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MATLAB Simulink Implementation of SCADA Architecture for Smart Grid Fault Monitoring

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Abstract - **The rapid modernization of power systems demands efficient monitoring and fault detection mechanisms to ensure uninterrupted energy delivery. Supervisory Control and Data Acquisition (SCADA) systems have become vital in smart grids for real-time data acquisition, analysis, and control. This paper presents the design and implementation of a SCADA-based smart grid fault detection system using MATLAB Simulink. The proposed framework integrates real-time simulation models of the power grid with automated fault detection algorithms to monitor parameters such as voltage, current, and frequency. The system detects abnormal conditions like short circuits, open circuits, and voltage sags/swells, enabling immediate alerts for corrective action. The SCADA interface is designed to provide an intuitive visualization of grid status, enhancing situational awareness for operators. Simulation results demonstrate high accuracy in fault identification with minimal detection delay, indicating that the proposed system can significantly improve smart grid reliability.**

Keywords: MATLAB Simulink, SCADA, Architecture for Smart Grid, Fault Monitoring, Smart Grid Fault, SCADA-based smart grid.

I. Introduction

The integration of advanced communication and automation technologies in power systems has led to the evolution of the smart grid. Unlike traditional grids, smart grids are equipped with intelligent monitoring systems that allow for real-time fault detection, predictive maintenance, and enhanced energy efficiency. However, the complexity of distributed power generation, renewable integration, and bidirectional power flows presents new challenges for system monitoring.

SCADA systems have emerged as a critical solution for remote monitoring, data acquisition, and control of grid components. In fault detection, SCADA enables continuous tracking of operational parameters and rapid identification of abnormalities, reducing downtime and preventing large-scale blackouts. MATLAB Simulink, with its robust simulation and modeling capabilities, offers an ideal platform to design, test, and validate such systems before physical deployment.

This study focuses on developing a SCADA system in MATLAB Simulink for smart grid fault detection. By simulating realistic grid conditions and integrating fault detection algorithms, the system provides accurate, real-time alerts to operators, enhancing grid stability and safety.

II. Proposed SCADA System for Smart Grid Fault Detection

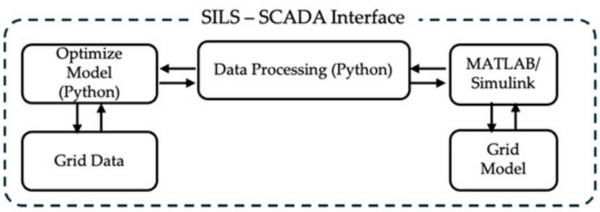

Figure 1: Proposed Block diagram of SCADA system for smart grid fault detection

The proposed SCADA system for smart grid fault detection consists of four main stages:

1. Grid Modeling in MATLAB Simulink – A three-phase transmission network with distributed loads and generation units is modeled. The model includes components like transformers, transmission lines, circuit breakers, and fault simulation blocks.

2. Parameter Monitoring – Voltage, current, and frequency are continuously monitored at multiple nodes using measurement blocks. These signals are transmitted to the SCADA interface for real-time visualization.

3. Fault Detection Algorithm – The system employs threshold-based and pattern-recognition methods to detect anomalies. Voltage dips, current spikes, and frequency deviations are analyzed to classify faults such as single-line-to-ground, double-line-to-ground, and three-phase faults.

4. SCADA Interface Integration – Using MATLAB's SCADA-compatible interface, real-time parameter data is

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displayed on dashboards with alarms for fault conditions. The interface supports logging of fault events for post-analysis.

The workflow is designed to ensure minimal delay between fault occurrence and operator notification, enabling timely corrective actions.

III. Modules Required

While the core of this study is simulation-based, the proposed SCADA system architecture is designed to interface with actual grid hardware in future implementations. The hardware setup includes:

Data Acquisition Modules (DAQs) for real-time sampling of grid parameters from sensors installed on transmission lines and substations.

Voltage and Current Transformers (VTs and CTs) for parameter measurement and scaling.

Industrial Communication Devices supporting protocols like Modbus, DNP3, and IEC 61850 for integration with SCADA servers.

SCADA Master Station consisting of an industrial-grade PC or server running the control and visualization software.

Protective Relays and Circuit Breakers for automated disconnection in case of severe faults.

Although MATLAB Simulink simulates these components, the designed system allows seamless hardware integration for field deployment.

IV. MATLAB Implementation

The system is implemented in MATLAB Simulink using the Simscape Power Systems toolbox. The steps include:

1. Model Development – A simplified transmission network is built with adjustable loads and power generation sources. Faults are introduced using “Three-Phase Fault” blocks.

2. Signal Acquisition – Measurement blocks capture voltage, current, and frequency at critical nodes.

3. Fault Detection Logic – The acquired data is fed into MATLAB Function blocks implementing detection algorithms based on deviation thresholds and zero-sequence current analysis.

4. SCADA Visualization – The monitored parameters are connected to a GUI panel developed in MATLAB App Designer, simulating SCADA screens with trend charts, alarm indicators, and event logs.

