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Mitigation of Power Quality Issues in Grid-Integrated Solar Power System

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Abstract: The increasing penetration of solar power into the electricity grid has raised concerns about power quality issues. Solar power is a variable and intermittent source of energy, and its integration into the grid can cause voltage fluctuations, harmonics, and other power quality problems. To address these issues, the use of Static Synchronous Compensator (STATCOM) has emerged as a viable solution. This research paper presents an in-depth analysis of power quality issues in grid-integrated solar power systems and the role of STATCOM in mitigating these issues. The paper reviews relevant literature on solar power integration, power quality issues, and the application of STATCOM in solar power systems. The paper also discusses the operating principle of STATCOM, its advantages, and its limitations. Furthermore, the paper presents case studies and simulation results to illustrate the effectiveness of STATCOM in improving power quality in grid-integrated solar power systems. The findings of this research provide valuable insights into the challenges and solutions related to power quality issues in grid-integrated solar power systems using STATCOM.

Keywords: Power quality, solar power, grid integration, STATCOM, voltage fluctuations, harmonics.

I. INTRODUCTION

The increasing demand for clean and sustainable energy has led to a rapid growth of solar power installations worldwide. Solar power systems are typically connected to the electricity grid to inject excess energy or draw power during low solar radiation periods. However, the integration of solar power into the grid can result in power quality issues due to the variable and intermittent nature of solar power generation. These issues can impact the performance and reliability of the grid, leading to voltage fluctuations, harmonics, and other power quality problems.

Power quality issues in grid-integrated solar power systems can have various adverse effects, such as increased equipment failures, reduced system efficiency, and increased operational costs. Therefore, it is crucial to address these power quality issues to ensure the reliable and efficient operation of grid-integrated solar power systems.

One of the promising solutions to mitigate power quality issues in grid-integrated solar power systems is the use of a Static Synchronous Compensator (STATCOM). STATCOM is a power electronics-based device that can regulate the grid voltage and current by injecting or absorbing reactive power in a controlled manner. STATCOM can provide fast and precise compensation for power quality issues, making it an effective solution for improving the power quality of grid-integrated solar power systems.

Power Quality Issues in Grid-Integrated Solar Power Systems

The integration of solar power into the grid can result in various power quality issues. Some of the common power quality issues in grid-integrated solar power systems are:

- Voltage fluctuations: Solar power generation is dependent on solar radiation, which can vary significantly over time. As a result, the output power of solar power systems can fluctuate, causing voltage fluctuations in the grid. Voltage fluctuations can lead to voltage sags or swells, which can affect the performance and reliability of grid-connected loads.
- Harmonics: Solar power systems can introduce harmonics into the grid due to the presence of power electronic converters used in the solar power generation process. Harmonics can cause distortion in the grid voltage and current waveforms, leading to increased losses in power distribution systems and interference with other sensitive loads.

- Reactive power imbalance: The variable and intermittent nature of solar power generation can result in reactive power imbalances in the grid. Reactive power imbalances can lead to low power factor, increased losses in power distribution systems, and reduced system efficiency.
- Grid instability: The integration of a large number of solar power systems into the grid can result in grid instability issues. Grid instability can lead to frequency deviations, voltage instability, and other grid-related problems, which can impact performance.
- Voltage Spikes & Transients: Spikes and transients are fast-moving, high-energy bursts that are overlaid on the typical mains power supply and last only a few milliseconds. They are brought on by the abrupt release of stored energy and can range in voltage from a few volts to several thousand volts (some can reach 6 kV or greater). In electrical storms and after a lightning strike, spikes and transients are frequent.

II. STATCOM

STATCOM, or Static Synchronous Compensator, is a power electronic device that controls the reactive power flow over a power network and so improves the stability of the power network by employing force-commutated devices like IGBT, GTO, etc. STATCOM is a shunt device, which means that it is shunt linked to the line. The terms Static Synchronous Compensator (STATCOM) and Static Synchronous Condenser (STATCON) both refer to the same device. It belongs to the FACTS (Flexible AC Transmission System) family of electronics.

A STATCOM device consists of a voltage source converter (VSC) connected in parallel with a capacitor. The VSC is capable of producing a controllable voltage of fixed frequency and magnitude, which is synchronized with the power system voltage. The capacitor provides the reactive power needed to compensate for voltage drops or surges in the system. STATCOMs are commonly used to improve the stability and efficiency of power systems, especially those with high levels of renewable energy sources such as wind or solar power. By providing rapid and precise control of reactive power, STATCOMs can help maintain the voltage level of the system and improve power quality.

Some of the advantages of STATCOMs include:

- Fast response time
- High efficiency
- Flexible and precise control of reactive power
- Improved power system stability and reliability
- Reduced system losses

STATCOMs have applications in a wide range of industries, including power generation, transmission, and distribution, as well as in industrial and commercial settings.

