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SIMULATION OF SINGLE PHASE RECONFIGURABLE SOLAR CONVERTER (RSC) TOPOLOGY FOR SOLAR ROOFTOP

Mr. Manthan Patel[1], Mr. Ronak Patel[2]
[1]P.G. Scholar, [2]Assistant Professor
Electrical Department, Grow more Faculty of Engineering, Himmatnagar, Gujarat, India

Abstarct:* In this paper modelling, simulation and control of grid tie PV system using multilevel inverter are described. The majority of PV systems require inverters as interfacing units. A reconfigurable single phase inverter topology for a hybrid ac/dc solar powered home is suggested here. This inverter possesses a single-phase single-stage topology and the main advantage of this converter is that it can perform dc/dc, dc/ac, and grid tie operation, thus reducing loss, cost, and size of the converter. This hybrid ac/dc home has both ac and dc appliances. This type of home helps to reduce the power loss by avoiding unnecessary double stages of power conversion and improves the harmonic profile by isolating dc loads to dc supply side and rest to ac side. Simulation is done in MATLAB/Simulink and the obtained results are validated through hardware implementation using Arduino Uno controller. Such type of solar powered home equipped with this novel inverter topology could become a basic building block for future energy efficient smart grid and micro grid.
Keywords: RSC, Solar PV, Grid, Converter,etc.

I. INTRODUCTION

Due to increasing power demand many new alternatives of power generation are used effectively. Out of all these photovoltaic generation is effective and can easily be implemented. The power from the PV system have different outputs depending on the condition of temperature and irradiance. To extract maximum power from PV array different MPPT algorithms are available such as, perturb and observe (P&O), incremental conductance (INC) and many more. Out of all these INC have some advantages and commonly implemented in many PV applications. This mppt controller is used to extract maximum power under all the irradiance conditions using boost converter. The output of PV system serves as DC link for the inverter. A power controlling method is employed to synchronize the PV system with grid.Generally, there are 2 main power stages in a grid tie PV system. First is DC link voltage control stage that maintains constant DC link voltage across inverter input and second stage consist of inverter current control that controls the current injected into the grid. Current control can be employed in many reference frames such as, stationary reference frame (α-β), synchronous reference frame (d-q) and natural reference frame (a-b-c). In the proposed system synchronous reference frame is employed using proportional integral (PI) controller.

Over recent years several research and investment has been carried out in hybrid power system who recommended an optimal design model for hybrid solar–wind system, which employs battery banks to calculate the system's optimum configurations in Power system. In particular, rooftop solar PV are gaining more popularity in distribution system due to reduction in cost of solar panel, appropriate government policies such as feed in tariffs promoting renewable energy utilization, modularity, less maintenance, etc. However, the intermittent nature of the renewable causes the significant stability and reliability issues in the distribution system. The restructuring of the electric supply industry has prompted the situation, where customer is a critical business player. To mitigate the uncertainty in solar PV generation, storage options such as battery system and fuel cells, etc., are introduced.To improve the productivity and comfortability, the modern household adds more and more nonlinear equipment, which are also main source of generating harmonics current in distribution feeder. This further adversely affects power quality, power losses and creating a significant challenge for electrical engineers. Modern household loads have different characteristics compared to loads present in earlier stage. However, harmonic mitigation and/or its minimizations are big challenges in distribution system.

The different researchers have presented a hybrid solar-wind system as a renewable source of power generation for grid connected application in any country. They also modelled a hybrid solar wind power plant in different countries two-year period using hourly solar irradiation and wind speed data. The limitations of global resources of fossil and nuclear fuel, has necessitated an urgent search for alternative sources of energy. Therefore, a new way must be found to balance the supply and demand without resorting to coal and gas fueled generators.

II. SOLAR PV SYSTEM

The Solar Photovoltaic Array is formed by connecting several solar panels in series and parallel combination to generate the required power. The smallest component of the solar photovoltaic array is called photovoltaic (PV) cell. The ideal solar photovoltaic cell is represented by the equivalent circuit shown in Fig 1. These cells are connected in series of 36 or 72 cells to form one module. Similarly, several modules are assembled into a single structure to form array. Finally, assembly of these photovoltaic arrays are connected in parallel to obtain the required power. In PV module, series resistance(R_s) is comparatively more predominant and R_{sh} is considered equal to infinity ideally. The open circuit voltage(V_{oc}) of the PV cell is directly proportional to solar irradiation and V_{oc} is inversely proportional to the temperature.

The PV Array is characterized based on the I-V and P-V characteristic. As we can see from Fig.2 and Fig. 3, the variation in irradiation result variation in the current and the curves of I-V characteristic vary largely for different level of irradiation. The irradiation directly affects the PV Array current while the change of temperature directly affects the voltage generated by the PV Array as shown in Fig. 4 and Fig. 5. So same observation we can made from the below graphs of I-V and P-V characteristics at different irradiation and temperature level.

