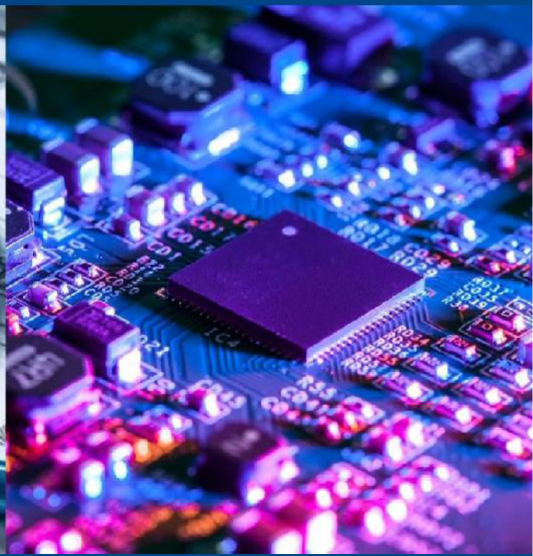
ISSN: 2582-7219





International Journal of Multidisciplinary Research in Science, Engineering and Technology

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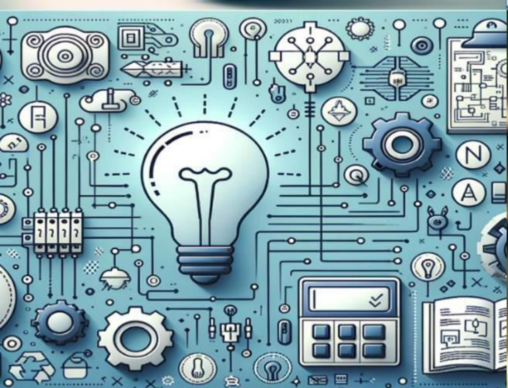

Impact Factor: 8.206

Volume 8, Special Issue 2, November 2025

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

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|| Volume 8, Special Issue 2, November 2025 ||

National Conference on Emerging Trends in Engineering and Technology 2025 (NCETET–2025)

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Grid Tied Solar PV System with Power Quality Enhancement using Adaptive Generalized Maximum Versoria Criterion

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ABSTRACT: This project presents a three-phase grid-tied solar photovoltaic (PV) system with features for power quality correction. This system compensates for a number of power quality (PQ) problems, including harmonics, redundant reactive power, and load unbalancing, while transferring power produced by a solar PV array to feed linear and nonlinear loads. A three-phase voltage source converter (VSC) is used to transform the DC electricity produced by the PV array into AC. For the grid-tied solar PV system to transfer active power and reduce PQ issues, an effective control method is needed.

The Perturb and Observe based maximum power point tracking (MPPT) algorithm is used to make efficient use of the solar PV array. An IGBT-based VSC and DSP (dSPACE DS-1202) are used in the lab to build the experimental grid integrated PV system setup. Using a laboratory prototype, the effectiveness of the AGMVC control mechanism is experimentally confirmed.

This control method is contrasted with several traditional controllers, including instantaneous reactive power theory (IRPT) and synchronous reference frame theory (SRFT), as well as newly created weight-based controllers, such as normalised kernel least mean fourth-neural network (NKLMF-NN), least mean mixed norm (LMMN), and least mean square (LMS). AGMVC is compared to the control methods mentioned above using a number of variables, including fundamental weight convergence, steady state error, computational complexity, phase lock loop (PLL) requirement, and harmonic compensation capacity. The IEEE-519 standard is used to verify the system's performance.

KEYWORDS: AGMVC - Maximum power point tracking - Power quality - Solar photovoltaic - Voltage source converter.

I. INTRODUCTION

1.1 GENERAL

The centralized power grid is experiencing a substantial burden, during a time when electricity consumption is at its peak. Considerable losses in transmission and distribution lines reduce the grid's efficiency. Power outages in the grid are caused by environmental (e.g., heavy rain or wind) and non-environmental (e.g., equipment failure) reasons. The large central power plants in India are generally based on fossil fuel, contributing around 1.026 billion tons of CO2 released each year into the environment. Moreover, a large portion of the rural population in India has no access to a reliable power supply; which hampers the socio-economic development of the people in a particular geographic region. To address these issues, solutions in the form of renewable sources of energy are needed and our country has a vast potential to generate electricity from solar energy [01-04].

