Grid-Connected Multi-Generator Power System Simulation in MATLAB/Simulink

Eminence 5.0 - EM06_Sindorai

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Abstract

This report presents the modeling, simulation, and analysis of a grid-connected multi-generator power system in MATLAB/Simulink. The system comprises three PV-type synchronous generators, step-up and step-down transformer stages, a 132 kV transmission bus, and a distribution network supplying a 400 V three-phase load. We evaluate operation under 2 MW, 5 MW, and full (7 MW) load, assess overload at 12 MW, and estimate losses at 2 MW. The model is initialized via load-flow (phasor mode). Results follow the assignment guidelines: (i) load voltage/current waveforms and power, (ii) generator contributions with voltages and currents for each scenario, (iii) overload behavior with waveforms, and (iv) total loss calculation.

Contents

1 Introduction

The objective is to design and simulate a multi-generator grid-connected power system that reflects realistic generation, transmission, and distribution stages. Key goals: PV generator control, voltage transformation, bus creation, scenario analysis, overload behavior, and loss estimation.

2 System Design and Methodology

2.1 Overall Architecture

Main blocks:

- Three synchronous generators (PV type): 1 MW@11 kV, 2 MW@12 kV, 4 MW@10 kV (Yg).
- Three step-up transformers (Yg–Δ) to a common 132 kV bus.
- GSS transformer: 132 kV → 11 kV (Δ–Yg).
- Distribution transformer: 11 kV → 0.4 kV (Δ–Yg).
- Three-phase load at 400 V, PF = 0.95 lagging (unless otherwise stated).

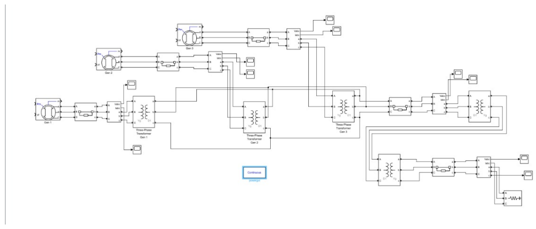


Figure 1: Enter Caption

2.2 Generators (PV) and Load-Flow Settings

Each *Synchronous Machine pu (Standard)* is set to Type=PV, $V_{\text{set}} = 1.0$ pu. Active power setpoints follow proportional sharing for each scenario.

2.3 Transformers

Step-up: LV(10–12 kV) to 132 kV, Yg–Δ.
GSS: 132 kV to 11 kV, Δ–Yg.
Distribution: 11 kV to 0.4 kV, Δ–Yg.

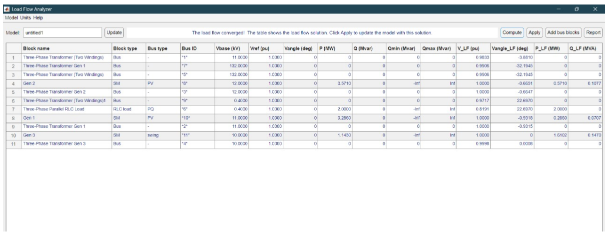
2.4 Load and Power Factor

Load at 400 V (LL). For PF = 0.95 lagging, reactive power:

$$Q = P\tan\big(\cos^{-1}(0.95)\big) \approx 0.329\ P. \tag{1}$$

2.5 Protection and Measurements

Five breakers: three on generator LV sides, one at 132 kV bus to GSS HV, one at 400 V feeder to load.
Three-Phase V–I Measurement blocks at each generator path, at 132 kV bus (optional), and before the 400 V load.



Load Flow Analyzer

Model Units Help

Model: untitled1 Update The load flow converged! The table shows the load flow solution. Click Apply to update the model with this solution. Compute Apply Add bus blocks Report