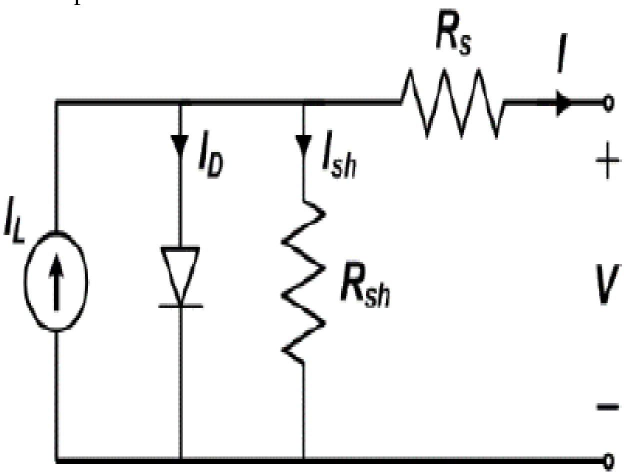

Figure 1: Equivalent circuit of PV cell

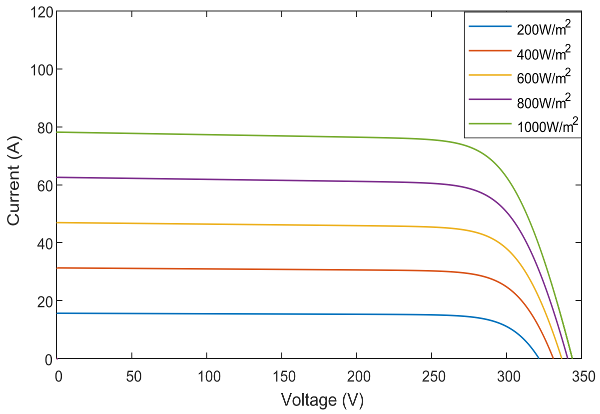

Figure 2: I-V characteristics of 20kW PV Array at different irradiation levels

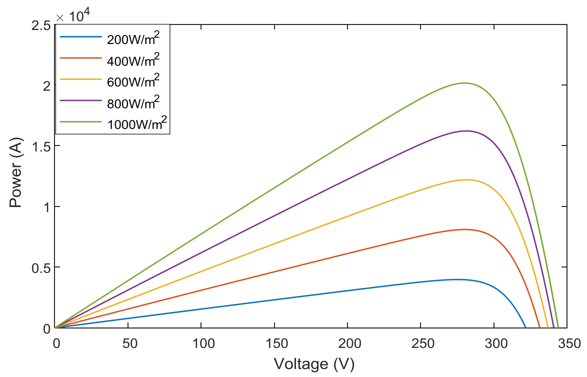

Figure 3: P-V characteristics of 20kW PV Array at different irradiation levels

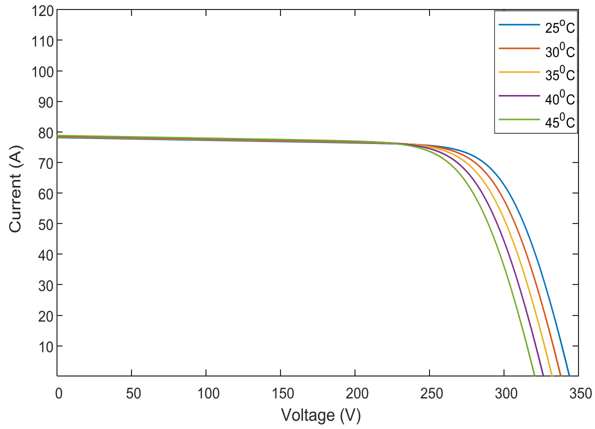

Figure 4: I-V characteristics of 20kW PV Array at different temperature levels

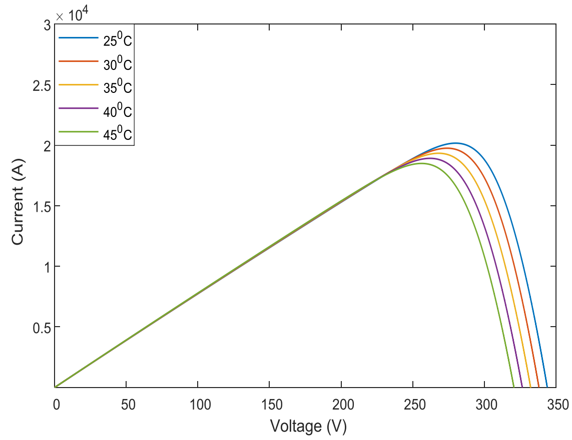

Figure 5: P-V characteristics of 20kW PV Array at different temperature levels

Single-Stage Solar PV Inverter for Small-Scale Systems
Compared to the single-stage one, the multistage power conversion is somewhat more expensive and affects the efficiency of the PV inverter. To reduce the volume and weight as well as the power conversion loss and cost, a hybrid PV battery-powered DC bus system was proposed in 2009 [2]. The DC to AC conversion stage-less DC bus system is very applicable to electronic equipment and appliances with high system efficiencies. The PV-battery-powered DC bus system is shown in Fig. For AC systems, a single-stage PV inverter was proposed in [2], and the circuit topology of single-stage inverter is shown in Fig. The proposed inverter performs a dual function: MPPT and outputting a sinusoidal current, which makes the control circuit complex. In [2], an alternative control technique was developed to reduce the complexity of the control circuit. However, the common-mode issue was not considered in the proposed single stage inverter systems. The neutral point clamped (NPC) converter topology has the opportunity to connect the grid neutral point to middle point.

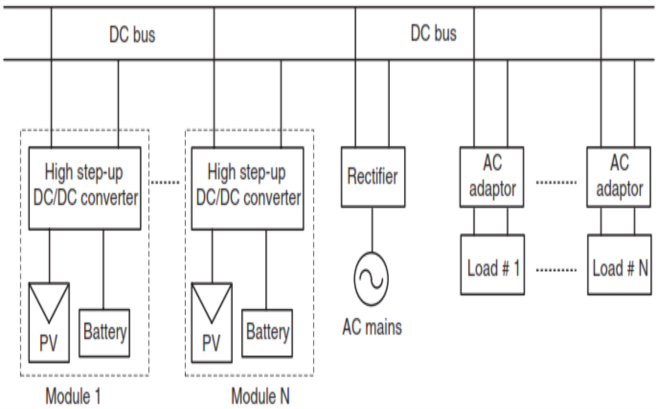

Fig.6PV-battery-poweredDCbussystem[2]

