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Power Quality Enhancement In Grid Connected Solar PV System Using Dynamic Active Compensation System (DACS)

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Abstract: Rapid Industrialization and demand for Energy makes the distribution system more complicated. To address such issue robust control system is being developed for newly implemented microgrid and smart grid concepts. These control systems being a complex structure interconnects the renewable sources with the conventional sources of energy production. The power quality issues arising due to interconnection of number of variable generation system makes it more dynamic and fault oriented. The dynamics of the system is due to the use of power conditioning unit in the renewable system. Most of the power conditioning unit are of current source inverter type. However if these inverters can be made up of voltage source type then reactive power compensation can be achieved in addition to the active power supplied by the inverter into the grid. Dynamic Active Compensation System (DACS) is simulated through MATLAB to validate the performance.

Keywords: PQ, Solar PV, D-STATCOM, etc.

I.INTRODUCTION

Conventional fossil fuels based power generation stations arise serious environmental pollution problems and degradation of fossil fuels reserves across the world [1,2]. On the other hand, increasing public awareness about environmental degradation resulted into innovation of new technologies. As a result, Non-Renewable Energy Sources (RES) like Solar PV System, Wind, Biomass, etc became more popular. Therefore, in a modern power grid, Distributed Generators (DG) units are implemented rapidly and new technologies are being developed to integrate these renewable energy sources without disturbing operation of the main power grid. But renewable energy resources are intermittent in nature due to meteorological factors, therefore integration of renewable power generation directly into utility power grids in a conventional way can lead to deterioration of system stability and reliability [1-7].

The microgrid concept has emerged as a prospective solution to problems associated with integration of renewable DG units. A microgrid is defined as a local distribution system, which integrates distributed generators, energy storage, dispersed loads, data acquisition, communication, protection and supervisory control devices etc. It can operate being connected or disconnected from the main power grid in an organized and coordinated fashion [3]. The microgrid allows increased penetration of small capacity DG units, where the generation is mainly localized at the customer end. It increases power generation capacity, reduces the pressure on existing transmission system as some loads are supplied by the microgrid, and load congestion of the conventional utility grid is also reduced. Moreover, a microgrid offers increased flexibility in control to satisfy power quality requirements and improve reliability of the system. Recent development of power electronic devices and advancement of control technologies facilitate integration of renewable based DG units to great extent. As a microgrid can be operated in an islanded mode or a grid-connected mode, it is susceptible to power quality problems originated from both DG and power grid sides. For example, non-controllable variability of renewable energy resources and grid side disturbances such as voltage sags can lead to voltage and frequency fluctuations in microgrids [2,5].

The high speed switching of the interfacing inverters can result in harmonic distortions. Moreover, the presence of nonlinear, unbalanced and reactive local loads can also cause deterioration of power quality. The microgrid can be operated in islanded mode when the power quality is not satisfactory due to grid side disturbances. However, according to modern grid codes, the distributed generation such as solar photovoltaic (PV) power plants must have the capability to ride through specific disturbances without disconnecting from power grids[1]. Therefore, switching to an islanded mode as soon as the grid side disturbance occurs is not always an option. Poor power quality can cause economic losses as the price of electricity is directly related to the quality of power delivered by DGs and microgrids; additional loss and overheating occurs in different power equipment; and stability of the system is also influenced by poor power quality at the grid interconnection point. Therefore, it is very important to ensure that good power quality is achieved by DG units[1].

When a microgrid is tied to a utility grid, any internal disturbance in the microgrid may cause power quality problems in the utility grid and vice versa. A power quality conditioner needs to be used between the microgrid and the utility grid to ensure that disturbances occurred in one side does not initiate power quality problems in other side. Different passive power quality conditioners such as, harmonic filters and capacitors are conventionally used, which have lower cost and are easy to maintain. The active power quality conditioners such as active power filter (APF), dynamic voltage regulator (DVR), power factor correction (PFC), unified power quality conditioner (UPQC), STATCOM etc. can offer superior performance and better flexibility compared to passive devices, and thus, being utilized more recently. However, no matter what mechanism is used, an additional device for power conditioning will involve installation and maintenance cost, and also require additional spaces. Such devices may also adversely impact stability and reliability of microgrids. One preferable solution to this problem is to utilize advanced control technologies through the inverter, which is interfaced between a DG unit and a microgrid, to provide power quality improvement [1-5].

The DG units are often integrated to microgrids with the aid of a power electronic converter, if a proper control strategy is employed for the interfacing converter, it can take part in ancillary services such as voltage and frequency regulation, harmonic suppression etc. and can effectively compensate power quality problems, along with maintaining its primary role which is control of power injection.

II.GRID INTEGRATION OF PV SYSTEM

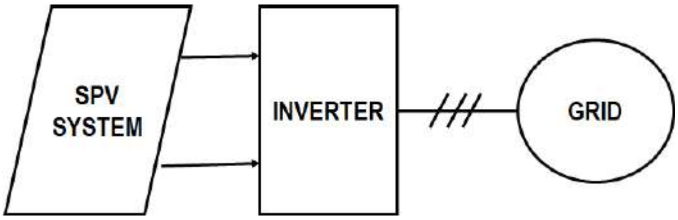

Fig. 2.1 Schematic diagram of grid integrated solar system

The power obtained from the Solar PV system is in the form of DC quantity. So to integrate the solar energy into the Three phase grid an inverter is required, which convert the DC voltage to AC. For integration, it is very important to match the frequency and phase of output AC voltage of Inverter with the Grid voltage. In addition to this, it is necessary that the voltage obtained across the inverter should be of higher magnitude than the grid so that the power can flow from PV source to grid. A schematic diagram of grid integrated PV system is shown in Fig. 1.

A. Types of SPV system

1) Standalone solar PV system (Off grid)

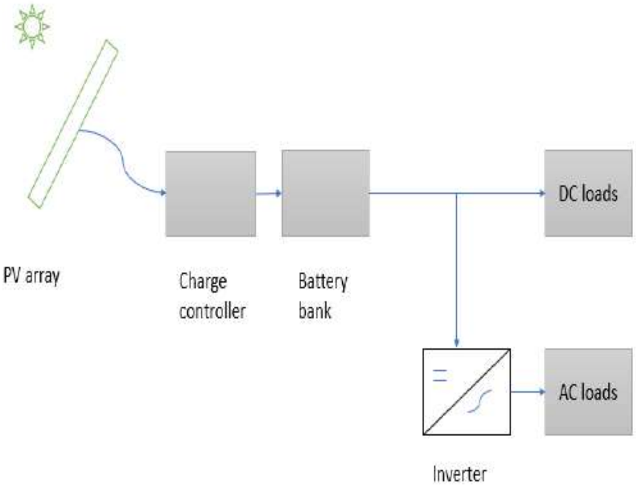

Fig. 2.2 PV system is stand-alone (off grid)

Stand-alone operates independently PV system of other power supplies any supplies electricity to dedicate loads storage facility like battery bank to supplies electricity provide during night & sunlight level down. Standalone system also often uses autonomous system since independent operation of other power source.

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2) Solar PV with Hybrid system

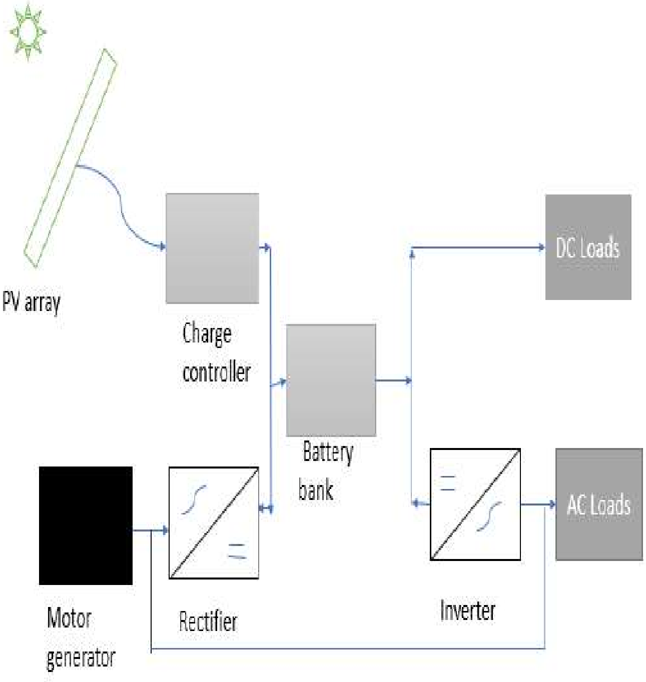

Fig. 2.3 Hybrid Solar PV system

In power system install one more power supply like diesel generator wind turbine to the system meet some of load requirement, these systems known as hybrid system. Hybrid system used in grid connected as well as standalone mode. Application but are more common in former because, provide the power supplies chosen complementary, allow reduction of the storage requirements without increase loss of load.

III.SOLAR PV WITH MPPT

Solar PV System is intermittent in nature due to meteorological factors like temperature, irradiation, angle of the sun, clouds, etc. This makes the output more dynamic and reduces the efficiency of the SPV System. To improve the efficiency of SPV, the Maximum Power Point Tracking (MPPT) technique is used. The voltage at which the PV module can produce maximum power is called maximum power point. In this paper, P&O algorithm is used for MPPT.

A. Photovoltaic system with MPPT (Grid connected)

Grid connected in two stage

Stage-1: - Grid connection PV systems connected to DC-DC boost converter & then fed to a DC-AC converter.

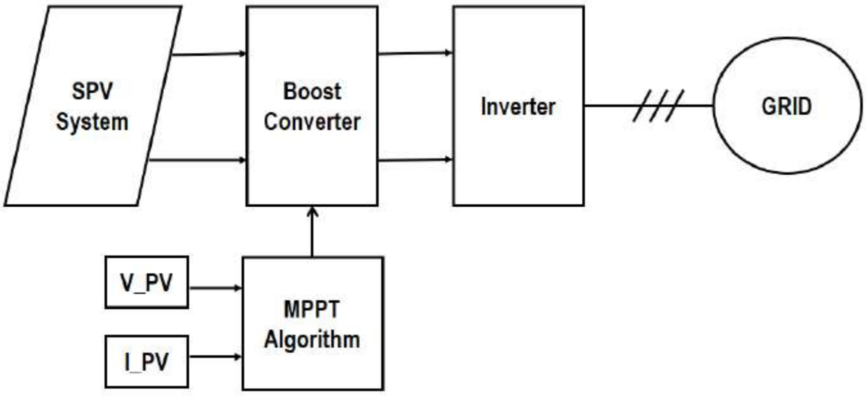

Fig. 3.1 Grid integrated Solar PV system with DC-DC converter and DC-AC converter

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- In this system have Boost converter and inverter circuit use and connected at grid side. Parallel operation with PV system is grid connected for conventional electricity distribution system. Electricity feed into grid system or power loads which can also fed from the grid.