Solar photovoltaic cells, along with power electronics based converters, forms a solar energy conversion system. This system can be operated in grid connected or standalone modes, depending on the grid availability. Standalone solar PV systems require battery storage, which increases its capital and maintenance costs. A grid interfaced solar PV system does not require battery storage, therefore these systems are more attractive. A solar PV array power at maximum rating can be extracted using a maximum power point tracking (MPPT) algorithm. Several MPPT algorithms, including incremental conductance (InC), Fuzzy logic control, hill climbing, perturb and observe (P&O), a numerical approach etc., have been documented in the literature.

Two topologies are suggested for integrating solar PV array with the utility grid, namely single stage and double stage. In single stage, the PV array is directly connected at the DC link of the VSC without any intermediate stage. The advantage with a single stage system is that it provides improved efficiency; while the double stage system offers better stability. Moreover, with the increasing penetration of nonlinear loads, such as LED lights, battery chargers, electronic ballasts, adjustable speed drives, uninterrupted power supply etc., harmonics are being injected in the power distribution system.

This could be possible with the introduction of fast, less complex and robust control techniques. Adaptive filters based control techniques are becoming more popular, because adaptive controllers use the information gathered in real time to modify their parameters and improve their performance in balanced and dynamic loading conditions. Several adaptive control techniques are reported in literature, these are, hyperbolic tangent function (HTF) based higher order adaptive control, least mean mixed norm, adaptive notch filter, adaptive enhanced phase lock loop, and multistage adaptive filter (MAF). The above mentioned literature reports PV system feeding active power as well as improving power quality, however limited features of active power filters are incorporated in the system. The proposed setup is a grid tied solar photovoltaic system (single stage). This system assists in reducing distribution losses and also provides ancillary services, such as harmonics mitigation, local generation of reactive power and balancing grid currents. Therefore, this system not only transfers active power to the grid/load, but also acts as a power quality compensator [05-06].

II. PROPOSED SYSTEM

BLOCK DIAGRAM

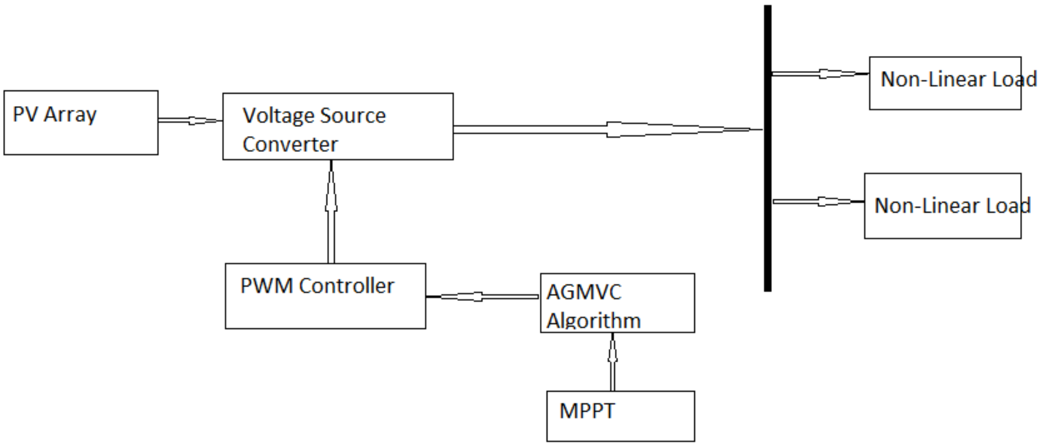

Fig 1; Block diagram of proposed system

It consist of a Voltage source converter fed from a PWM controller. The PWM controller is received input from MPPT. Adaptive generalized maximum Versoria criterion (AGMVC) algorithm is used to tune the PWM controller. The AGMVC is a powerful algorithm which will give better output from the PWM controller to energise the voltage source converter. The PV array is connected to Grid through a VSC. Non-linear loads are considered in the proposed system [07-12]. The AGMVC can adjust the firing pulse to the VSC and can mitigate the power quality issues at the earliest. Block of the proposed system is shown in figure 1.

