PHOTOVOLTAIC SOLAR SYSTEM FOR ACTIVE POWER GENERATION AND REACTIVE POWER SUPPORT IN MICRO GRID

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Abstract— The power generated with the photovoltaic (PV) systems will be in DC. To connect this system to electric grid, the generated power needs to be converted to AC which is done through power conditioning unit (inverter). The majority of contemporary inverters used in DG systems are current source inverters (CSI) operating at unity power factor. If, however, we assume that voltage source inverters (VSI) can replace CSIs, we can generate reactive power proportionally to the remaining unused capacity at any given time. The aim of the work is to control the flow of active power to grid according to availability of insolation level. This work also presents the control of reactive power, i.e. reactive power supplied to and absorbed from the grid according to availability of active power from PV system.

Keywords —Voltage Source Inverter (VSI).

I. INTRODUCTION

In developed countries such as USA, Japan, Europe etc., the photovoltaic systems or PV plants are generally connected to electrical grid and these are considered as distributed generation (DG) system. Generally the power generation plants will be away from localities. Before the energy gets transferred to consumers it undergoes various processes like generation, transmission and distribution. For remote areas it is very difficult to transfer energy. In such areas distributed generation is employed near the consumption points.

Energy generated from distribution systems can also be connected to the electrical grids, which reduces difficulties faced in the process of power transfer to various systems. Subsequently, such a perfect location can delay the immediate need of new investments. This will reduce the level of grid and transformer loadings which results in reduction of losses. More concentration on renewable energy generation also brings environmental profits by stopping secretion of pollution agents. In Germany, they are giving special attention to where they are planning to install 1 lakh solar roofs and photovoltaic systems in schools. This program was encouraged by the federal government and native energy firms.

We cannot connect power generated by a PV system to electrical grid and operate. This can be achieved by application of an inverter, which will convert the DC to AC and helps in proper application of the energy generated from the photovoltaic system. It is essential to note that, almost all cases CSI are used for linking photovoltaic systems to power grid. With the usage of CSI, only active power support to grid can be given because they are operating with UPF. In those systems which are employing CSI, the substations or primary distribution system will be supported by a capacitor bank which will support through the reactive power needed for loads. Therefore, in night or whenever insolation is week generated power by the PV systems will be low or it is zero. So these systems will be useless during night and the all the loads will be supplied from the power grid.

But if the CSI are replaced by voltage source inverters, the control of both active and reactive power done simultaneously. According to the availability of active power from the PV system and capacity of the inverter the reactive power compensation can be done. Hence here the VSI connected to the electrical grid simultaneously can perform both the tasks and which will reduce cost necessary for capacitor banks. Therefor when insolation level low i.e. at night PV system will not produce any power and in this case it will be shut down. So in place of keeping it idol, it can be used for RPC. This helps to improve energy quality of the grid. The simulation results with VSI and theoretical analysis will confirm the methodology followed in this work.

The photovoltaic (PV) system produces energy in the form of DC. These systems act as DG systems. Power conditioning unit like an inverter is employed for linking energy The energy produced from PV is sent to the electrical grid through a produced from a photovoltaic system to grid. But most of the DG systems use CSI for linking with the grid, which operate at UPF. If the Current Source Inverters (CSI) are switched by Voltage Source Inverters (VSI), it is assumes that reactive power can be generated equivalently to the unexploited capacity at any point of time. From the principle of instantaneous power, the reactive power of the inverter can be monitored by altering the magnitude of its output voltage. And by changing phase angle of the output voltage the inverter active power can be modified. On the basis of such philosophy, both the active power supply and the reactive power compensation (RPC) can be accomplished at the same time.