Stage-2: - Directly connected to DC-AC converter & the grid connection to PV system.

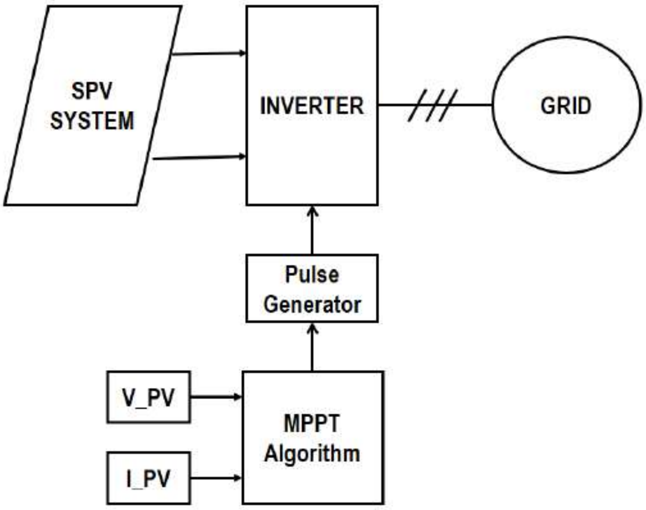

Fig. 3.2 Grid integration PV system with DC-AC converter

But the Grid integrated PV system with DC-DC converter & inverter is preferred DC-AC converter are useful noise isolation & power bus regulation.

B. Introduction of Solar Inverter

Solar inverter defined as a one type of converter that change a DC output of solar PV into an alternative current. This current used for different application purpose like off grid electrical supply, grid connected supply. BOS (balance of system) is dangerous is allows to uses of abnormal AC powered components. Inverter have many functions with PV array power tracking maximum power & anti-islanding protection. For residential use of solar system, we are select installation inverter is important. So, inverter is essential part of solar system.

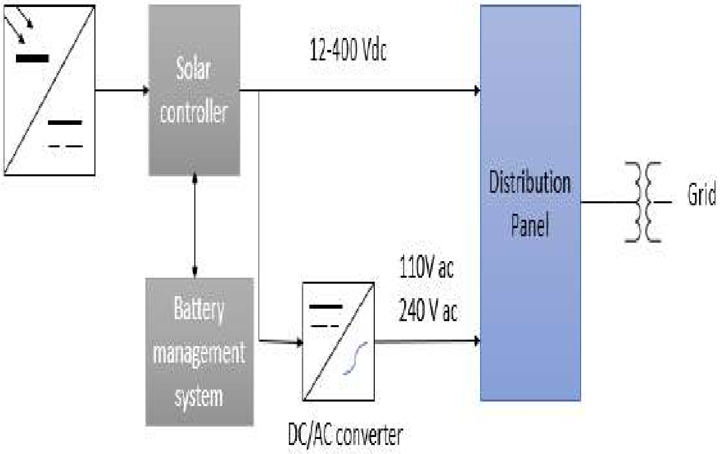

Fig. 3.3 Schematic diagram of grid integrated inverter PV system.

Solar inverter is an important part in power supply system.it convert DC power output into AC current fed into grid and directly influence efficiency and reliability of solar energy system. Output of solar PV is mostly 12V, 24V and 48V, so necessary to use DC-AC inverter to supply power at 230V AC in device. The range of generated power is 250V to 600V. This process conversion can be done with IGBT’S. When solid state is connected in form H bridges then oscillates from the DC power to AC power

1) Types of Solar Inverters

- Stand-alone inverter

Inverter draw its DC energy from batteries charge by PV array in isolated system in standalone inverter also, incorporate battery charge to battery from AC source do not interface in way to utility grid & not needed have islanding protection.

- Hybrid Inverter-

This inverter is also known as a multi-mode inverter also allows to install batteries in the solar power system. It connects the battery to what is known as DC coupling. Electronics handles battery charging and discharging. Therefore, there is an incomplete selection of these inverters.

- Battery based Inverter

Battery-based inverters are increased day by day. These are uni-directional and include both an inverter & battery charger. This operation can be performed with the help of a battery. These inverters are separated by a separate grid, interacting with the grid on and off the grid, based on UL design and measurement. The great advantage of this is that, they provide endless performance of critical loads depending on the grid status. In all occurrences, these inverters carry power between grid and parallel components while charging batteries, and monitor battery status and control how they are charged.

- PWM base Controlling of inverter

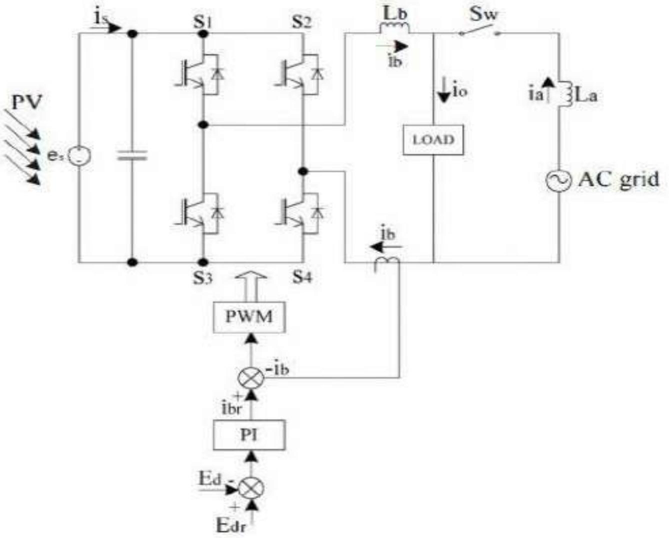

Fig. 3.4 PWM control inverter

Working voltage of PV array Ed, the Edr standard voltage matched with working voltage when PV array in the maximum power output state. The standard current Ibr should kept in sinusoidal while power factor should keep one realized PWM control technique. Protect inverter by SW switch & cuts the inverter system when off. Three parts of control system is mainly three parts AC voltage control, DC voltage control & phase angle control. In AC voltage control part, AC output voltage Eo and its standard voltage is Ear, signal reflect the source voltage directly effects on power transmission between DC system & AC grid Add a control signal. A DC voltage regulator based on the two signals, sine function generator generates AC control voltage, inside voltage control loop contain current control loop which not affect result of voltage control.

IV.PROPOSED WORK

The proposed topology shows the effective interconnection of solar photovoltaic into the distribution system. Here solar PV system is used to provide the required DC link for the operation of an inverter. Fig.s. 8 and 9 shows the general block diagram of the grid connected renewable energy sources (RES) which is used for dual operation i.e. providing active power during day time and reactive power compensation during non-sun shine hour and there by compensating both reactive power and harmonic reduction. The D-STATCOM will provide real time solution to the power quality issues.

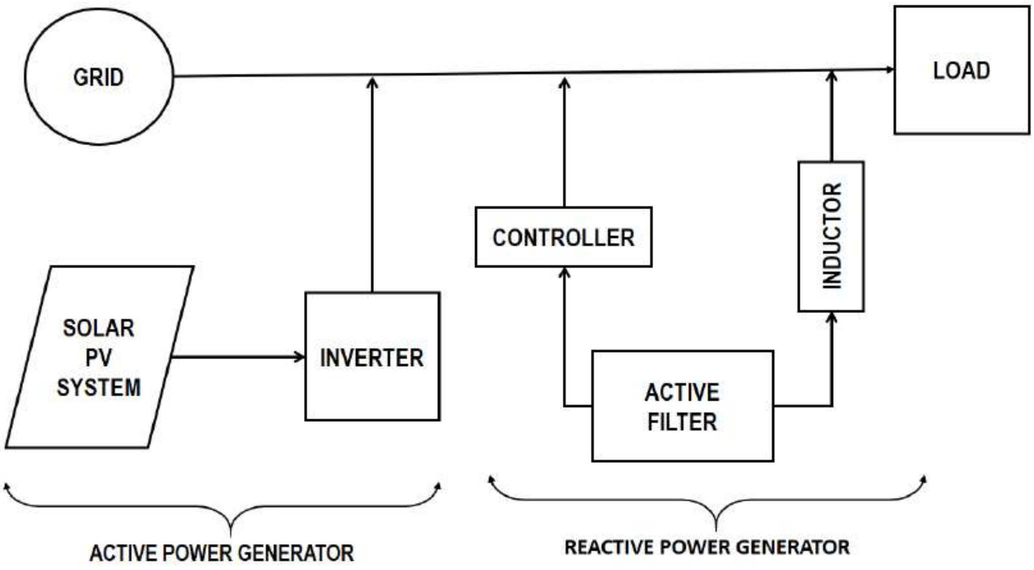

Fig. 4.1 General Block diagram of proposed system [1]

The system consists of a solar photovoltaic cell, a dc to dc converter, two nos. of capacitor. The structure of the system is shown in the Fig. 10. Required variables VPV, IPV, VS are to be measured for implementation of MPPT. In order to make the voltage constant across the capacitor a close loop circuit is considered because the output of the inverter is proportional to the isolation and temperature. To make the system more dynamic here Hysteresis controller is considered instead of PI-Controller. As shown in Fig. 10, Comparator compares the measured three phase grid voltage with the reference voltage and calculates the error present in the system. If it is assumed that measured voltage as positive and reference voltage as negative then more the error present in the system more active power it generates.

