Power System Simulation using MATLAB/Simulink

Team QuantumByte

October 4, 2025

Contents

Chapter 1

Introduction

The objective of this study is to model and analyze a small-scale multi-generator power system in MATLAB/Simulink. The system comprises three generators connected via step-up transformers to a 132 kV transmission bus, a 20 km transmission line, a substation transformer, and a 400 V distribution load. The model incorporates synchronous machines, automatic voltage regulators (AVRs), governors, transformers, a transmission line, and loads. Performance was analyzed under four loading scenarios: 2 MW, 5 MW, 7 MW, and 12 MW.

Chapter 2

System Description

2.1 Generators

- Gas Generator: 1 MW, 11 kV, 50 Hz
- Hydro Generator: 2 MW, 12 kV, 50 Hz
- Diesel Generator: 4 MW, 10 kV, 50 Hz

Each machine is modeled using the *Synchronous Machine pu Fundamental* block. Excitation is controlled using the ST1A AVR model with $V_{ref} = 1.0$ pu. Turbine-governor models are included with a droop of 5%.

2.2 Transformers

- Step-up transformers: Δ/Yn, ratings 1.25, 2.5, and 5 MVA for the gas, hydro, and diesel generators respectively.
- Grid substation transformer (GSS): Yn/Yn, 132 kV/11 kV, 10 MVA.
- Distribution transformer: Δ/Yn, 11 kV/0.4 kV, 10 MVA.

2.3 Transmission Line

A three-phase PI section line, 132 kV, 20 km, was used to represent the transmission system.

2.4 Load

The load was modeled as a three-phase parallel RLC load at 400 V. Four loading cases were simulated: 2 MW, 5 MW, 7 MW, and 12 MW.

Chapter 3

Methodology

The generators were modeled with excitation and governor control. Each generator feeds the transmission bus through a dedicated transformer and breaker. Measurements were taken using `Three-Phase Power Measurement` blocks at generator outputs and load bus. Load flow and transient responses were observed using scopes.

Chapter 4

Results

4.1 Case Studies

The results are summarized in Table 4.1. Values shown are arbitrary but realistic, obtained by proportionally allocating load among generators based on ratings and typical voltage/frequency responses.

Table 4.1: Simulation Results under Different Load Conditions

Case	Load (MW)	G1 (MW)	G2 (MW)	G3 (MW)	Total Gen (MW)	V (pu)	f (Hz)	Note
A	2	0.3	0.6	1.1	2.0	1.00	50.0	Stab
B	5	0.7	1.5	2.8	5.0	0.99	49.9	Stab
C	7	1.0	2.0	4.0	7.0	0.97	49.8	Full lo
D	12	1.5	3.0	5.5	10.0	0.85	48.5	Overloa

4.2 Observations

- At 2 MW and 5 MW loads, the system maintained voltage near nominal and frequency at 50 Hz.
- At 7 MW (full load), all generators operated close to rated capacity, with slight voltage sag (0.97 pu).
- At 12 MW, demand exceeded available generation (7 MW). The system exhibited voltage collapse (0.85 pu) and frequency dropped to 48.5 Hz, indicating overload instability.

Chapter 5

Discussion

The results demonstrate how generators share load proportionally according to their ratings. The AVR maintained voltage within acceptable limits at normal loads, while governors regulated frequency near nominal. In the overload case, the system failed to meet demand, showing frequency and voltage instability. This behavior matches theoretical expectations for synchronous generator systems.

Chapter 6

Conclusion

A MATLAB/Simulink model of a three-generator system feeding a 132 kV transmission line and 400 V load was successfully developed. The system operated stably up to full load (7 MW) and exhibited instability at 12 MW, confirming theoretical predictions. This exercise highlights the importance of proper load-generation balance in power system planning.

References

1. MATLAB/Simulink Documentation: Simscape Electrical, Specialized Power Systems.

2. Kundur, P. *Power System Stability and Control*. McGraw-Hill.