II. MODULE DISCRIPTION

The complete module consists of different sections. It starts with photovoltaic system where energy is produced which is Direct Current type. The voltage level of the photovoltaic scheme is lower compared to voltage level required by the inverter. To overcome this problem a converter is used. A boost converter is utilized to step up the voltage. A MPPT model is used for PV system to obtain the maximum available energy from the PV. Further supplying the power produced from PV system to micro grid it should be in AC. To obtain the power in AC an inverter with 1KVA rating is used. The last section consists of inverter control. In this section the triggering pulses are generated for control the reactive power support to the grid. All the sections are explained in detail in further section of the report.

A. PV ARRAY

A photovoltaic system is the arrangement of number PV cells in series-parallel combination. A PV cell is the simple construction block of a PV array. Basically the size of PV cells vary from 1cm to about 10cm across. The capacity of each cell will be around 1 or 2 watts depends on the type of material used. The generated energy from a single PV cell is not enough for power applications. To achieve the necessary power output, these PV cells are coupled electrically into a packed weather-tight unit. The available PV panels in the market are having maximum capacity of 1kW. These units are linked to obtain a PV array. The arrays are employed in power plants. Thousands of such modules are coupled in series-parallel arrangement to attain higher power output. Number of modules to be connected depends on the required power output.

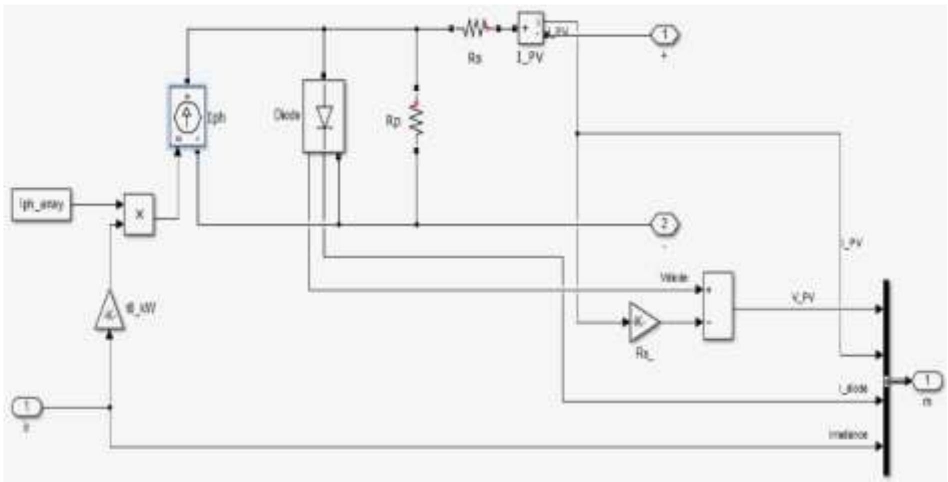

Fig 1: internal circuit of pv array in matlab.

B. MPPT

As per the discussion on the solar PV cell in previous sections, the output from the PV system will not be constant. It is totally dependent on the irradiance level and the temperature. Therefor MPP of solar panel varies, it will not be constant. It is necessary to use MPPT technique to obtain maximum power from solar array. Here perturb and observe MPPT technique is use. Fig 2 shows simulation model of P&O technique.