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MPPT Algorithm

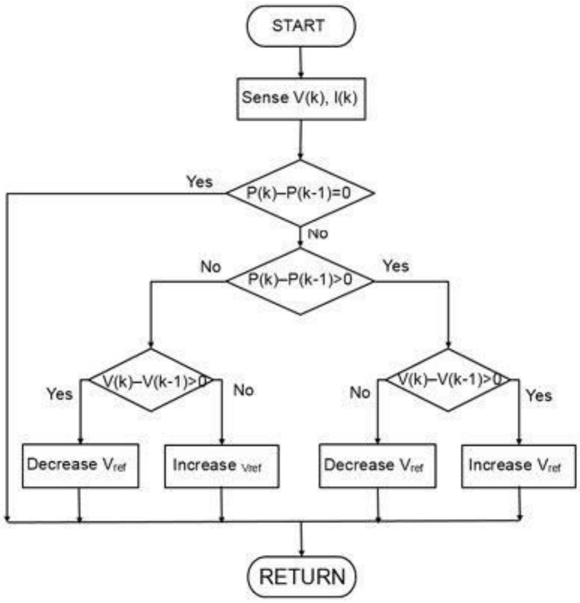

Fig 2; Flow chart of MPPT

An MPPT (Maximum Power Point Tracking) algorithm is a control system used in solar power and other renewable energy systems to ensure the device operates at its maximum possible power output. It does this by continuously adjusting the load to find the point where the voltage and current are optimized to produce the highest power under changing conditions like sunlight intensity and temperature. Common algorithms include Perturb and Observe (P&O) and Incremental Conductance (IC), which are popular for their simplicity and effectiveness, but more advanced methods like artificial neural networks (ANNs) are also used. The flow chart for the MPPT is shown in figure 3.

Circuit Diagram of Voltage Source Converter

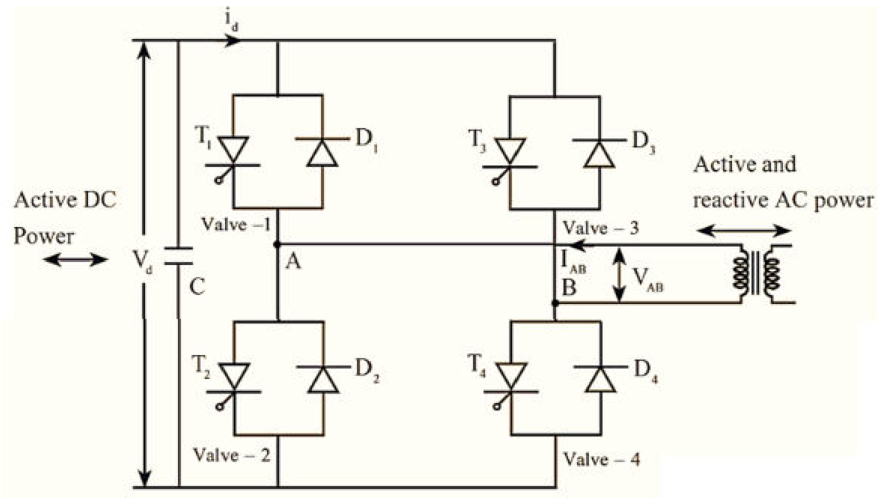

Fig 3; VSC with Isolation Transformer

Voltage source converter generates A.C voltage from D.C voltage. A single phase full wave bridge converter consists of 4 valves, namely valve-1, valve-2, valve-3 and valve-4 and each valve consists of a turn-off device T, and diode D,

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connected in series with each other. On the D.C side, as the voltage is unipolar, it is supported by a capacitor. The capacitor is used to handle the current that accompanies the switching sequence of the converter valve and shifts in phase angle of the switching valves without change in D.C voltage and two ac connection points A and B. The circuit diagram of VSC is shown in figure 5.

