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Integration of PV based DG Source in AC Microgrid with Interconnection to Grid

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Abstract

Objectives: This aim of the paper is to achieve most edges from the grid-interfacing inverters, implementing in three-phase four-wire distribution systems. **Statistical Analysis:** The work is carried out using MATLAB/SIMULINK software. This work overcomes the power quality problems by including grid interface inverter control. **Findings:** The grid for three phase four wire distribution is integrated with photo voltaic system which is a renewable energy supplier. Electrical converter is made to perform as multifunction device by introducing active power filter. So this is a novel approach in which inverter can be utilized as: Power converter to injecting power to the grid, and it compensates current unbalance, harmonic current, and load neutral current through shunt Active Power Filter. To improve the performance of the system when highly nonlinear loads are present all of these functions can be accomplished at the same time or individually. **Application/Improvements:** This work is used in power system applications.

Keywords: Distributed Generation (DG), Photo Voltaic (PV), Power Quality (PQ), Renewable Energy Supply (RES), Shunt Active Power Filter (SAPF)

1. Introduction

Photo Voltaic Inverter along with Active power filter[1] is used to eliminate the harmonics current and overheating of equipment. The grid interface inverter is used for Injecting power to the grid by using power converter[2] and the non-linear, unbalanced and load current harmonics are compensated. PV inverter will act as a Shunt Active Power Filter[3].

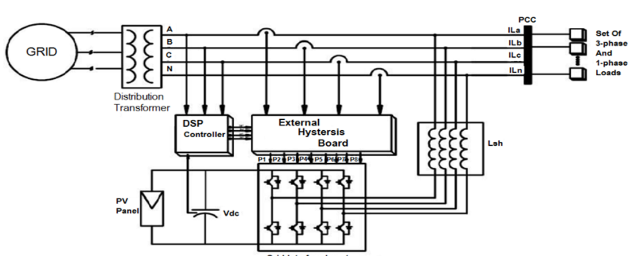

Figure 1. Proposed circuit with Renewable Energy System.

2. System Description

As in the Figure 1 the DC link capacitor is interface between the current controlled voltage source inverter (or) Grid interface inverter and RES. The grid interface inverter is interconnected between the grid[4] and Renewable energy sources. The RES may be DC source or AC source with rectifier coupled to the dc-link. Usually dc-link plays a major role is to transferring the variable power from RES to grid. A unidirectional DC/DC converter is used to supply high voltage DC to grid interface inverter so power conditioned is needed to RES. Power conditioned is nothing but dc/dc or ac/dc, before connecting on dc link. Inverter and filter configurations are used to converters the DC voltage to AC voltage.

2.1 Modeling of PV System

2.1.1 Working of PV Cell

PV cells are unit of PV module which produces the current carries when it is encounters the sunlight. Number of such PV cells is connected in series (or) parallel fashion such that the output power will be increased. A boost converter is used to boost up the output voltage of PV cells, if it is required.

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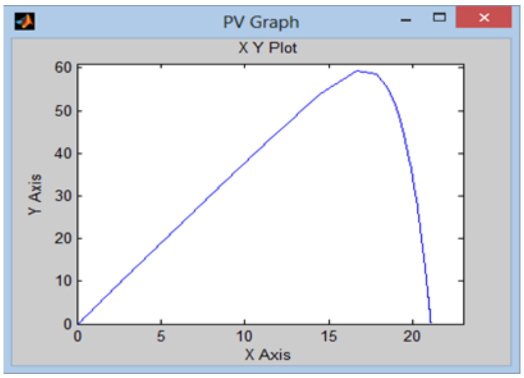
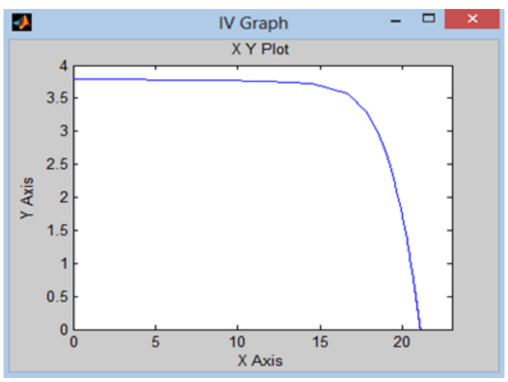
If the PV Module is represented by a characteristics equation as follows according to Figure 2.