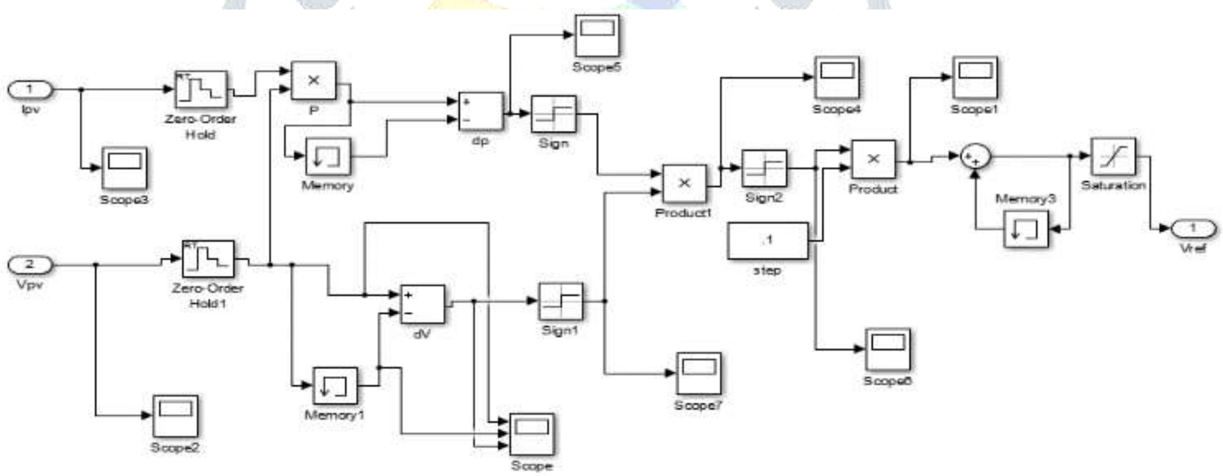

Fig 2: simulation model of perturb & observe mppt technique.

C. CONVERTERS AND INVERTER

These are the circuits power electronic circuits which converts dc voltage from one level to another (step-up or step-down) level. Many translation approaches are existing like capacitive, electronic, switched mode, magnetic, linear. Generally whenever power electronic switches are employed in power conversion, such converters are called as switched mode power supplies (SMPS). A variety of converters existing like Buck, Boost, CUK and SEPIC and Buck-Boost converters available. Based on the application we can select one of these converters. In this work voltage level of the power generated from PV system is lower than that of required at inverter input side voltage. So achieve necessary voltage level, it is required to step up the voltage. This can be attained by using a Boost converter between the photovoltaic system and the inverter. Fig 3 shows circuit for a boost converter. And for inverter operation available inverter model in MATLAB is used.

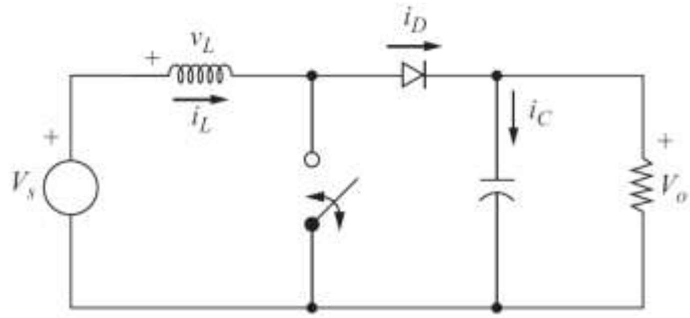

Fig 3: circuit diagram of a boost converter (ref. [15]).

III.OPERATION PRINCIPLE AND CONTROL TECHNIQUE

The theme of this exertion is to have reactive power transfer between the grid and inverter when there is no generation from PV system. Active power will be provided by generation from PV system. But reactive power transfer can be attained by providing amplitude difference between grid and inverter. The track of active power supply is decided by the phase difference between the grid and inverter voltages. If the inverter has same magnitude and advanced in phase, then active power transfer from inverter to grid can be achieved. Fig 4.2 shows the phase diagram of the inverter action in four operational conditions [1].

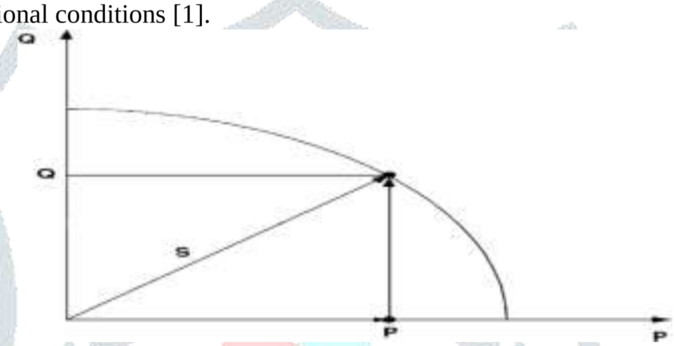

Fig 4: operational modes of inverter.

