1) **Project Reference Number** - 46S_BE_4719

2) **Title of the Project:** Design and Hardware Implementation of PV-STATCOM for Power Quality Improvement

3) **Name of the College and Department:** MVJ COLLEGE OF ENGINEERING, BENGALURU
ELECTRICAL AND ELECTRONICS ENGINEERING

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6) **Keywords:** Photovoltaic (PV), Static Compensator (STATCOM), Power Quality, Voltage Sag, Harmonics, Phase locked loop (PLL), Distribution Static Synchronous Compensator (D-STATCOM)

7) **Introduction:** Photovoltaic (PV) is most dominant among other renewable energy sources as it is economical and can be easily adopted to different load requirements. And PV system is that flexible in operation, simple in construction, compatible with existing electrical installations. The integration of Photovoltaic energy with the existing installation presents some technical challenges which considers stability, voltage regulation and power quality problems. Power Quality most essential measure which is highly affected by the power system operation. Poor power quality at the load side caused malfunctioning and damage of the equipment. Therefore, reactive power compensation, harmonics mitigation, load unbalances are some major issues addressed under Power Quality.

In grid-connected PV systems, transformers have traditionally been used to step up the low output voltages of PV panels. However, the high costs and losses of transformers have made solar inverters the least efficient and most expensive component in these systems. To overcome these challenges, the transformer has been eliminated from solar inverters, resulting in smaller, more cost-effective, and highly efficient transformer less solar PV inverters. After this, the 12-pulse STATCOM controller was found to be highly efficient in operation which includes PLL and pulse generator modules for controlling the firing angle of the inverter, as well as circuitry for charging the DC capacitor. Reactive power compensation was achieved by connecting a multi-level, hexagram converter-based STATCOM using one cycle control (OCC). By incorporating a battery energy storage system (BESS) within the STATCOM, both real power (P) and reactive power (Q) interchange became possible. The integration of a STATCOM with a BESS in the electrical system effectively minimized power system transients, leading to enhanced performance. The BESS/STATCOM maintained the power quality of the system and also cancelled out the harmonic sections of the load current. In order to address transient stability, frequency stability, and power flow capacity issues in a wide-range electrical system, a combination of STATCOM and battery energy storage system (BESS) was utilized. To further improve system performance, a proportional integral (PI)-lead and lead-lag controller was implemented for the BESS.

Additionally, a particle swarm optimization (PSO) method was introduced to mitigate power losses and provide voltage control at nodes, combining a mathematical algorithm with a STATCOM as a FACTS device, resulting in reduced active power losses.

8) **Objectives:** The integration of renewable energy sources into the electricity grid is crucial for sustainable energy production. However, this integration requires the development of new strategies for the operation and management of the electrical grid to maintain or improve power supply reliability and quality.

The integration of renewable energy sources, specifically photovoltaic (PV) systems, into the power grid poses power quality challenges such as voltage sag, swell, and harmonics. To address these issues, a PV-STATCOM (Static Synchronous Compensator) is proposed as a solution. PV-STATCOM is a power electronic device that combines the capabilities of a PV system and a STATCOM to improve power quality in PV systems. It provides reactive power compensation, voltage regulation, and harmonic mitigation to mitigate voltage fluctuations and maintain grid stability. PV-STATCOM dynamically controls the reactive power injection and voltage at the point of common coupling (PCC) to mitigate voltage sags and swells caused by PV system intermittency. It also filters out harmonics generated by PV inverters, reducing harmonic distortion in the grid. By enhancing power quality, PV-STATCOM enables reliable and efficient operation of the grid with increased penetration of PV systems, facilitating their integration into the existing power infrastructure.

9) **Methodology:** This project discusses the use of a STATCOM with a dc link capacitor as an energy storage system for grid-connected renewable energy resources. The focus is on solar PV systems, which are gaining popularity due to their eco-friendliness and reliability but can pose challenges for integration into utility grids due to fluctuations in output power. The proposed solution is to use a STATCOM to regulate voltage and maintain a constant load voltage despite

fluctuations in solar irradiance and heavy loads on the load side. The phase angle adjustment mechanism is a method used to control the reactive power generated or absorbed by the STATCOM.