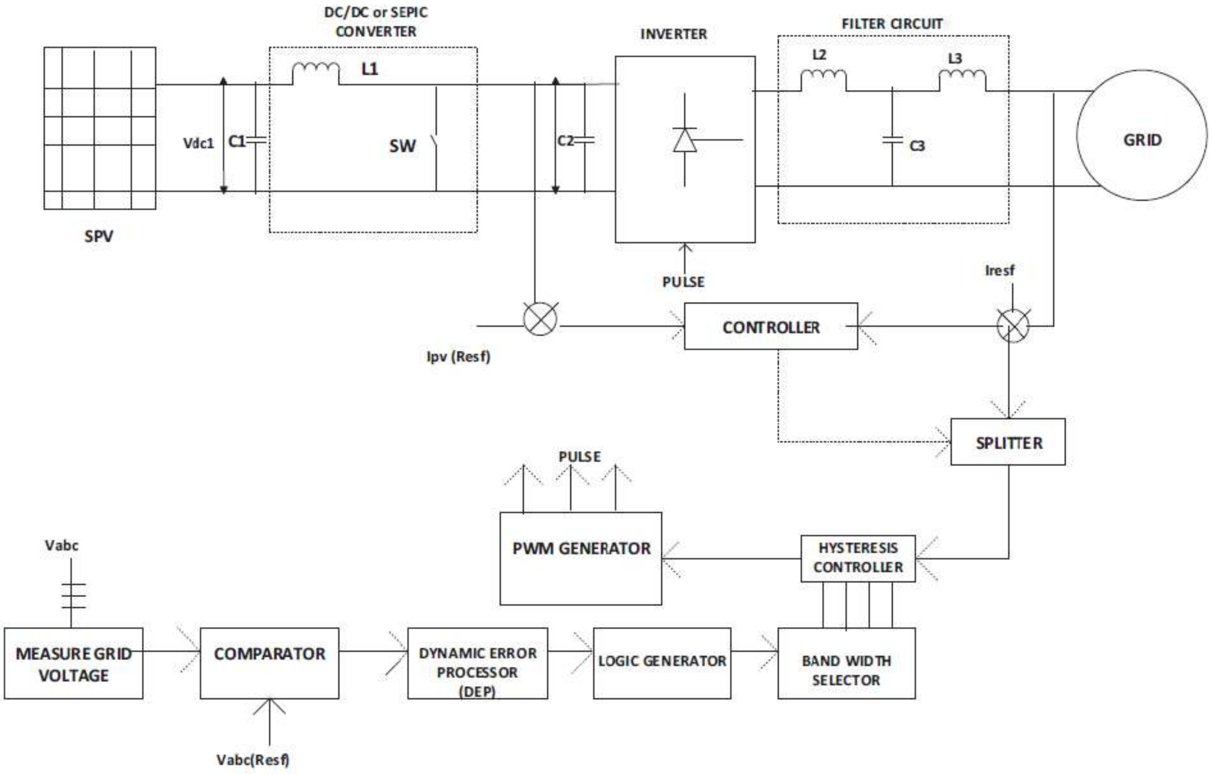

Fig. 4.2 Proposed circuit diagram of hysteresis controller based SPV grid interconnection [1]

So the following equation may be used for this one. Three phase voltage may be concentrated on a single quantity by evaluating the RMS voltage.

$$V_m = \left\{\frac{2}{3}\left(V_a^2 + V_b^2 + V_c^2\right)\right\}^{\frac{1}{2}}$$

Where Vm represents the RMS voltage and Va, Vb, Vc represents three phase voltages.
Weight function for the three phases may be evaluated as

$$W_a = \frac{V_a}{V_m}$$

$$W_b = \frac{V_b}{V_m}$$

$$W_c = \frac{V_c}{V_m}$$

V. SIMULATION AND RESULTS

A. MATLAB Simulation of Grid Connected Solar PV System

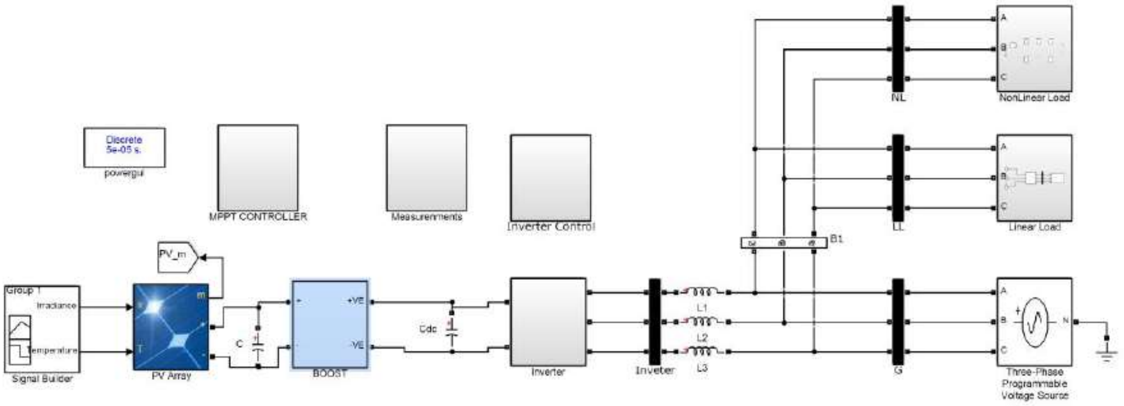

Fig. 5.1 MATLAB Simulation of Grid Connected Solar PV System

As shown in above Fig. 5.1 the MATLAB simulation of grid connected solar PV system includes the modelling of Solar PV system with MPPT & Boost Converter control. The regulating DC output Voltage is given to the Inverter for DC to AC conversion. The AC output from the inverter output is given to the grid side. The closed loop control from the grid is connected for the regulation of AC grid parameters. The linear and Non-linear load is connected in the proposed system for regulation of entire system parameters.

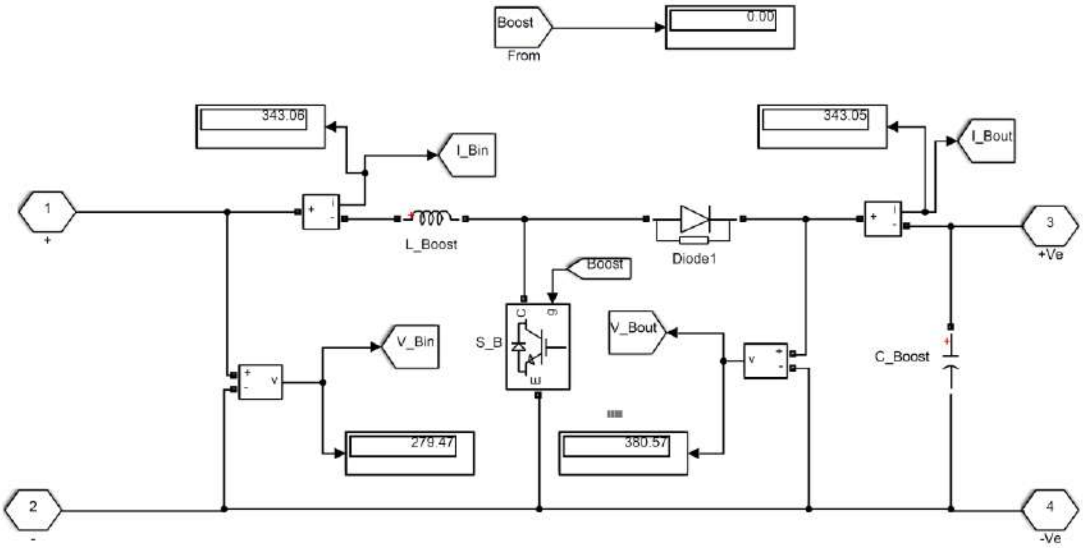

Fig. 5.2 Simulink subsystem of DC to DC boost converter

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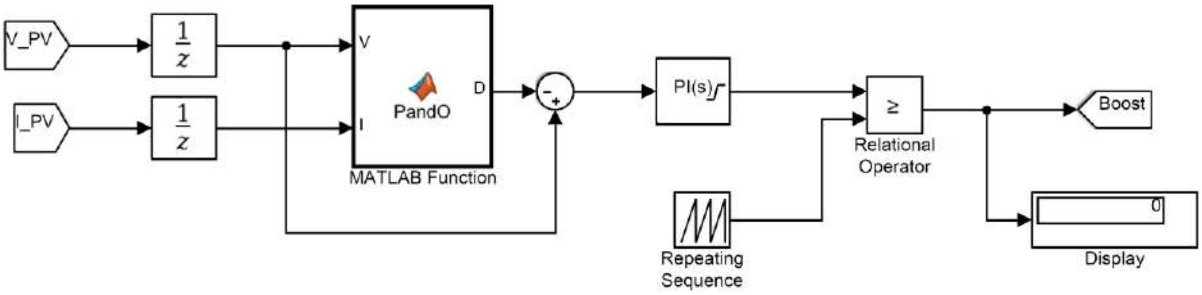

Fig. 5.3 Simulink subsystem of MPPT Controlling Subsystem

The above two figures 5.2 and 5.3 shows the modelling of Boost converter and MPPT for Solar PV system. The P&O algorithm used for the MPPT control in this project. The duty cycle set by the MPPT gives to triggering pulse block for boost converter pulses in this system. The DC output is regulated in the system using both configuration in this project.

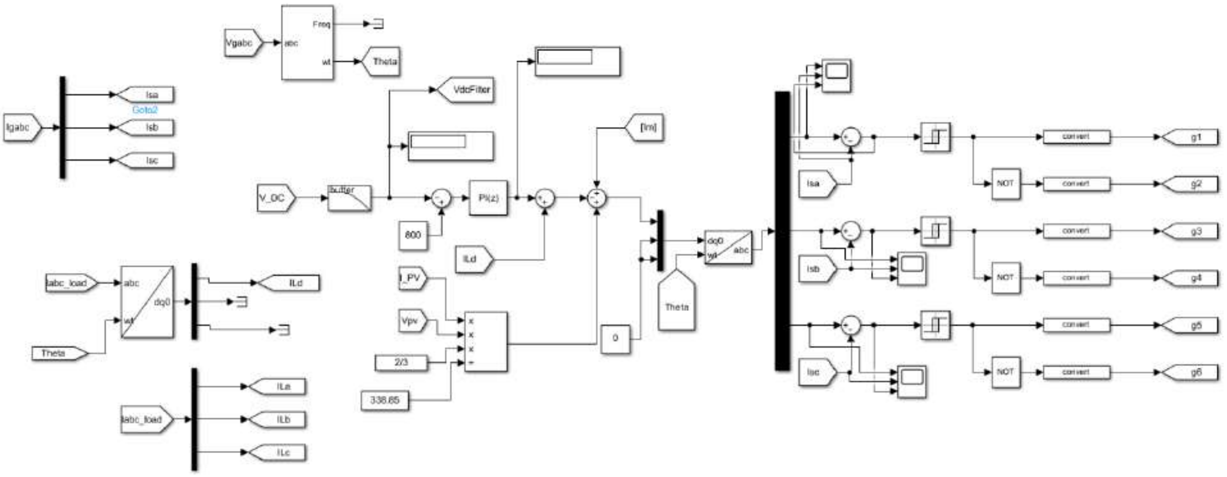

Fig. 5.4 Inverter Controlling Subsystem

Fig. 5.4 is implementation of Fig. 4.2 proposed block diagram of controlling and integrating grid with solar PV system.