All the parameters explained in the previous section, the active power transfer and reactive power absorption can be controlled individually. . Here in this work active power is delivered from the photovoltaic system. Only the mechanism of active power transfer is done based on the generation from PV system with respect to irradiance available and at standard temperature. Based on active power supplied to grid and from standard equation of active, reactive and apparent power from power triangle, the wattles power to be delivered to the grid can be calculated. Fig 4 shows the reactive power to be delivered to or absorbed from the grid based on active power value can be monitored by the apparent power S.

$$Q = \sqrt{(S^2 - P^2)} \qquad (1)$$

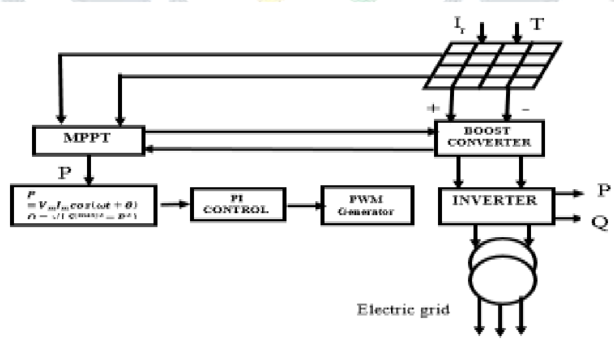

Fig 5: power system and control of the pv connected to the electrical grid (ref. [1]).

Fig 5 shows the block diagram of the PV connected to grid. It consists of a PV panel, a boost converter, MPPT for PV system, inverter, control block for inverter for active and reactive power control. When it comes to reactive power, the generation of the reactive power is based on the power triangle. The inverter which we have considered in this work is with a capacity of 1kVAr. And the maximum capacity of the PV system is 1Kw. The generated active power will be supplied to the grid directly. But the reactive power transfer to the grid is based on the equation 1.1 (Q=√(S^(2)-P^2)).

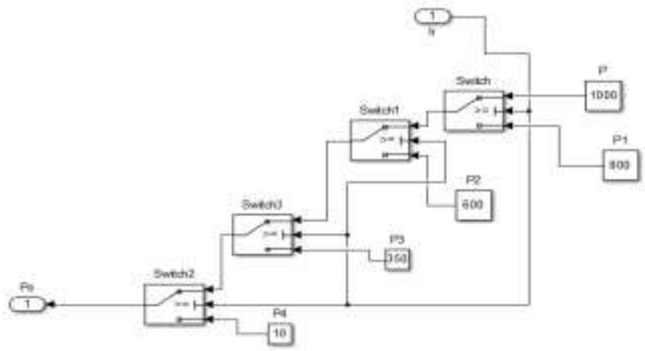

Fig 6: active power control model.

The output from active power control block is compared with the present value of active power. The difference is given to a PI controller, which generates a current signal Im. Fig 6 shows the simulation model of active power control. The output Po is given to a PI controller.

For linking voltage obtained from inverter to the grid, it taken through PLL. Application of PLL is made here to achieve synchronization. A Phase Locked Loop (PLL) scheme is utilized to synchronize on a variable frequency sinusoidal signal. The PLL controller adjusts the input (phase error) according to magnitude of input signal, when of Automatic gain controller is enabled. The output from the PLL is "wt".

In the reactive power control technique, initially the reactive power to be generated for particular value of active power output is calculated. Using equation 1.1 the necessary calculation is done. This gives amount of wattles power to be delivered to the grid. This value is compared with present value of reactive power and the difference is given to the PI controller. Here PI controller gives power factor angle θ.

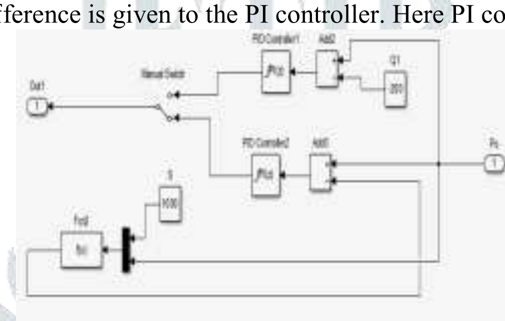

Fig 7: simulation model of reactive power control.

