed on time, within budget, and to the required quality standards. His role would involve coordinating with various teams, managing resources, and applying his technical expertise in the control and instrumentation field to drive project success. TNB Remaco, established in 1995, focuses on the overhaul and repair of various energy systems, including gas, steam, and hydro turbines, as well as boilers and generators. He can be contacted at email: wsuhaimiwj@tnb.com.my.