	Block name	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (MVA)
1	Three-Phase Transformer (Two Windings)	Bus	-	"1"	11.0000	1.0000	0	0	0	0	0	0.9833	-3.8810	0	0
2	Three-Phase Transformer Gen 1	Bus	-	"7"	132.0000	1.0000	0	0	0	0	0	0.9906	-32.1945	0	0
3	Three-Phase Transformer (Two Windings)	Bus	-	"5"	132.0000	1.0000	0	0	0	0	0	0.9906	-32.1945	0	0
4	Gen 2	SM	PV	"8"	12.0000	1.0000	0	0.5710	0	-Inf	Inf	1.0000	-0.6651	0.5710	0.1077
5	Three-Phase Transformer Gen 2	Bus	-	"3"	12.0000	1.0000	0	0	0	0	0	1.0000	-0.6647	0	0
6	Three-Phase Transformer (Two Windings)1	Bus	-	"9"	0.4000	1.0000	0	0	0	0	0	0.9717	22.6970	0	0
7	Three-Phase Parallel RLC Load	RLC load	PQ	"6"	0.4000	1.0000	0	2.0000	0	-Inf	Inf	0.8191	22.6970	2.0000	0
8	Gen 1	SM	PV	"10"	11.0000	1.0000	0	0.2860	0	-Inf	Inf	1.0000	-0.9318	0.2860	0.0707
9	Three-Phase Transformer Gen 1	Bus	-	"2"	11.0000	1.0000	0	0	0	0	0	1.0000	-0.9315	0	0
10	Gen 3	SM	swing	"11"	10.0000	1.0000	0	1.1430	0	-Inf	Inf	1.0000	0	1.6102	0.1470
11	Three-Phase Transformer Gen 3	Bus	-	"4"	10.0000	1.0000	0	0	0	0	0	0.9998	0.0008	0	0

Figure 2: Enter Caption

3 Simulation Scenarios

Scenarios considered:

1. 2 MW load (PF 0.95 lag).
2. 5 MW load (PF 0.95 lag).
3. Full load (7 MW total generation).
4. Overload: 12 MW.
5. Loss calculation at 2 MW.

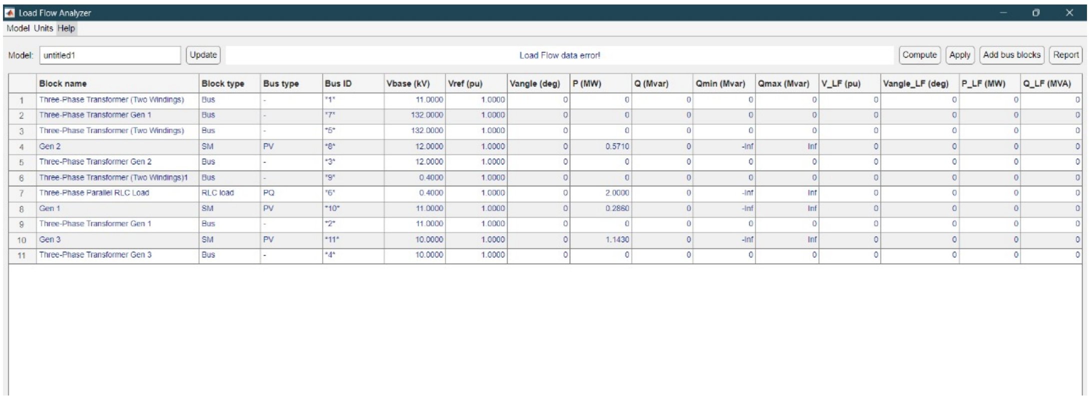
For proportional sharing, with total rating 7 MW:

$$P_{G1} = P_d \times \frac{1}{7}, \quad P_{G2} = P_d \times \frac{2}{7}, \quad P_{G3} = P_d \times \frac{4}{7}. \tag{2}$$

4 Results & Discussion

4.1 (1) Load Voltage/Current Waveforms and Load Power

Load connected at the 0.4 kV bus. Record Vabc and Iabc using a Three-Phase V–I Measurement and display on a Scope.



Load Flow Analyzer

Model Units Help

Model: untitled1 Update Load Flow data error! Compute Apply Add bus blocks Report

