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Enhancement of Power Quality in Grid-Connected Solar Systems Using PV-STATCOM: A Comprehensive Analysis

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Abstract—This study investigates the integration of Static Synchronous Compensator (STATCOM) technology with photovoltaic (PV) systems to address power quality challenges in grid-connected solar installations. The research focuses on the implementation of PV-STATCOM for reactive power compensation and voltage regulation. Using MATLAB/Simulink simulations, we demonstrate that the PV-STATCOM system effectively manages reactive power, improves voltage stability, and enhances overall power quality. Results show significant reduction in voltage distortions and improved power factor correction, with reactive power compensation capabilities of up to 60 KVAR in a 90 kW system. The integration of Artificial Neural Network (ANN) control strategies further optimizes the system's performance, particularly during varying solar irradiance conditions.

Keywords-PV-STATCOM, reactive power compensation, power quality, grid stability, artificial neural networks

I. INTRODUCTION

The increasing integration of renewable energy sources, particularly solar photovoltaic systems, into existing power grids has introduced new challenges in maintaining power quality and system stability. While solar PV systems offer clean and sustainable energy generation, their inherent intermittent nature poses significant challenges for grid operators. These challenges include voltage fluctuations, reactive power management, and overall power quality issues.

The concept of combining PV systems with STATCOM technology (PV-STATCOM) has emerged as a promising solution to address these challenges. This integration allows for dynamic reactive power compensation while maximizing the utilization of solar power infrastructure. Traditional methods of reactive power compensation, such as fixed capacitor banks, lack the flexibility and rapid response capabilities required in modern grid systems.

II. METHODOLOGY

A. System Architecture

The proposed system integrates three main components:

a. Solar PV array configuration (225.30W panels)

b. Bidirectional DC-DC converter

c. Three-phase DC-AC boost inverter with STATCOM functionality

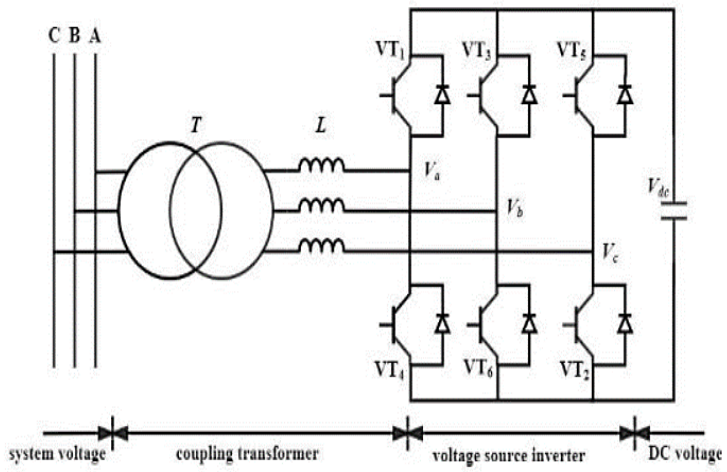

Figure 2.1 Fundamental Architecture of STATCOM

B. Control Strategy

The control system employs an Artificial Neural Network (ANN) trained using Levenberg-Marquardt back propagation. The ANN controller:

- Monitors the difference between reference voltage (375V) and actual DC link voltage
- Generates appropriate switching pulses for the shunt converter
- Adjusts reactive power output based on grid conditions

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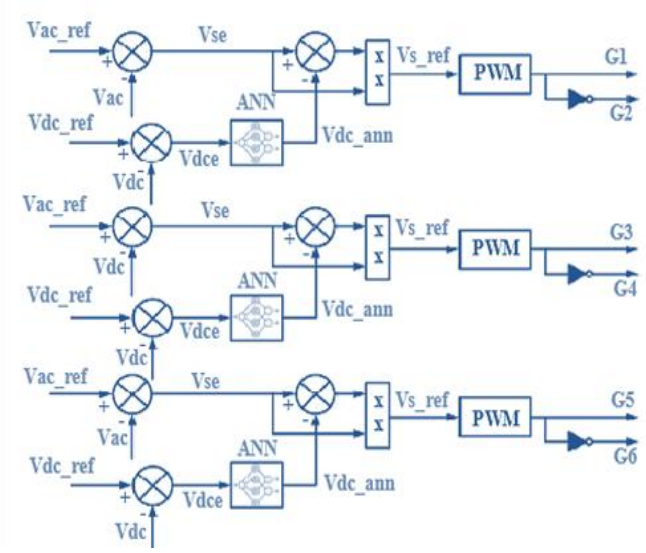

Figure 2.2 DC-AC boost inverter system control design

C. Simulation Setup

The system was simulated using MATLAB/Simulink with the following parameters:

- Simulation duration: 0.8 seconds
- Solar irradiance variation: 1000W/m² to 500W/m²
- Switching frequency: 10 kHz
- Control system sample time: 100 µs
- PWM generator sample time: 1 µs