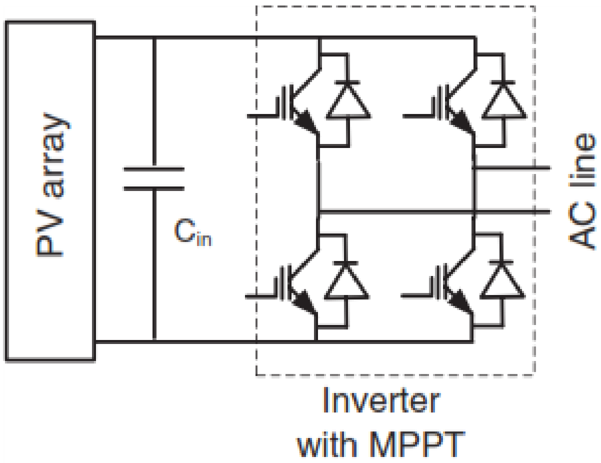

Fig.7 Full-bridge with MPPT- based circuit topology of single- stage inverter[2]

Of the DC link, reducing the ground leakage currents. In this context, an NPC topology-based single-phase PV inverter as shown in Fig. was presented in [3] and a three phase PV inverter system in Fig. was implemented in [3]. Since the presented circuits are run as buck converters, the PV array voltages should be greater than the peak values of the output AC voltages. If V is the inverter output AC voltage and R is the reservation factor, the minimum array voltage can be calculated as

$$V_A = \sqrt{2} V_{rms} R. \quad \text{.... (1)}$$

Therefore, a few PV arrays in series connection are necessary to obtain the desired voltage. From the available literature, several single-stage topologies have been proposed based on either boost or buck–boost configurations. An integrated (boost converter and full-bridge inverter) PV inverter circuit topology shown in Fig. was presented in [3]. The output power quality and the efficiency of the inverter are limited by the fact that the boost converter cannot generate the output voltage lower than the input voltage. A universal single-stage PV inverter shown in Fig. was presented in that can operate as a buck, boost, or buck–boost converter. This inverter can operate with a wide range of input voltage, improving the power quality and the efficiency. Using the integrated buck–boost and inversion functions, several modified configurations have been presented in [3].However, these topologies are only suitable for small-scale (e.g., <100 kW) PV systems, where the PV array normally interconnects with a low-voltage public network.

III. RECONFIGURABLE SOLAR CONVERTER (RSC)

Conventional grid connected inverter uses high dc link voltage, which will be the peak magnitude of the line–line grid voltage [1]. For this particular purpose, two stage conversions are required to boost up the dc voltage and to invert it. However, this will increase the cost, size, and loss of the system. To avoid this, single-phase single-stage topologies of inverter are suggested in [1]–[2]. In the single-phase inverter topology, transformer less inverter gained significant research interest as suggested in [1]. Transformer less inverter has the advantage of low size and cost by avoiding the transformer but this will eliminate the galvanic isolation and inverter will become very sensitive to grid disturbances. The solar PV is limited by its inherent intermittency aspects and, hence, battery storage (assumed here) is required to supply the power when there are not enough solar radiations. But having a separate converter for battery's power management system will increase the cost and size of the converter as well. Hence, a three-phase topology of reconfigurable solar inverter is introduced in [1] and [2] for utility system with battery storage. This reconfigurable system is suitable to solar and wind farm applications. This topology is tested with a new algorithm and validated the results. Normally, every solar powered household have a battery system to provide reliable supply system. These batteries are charged when connected to ac system or they need a separate converter to manage the charging operations when it connected to dc supply side.

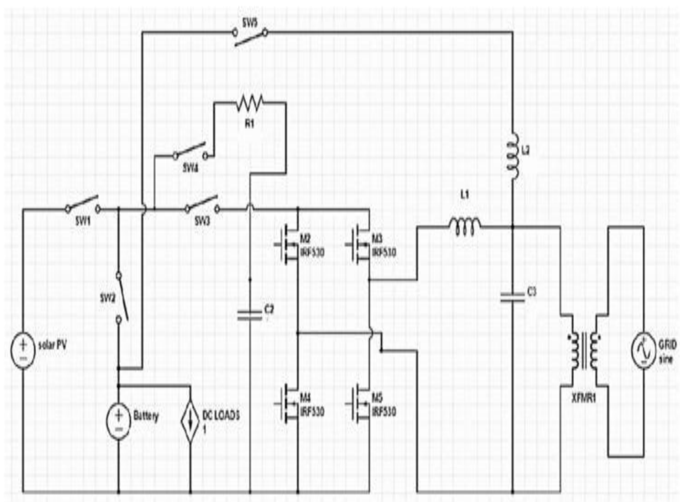

Fig.8 Schematic of the proposed RSC circuit[1]

Therefore, the main contribution of this paper is to implement single-phase single-stage solar converter called reconfigurable solar converter (RSC) in the solar powered hybrid ac/dc residential building with energy storage devices.

The basic concept of the RSC is to use a single power conversion system to perform different operational modes such as solar PV to grid (Inverter operation, dc–ac), solar PV to battery/dc loads (dc–dc operation),battery to grid (dc–ac), battery/PV to grid (dc to ac) and Grid to battery (ac–dc) for solar PV systems with energy storage.