All the values from the controller Im, wt and θ are combined using a mux block available in the Simulink. Using a function block current equation "I_m sin(wt+θ)" is formed. This current is compared with the present value of the output current of the inverter. And the difference is given to a pulse generating block. Fig 8 shows simulation model of the pulse generating block.

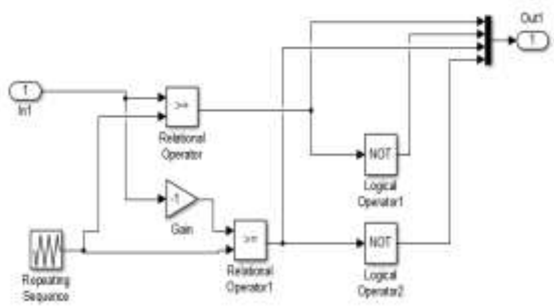

Fig 8: pulse generation block.

The simple idea of the controller is to apply a pulse with modulation (PWM) pattern to a constant DC bus voltage with the key objective to set the power angle in accord with the energy supplied by photovoltaic system. This condition can be attained by setting the value of voltage of the DC bus capacitor which is connected PV system. Because of this PV supplies the active power generated by the PV it in accordance with the change in insolation level. This is all about active power supply to the grid.

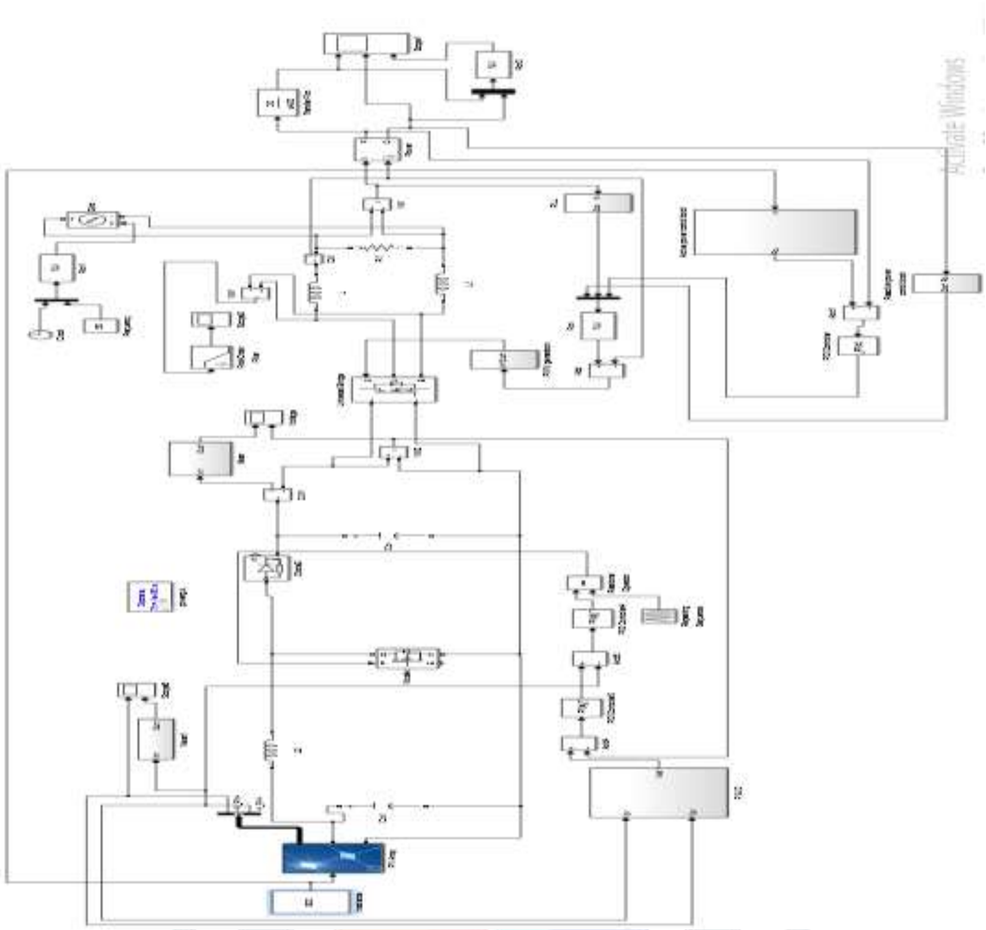

Fig 9: simulation model of a pv system connected electrical grid.

IV. RESULTS AND DISCUSSION