Conversion of AC voltage to D.C voltage is possible by changing the turn-ON and turn-OFF sequence of valves. In one cycle the single phase full wave bridge operates in four different operating modes as given below,

1. T_1 and T_4 ON, T_2 and T_3 OFF (Inverter)
2. T_1 and T_4 ON, T_2 and T_3 OFF (Rectifier)
3. T_1 and T_4 OFF, T_2 and T_3 ON (Inverter)
4. T_1 and T_4 OFF, T_2 and T_3 ON (Rectifier)

From the 1st operating mode time t_a to t_b with the turn-off devices T_1 and T_4 ON and T_2 and T_3 off, V_{AB} is positive and current i_{AB} is negative. Here power flow is from D.C to A.C. Hence inversion action takes place. In 2nd operating mode time t_b to t_c, the current i_{ab} is positive and flows through diodes D_1 and with power flow A.C to D.C. Hence, it acts as a rectifier. Similarly 3rd and 4th operating modes are conducted.

III. SIMULATION DIAGRAM

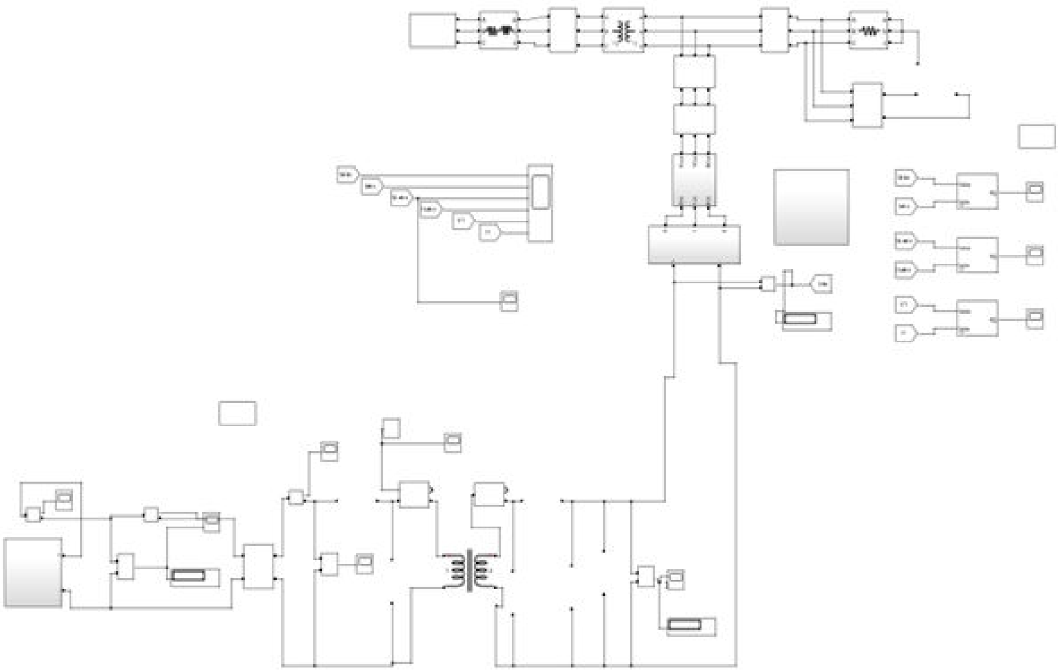

Fig 4; Simulation diagram of proposed system

The simulation diagram of the proposed system is shown in the diagram. It has a PV array with converter and connected to the grid through isolator. The non-linear loads are connected with the grid. Two conditions were checked (i) Isolator in open condition (ii) Isolator in closed condition.