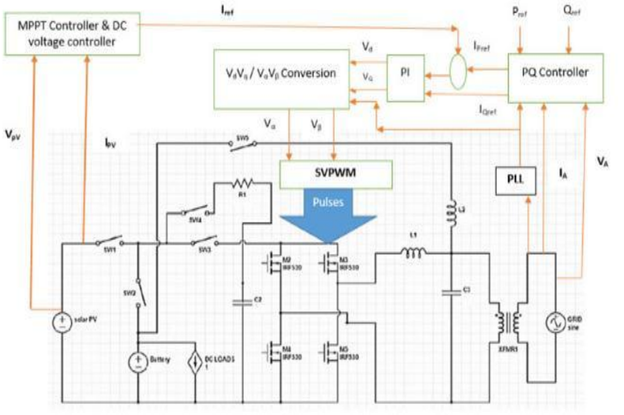

Fig.9 DC/AC inverter operation[1]

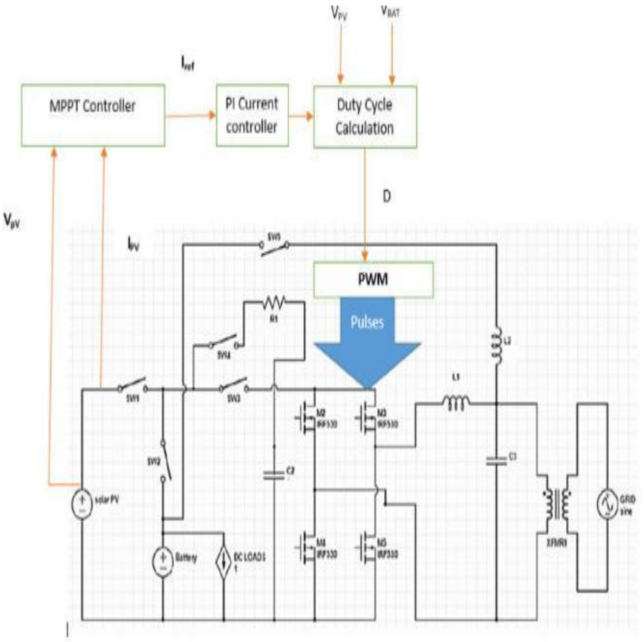

Fig.10 DC/DC chopper operation[1]

The control diagram for different modes of operations of the RSC is given in Figs.9 and 10.In Fig. 9, the inverter operation of the RSC is explained. From voltage and current measurement from the solar panel, voltage is set to extract maximum power from the panel using MPPT algorithm. This voltage is compared with the set dc-link voltage and error is given to a PI controller for DC link voltage regulation. This error is given to a PI controller, which will generate reference voltage for active power control. Reactive power is separately controlled using another PI controller. These reference voltages are converted to rotating reference frame voltages and given to space vector pulse width modulation (PWM) to drive the inverter.

IV. SIMULATION AND RESULT DISCUSSION

Simulation of PV Array with boost converter and MPPT controller (20kW)

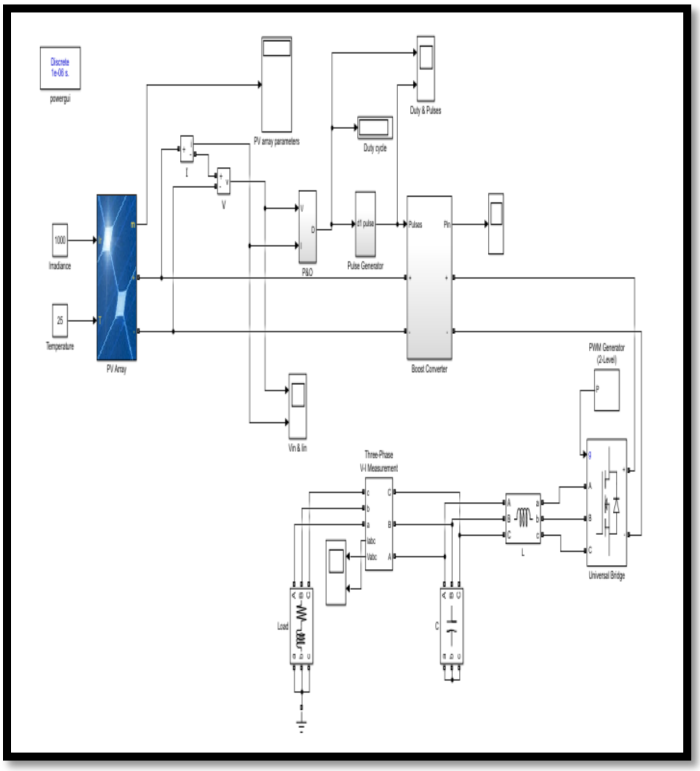

Figure 11: PV Array with Boost Converter and MPPT Controller

PV Array of 20 kW is shown in the figure along boost converter and MPPT controller. Here Design of 20 kW PV Array is shown in above figure.