The model is simulated for five different conditions for supplying reactive power to grid. Here the inverter considered is 1kVAr. The capacity of the PV system used here in this work is 1kW. The simulated and calculated values must match. Using equation 1 the quantity of reactive power to be delivered to the grid can be calculated. According to the value of current produced triggering pulses for inverter are produced for the control of active and reactive power. Table 1 shows the values of active and reactive power for different cases of RPC. The simulation results show the active power and reactive power supplied to the grid.

table1: Different cases and corresponding active and reactive power

Cases	Insolation level	Active power (watts)	Reactive power(kVAr)
Case1	100%	1000	0
Case2	80%	800	600
Case3	60%	600	800
Case4	35%	350	936
Case5	20% ≤	10	1000

Fig 10: simulation results showing active, reactive and apparent power for 100% insolation.

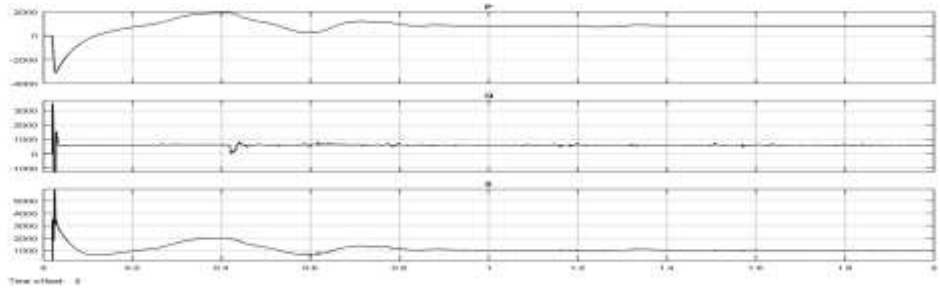

Fig 11: simulation results showing active, reactive and apparent power for 80% insolation.

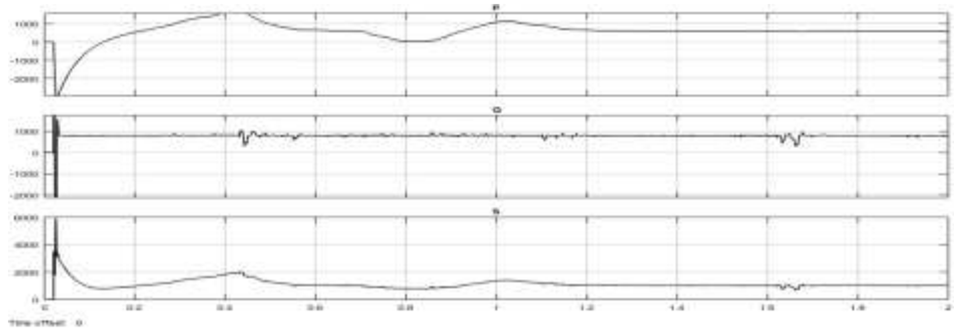

Fig 12: simulation results showing active, reactive and apparent power for 60% insolation.