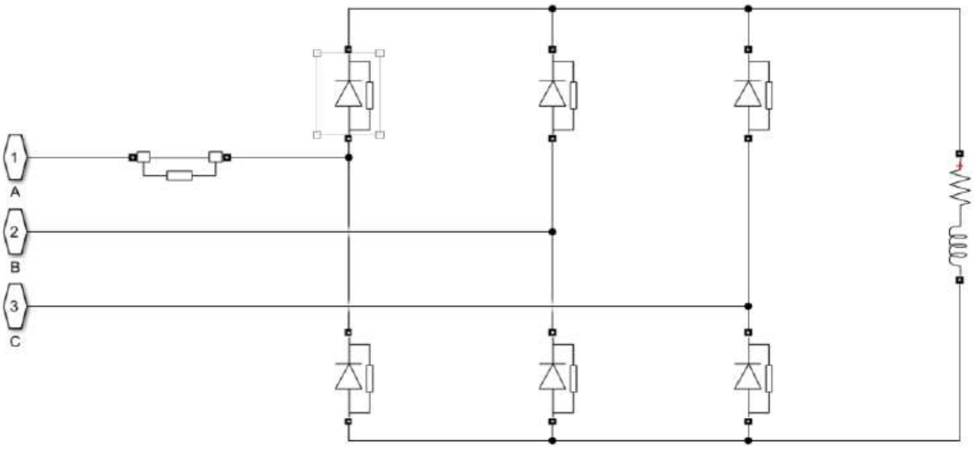

Fig. 5.5 Non-Linear Load Subsystem

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B. MATLAB Results of Grid Connected Solar PV System