Table.1 Simulation Parameters

Quantity	Value
Pmp	20160 W
Vmp	280 V
Imp	72 A
Voc	344 V
Isc	78.16 A
Ns	72

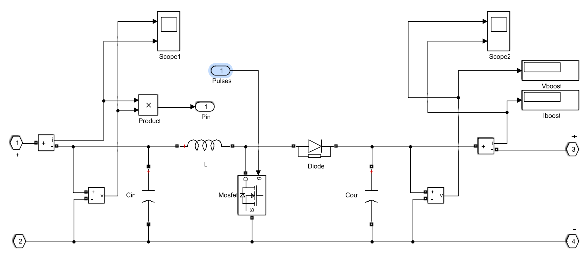

Figure 12: Boost Converter

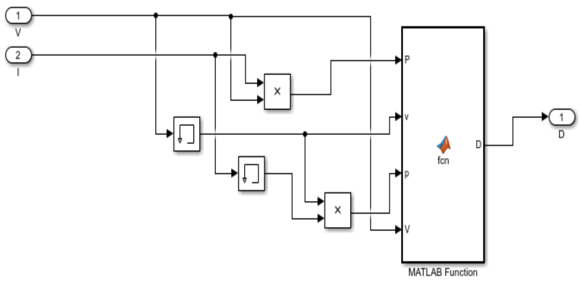

Figure 13: P & O Method

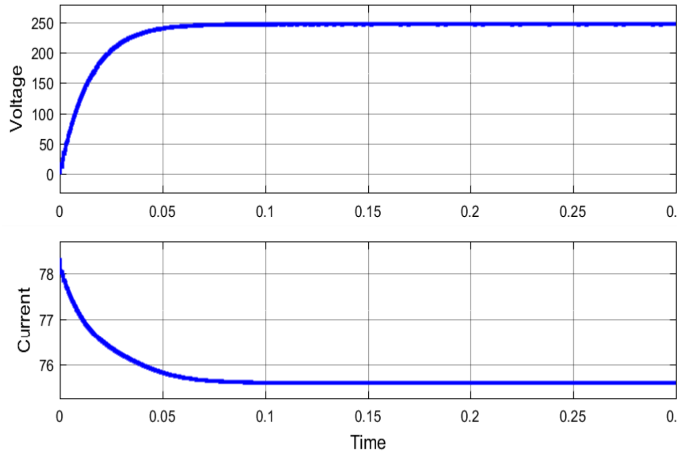

Figure 14: Input voltage and input current w.r.t time (sec)

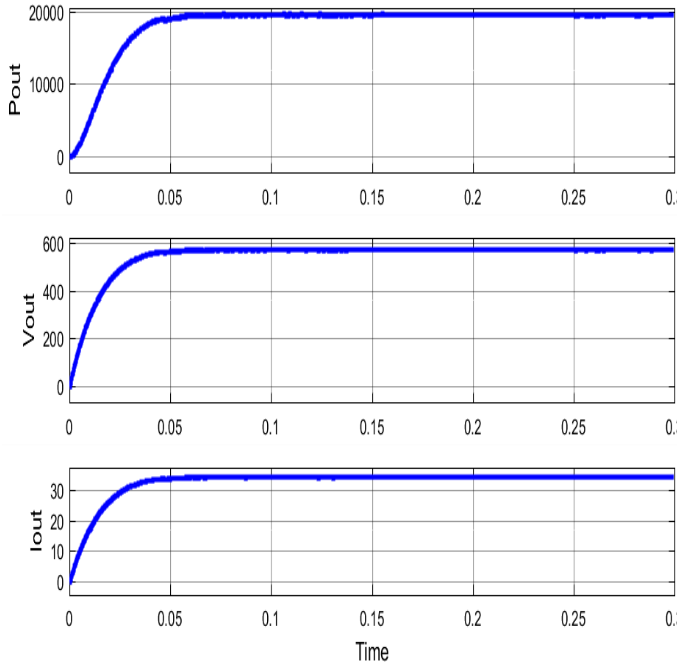

Figure 15: Output power, Output voltage and Output Current w.r.t time (sec)