III. LITERATURE SURVEY

Renewable energy sources, including solar, wind, biomass, hydro, cogeneration, etc., are necessary to meet energy demand through the asset energy system, energy conservation, and other means in order to achieve supportive development and social advancement. sustainable power. Sources serve as crucial models. In order to lessen the environmental impact of conventional power plants, the power system needs to incorporate renewable energy sources like solar energy. Solar power generation is expanding quickly, and large-scale solar plants all over the world are being connected to power networks as a result of increased demand for electricity and environmental concerns. Due to the nature of the air fluctuations, the power quality is compromised when alternating energy is introduced into the utility grid. The IEC standard states that the effectiveness of solar generators determines power quality. By mounting a solar panel with a grid, power quality issues such as voltage variation, flicker, and harmonics are exhibited throughout this experiment. To solve these problems with the quality of the energy, Fact's equipment can be employed.

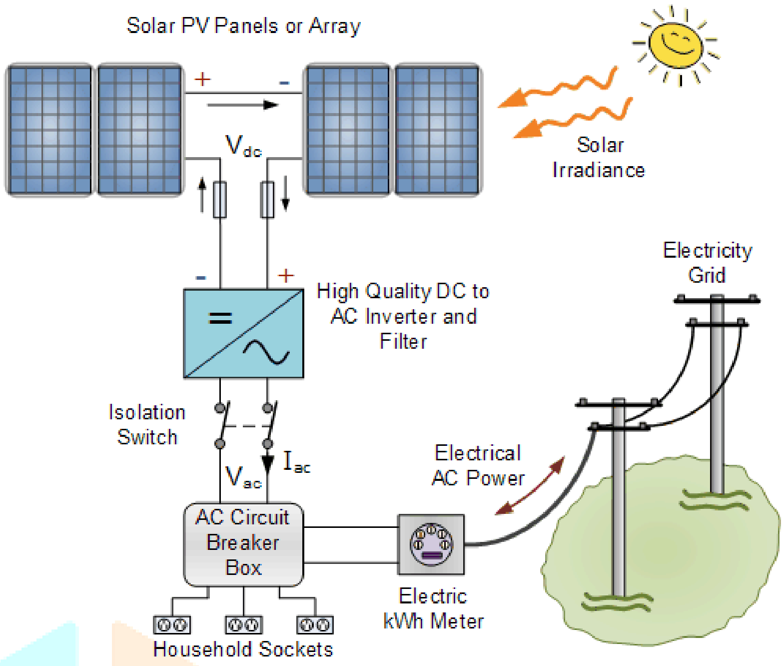

Figure.1. Simplified Grid-connected PV System

IV. SIMULATIONS AND RESULTS

With the help of Simulink MATLAB, the operation and control scheme are simulated in a power system block set. This simulation illustrates the effect of the presence of STATCOM in the power system.