$$I = I_{pv} - I_0\left[\frac{\exp(q(v+IR_s))}{\alpha KT} - 1\right] - \frac{v+IR_s}{R_{sh}}$$



(a)



(b)

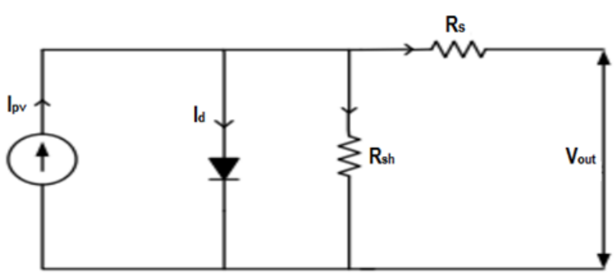


Figure 2. Equivalent circuit of PV. **(a)** PV Graph of Solar cell. **(b)** VI Graph of Solar cell.

The boost converter of solar model is used inMatlab simulation. Graph (a) results of PV obtained by the Matlab model (b) results of VI curves obtained by the Matlab.With this module we can observe characteristics of varying temperature and varying irradiation in Solar PV module.

2.2 DC-Link Voltage and Power Control Operation

The generated power by RES is of variable nature. The dc-link[5] plays an important role in transferring the variable power from RES to grid. And dc-link is interconnected between the RES and grid-interfacing inverter[3].

$$I_{dc1} = \frac{P_{RES}}{V_{dc}}$$

In above equation current injected by renewable energy source into dc-link

P_{RES}- Power generated from RES.

$$I_{dc2} = \frac{P_{inv}}{V_{dc}} = \frac{P_G + P_{Loss}}{V_{dc}}$$

I_{dc2} -The current flow on the other side of dc-link.
P_{inv} - Grid-interfacing inverter power,
P_G- Active power supplied to the grid,
P_{LOSS} - Inverter losses.
Assuming inverter losses are negligible

$P_{RES} = P_G$

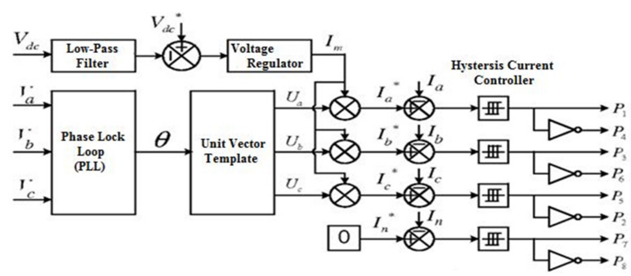


Figure 3. Block diagram representation of grid-interfacing inverter control.

2.3 Control of Grid Interfacing Inverter

Control unit of grid interface inverter is shown in Figure 3. Neutral current is compensated by four leg grid interface inverter. If unbalanced load is connected to point of common coupling in the control approach compensates the harmonic currents, unbalanced and neutral currents. By varying the duty ratios of inverters switches balanced power appears at resistive load[6] of grid. The active power flows from between renewable energy source and grid can be obtained from regulation of the dc-link voltage. Therefore dc-link voltage output results in active current (I_m) which when multiplied with unity grid voltages (U_a,

U_b and U_c) generate reference grid currents (I_a^*,I_b^*, and I_c^*).

Phase Lock Loop (PLL) is used to obtain grid synchronous angle (θ)

$U_a = \sin\theta$

$$U_a = \sin\theta$$

$$U_b = \sin\left(\theta - \frac{2\pi}{3}\right)$$

$$U_c = \sin\left(\theta + \frac{2\pi}{3}\right)$$

U_a, U_b, U_c- Unity grid vector voltages

First order Low Pass Filter (LPF) is used to eliminates the switching ripples on dc-link voltage (V_{dc}) in generated reference current signals (V^*_{dc}). Under varying generations and load conditions, PI discrete regulation[7] is used to maintained constant dc link voltage.