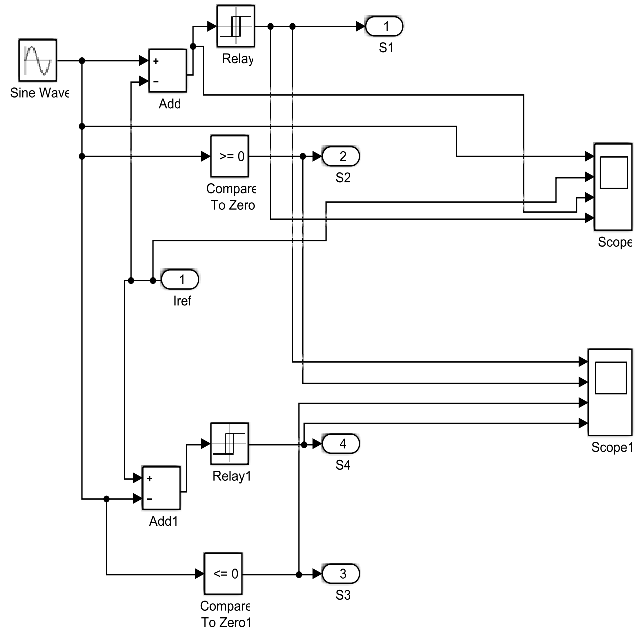

Figure 16: Control of Single leg

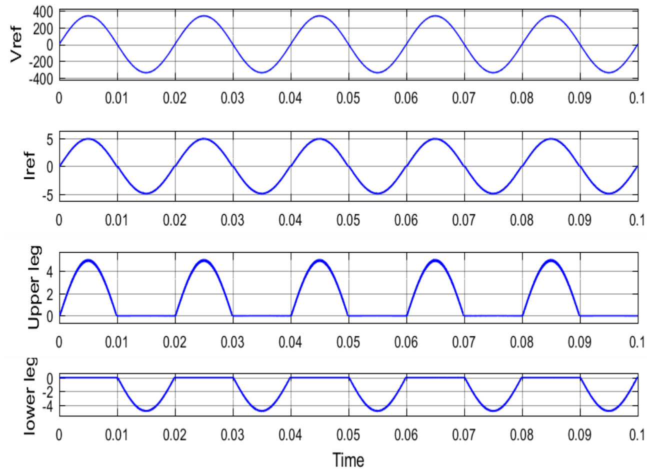

Figure 17: $V_{ref,}$ I_{ref}, Upper and lower leg Current

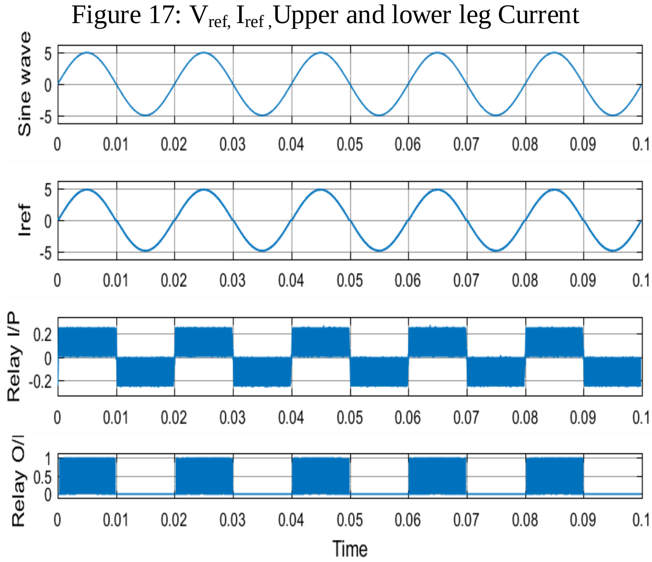

Figure 18: Sine Wave, I_{ref}, Relay I/P, Relay O/P

Simulation of 3 Level NPC Inverter

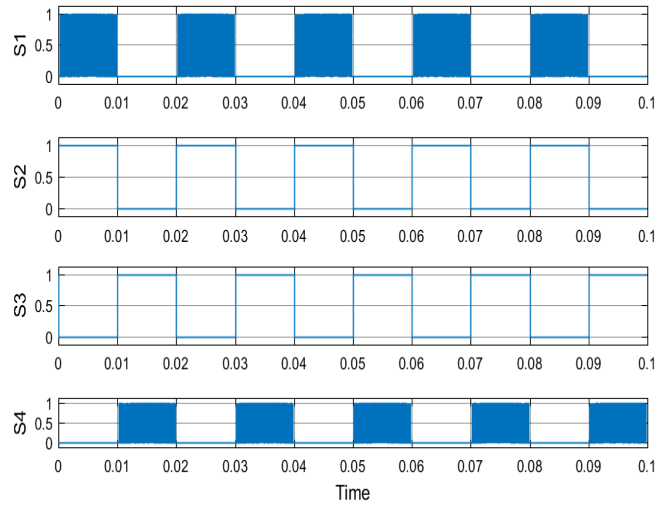

Figure 19: Switching States

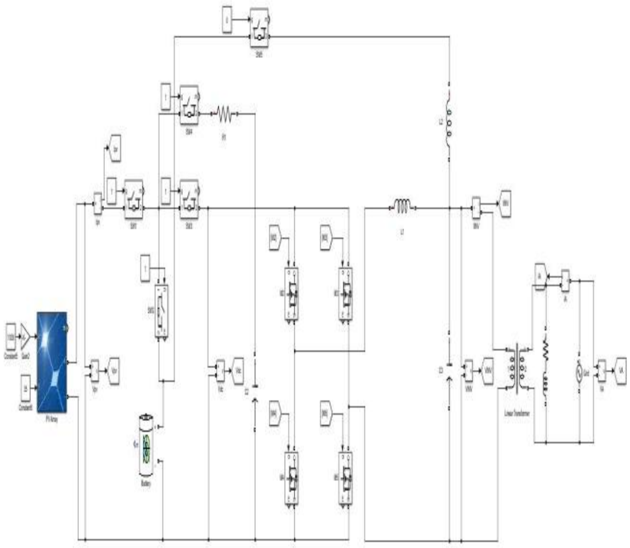

Fig 20- Main system of Solar PV with RSC converter configuration

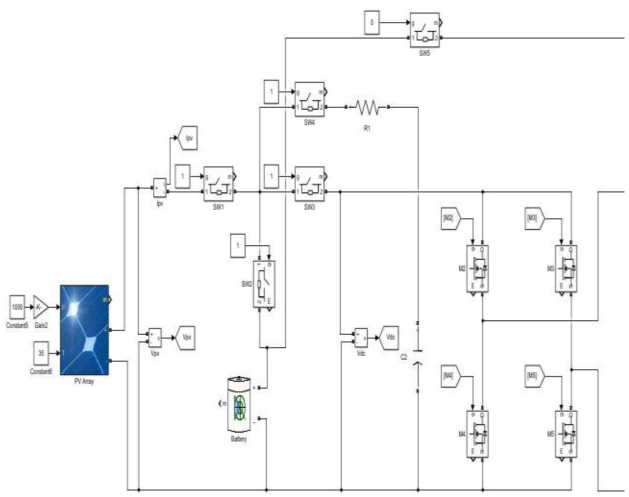

Fig 21- Solar PV with RSC converter side connection

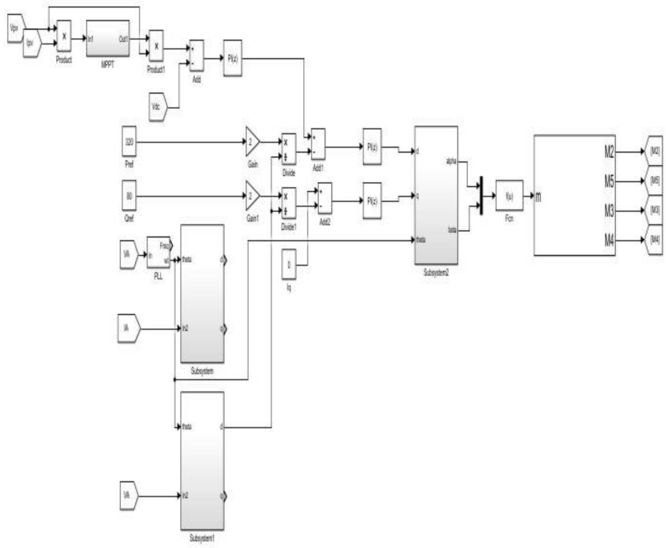

Fig 22- Controlling subsystem of RSC converter

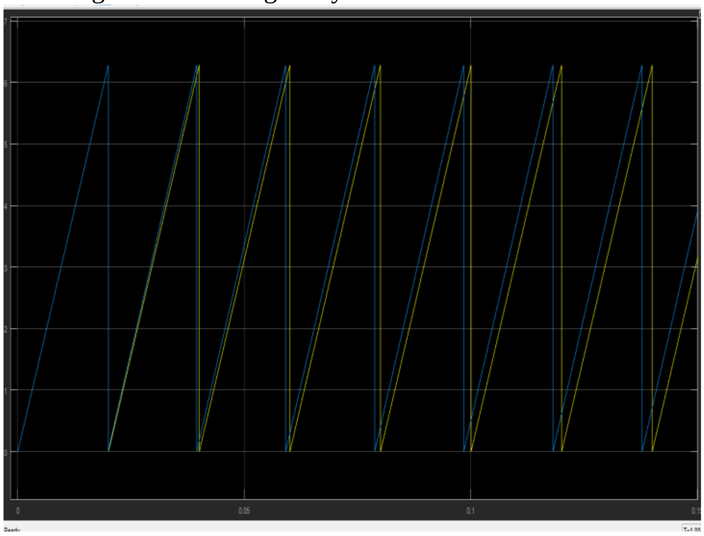

Fig 23-Phases in radians

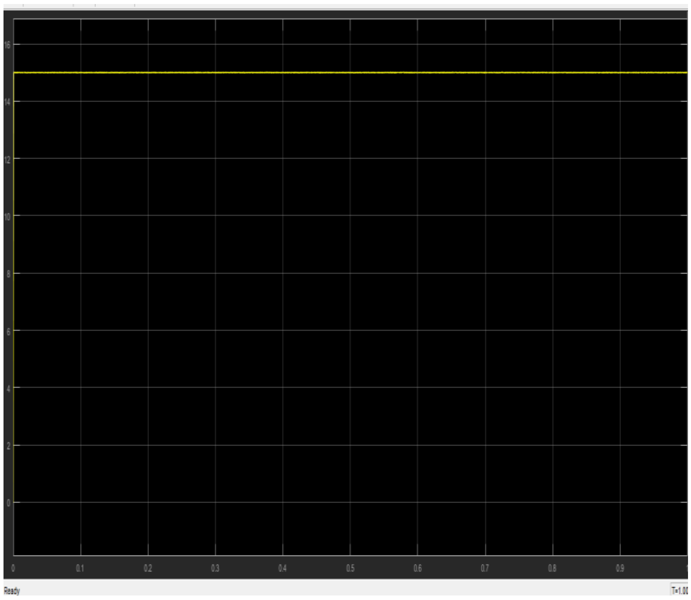

Fig 24-Battery voltage

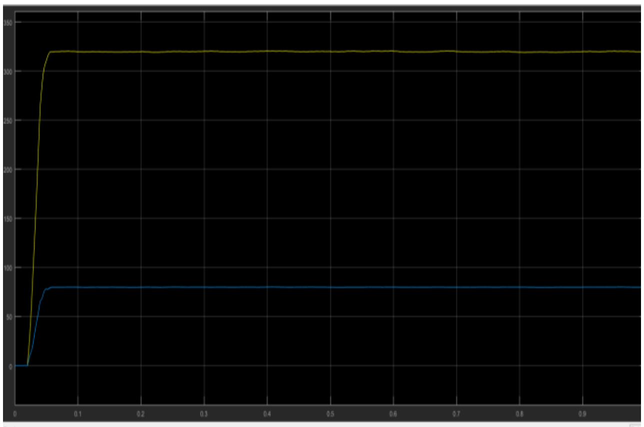

Fig 25-Active and reactive power generation

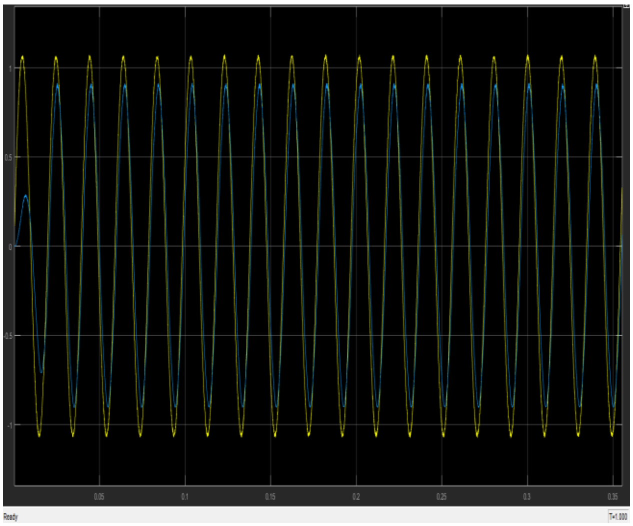

Fig 26-Grid and inverter voltage

V. CONCLUSION

As shown in the graph the P-V and I-V characteristics of PV system changes as per the change in temperature as well as irradiation. So, the PV Generation is very sensitive to any change in the value of temperature as well as irradiation. So accordingly, the output values of all the components connected will be directly affected to this variation. To achieve maximum power point, we can control the current or regulate the voltage to maintain the power. In the proposed system, MPPT regulates the duty cycle to maintain voltage and achieve maximum power. This paper suggested a more suitable converter topology for a solar powered hybrid ac/dc home. The main idea of this topology is to utilize single conversion of ac power to dc and vice versa, which improves the efficiency, reduces volume, and enhances the reliability. The hardware implementation validates that the suggested converter topologies would be helpful to reduce significant amount of harmonics in the residential feeders of the future smart grid. Though, here only solar PV is considered as source of power, this topology could be equally applicable to wind, fuel cells, etc.