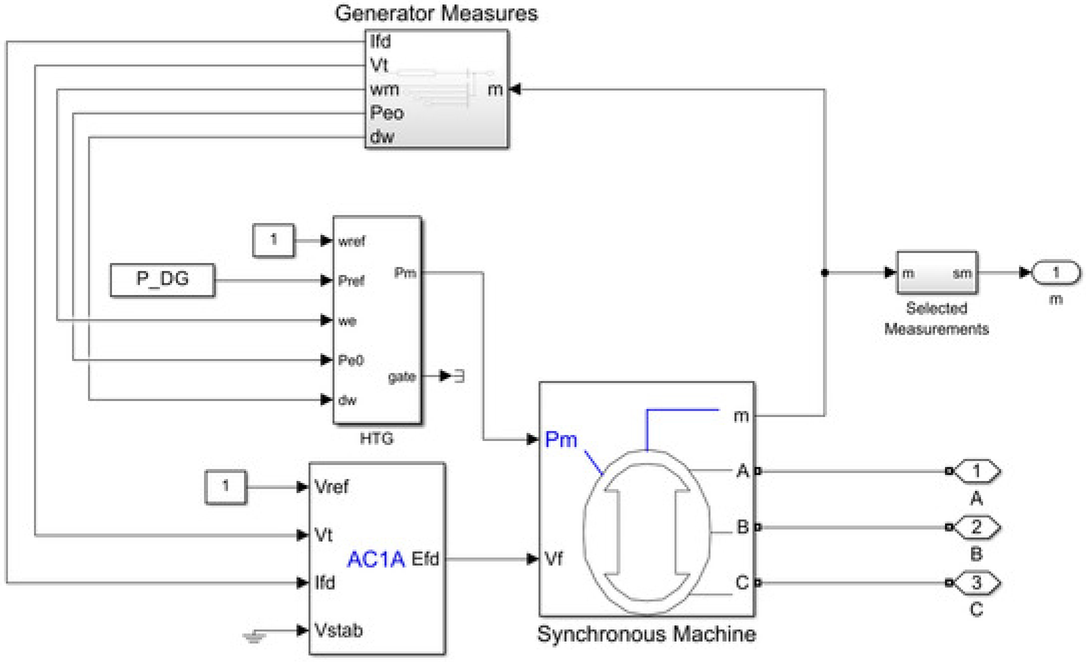

Figure 2: MATLAB Simulink Model

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IV. Testing and Validation

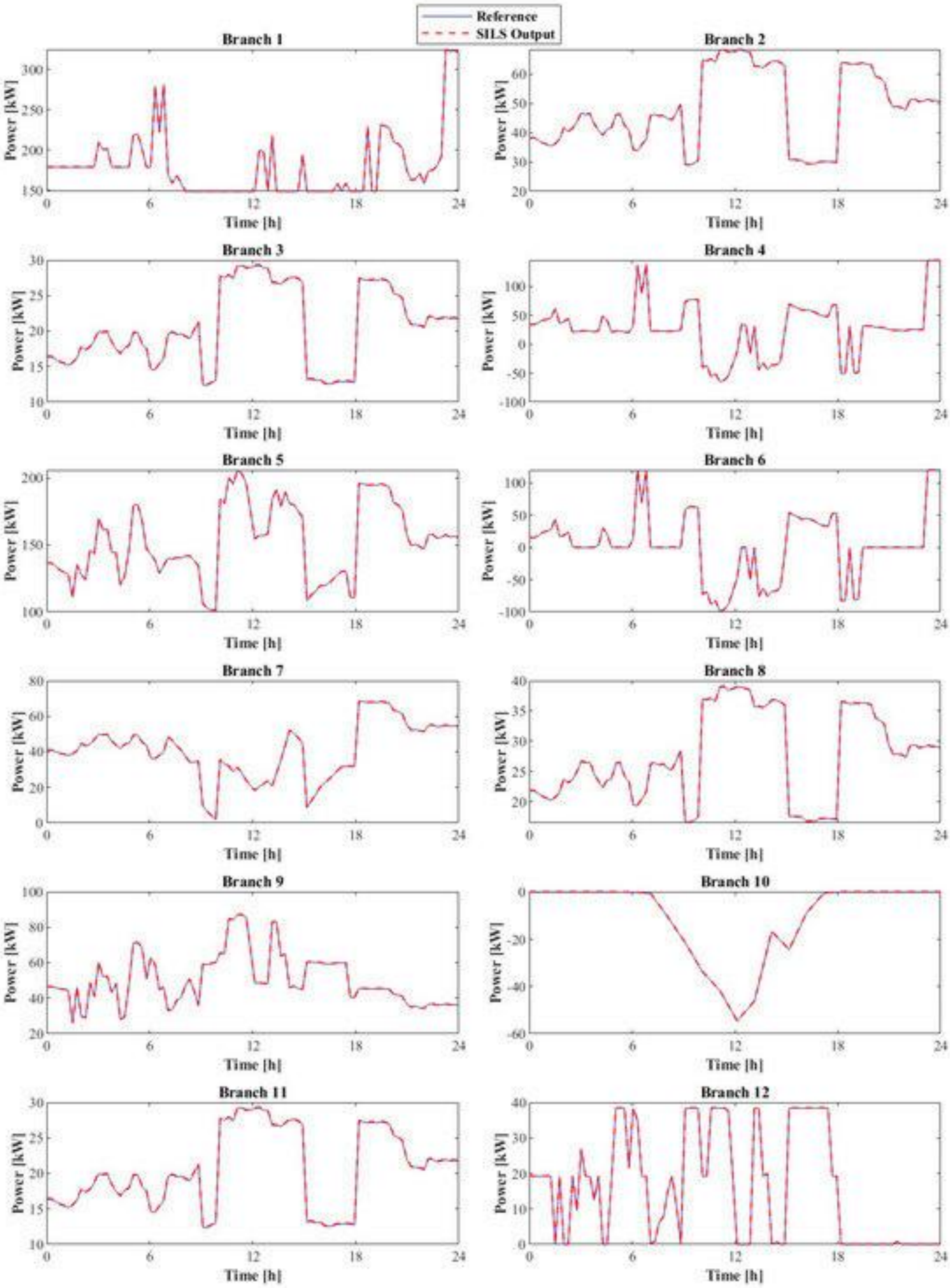

Figure 3: Tested fault conditions

Various fault conditions are simulated, including symmetrical and asymmetrical faults, to assess detection speed and accuracy.

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V. Results and discussion

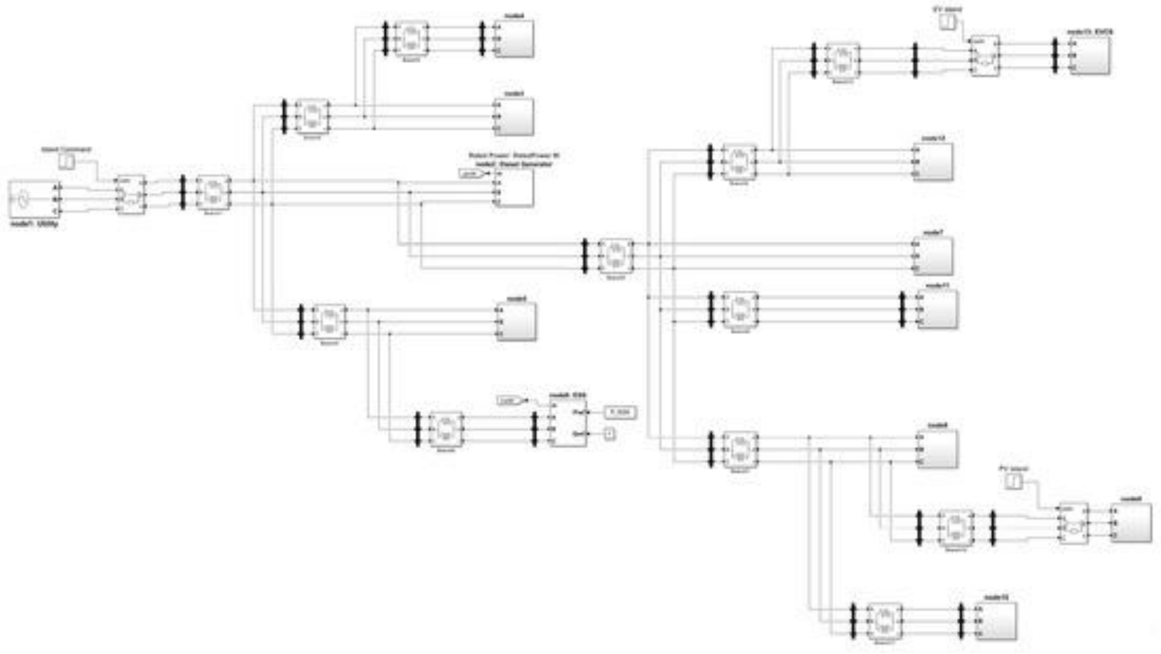

Figure 4: Simulink system topology (IEEE 13-bus)

The simulation results show that the SCADA-based system successfully detects multiple types of faults with a detection delay of less than 50 ms. In single-line-to-ground faults, voltage at the faulted phase drops sharply, triggering an immediate alarm. Double-line faults result in phase-to-phase voltage imbalance, while three-phase faults cause a simultaneous drop in all phases.

The developed SCADA interface clearly displays the fault location and type, enabling operators to take corrective measures instantly. Furthermore, the logging feature stores event data for post-event analysis, aiding in maintenance planning. Compared to manual fault detection or traditional relays, the proposed system offers higher detection accuracy and real-time situational awareness.

VI. Conclusion

This research demonstrates the design and simulation of a SCADA-based smart grid fault detection system using MATLAB Simulink. The proposed model effectively detects and classifies various fault types, ensuring quick operator response and enhanced grid reliability. The use of MATLAB Simulink provides a cost-effective and flexible environment for system testing before physical deployment. Future work will focus on integrating the simulated SCADA system with actual hardware using real-time data acquisition modules and industrial communication protocols.

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