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Modified Direct Power Control of PV Sourced Inverter

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Abstract: In this era of uneconomical energy resources there is growing concern about renewable energy. Out of this various method of harnessing renewable energy, solar energy is growing at a great pace. This study deals with the control of solar power supplied to the grid using Extends Direct Power Control method (EDPC) which is a generic approach of Direct Power Control (DPC). Current power availability of PV system is calculated using irradiance meter denoted by P_{pv}. This P_{pv} is compared with the required power of the grid and the error is calculated. The dc output of the photovoltaic (PV) system, in fed to the inverter. The controller consists of a Maximum Power Point Tracking (MPPT) block and a DPC block. MPPT generates reference voltage levels using which the error signals are generated. This error signal along with the feedback from the output of the inverter when fed to the multilevel DPC block generates the required control signals to the inverter. The power output requirements of the standalone grid are matched using the direct power control.

Key words: Direct power control, MPPT, photovoltaic system

INTRODUCTION

In the last decades there has been a growing concern about energy resources, as the energy consumption trend does not seem to be sustainable. This situation has led to research in renewable energies. Distributed Generation (DG) (Chayawatto *et al*., 2010) systems are small-scale power generation technologies (typically in the range of 3 to 10,000 kW) used to provide an alternative to or an enhancement of the traditional electric power system Photovoltaic systems (Preethishri *et al*., 2011). And also the advantages is that power plant size is reduced, which leads to the reduced sum of energy losses in transmitting electricity because of the electricity is generated very near where it has been used, perhaps even in the same building, this also reduces the size and number of power lines that must be constructed, low maintenance, low pollution and high efficiencies and these energy sources meet both the increasing demand of electric power and environmental regulations (Alonso-Martinez *et al*., 2010; Albuquerque *et al*., 2010). This study addresses the control of solar power supplied to the grid using extends direct power control method (EDPC) which is a generic approach of Direct Power Control (DPC).

MODELING OF PV CELL

PV cell is the basic component of a PV energy system. But the output of a single cell is only a few watts. For this reason, the individual PV cells are arranged in the form of arrays that have a power rating, ranging from a few hundreds to thousands of watts. According to the purpose for which they have been installed, the number of cells in an array and/or the number of arrays are chosen. There is no fixed definition on the size for an array.

A model has been generated using DSC processor to simulate the operation of the PV array. The output voltage, current and power of the PV array have been mathematically formulated using which the real time values of the above can be estimated. The temperature of the array and the irradiation on the panel at that instant are fed as variables.

The most commonly used model for a PV cell is the one-diode equivalent which is shown in Fig. 1.

The array output power, which depends on the AC loop parameters, can be formulated as in:

$$P_{PV} = \frac{AN_S kT}{q} \ln\left(\frac{I_{PH} - I_{PV} + I_0}{I_0}\right).I_{PV} - I_{PV}{}^2.R_S$$

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Table 1: Experimental output power of the PV cell (without shadow)

Irr ($Wb\ m^{-2}$) Temp. (°C)	2	2.5	3	3.5	4	4.5	5
20	38.01	48.27	58.69	69.26	79.96	90.77	101.71
25	47.41	60.18	73.14	86.27	99.55	112.96	126.51
30	56.82	72.09	87.59	103.28	119.14	135.15	151.31
35	66.22	84.01	102.04	120.29	138.73	157.34	176.11
40	75.63	95.92	116.49	137.30	158.32	179.53	200.92
45	85.03	107.83	130.94	154.31	177.91	201.72	225.72

Table 2: Experimental output power of the pv cell (with shadow)

Irr ($Wb\ m^{-2}$) Temp. (°C)	2	2.5	3	3.5	4	4.5	5
20	30.41	38.61	46.95	55.41	63.96	72.62	81.36
25	37.93	48.14	58.51	69.01	79.64	90.37	101.21
30	45.45	57.67	70.07	82.62	95.31	108.12	121.05
35	52.98	67.20	81.63	96.23	110.98	125.87	140.89
40	60.50	76.73	93.19	109.84	126.65	143.62	160.73
45	68.02	86.26	104.75	123.44	142.33	161.37	180.57

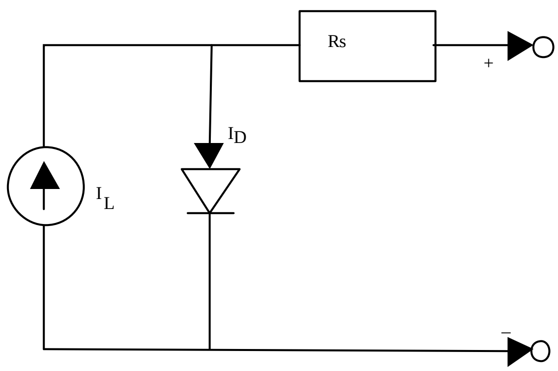

Fig. 1: Model of single-diode PV cell

The Table 1 and 2 shows the estimated PV cell output power (without shadow) and (with shadow) for different values of temperature (temp.) and irradiance (irr) respectively which is taken experimentally.