REFERENCES

[1] NIKHIL SASIDHARAN AND JAI GOVIND SINGH, "A NOVEL SINGLE-STAGE SINGLE-PHASE RECONFIGURABLE INVERTER TOPOLOGY FOR A SOLAR POWERED HYBRID AC/DC HOME", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 64, NO. 4, APRIL 2017.
[2] YAM P. SIWAKOTI, FREDE BLAABJERG, "A NOVEL FLYING CAPACITOR TRANSFORMER LESS INVERTER FOR SINGLE-PHASE GRID CONNECTED SOLAR PHOTOVOLTAIC SYSTEM", 2016 IEEE.
[3] AYOUB NOUAITI, ABDALLAH SAAD , ABDELOUAHED MESBAHI, MOHAMED KHAFALLAH, MOUSSA REDDAK, "SINGLE PHASE SEVEN-LEVEL INVERTER FOR PV SOLAR PUMPING SYSTEM", 2016 IEEE.
[4] DORIN PETREUS, TOMA PATARAU, RADU TRUTA, CRISTIAN ORIAN AND RADU ETZ, "SINGLE-PHASE INVERTER FOR SOLAR ENERGY CONVERSION CONTROLLED WITH DSPACE DS1104", 2016 IEEE 22ND INTERNATIONAL SYMPOSIUM FOR DESIGN AND TECHNOLOGY IN ELECTRONIC PACKAGING (SIITME).
[5] REMEI HAURA JUNIOR; MARCIO MENDES CASARO, "SINGLE-PHASE DUAL-STAGE ISOLATED MULTILEVEL INVERTER APPLIED TO SOLAR ENERGY PROCESSING", 2017 IEEE.
[6] SUBHENDU DUTTA, DIPANKAR DEBNATH, AND KISHORE CHATTERJEE, "A GRID CONNECTED SINGLE PHASE TRANSFORMER-LESS INVERTER CONTROLLING TWO SOLAR PV ARRAYS OPERATING UNDER DIFFERENT ATMOSPHERIC CONDITIONS", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 2016 IEEE.
[7] JEANETTE LAM MIN YI, R.T. NAAYAGI, THILLAINATHAN LOGENTHIRAN, "MODELLING AND IMPLEMENTATION OF SINGLE PHASE DUAL STAGE GRID-TIED SOLAR POWER INVERTER", 978-1-5090-2597-8/16/2016 IEEE.
[8] B. MARIAPPAN, B. G. FERNANDES, AND M. RAMAMOORTY, "A NOVEL SINGLESTAGE SOLAR INVERTER USING HYBRID ACTIVE FILTER WITH POWER QUALITY IMPROVEMENT," IN PROC. 40TH ANNU. CONF. IEEE IND. ELECTRON. SOC., OCT. 29, 2014– NOV. 1, 2014, PP. 5443–5449.
[9] C.-M. WANG AND C.-H. YANG, "A NOVEL HIGH INPUT POWER FACTOR SOFTSWITCHING SINGLE-STAGE SINGLE-PHASE AC/DC/AC CONVERTER," IN PROC. IEEE CONF. VEH. POWER PROPULSION, SEP. 7–9, 2005, P. 5.

[10] K. M. SHAFEEQUE AND P. R. SUBADHRA, “A NOVEL SINGLE-PHASE SINGLE-STAGE INVERTER FOR SOLAR APPLICATIONS,” IN PROC. 3RD INT. CONF. ADV. COMPUT. COMMUN. AUG. 29–31, 2013, PP. 343–346.
[11] S. Z. MOHAMMAD NOOR, A. M. OMAR, N. N. MAHZAN, AND I. R. IBRAHIM, “A REVIEW OF SINGLE-PHASE SINGLE STAGE INVERTER TOPOLOGIES FOR PHOTOVOLTAIC SYSTEM,” IN 4TH IEEE CONTROL SYST. GRADUATE RES. COLLOQ., AUG. 19–20, 2013, PP. 69–74.
[12] E. S. SREERAJ, K. CHATTERJEE, AND S.BANDYOPADHYAY, “ONE-CYCLE-CONTROLLED SINGLE-STAGE SINGLE-PHASE VOLTAGE-SENSORLESS GRID-CONNECTED PV SYSTEM,” IEEE TRANS. IND. ELECTRON., VOL. 60, NO. 3, PP. 1216–1224, MAR. 2013.
[13] H. PATEL AND V. AGARWAL, “A SINGLE-STAGE SINGLE-PHASE TRANSFORMER-LESS DOUBLY GROUNDED GRID-CONNECTED PV INTERFACE,” IEEE TRANS. ENERGY CONVERS., VOL. 24, NO. 1, PP. 93–101, MAR. 2009.
[14] H. KIM, B. PARKHIDEH, T. D. BONGERS, AND H. GAO, “RECONFIGURABLE SOLAR CONVERTER: A SINGLE-STAGE POWER CONVERSION PV-BATTERY SYSTEM,” IEEE TRANS. POWER ELECTRON. VOL. 28, NO. 8, PP. 3788–3797, AUG. 2013.
[15] W. SRIPIPAT AND S. PO-NGAM, “SIMPLIFIED ACTIVE POWER AND REACTIVE POWER CONTROL WITH MPPT FOR SINGLE-PHASE GRID-CONNECTED PHOTOVOLTAIC INVERTERS,” IN PROC. 11TH INT. CONF. ELECTR. ENG./ELECTRON., COMPUT., TELECOMMUN. INF. TECHNOL., MAY 14–17, 2014, PP. 1–4.
[16] B. PARKHIDEH AND H. KIM, “RECONFIGURABLE POWER SYSTEMS AND CONVERTERS,” U.S. PATENT APPL. 2012/0 261 999 A1, OCT. 18, 2012.