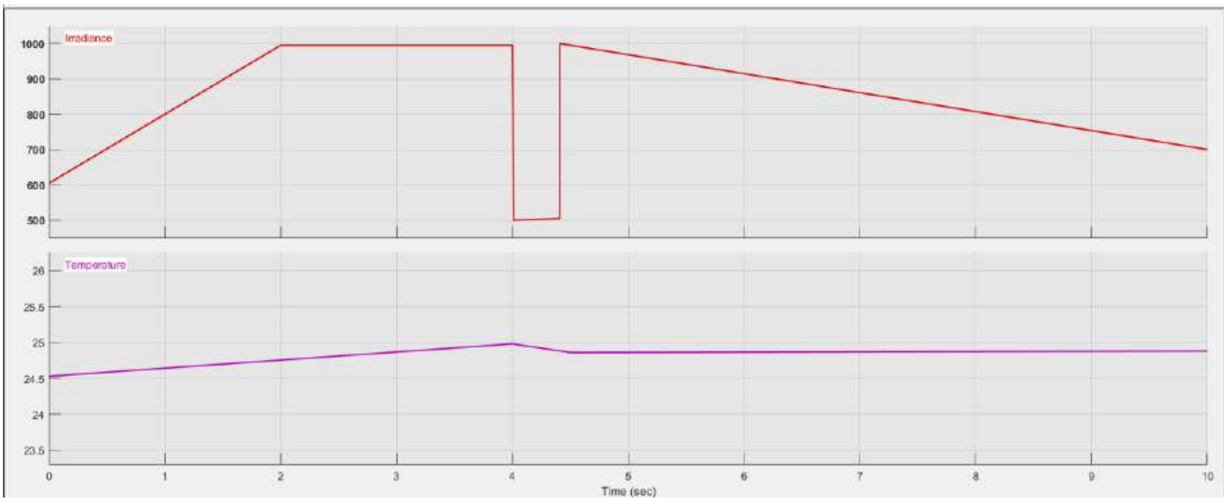

Fig. 5.6 Simulation Result of Solar PV Radiation & Temperature

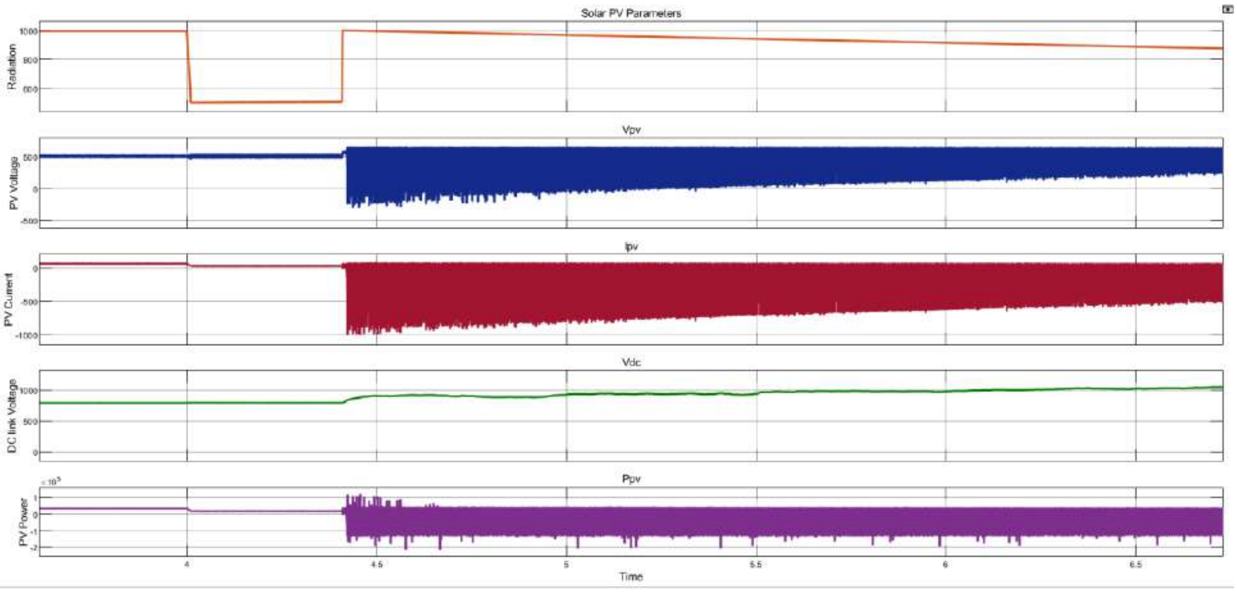

Fig. 5.7 Solar PV output Parameters in Radiation Effects

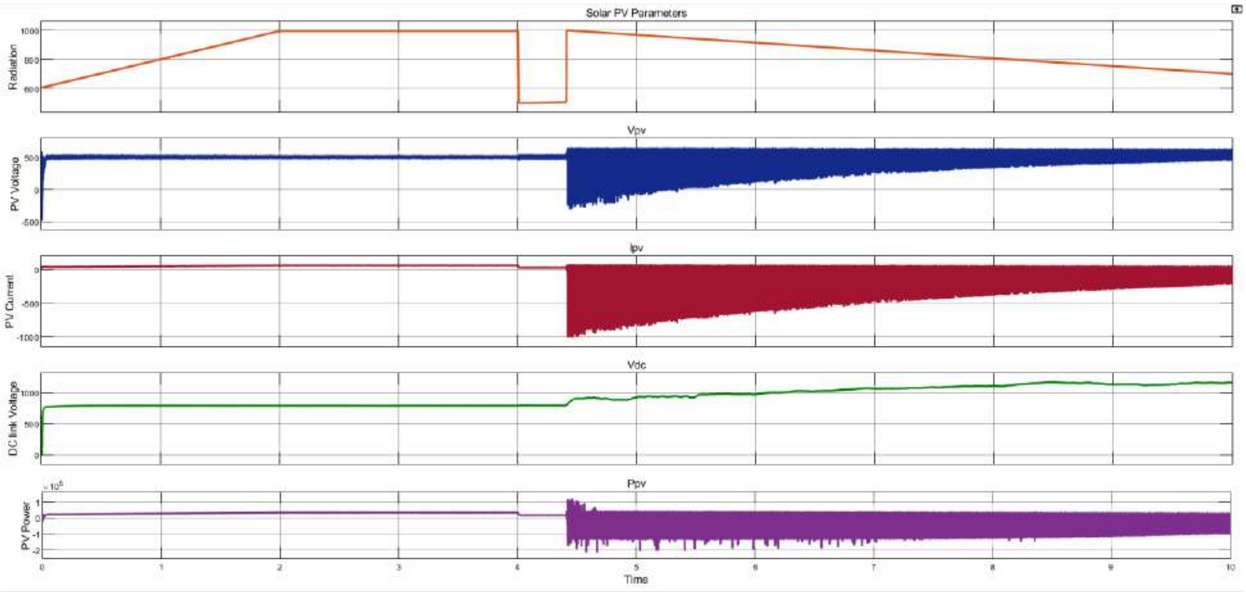

Fig. 5.8 Solar PV output parameters

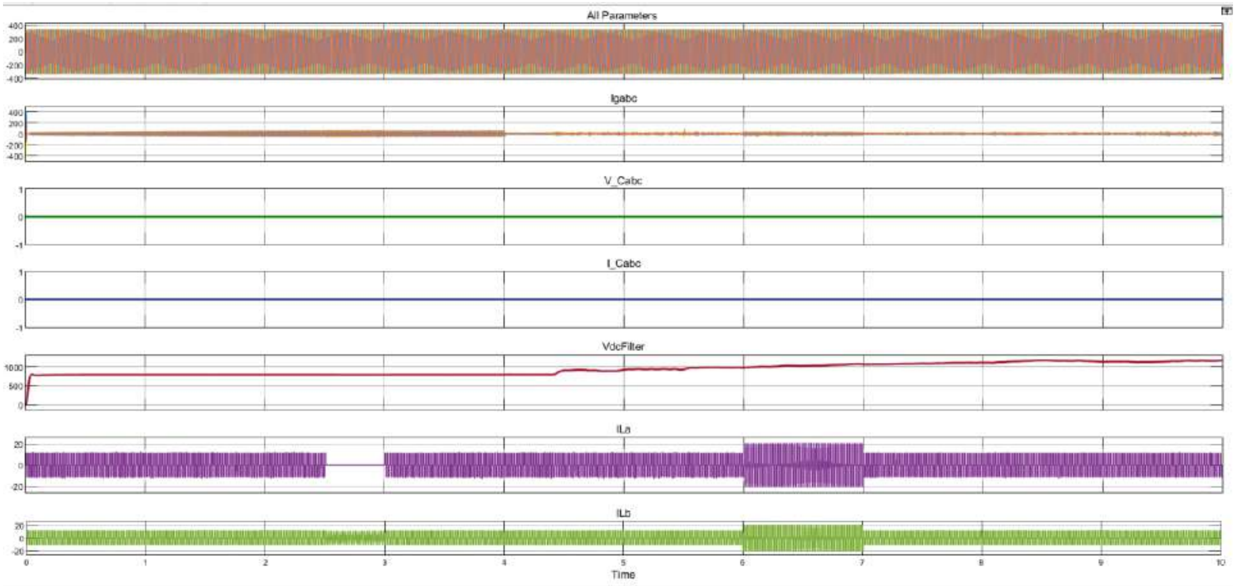

Fig. 5.9 Simulation Results of Solar PV output parameters

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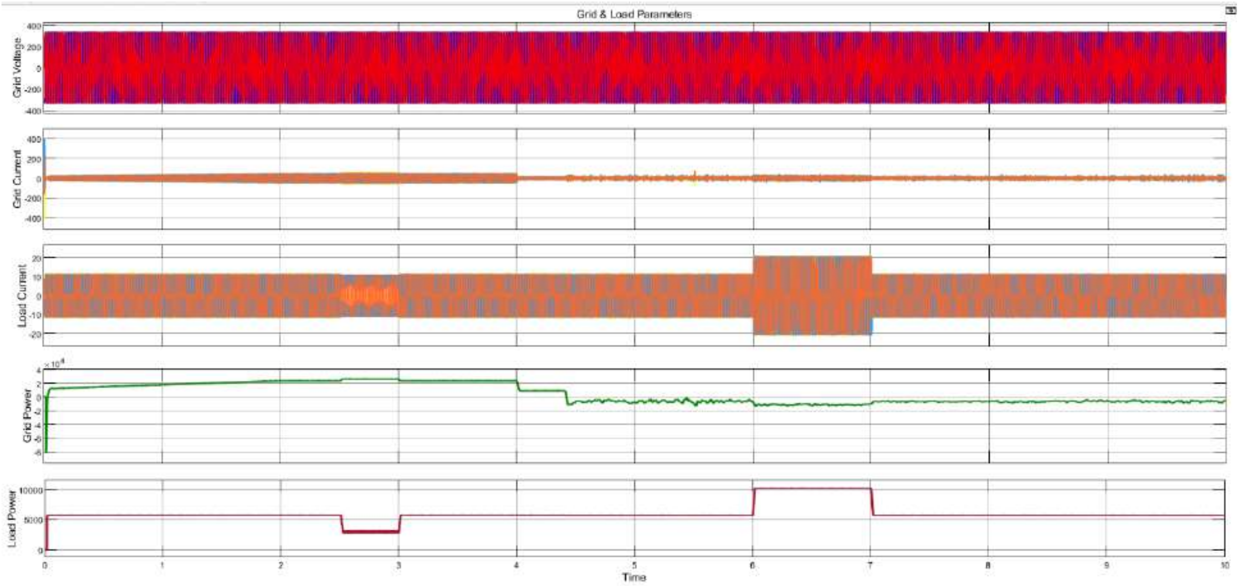

Fig. 5.10 Simulation Results of Grid Side & Load Side Parameters

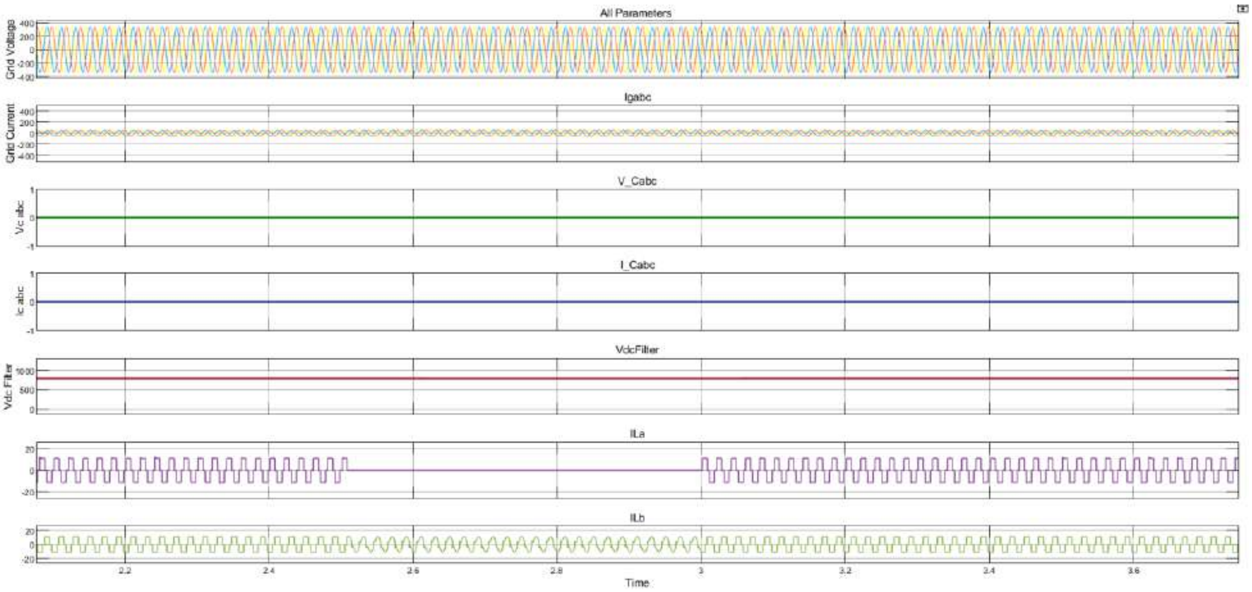

Fig. 5.11 Simulations Results in Load Current Phase-A removal

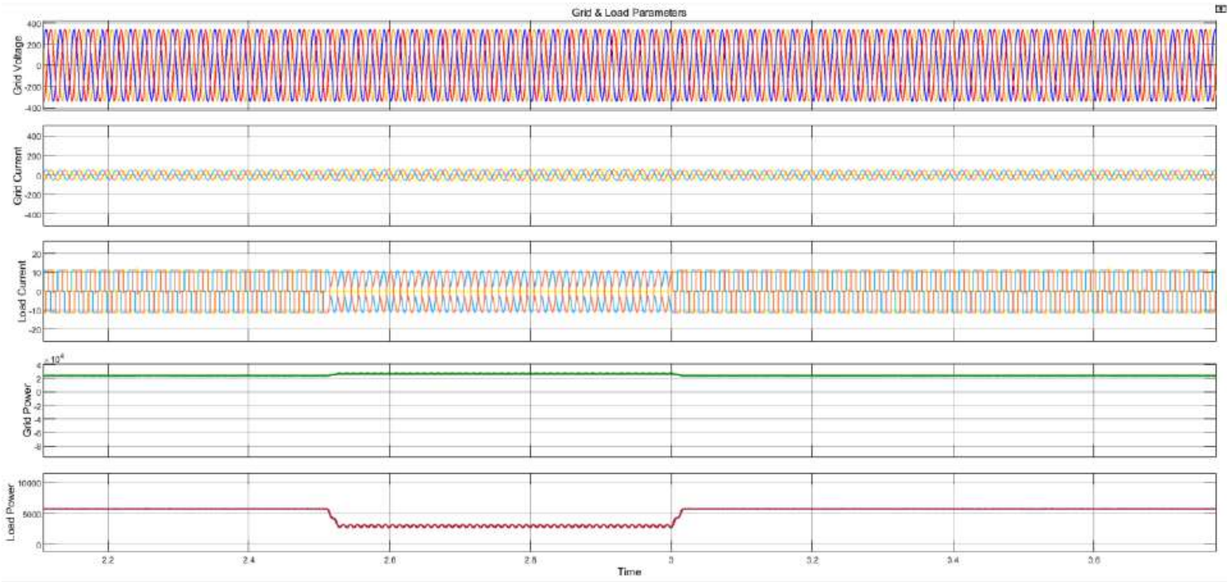

Fig. 5.12 Load Current Phase-A removal effect in Non-Linear Load condition

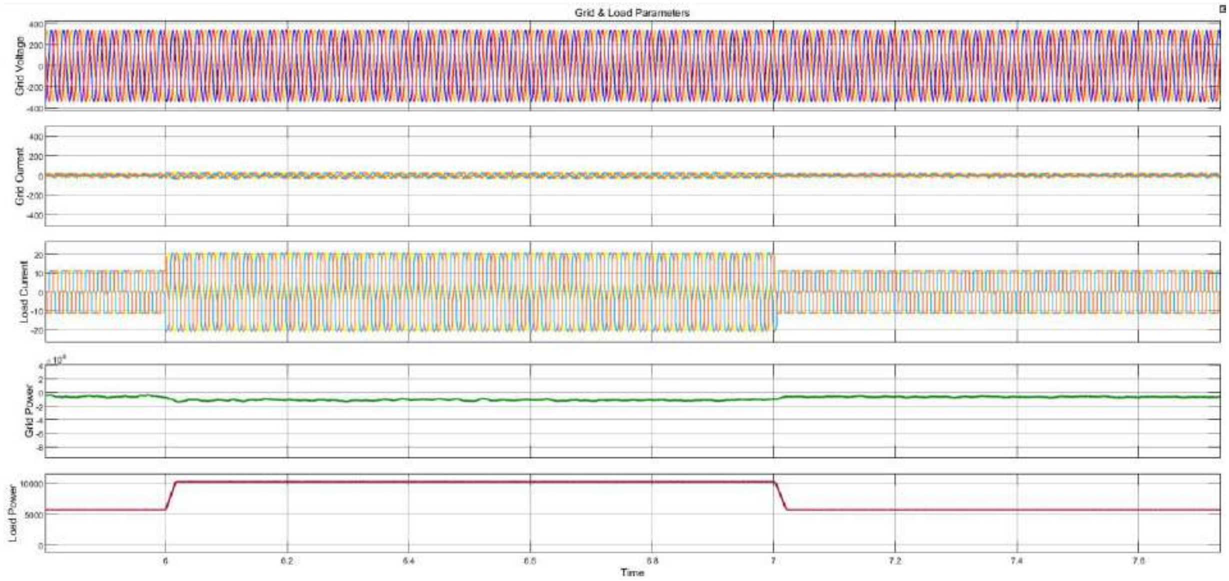

Fig. 5.13 Simulation Results of Load Current in Non-Linear Load effects

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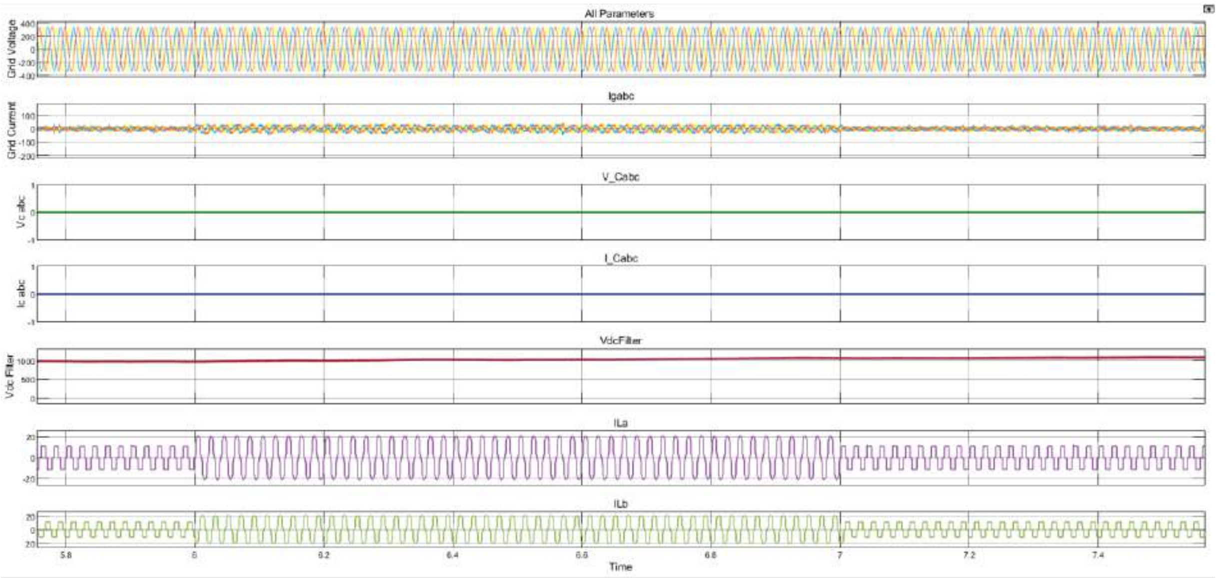