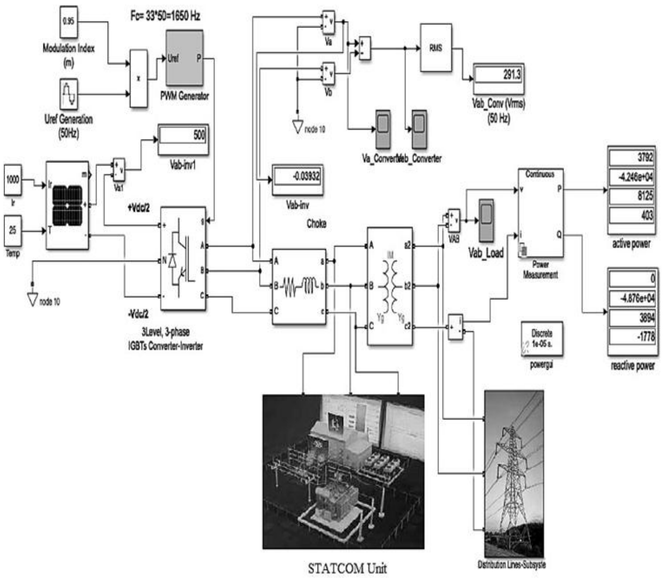

Figure 2.3 STATCOM in a grid connected system

III. RESULTS AND DISCUSSION

A. Voltage Regulation Performance

The implementation of PV-STATCOM showed significant improvements in voltage regulation:

- Pre-STATCOM: Notable distortions in AC voltage waveform.
- Post-STATCOM: Smoother voltage profile with reduced harmonics.
- Voltage stability maintained even during solar irradiance fluctuations.

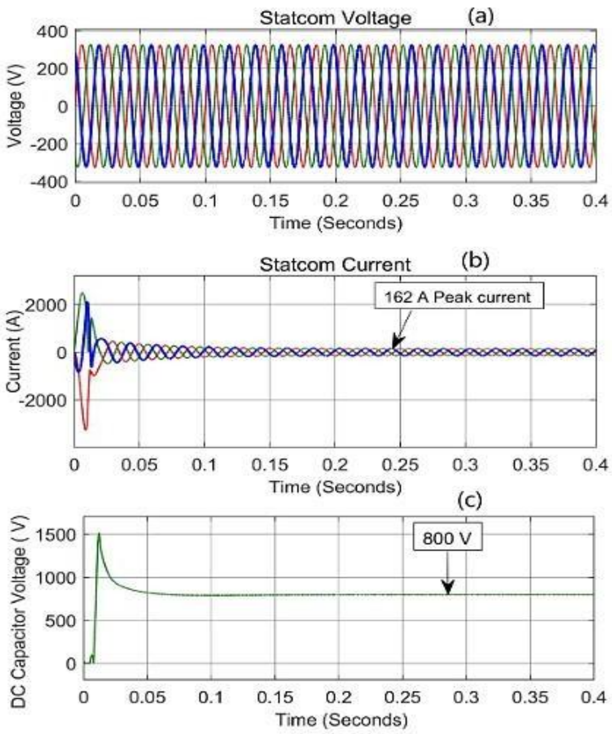

Figure 3.1 Analysis of Output Characteristics for Grid Stability

B. Reactive Power Compensation

The system demonstrated effective reactive power management:

- Maximum reactive power compensation: 60 KVAR
- Dynamic adjustment capability during varying load conditions
- Improved power factor correction

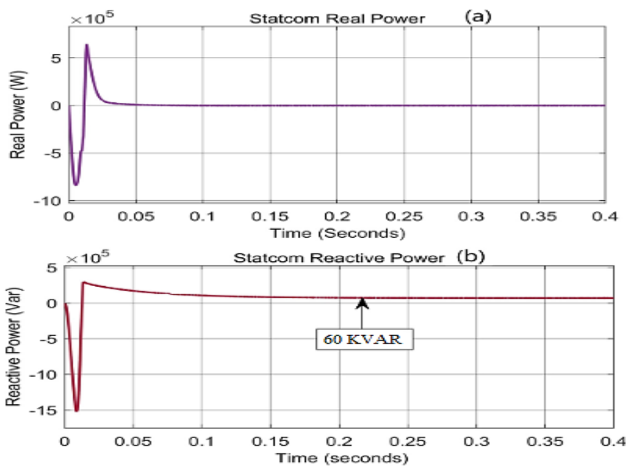

Figure 3.2 a) Active, b) reactive Power Supply by STATCOM

C. System Response to Solar Irradiance Changes During the simulation period:

- Initial active power output (1000W/m²): 10.137 kW
- Reduced output (500W/m²): 8.32 kW
- System maintained stability during transition
- ANN controller response time: approximately 0.2 seconds

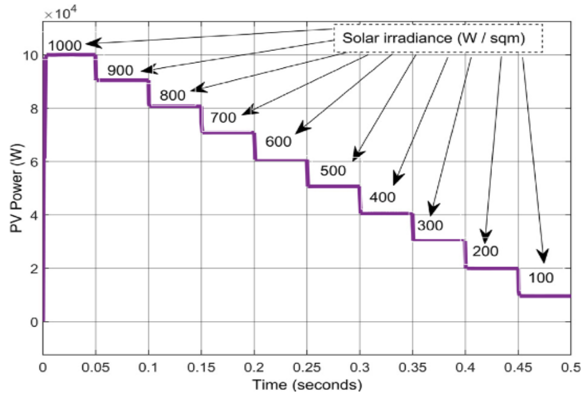

Figure 3.3 Optimizing PV Array Power Output in the Face of Solar Irradiance Fluctuations: A Controller Approach

IV. CONCLUSION

The integration of STATCOM functionality with PV systems shows promising results in addressing power quality challenges in grid-connected solar installations. The ANN-based control strategy effectively manages reactive power compensation and voltage regulation, even under varying solar irradiance conditions. The system demonstrates robust performance in maintaining power quality and grid stability, making it a viable solution for large-scale solar power integration.

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