- **Block diagram without STATCOM**

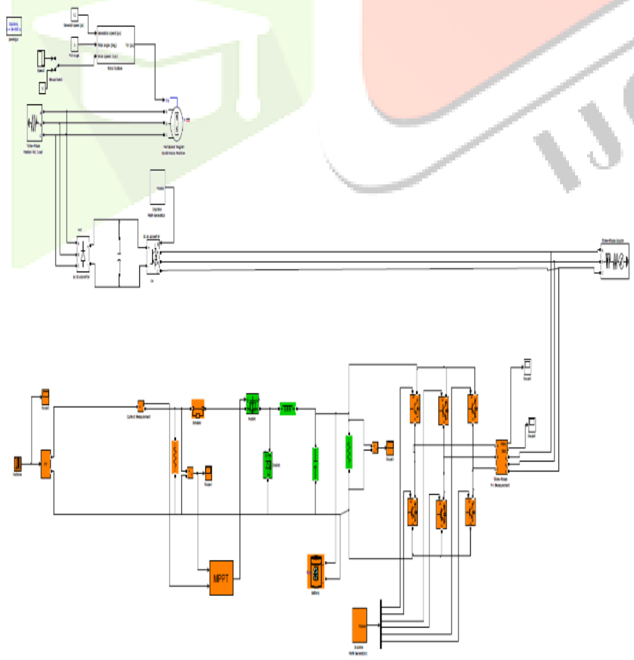

Figure.2. Simulation without STATCOM

- **Block diagram with STATCOM**

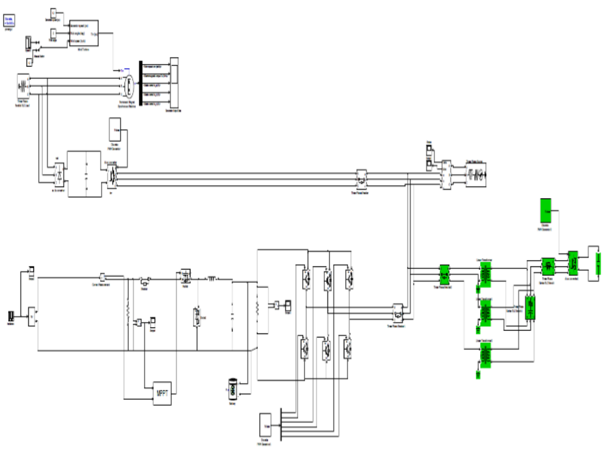

Figure.3. Simulation with STATCOM

V. SYSTEM PERFORMANCE

The wind generator's non-linear load and distortion are removed by the three-phase current STATCOM injects into the grid. A transformer connects the IGBT-based three-phase inverter to the grid. In the hysteresis band of 0.08, signals switching from the reference current are simulated. The system's small hysteresis band switching option enhances current quality. As depicted in Fig.3, the switching frequency's control signal falls inside the operating band of 0.08. The operating voltage and the transformer impedance used for the interface determine which current band should be used. The current inverter compensates for non-linear load and reactive power. This inverter's controller permits actual power transfer from the battery as well. The current injected by the three-phase inverter is shown in Fig.4.

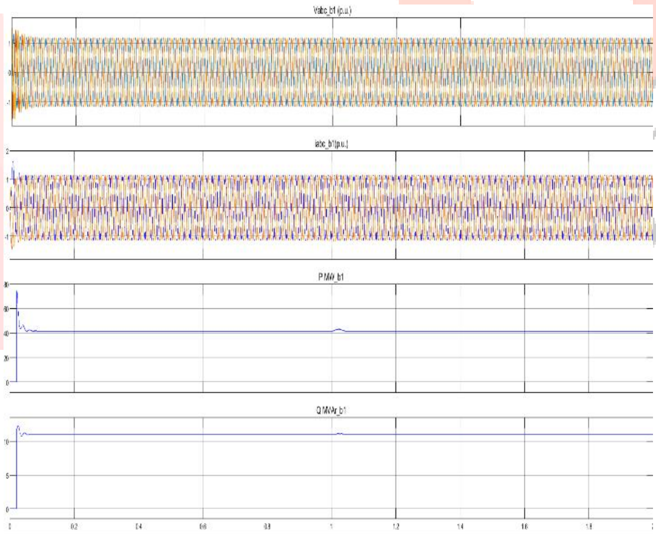

Figure.4. Variation in parameters before a fault

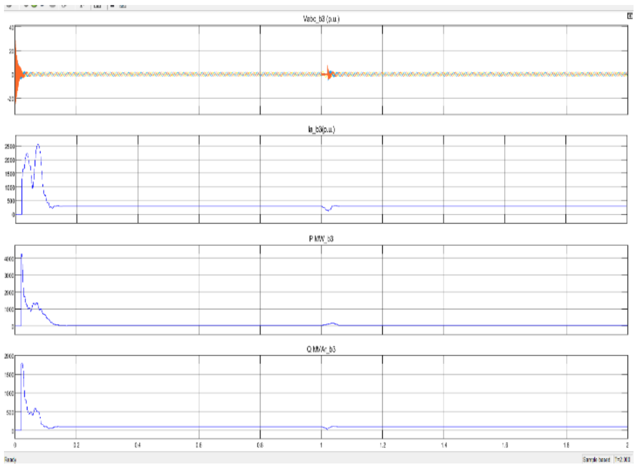

Figure.5. Variation in parameters after fault

+

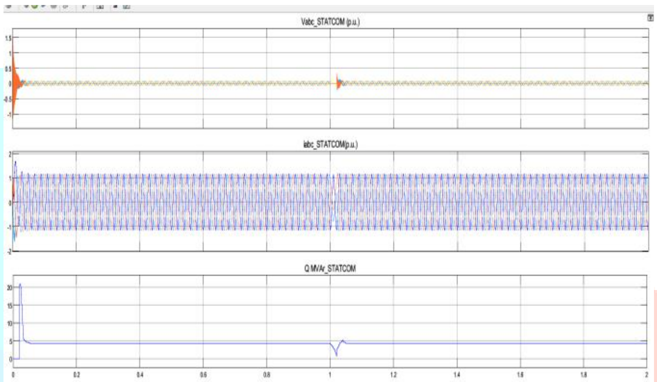

Figure.6. Variation in parameters with STATCOM

VI. CONCLUSION

This study offered Power quality has long been a top priority since power system breakdowns can have serious consequences. The project illustrates the power quality and a number of power quality issues that develop when a PV system is connected to the grid. Data loss, the process halts, insulation failure, overheating, inefficiency, and decreased equipment service lives are all manifestations of poor power quality. Although the causes cannot entirely be removed, actions must be taken to decrease the power quality issues. Attenuation is necessary to meet the requirements for power supply quality and ongoing supply results.

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