Fig. 5.14 Solar Radiation Effects in Simulation Results

C. Simulation Results of Proposed Work

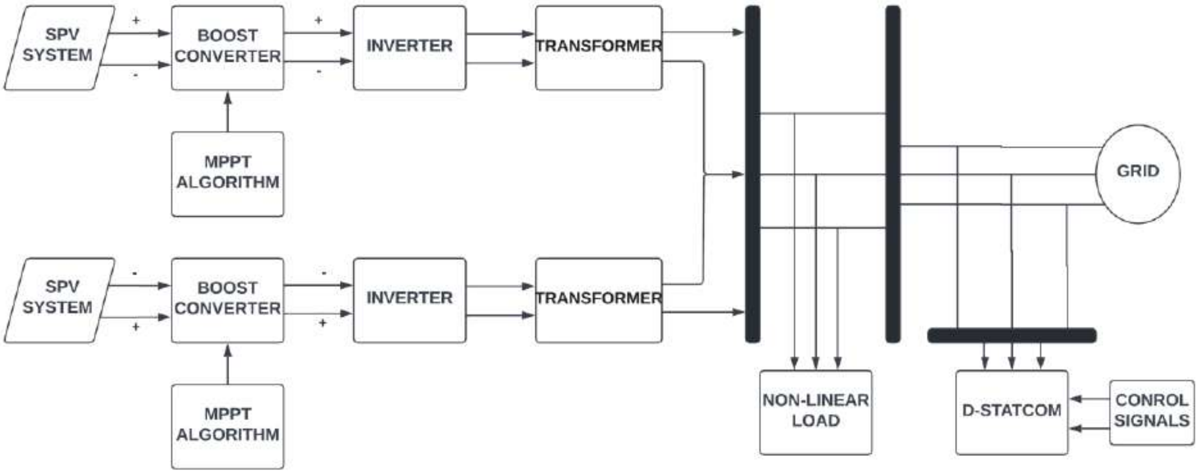

Fig. 5.16 Proposed System Configuration for grid connected cascaded MLI [15]

Fig. 5.16 illustrates the schematic of a MLI employing a cascaded transformer. As can be seen in Fig. 5.16, two H-bridge modules are inserted, each comprising a set of Insulated Gate Bipolar Transistors (IGBT). Upper and lower IGBTs are responsible for generation of positive and negative voltages. Two SPV arrays of 100 kW are also connected which are capable to generate power under variable conditions. Two transformers connected in cascade for complete perception of the system. In this instance, transformers are connected in cascade to reduce the number of switches.

Case-I Simulation of SPV with MLI Configuration

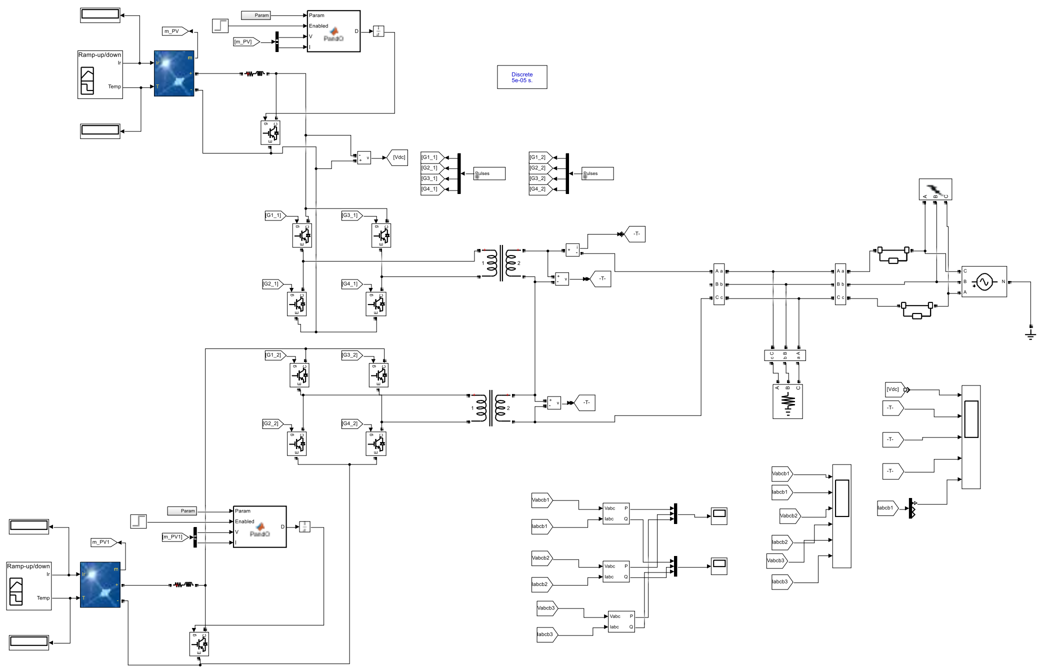

Fig. 5.17 MATLAB Simulation of MLI system with a SPV array and connected load

The simulation results of different parameters of proposed system are shown below:

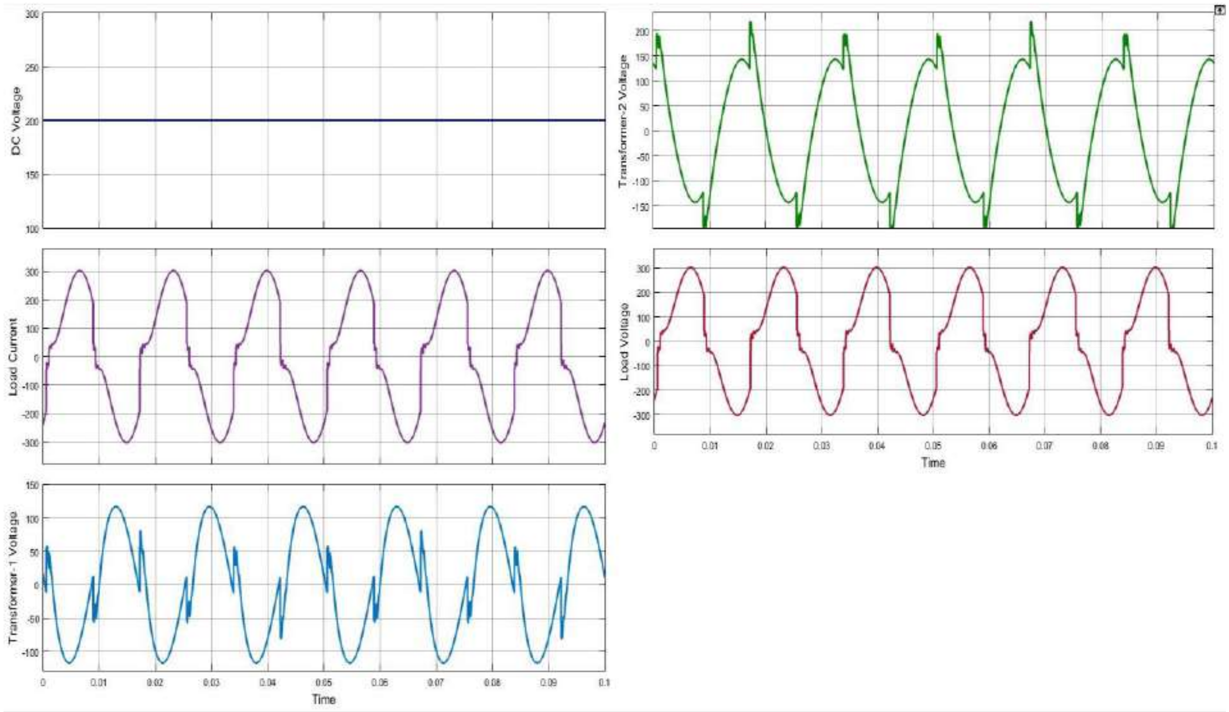

Fig. 5.18 Simulation waveforms of (a) DC input voltage to MLI system (b) load current (c) Output voltage across T1 (d) Output voltage across T2 (e) Load voltage, at R load

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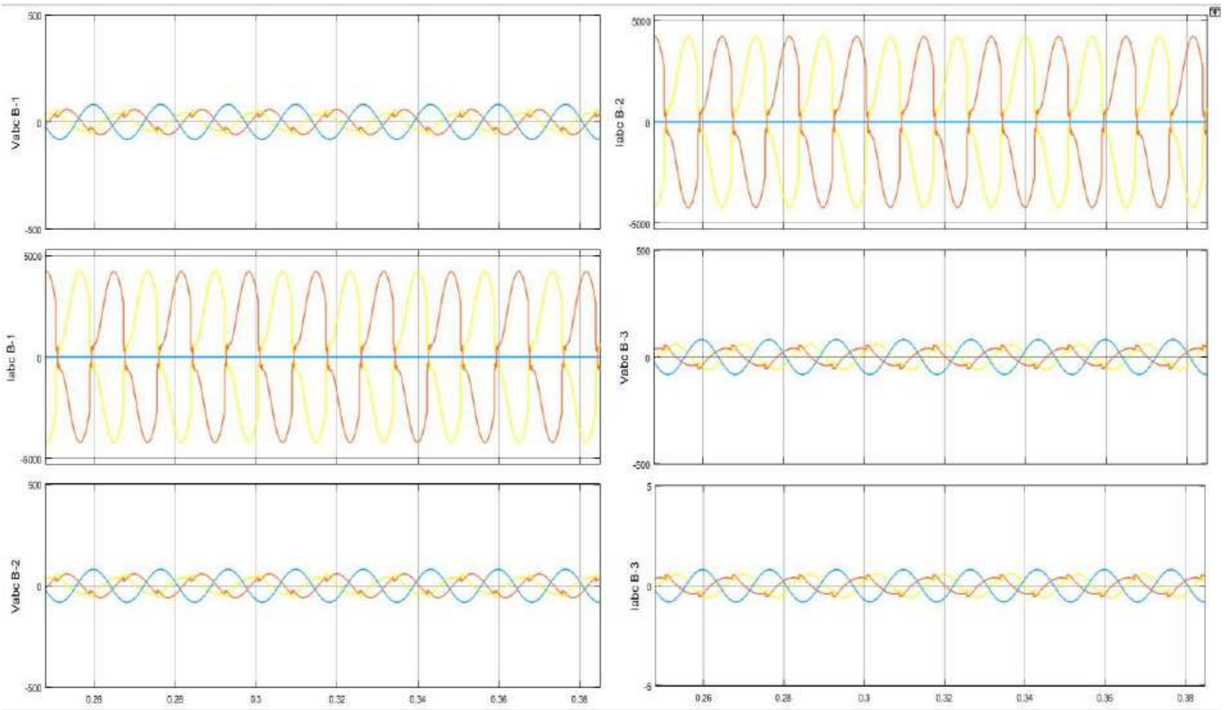