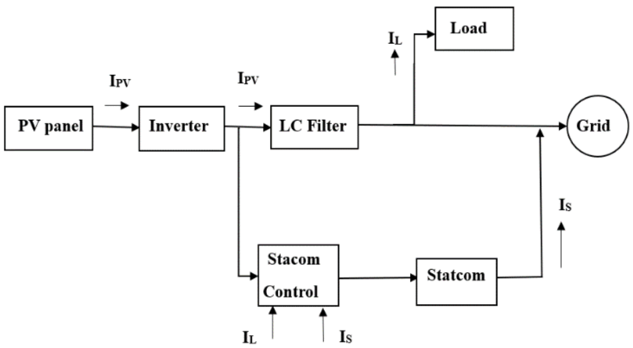


Figure 1. Block diagram of proposed system

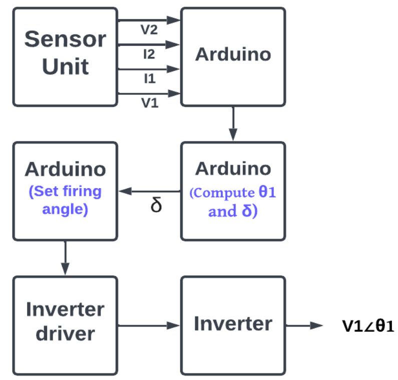


Figure 2. Block diagram of Phase angle adjustment mechanism

10) Results:

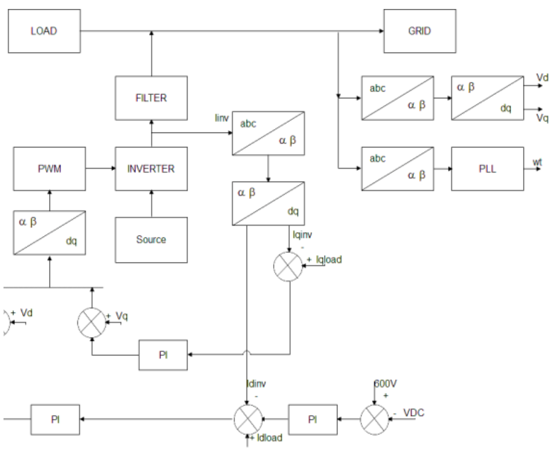
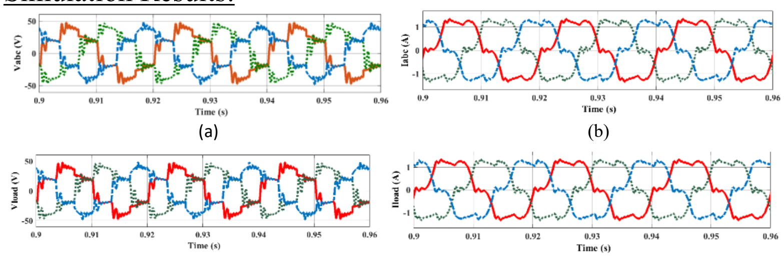


Figure 3. Flowchart of proposed system simulation

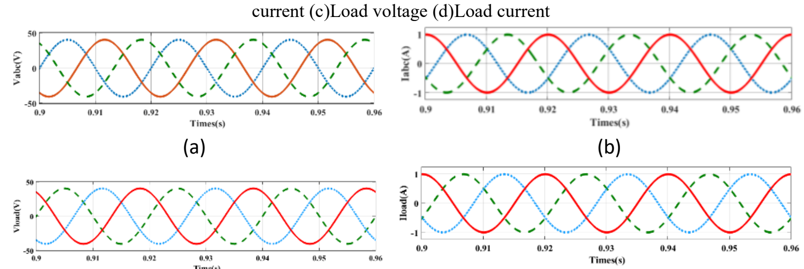
Simulation Results:



(a) (b)

(c) (d)

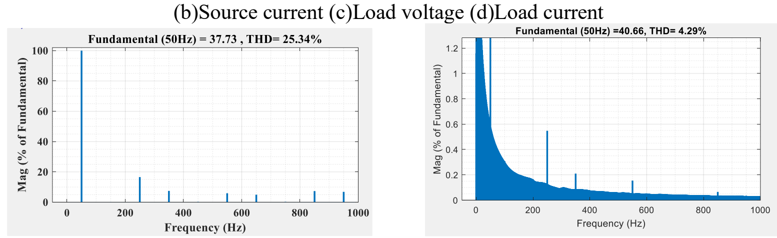
Simulation results of STATCOM with non-linear load before compensation (a)Source voltage (b)Source current (c)Load voltage (d)Load current



(a) (b)

(c) (d)

Simulation results of STATCOM with non-linear load after compensation (a)Source voltage (b)Source current (c)Load voltage (d)Load current



(a) (b)

THD (a)Before compensation (b) After Compensation

Hardware Implementation:

The hardware set up of the proposed system consists of following components:

1. Voltage Source Inverter
2. Transducer circuit
3. Synchronizing circuit
4. Blanking Circuit

5. Power supply modules

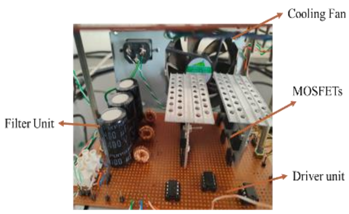


Figure.7. Voltage source inverter

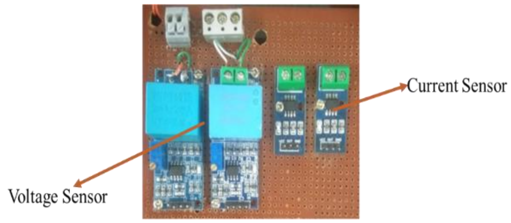


Fig.8. Transducer circuit

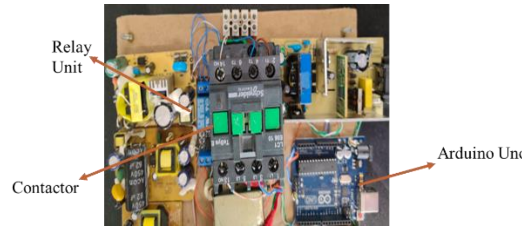


Figure.9. Synchronizing circuit

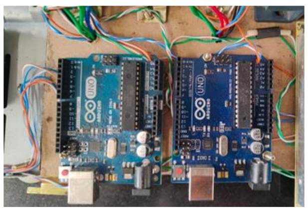
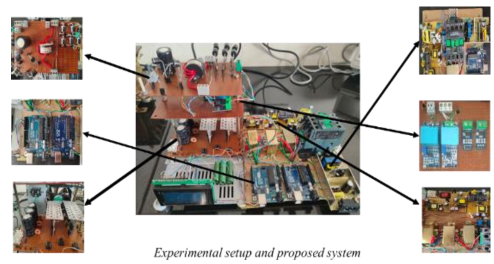


Figure.9. Blanking Circuit

Figure.10. Power supply module



Experimental setup and proposed system

Hardware Results

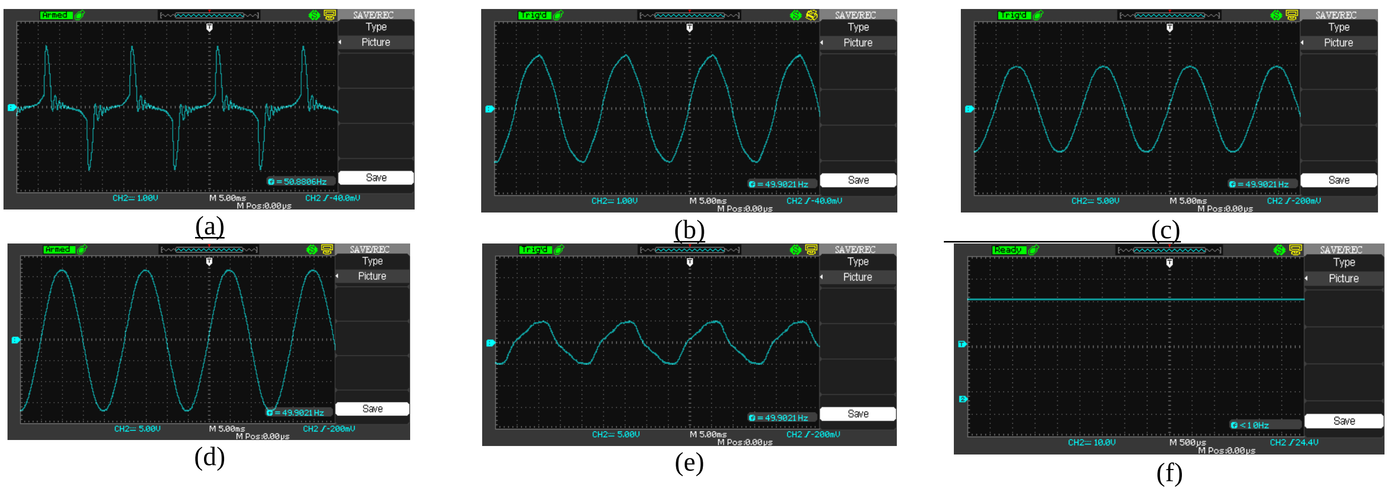


Figure 11. Hardware output of STATCOM (a) Source current before compensation (b) Source current after compensation (c)Source voltage before compensation (d) Source voltage compensation (e)Filter current (f)DC link voltage

11) **Innovation:** Enhanced Power Quality, Grid support During Faults, Scalability and Modular Design, Smart Grid Integration, High-Penetration Renewable Integration

12) **Scope for future work:** Advanced Control Strategies, Integration with Energy Storage Systems, Grid-Forming Capability, Optimal Placement and Sizing, Hybrid PV-STATCOM Systems, Impact of PV-STATCOM on Distribution System Protection, Economic Viability, Cybersecurity and Communication, Reliability and Fault Ride-Through Capability, Harmonic Mitigation Techniques, Economic Incentives and Policies.

13) **Conclusion:** In conclusion, the DC link capacitor-based PV-STATCOM is an effective solution for reactive power compensation and voltage regulation in photovoltaic power systems. It provides fast and accurate control of reactive power exchange between the PV system and the grid, while also mitigating the effects of voltage fluctuations and harmonic distortions. The use of power supply modules and other hardware components allows for precise control and monitoring of the system, ensuring reliable and efficient operation.