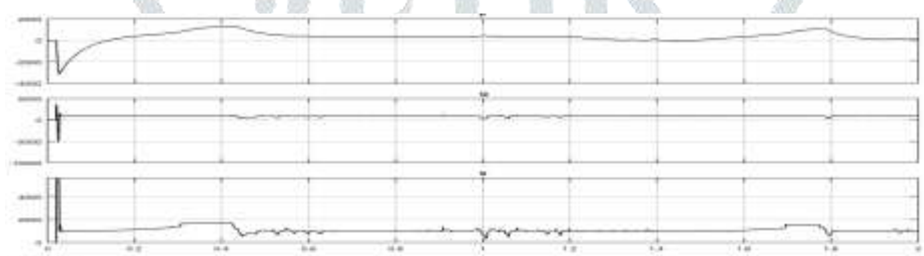

Fig 13: simulation results showing active, reactive and apparent power for 35% insolation

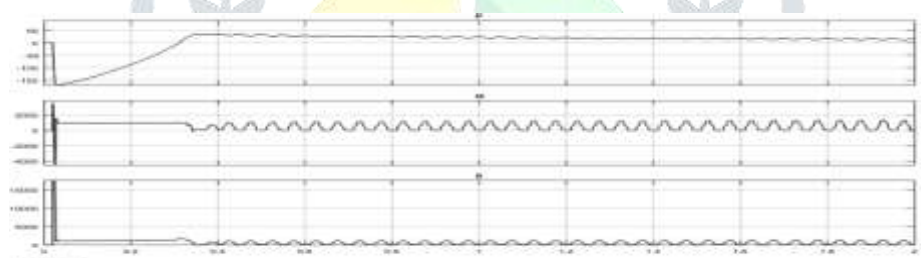

Fig 14: simulation results showing active, reactive and apparent power for 20% insolation.

The simulation results shown from Fig.10 to Fig.14 are showing the reactive power supplied to the grid. The simulation results obtained are matching with the calculated values.

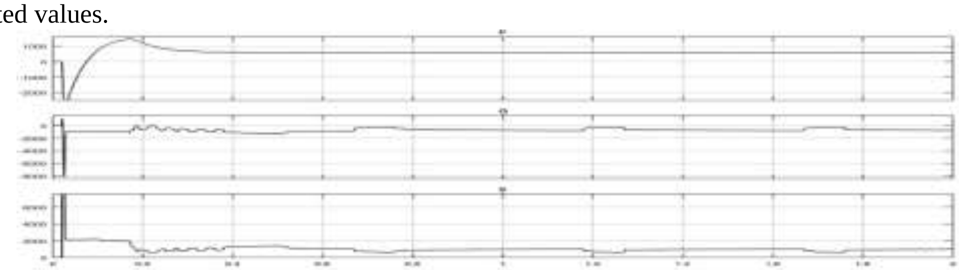

Fig 15: simulation results showing active, reactive and apparent power for 60% insolation for reactive power supplied by the grid.

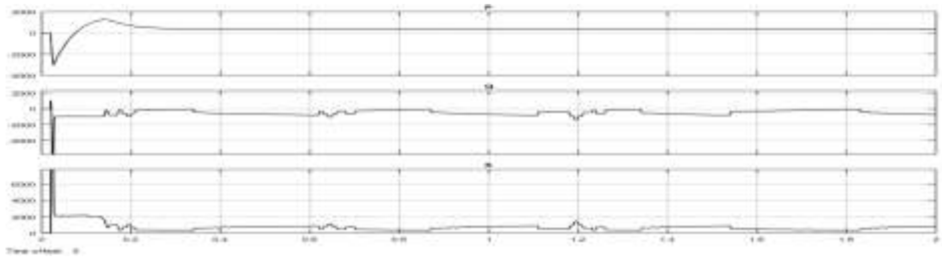

Fig 16: simulation results showing active, reactive and apparent power for 40% insolation for reactive power supplied by the grid

Only for two different cases of insolation levels, the reactive power supplied by the grid is shown. Here the value of the reactive power is negative, showing that it is supplied from the grid.