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PV – Array Sub-System

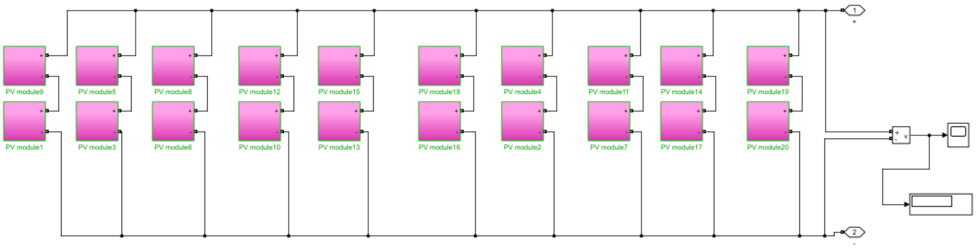

Fig 5; PV array

The PV array which is connected number of PV panels in series-parallel combination and connected to grid through inverter.

Voltage Source Converter sub-system

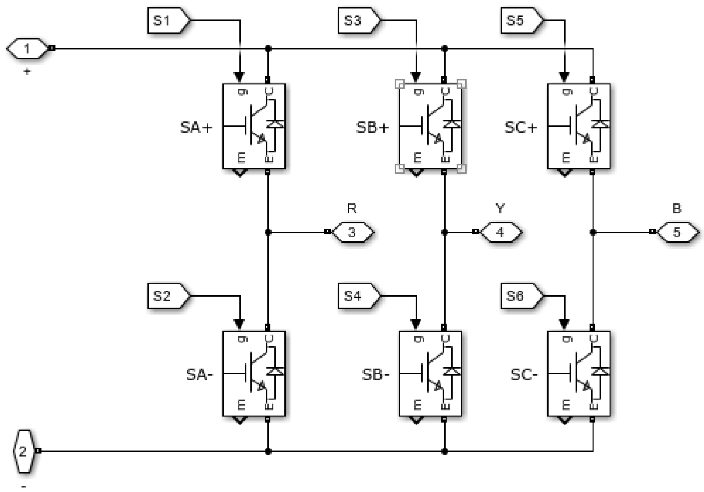

Fig 6; Circuit diagram of VSC

Filter sub-system

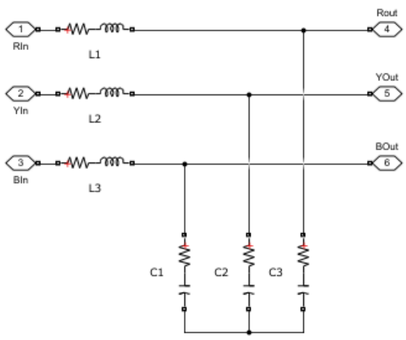

Fig 7; Filter Circuit

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Conversion of d-q parameters; sub-System