MODELING OF GRID CONNECTED INVERTER

PV cell is the basic component of a PV energy system. But the output of a single cell is only a few watts. For this reason, the individual PV cells are arranged in the form of arrays that have a power rating, ranging from a few hundreds to thousands of watts. The inverter is integrated with distributed grid with the source of PV based DC supply. A Ceq capacitor is the DC line capacitor, connected across the input side of the VSI to smoothen the waveform. The output of the inverter is given to a filter that allows only the fundamental components to flow through and smoothening of the waveform. The filtered AC output is connected to the grid. The current and voltage value compensation requirement is calculated by the controller block. The values in the abc frame are converted to dq frame using park transformation. The PLL (phase locked loop) is programmed to find the compensation required. Figure 2 shows the Proposed Model of Grid connected inverter.

The non fundamental component compensation requirement is also calculated by htis block. The 3rd harmonic injected PWM signal generator is used for harmonic elimination. This is achieved using the FFD block in the DSC. The actual DC terminal voltage and the reference voltages are compared and the power value is given to the controller. This may be a KI controller block. This block generates the real and reactive power references to be given to the manipulator block. The current and voltage controllers provide the reactive power reference value for the reference signal generator. The compensators in DQ frame block manipulates the error and decides how much compensation in real and reactive power is needed and adjusts the PWM pulses as per the requirement.

The following (conventional) state-space model represents (Twining and Holmes, 2001) the AC filter in the synchronous dq frame:

$$X = AX+BU$$

and:

$$Y = CX$$

Where:

$$X = (i_{1d}\ \ i_{1q}\ \ i_{2d}\ i_{2q}\ \ u_{cd}\ \ u_{cq})^T$$

where, i_{1d}, i_{1q}, i_{2d}, i_{2q} are system inputs:

$$U = (u_{1d}\ \ u_{1q}\ u_{2d}\ u_{2q})^T$$

where, u_{1d}, u_{1q}, u_{2d}, u_{2q} are state variables:

$$Y = (i_{2d}\ \ i_{2q})^T$$

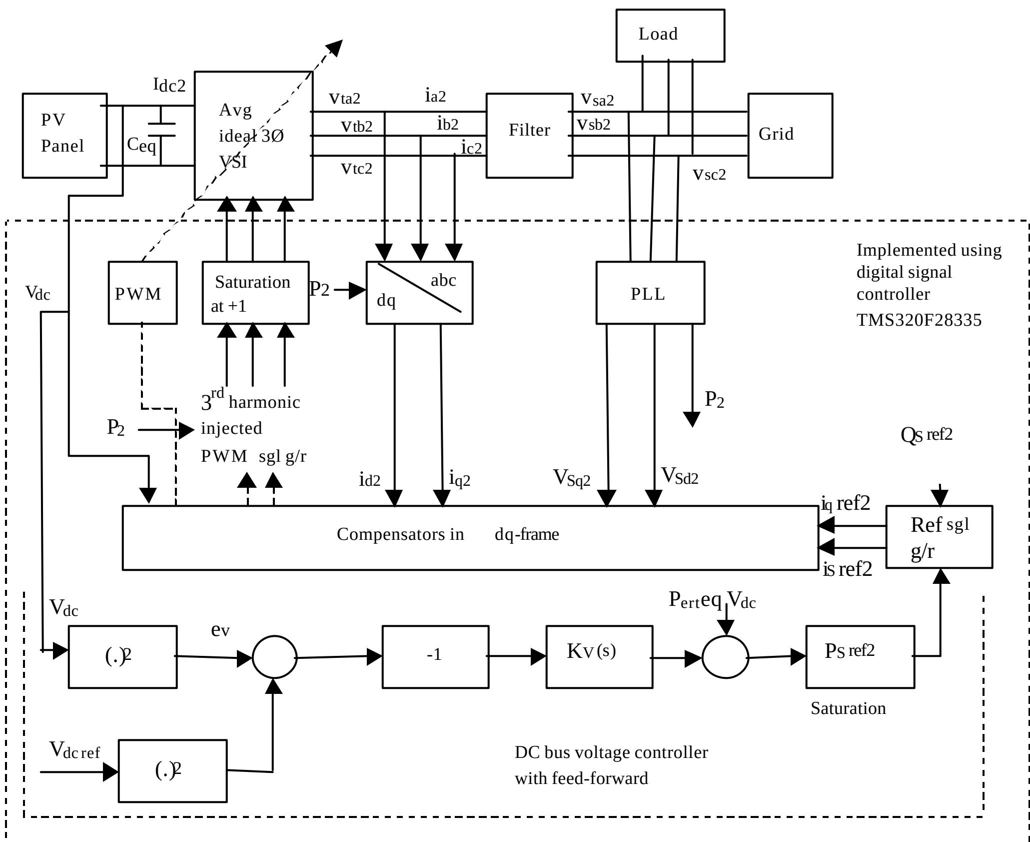

Fig. 2: Proposed model of grid connected inverter

$$A = \begin{bmatrix} -R_1/L_1 & \omega & 0 & 0 & -1/L_1 & 0 \\ -\omega & -R_1/L_1 & 0 & 0 & 0 & -1/L_1 \\ 0 & 0 & -R_1/L_1 & \omega & -1/L_2 & 0 \\ 0 & 0 & -\omega & -R_1/L_1 & 0 & -1/L_2 \\ 1/C_f & 0 & -1/C_f & 0 & 0 & \omega \\ 0 & 1/C_f & 0 & -1/C_f & -\omega & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 1/L_1 & 0 & 0 & 0 \\ 0 & 1/L_1 & 0 & 0 \\ 0 & 0 & -1/L_2 & 0 \\ 0 & 0 & 0 & -1/L_2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

where, R1, R2 = resistance values associated with L1, L2.

The DC voltage is defined by following equation:

$$\frac{dV_{dc}}{dt} = \left(\frac{u_{1d}i_{1d} + u_{1q}i_{1q}}{C_{dc}\,V_{dc}}\right) - \frac{i_1}{C_{dc}}$$

The inverter system defined by above equation is nonlinear (Chayawatto *et al*., 2010) because f (X,U) is a non-linear function. To obtain the closed loop response, the inverter outputs (filter inputs), u1dand u1q, are taken from the outputs of the inner loop PI controllers, as:

$$\begin{bmatrix} u_{1d} \\ u_{1q} \end{bmatrix} = \begin{bmatrix} Kp + \frac{K_i}{s} & 0 \\ 0 & Kp + \frac{K_i}{s} \end{bmatrix} \begin{bmatrix} i^*_{1d} - i_{1d} \\ i^*_{1q} - i_{1q} \end{bmatrix}$$

where, i1d*and i1q* are the reference currents. Kp and Ki are the proportional and integral gain constants respectively. These gain constants are set by tuning the controller for optimal response. The DC voltage is maintained at a constant value using a PI controller which provides the real current reference of:

$$i^*_{1d} = \left(K'_p + \frac{K'_i}{s}\right)(V_{dc} - V^*_{dc})$$

where, V_{dc}*is the DC voltage target. As mentioned above, the inverter system is non-linear and cannot be solved analytically. As the high frequency switching operations are not included in the ASM the computation requirements are significantly less than those of the switched model, resulting in a greatly reduced simulation time.

SOFTWARE DESCRIPTION AND ALGORITHM

The PV panel working has been simulated using the ARM processor. The temperature of the cells and the irradiance at that instant are fed as variables to the system. The processor is programmed in C language. Encoding is achieved through IAR software.