Fig. 5.19 Simulation Results of Proposed system without control (a) Load current (b) Output voltage across T1 (c) Output voltage across T2 (d) Load voltage, with RL load connected

Case-II Simulation of SPV with D-STATCOM using MLI Configuration

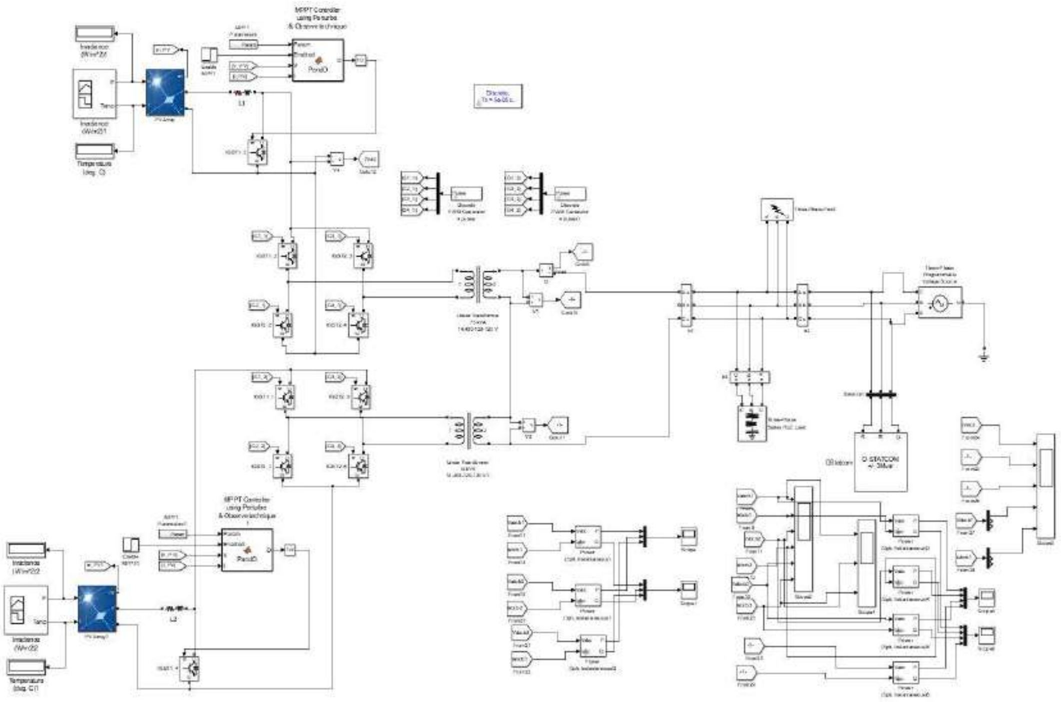

Fig. 5.20 MATLAB Simulation of MLI system with a SPV array, connected load and D-STATCOM

The design of D-STATCOM implies the selection of appropriate values of coupling inductor, determining the capacitor value and its operating voltage level. In general, for medium voltage applications, IGBTs are used as power electronic switches. Another important aspect of proposed H-bridge MLI topology is its ability to interface with a SPV array and D-STATCOM. As described above, the PQ evaluation of proposed system is elaborated using D-STATCOM. D-STATCOM is connected at utility-grid side to alleviate the impact of dynamic fault under the unbalanced conditions.

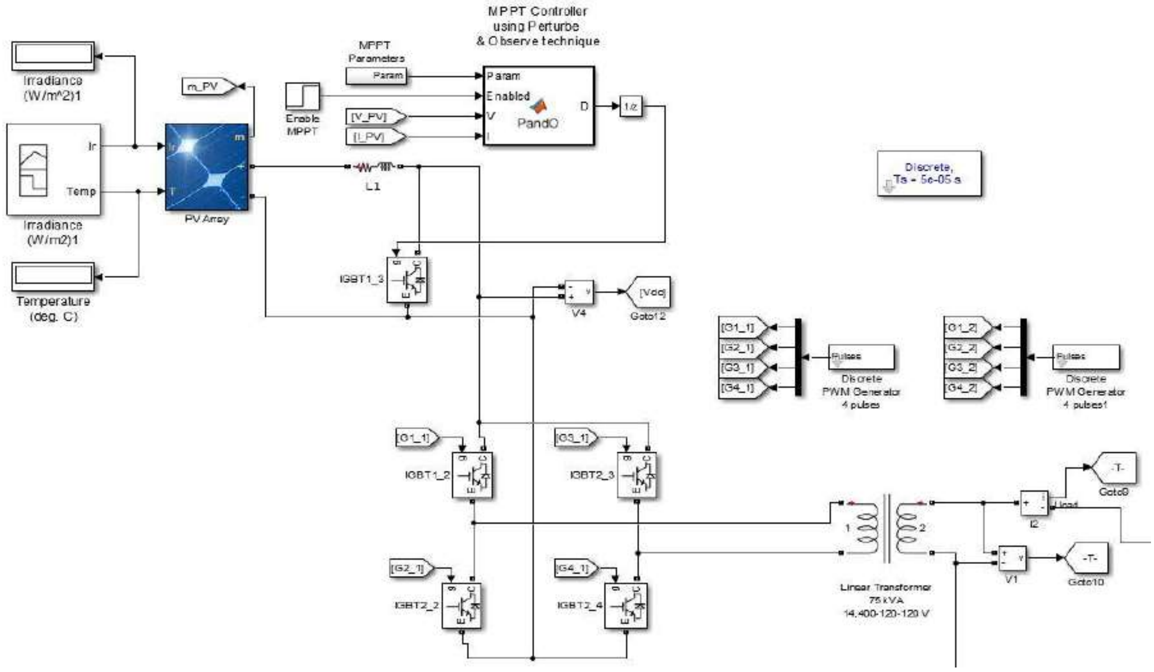

Fig. 5.21 MATLAB Simulation of Upper Half System

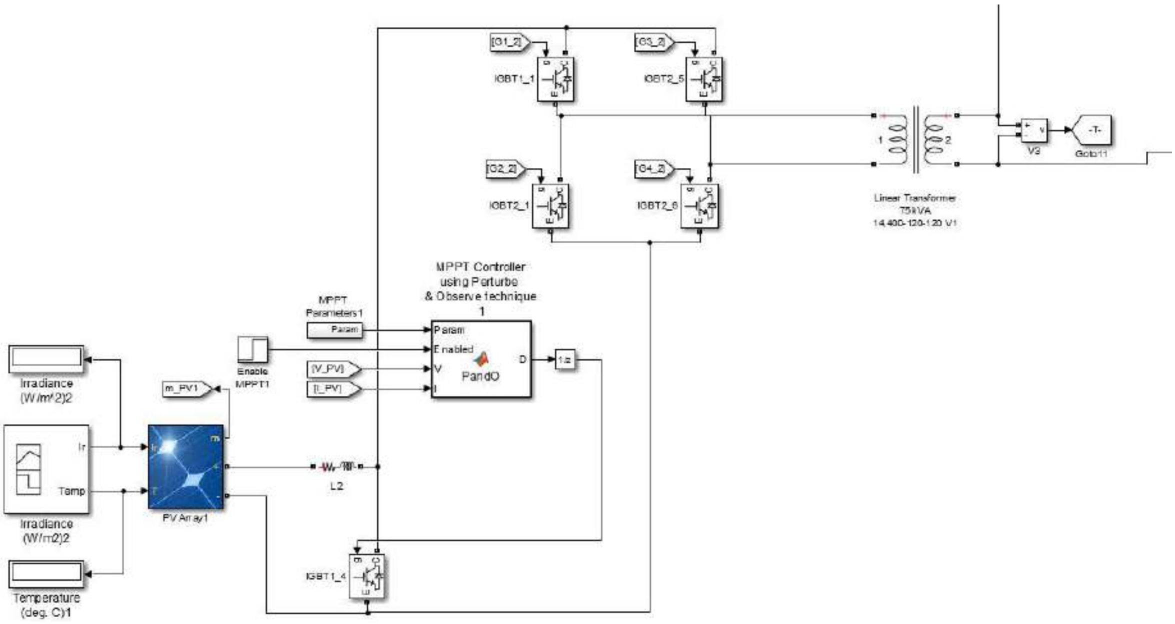

Fig. 20- MATLAB Simulation of Lower Half System

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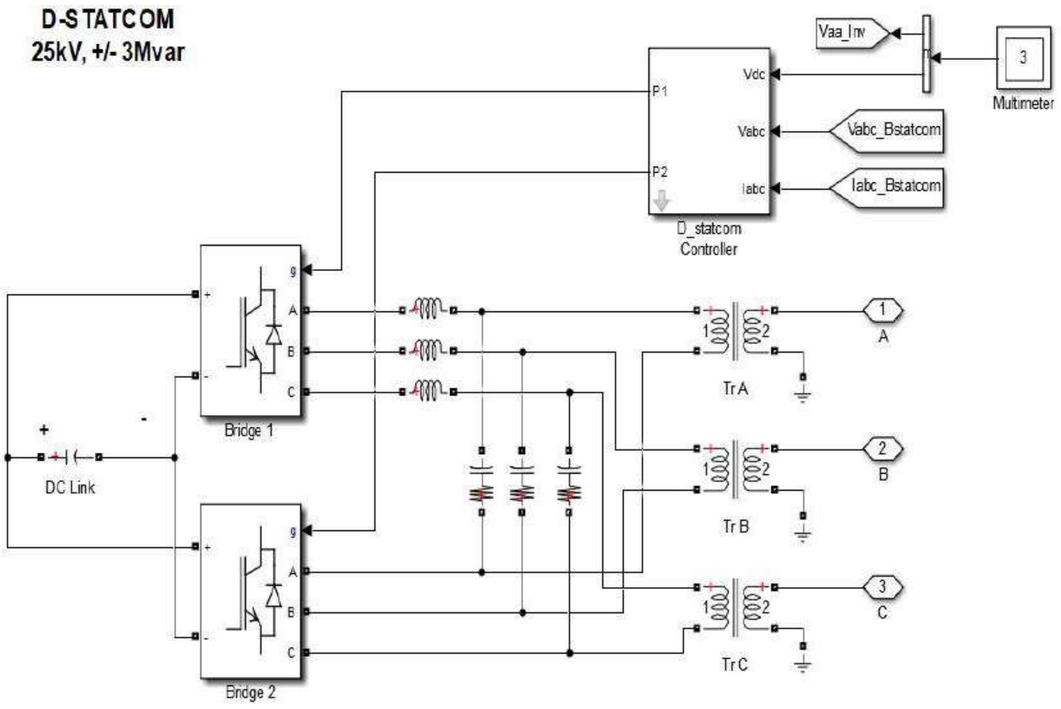