V. CONCLUSION AND FUTURE WORK

The simulation of the proposed model is done successfully. In the simulation control of power angle and voltage amplitude at the coupling of the grid is done successfully. The aim of the work is to control the flow of active power to grid according to availability of insolation level. This work also presents the control of reactive power, i.e. reactive power supplied to and absorbed from the grid according to availability of active power from PV system. The control of reactive power flow also improves power factor of the grid, transformer and cable overloads are avoided, decreases transmission losses and support local voltage.

And this work also presents the importance of VSI in distributed generation systems. The implementation of such a system is helpful power remote areas and its cost effective. With this the application of PV systems can be extended, i.e. PV systems were used only day time when insolation is available. But with this proposed system PV system can also be used in when there is no availability of the insolation, as a reactive power supporting system to grid. In the proposed work the active power control is done manually using the switches. In future this control can be made automatically. Developing a hardware prototype of the simulated circuit.

REFERENCES

[1] Fabio L. Albuquerque *, Ade´lio J. Moraes, Geraldo C. Guimara˜es, Se´rgio M.R. Sanhueza, Alexandre R. Vaz "Photovoltaic solar system connected to the electric power grid operating as active power generator and reactive power compensator".

[2] Ackermann, Thomas, Andersson, Goran, Soder, Lennart, 2001. Distributed generation: a definition. Electric Power Systems Research 57, 195–204

[3] Mekhilef, S., Rahim, N.A., 2004. Implementation of grid-connected photovoltaic system with power factor control and islanding detection In: 35th Annual IEEE Power Electronics Specialists Conference, Aachen, Germany, pp. 1409–1412.

[4] E. Demirok, D. Sera, R. Teodorescu, P. Rodriguez, and U. Borup, "Evaluation of the voltage support strategies for the low voltage grid connected PV generators," in Energy Conv. Congr. Exp. (ECCE), Atlanta, GA, Sep. 2010, pp. 710–717.

[5] Pedram Jahangiri Iowa State University," Voltage and reactive power regulation by photovoltaics in distribution systems".

[6] F. Vignola, F. Mavromatakis, and J. Krumsick, "Performance of PV inverters," in Proc. of the 37th ASES Annual Conference, San Diego, CA, 2008.

[7] K. Turitsyn, P. Sulc, S. Backhaus, and M. Chertkov, "Options for control of reactive power by distributed photovoltaic generators," in Proc. IEEE Power Energy Soc.,June 2011.

[8] T. Esram, P.L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439- 449, June 2007.

[9] V. Fernao PiresJ. F. Martins&, J. Fernando Silva," A Control Structure for a Photovoltaic Supply System with Power Compensation Characteristics Suitable for Smart Grid Topologies

[10] Importance of Reactive Power for System, https://www.google.co.in/search?q=Importance+of+Reactive+Power+for+System&oq=Importance+of+Reactive+Power+for+System &aqs=chrome..69i57j0l2.746j0j7&sourceid=chrome&ie=UTF-8

[11] Siddhartha Mozumder, Shriram S Rangarajan" Coordinated Operation of multiple Inverter Based Renewable Distributed Generators as an Active Power Injector and Reactive Power Compensator

[12] Md.W.Shah, Robert L.Biate "Design and Simulation of Solar PV Model Using Matlab/Simulink"

[13] Snehamoy Dhar1, PG Scholar; R Sridhar2, Asst. Professor "Modeling and Simulation of Photovoltaic Arrays"

[14] Guangzheng Yu, Xian lei Liu "A reactive power generator based on voltage source Inverter"

[15] Daniel W. Hart, "Power Electronics". Chapter 6, DC-DC converters, ISBN 978-0-07-338067-4, Page 196-211.

[16] J.Rodrigues, J.S Lai, and F.Z.Peng, "Multilevel inverters: a survey of topologies, controls and applications,"IEEE Trans.Ind.Electron.,vol,no.4pp.724-738,aug2002.