ALGORITHM

- **Step 1:** Read the input parameters-modulation index, carrier frequency and number of pulses per half cycle
- **Step 2:** Initialize the GPIO ports and PWM ports
- **Step 3:** Calculate the time delay value of each pulse
- **Step 4:** Calculate the delay value placed in timer register to start up the timer
- **Step 5:** Based on the timer inputs PWM ports set to be enable or disable
- **Step 6:** The subsequent PWM port are displaced by 120 degree
- **Step 7:** The opposite switch model of each leg is delayed by 180 degree
- **Step 8:** Whenever start interrupt flag is set to be enable PWM port latches are enabled for getting the PWM pulses
- **Step 9:** The PWM pulses values are set and reset by GPIO control bits
- **Step 10:** The modulation index value of the PWM signal is varied according to the AD input port at the clock of 100 MHz

SIMULATION AND RESULTS

Figure 3 shows the proposed simulation. The 3 phase input is given to the multiplexer. The output is given as a signal to the PWM generator. The PWM generator block gives the pulses required for the triggering of the MOSFET. The triggering pulses are given to the gate of the inverter MOSFETs.The power source is the PV array

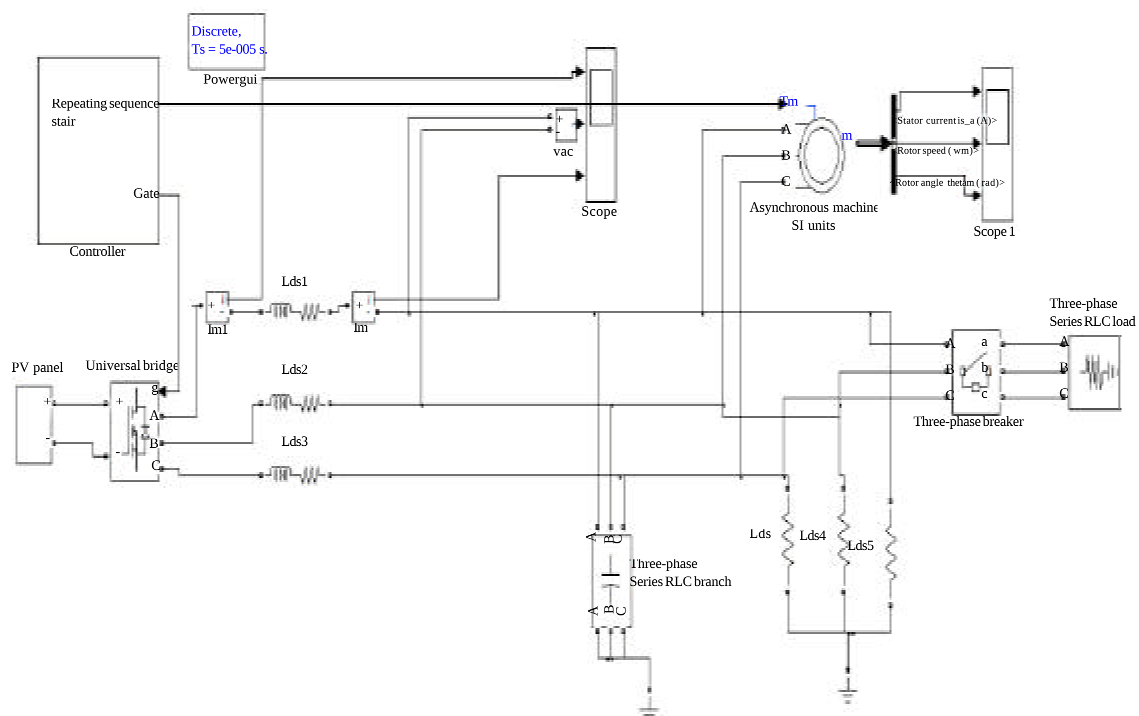

Fig. 3: Proposed simulation model

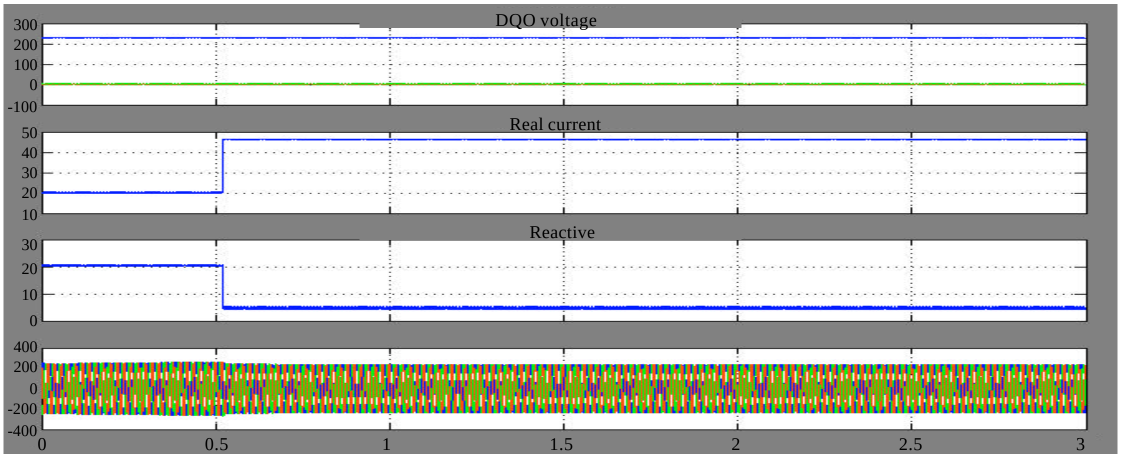

Fig. 4: Waveforms of different quantities with respect to time obtained from the proposed method

Fig. 5: Hardware model of the proposed three phase inverter

system. The output of the PV system is DC and it needs to be inverted. So, it is connected to the inverter. The DC output of the PV system is replaced by the DC voltage source for the simulation purposes. Therefore the inverter's DC input is from the DC voltage source.

The source resistance is also taken into consideration. In the output side of the inverter the line resistance and inductance are also taken into consideration in order to achieve real time simulation output results. The three phase RLC series branch is used to provide real time reactive power drop of the line side. It also includes the capacitive reactance of the line into consideration in order to achieve more accurate simulation results. The three phase dynamic load is included to provide the voltage sag or swell that takes place when a real time load is used. In other words it is used to create the sag or swell caused by the turning on or off of loads, respectively. The asynchronous machine is added to act as a load for the simulation. Figure 4 shows the resultant waveform of the proposed simulation.

Figure 5 shows the hardware model of the proposed three phase inverter. The inverter used is basically a three phase inverter in which MOSFET is used as a power module. MOSFET selected for this inverter is IRFP460