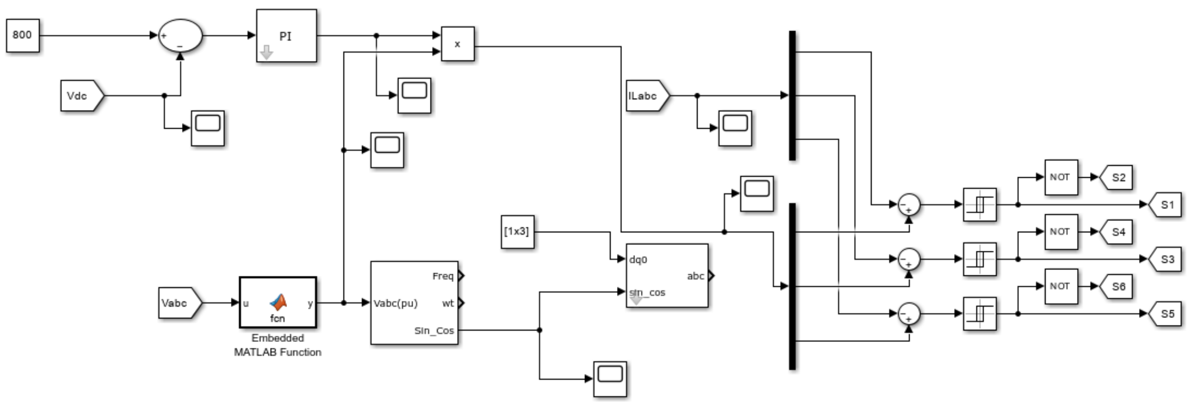

Fig 8; Simulation Sub-system for d-q parameters

3.1 SIMULATION OUTPUT

Simulation Output - Isolator open condition

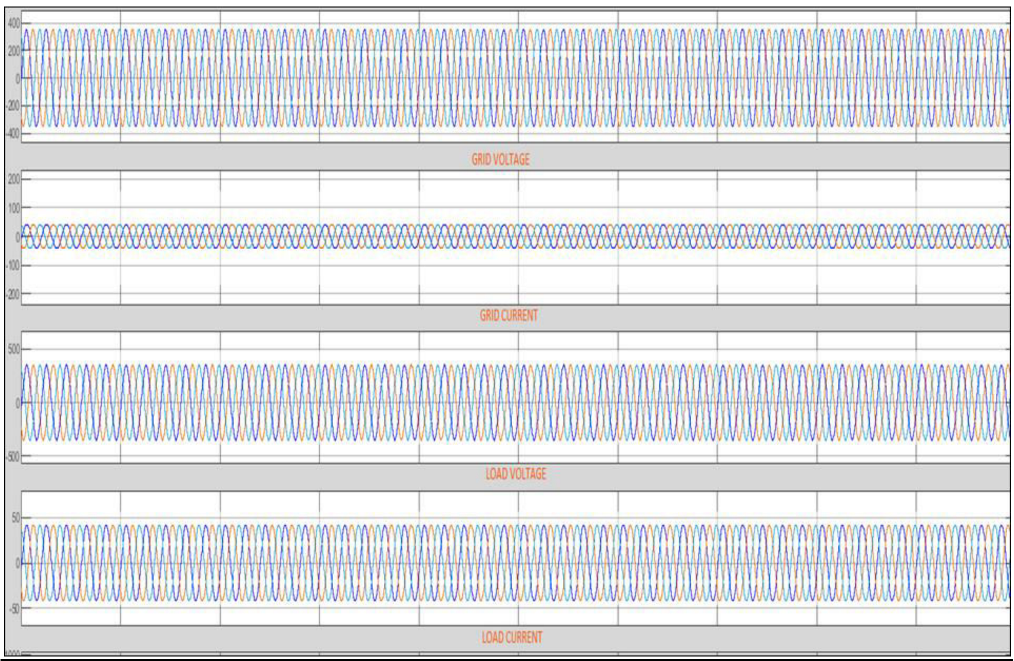

Fig 9: Output of the proposed system when Isolator is opened

The proposed system is analysed with non-linear loads. There are 2 condition verified in this system.
1. When the isolator is closed; that is the non-linear loads are included in the total circuit diagram. Generally power quality issues are originated when the non-linear loads are included. The objective of this experiment is to remove the power quality issues when switch is closed that is the non-linear loads are connected in the circuit.
2. When the isolator is opened; During this condition, the non-linear loads disconnected from the circuit. Therefore there will not be any power quality issue during this condition.

The output of the proposed system compared in both connections.

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Simulation Output - Isolator closed condition