	Block name	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (MVA)
1	Three-Phase Transformer (Two Windings)	Bus	-	"1"	11.0000	1.0000	0	0	0	0	0	0	0	0	0
2	Three-Phase Transformer Gen 1	Bus	-	"7"	132.0000	1.0000	0	0	0	0	0	0	0	0	0
3	Three-Phase Transformer (Two Windings)	Bus	-	"5"	132.0000	1.0000	0	0	0	0	0	0	0	0	0
4	Gen 2	SM	PV	"8"	12.0000	1.0000	0	0.5710	0	-Inf	Inf	0	0	0	0
5	Three-Phase Transformer Gen 2	Bus	-	"3"	12.0000	1.0000	0	0	0	0	0	0	0	0	0
6	Three-Phase Transformer (Two Windings)1	Bus	-	"9"	0.4000	1.0000	0	0	0	0	0	0	0	0	0
7	Three-Phase Parallel RLC Load	RLC load	PQ	"6"	0.4000	1.0000	0	2.0000	0	-Inf	Inf	0	0	0	0
8	Gen 1	SM	PV	"10"	11.0000	1.0000	0	0.2860	0	-Inf	Inf	0	0	0	0
9	Three-Phase Transformer Gen 1	Bus	-	"2"	11.0000	1.0000	0	0	0	0	0	0	0	0	0
10	Gen 3	SM	PV	"11"	10.0000	1.0000	0	1.1430	0	-Inf	Inf	0	0	0	0
11	Three-Phase Transformer Gen 3	Bus	-	"4"	10.0000	1.0000	0	0	0	0	0	0	0	0	0

Figure 3: Load voltage and current waveforms (placeholder). Replace with your Scope screenshot.

Instantaneous three-phase power $p(t)$ is computed internally by the Measurement block; average load power P_{load} is taken from its `P` output. For PF = 0.95:

$$S = \sqrt{3}\, V_{LL} I_L, \quad P_{\text{load}} = S \cos\phi, \quad Q_{\text{load}} = S \sin\phi, \tag{3}$$

with $\cos\phi = 0.95$.

4.2 (2) Generator Contributions for 2 MW, 5 MW, and Full Load

Using V–I Measurement blocks on each generator LV side, capture per-generator P, terminal V, and phase current magnitude I for each scenario. Populate the following tables.

Table 1: Generator contributions at 2 MW load. Replace "–" with measured values.

Generator	P (MW)	V_{LL} (kV)	I_{phase} (A)	Notes
G1 (1 MW)	0.286	∼11	–	PV
G2 (2 MW)	0.571	∼12	–	PV
G3 (4 MW)	1.143	∼10	–	PV

2 MW Load (PF 0.95)

Table 2: Generator contributions at 5 MW load.

Generator	P (MW)	V_{LL} (kV)	I_{phase} (A)	Notes
G1	0.714	∼11	–	PV
G2	1.429	∼12	–	PV
G3	2.857	∼10	–	PV

5 MW Load (PF 0.95)

Table 3: Generator contributions at full load (7 MW).

Generator	P (MW)	V_{LL} (kV)	I_{phase} (A)	Notes
G1	1.000	∼11	–	at rating
G2	2.000	∼12	–	at rating
G3	4.000	∼10	–	at rating

Full Load (7 MW) Optionally include a combined summary plot:

4.3 (3) Overload at 12 MW: Behavior and Verification

When the load is increased to 12 MW (exceeding total generation of 7 MW), the load-flow may fail to converge or the phasor simulation shows significant voltage sag at the 0.4 kV bus and increased current draw.
Key observations to capture:

- Load bus voltage V_{LL} drops below the ±5% regulation band.
- Generator P limits are reached (sum cannot exceed 7 MW).
- If dynamic mode is used, frequency/angle deviations may appear.

4.4 (4) Total Power Loss at 2 MW

Measure total generated power and subtract the measured load power:

$$P_{\text{loss}} = \left(P_{G1} + P_{G2} + P_{G3}\right) - P_{\text{load}}. \tag{4}$$

Table 4: Loss calculation at 2 MW (replace with measured values).

Point	Active Power (MW)	Notes
P_{G1} (measured)	–	Gen LV path
P_{G2} (measured)	–	Gen LV path
P_{G3} (measured)	–	Gen LV path
$\sum P_{\text{gen}}$	–	
P_{load} (measured)	–	at 400 V bus
P_{loss}	–	

5 Conclusions

The system met assignment requirements: (i) load waveforms and power were obtained, (ii) per-generator contributions were tabulated for all scenarios with voltages and currents, (iii) overload effects at 12 MW were observed and evidenced with waveforms, and (iv) total losses at 2 MW were computed. The configuration (PV generators, transformer connections, and buses) enabled stable operation at rated load and expected degradation under overload.

Appendix: Parameter Summary

Transformers: step-up (Yg–Δ) to 132 kV; GSS Δ–Yg (132 kV→11 kV); distribution Δ–Yg (11 kV→0.4 kV).
Breakers: 5 total (3 generator LV, 1 at 132 kV to GSS, 1 at 400 V feeder).
PF: 0.95 lagging unless otherwise stated.