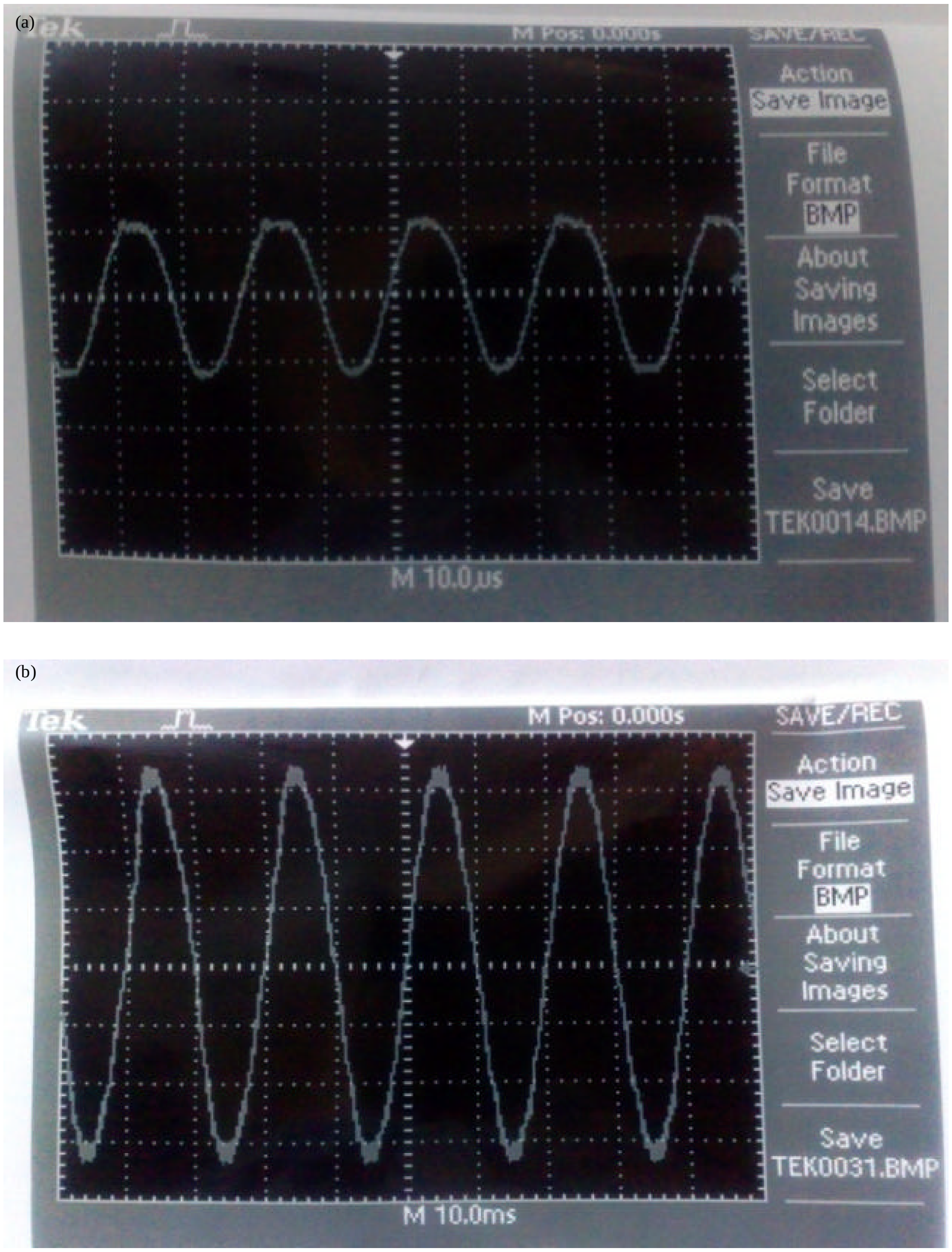

Fig. 6(a-b): Output waveform of the inverter at different time interval, (a) At 10.0 m sec and (b) At 10.0 μ sec

which is capable of a power dissipation of 280 W. This N-channel MOSFET module can handle up to 500 V. Four MOSFETs are combined in series to obtain the power output of 1 kW which is a required value of this hardware model. The amplitude of the PWM pulse which is to drive the MOSFET should be of 30 V. The PWM pulse for gate terminal of the MOSFET module is provided from digital signal controller. The PWM pulse output from the digital signal controller is of 150 MHz. The PWM pulse is then amplified from the primary level of 3.3 to 30 V using the driver circuit which is explained in the next section.A snubber resistance of 1MΩ is added across drain and the source terminals of each MOSFET module.A diode IN4007 is connected between the source and drain terminal to protect the MOSFET module against any short circuit. Figure 6 shows the output waveform of the inverter using DSO.

DESIGN SPECFICATION

- MOSFET: IRFP460
- Diode: 1N4007
- Capacitors:1000 uF/50 V; 1000 uF/25 V
- Optocoupler: MCT2E
- Transistors: 2N2222; CK100
- Resistors: 1k ; 100 ohm
- Transformers: 230/50 V

CONCLUSION

In this study, the control of solar power supplied to the grid using Extends Direct Power Control method (EDPC) which is a generic approach of direct power control (DPC).Current power availability of PV system was calculated using irradiance measurement table. P_{pv} compared with the required power of the grid and the error was calculated. The dc output of the photovoltaic (PV) system, was fed to the inverter. The input