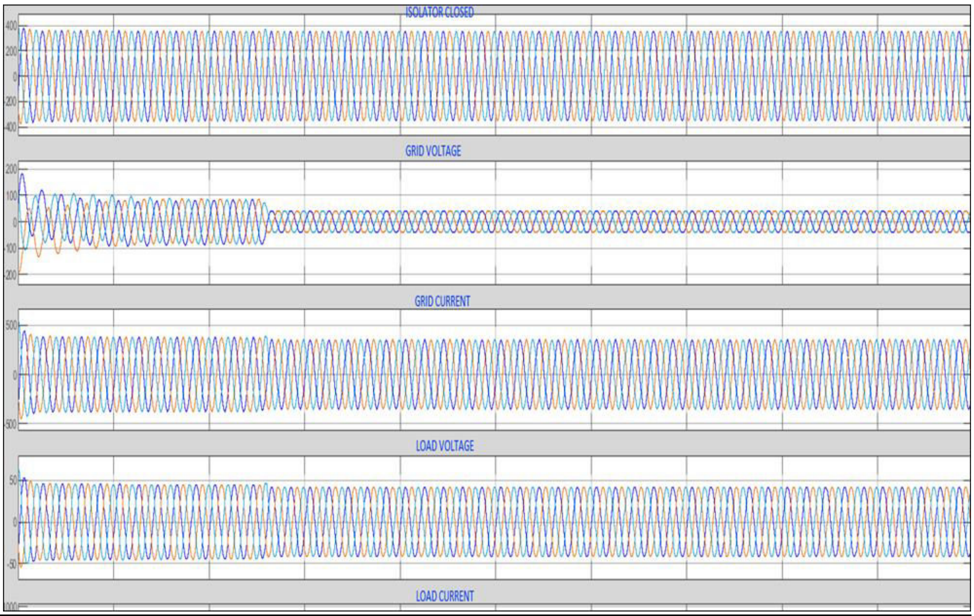

Fig 10: Output of the proposed system when Isolator is closed

The output taken during the isolator is closed, that is connected. The output received in this condition is similar to the previous case.

3.2 Simulation Output - Gate Pulse to MOSFET

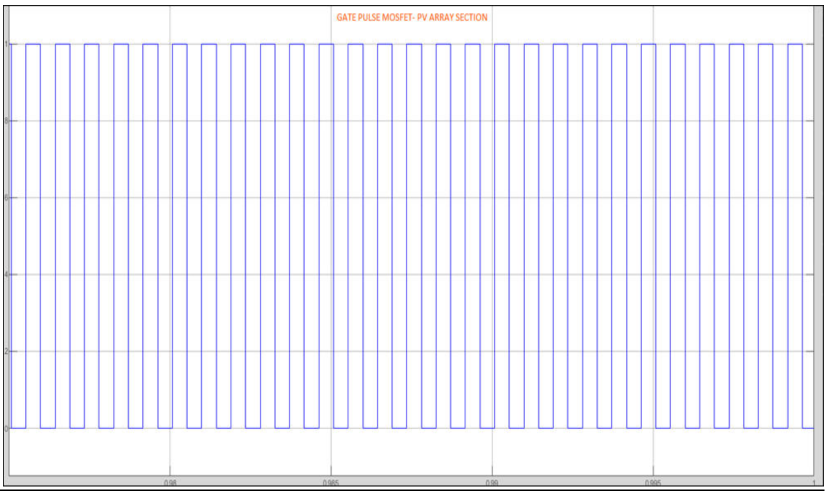

Fig 11: Gate Pulse to the Converter

The converter is triggered by the gate pulses as shown in the figure. PWM pulses are used to turn on the devices. The AGMVC algorithm is used to drive the PWM pulses.

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IV. CONCLUSION

In this project, a 3-phase grid tied solar PV system is designed and realized. This system operates to feed active power to the linear/nonlinear loads with power quality compensation features viz., harmonics, immoderate reactive power and unbalancing. These features of a solar PV system are performed with a 3-phase voltage source converter (VSC). An adaptive generalized maximum Versoria criterion (AGMVC) based control technique is developed to achieve multifunctional capability of VSC in the solar PV system. The control approach is designed for the converter in such a way that the PV system can perform active power transfer along with power quality compensation. The performance of AGMVC controller is realized in both simulation and experimentally. Results with solar PV system controlled using the proposed control technique demonstrate effective results in reducing the THD percentage of the grid current 3.7% experimentally, whereas the load current THD percentage is 24.1%.

The AGMVC control technique has also been tested for unbalanced load conditions. During unbalanced load current, the grid current has been observed balanced and sinusoidal due to the controller action. The performance of the AGMVC control approach has been compared with SRFT, IRPT, LMS, LMMN and NKLMF-NN in terms of weight convergence, error (between actual and estimated load currents), PLL requirements, computational time and harmonics compensation. The AGMVC controller for the solar PV system has demonstrated improved performance over other mentioned controllers in the majority of the features evaluated.

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