Fig. 5.22 MATLAB Subsystem of D-STATCOM Operation

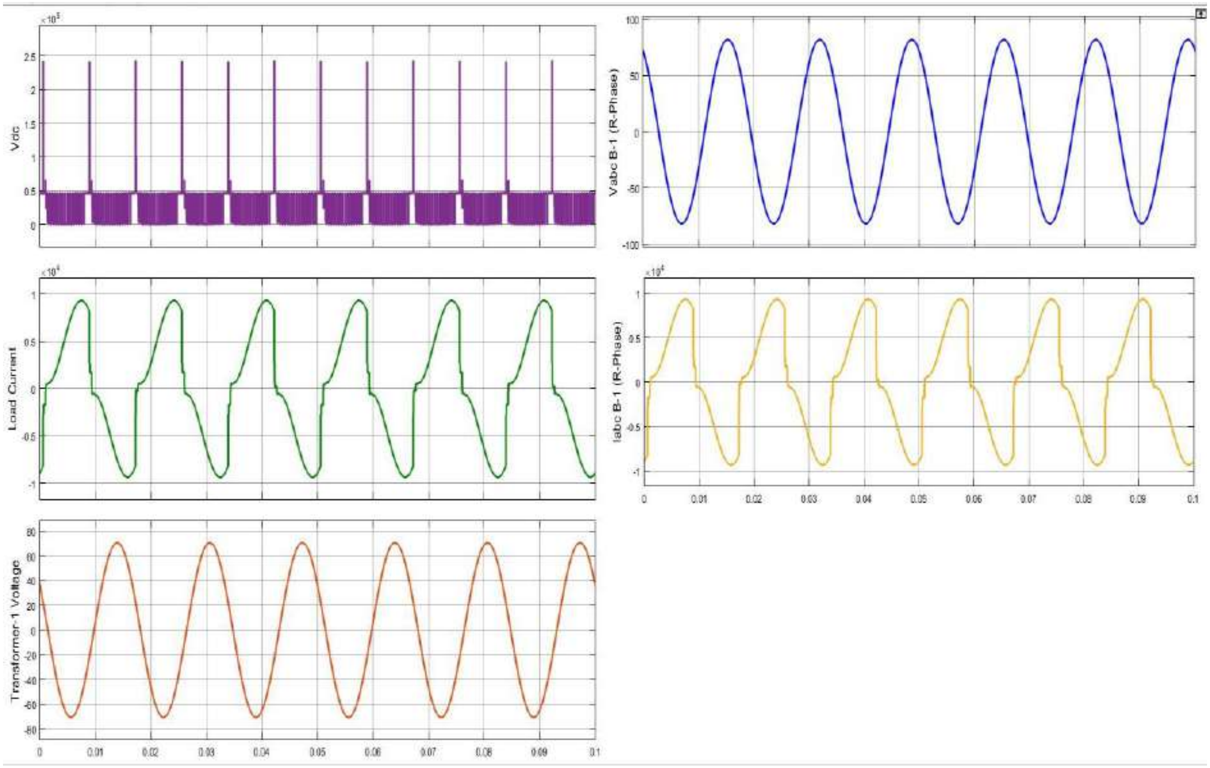

Fig. 5.23 Simulation Results of All Parameters with D-STATCOM

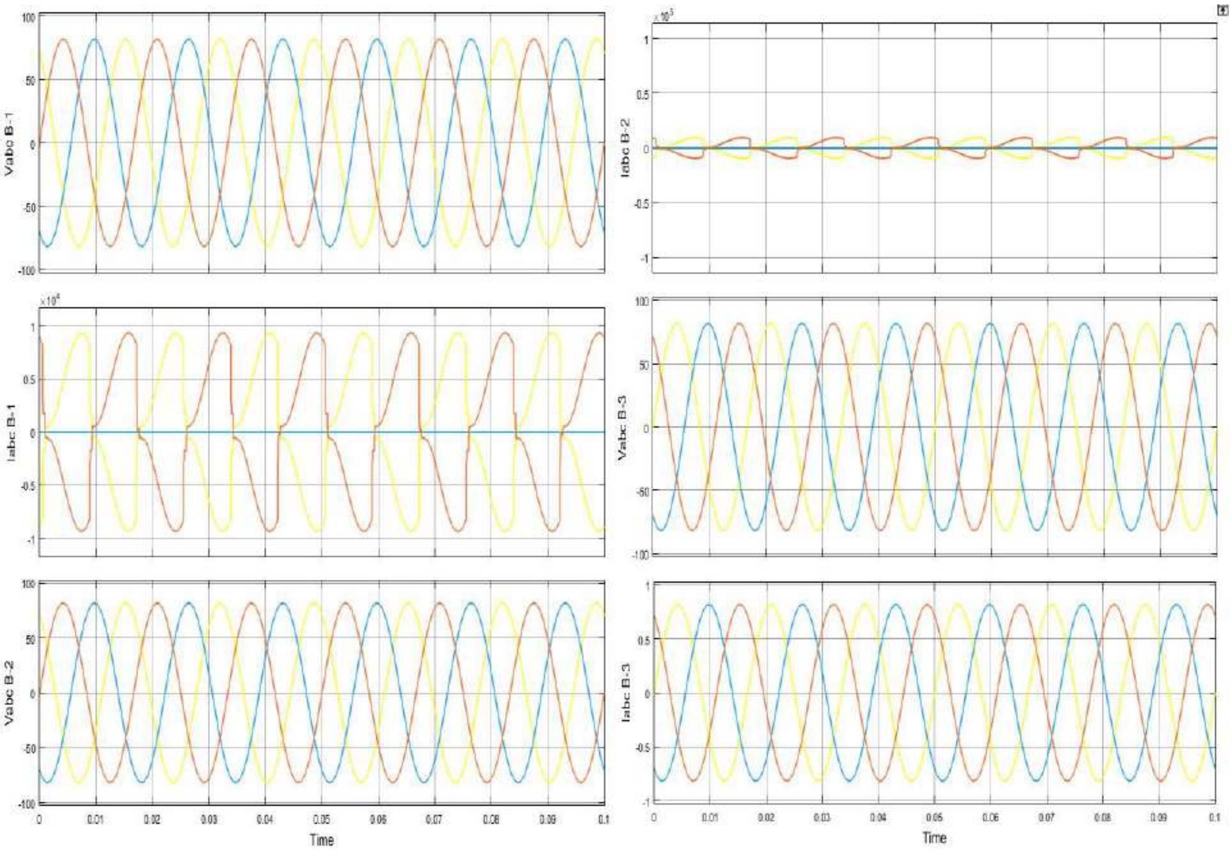

Fig. 5.24 Simulation Result during Fault Condition with D-STATCOM

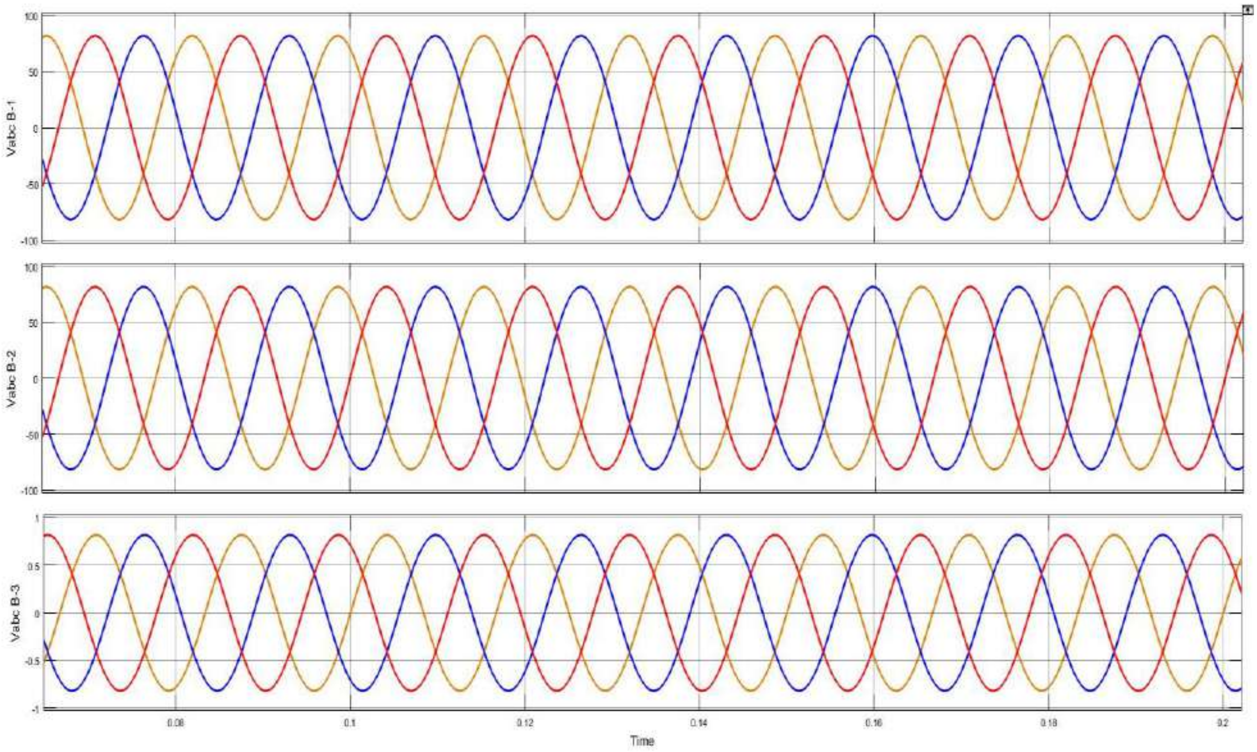

Fig. 5.25 Simulation Results of All Bus Voltage output with D-STATCOM with SPV and Load Connected System

VI. CONCLUSION

The proposed topology shows the effective interconnection of solar photovoltaic into the distribution system. Here solar PV system is used to provide the required DC link for the operation of an inverter. This work has investigated the role of D-STATCOM and UPQC controls on the operation of a proposed three-phase cascaded H-bridge MLI conFig.uration. Here, the galvanic isolation is provided by two transformers connected in cascade. Two case studies are undertaken which elaborate the PQ concerns during faulted conditions. The main objective of reactive power requirement is accomplished through the utility-grid during the faulted period. Contributions of D-STATCOM are discussed through different simulation and results analysis respectively in this project work. Purity of voltage and current waveforms at output at various PCCs is advocated D-STATCOM. D-STATCOM has demonstrated its effectiveness and improved the dynamic response because the proposed MLI system ensures the fast settling-time of output waveforms.

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