of the current control was received from voltage control block. The current control will deliver the instantaneous magnitude and angle value for modulating signals to the PWM generating circuit. The proposed control method which neutralized the voltage sag and swells at the point of common coupling with proper injection of reactive power from the PV sourced inverter.

REFERENCES

Albuquerque, F.L., A.J. Moraes, G.C. Guimaraes, S.M.R. Sanhueza and A.R. Vaz, 2010. Photovoltaic solar system connected to the electric power grid operating as active power generator and reactive power compensator. Solar Energy, 84: 1310-1317.

Alonso-Martinez, J., J. Eloy-Garcia and S. Arnaltes, 2010. Direct power control of grid connected PV systems with three level NPC inverter. Solar Energy, 84: 1175-1186.

Chayawatto, N., N. Patcharaprakiti, V. Montauk, K. Kirtikara and K. Tunlasakun, 2010. Distributed Generation and Islanding-Study on Converter Modeling of PV Grid-Connected Systems under Islanding Phenomena. In: Distributed Generation, Jenkins, N., N. Jenkins, J.B. Ekanayake and G. Strbac (Eds.). Institution of Engineering and Technology, USA.

Preethishri, T.P.V., K.S. Kumar and P. Sivakumar, 2011. Embedded emulator of photovoltaic array and wind driven induction generator by using digital signal controller (tms320f28335). Proceedings of the India International Conference on Power Electronics, January 28-30, 2011, New Delhi, pp: 28-30.

Twining, E. and D.G. Holmes, 2001. Modeling grid-connected voltage source inverter operation. Proceedings of the Australasian Universities Power Engineering Conference, September 23-26, 2001, Millennium Power Vision, pp: 501-506.