The error in the dc-link voltage when compared to reference dc-link voltage (V^*_{dc}) is given to PI regulator to obtain a constant dc-link voltage.

The n^{th} sample of PI regulator is given as

$I_{loss(n)} = I_{loss(n-1)} + K_{P_{d(Vde(n)}} - V_{de(n-1)} + K_{I_d\ Vde(n)}$

Where,

K_{P_d}-Proportional gain of the PI controller.

K_{I_d}- Integral gain of the PI controller.

Thus instantaneous values of 3-phase reference grid currents is computed as

$$I_a^* = I_m . U_a$$

$$I_b^* = I_m . U_b$$

$$I_c^* = I_m . U_c$$

I^*_a, I^*_b, I^*_c. - Generating reference grid currents

As the fourth leg of the grid interface inverter compensates the neutral current, the grid neutral reference current is considered as a zero i.e.,

$$I_n^* = 0$$

The current errors are computed by comparing actual grid currents (I^*_a, I^*_b, I^*_c) and reference grid currents (I_a, I_b, I_c,I_n) are given as

$$I^*_{aerr} = I^*_a \text{ - } I_a$$

$$I^*_{berr} = I^*_b \text{ - } I_b$$

$$I^*_{cerr} = I^*_c \text{ - } I_c$$

Switching pulses for grid interfacing inverters are produced by current errors by giving them to hysteresis current controller. By the following state space equations, the model of four-leg inverter can be obtained as

$$\frac{dI_{a,Inv}}{dt} = \frac{\left(V_{a,Inv} - V_a\right)}{L_{sh}}$$

$$\frac{dI_{b,Inv}}{dt} = \frac{\left(V_{b,Inv} - V_b\right)}{L_{sh}}$$

$$\frac{dI_{c,Inv}}{dt} = \frac{\left(V_{c,Inv} - V_c\right)}{L_{sh}}$$

$$\frac{dI_{n,Inv}}{dt} = \frac{\left(V_{n,Inv} - V_n\right)}{L_{sh}}$$

$$\frac{dV_{dc}}{dt} = \frac{\left(I_{ad,inv} + I_{bd,inv} + I_{cd,inv} + I_{nd,inv}\right)}{C_{dc}}$$

These voltages can be modelled in terms of instantaneous dc bus voltage and switching pulses of the inverter as

$$V_{a,Inv} = \frac{\left(P_1 - P_4\right)}{2} V_{dc}$$

$$V_{b,Inv} = \frac{\left(P_3 - P_6\right)}{2} V_{dc}$$

$$V_{c,Inv} = \frac{\left(P_5 - P_2\right)}{2} V_{dc}$$

$$V_{n,Inv} = \frac{\left(P_7 - P_8\right)}{2} V_{dc}$$

V_{inva}, V_{invb}, V_{invc},- Three-phase ac switching voltages produced at the output terminal of inverter.

Let $I_{ad,Inv}$,$I_{bd,Inv}$,$I_{cd,Inv}$ be the charging currents on dc bus due to the each leg of inverter can be given as

$I_{ad,Inv} = I_{a,Inv}(P_1\text{-}P_4)$

$I_{bd,Inv} = I_{b,Inv}(P_3\text{-}P_6)$

$I_{nd,Inv} = I_{n,Inv}(P_7\text{-}P_8)$

Error between actual and reference current of inverter gives the switching pattern of each IGBT inside inverter will be:

- If, $I_{ad,Inv} < (I^*_{a,Inv} - h_b)$ then upper switch will be OFF (p_1=0) and lower switch will be ON (p_4 =1) in the phase "a" leg of inverter.
- If, $I_{a,Inv} < (I^*_{a,Inv}\text{-}h_b)$ then upper switch S_1 will be ON (p_1 =0) and lower switch S_4 will be OFF (p_4 =0) in the phase "a" leg of inverter.

h_b- Width of hysteresis band. Thus, the switching pulses for the other remaining three legs can be derived.

3. Simulation Results

Simulation results for 3 phase 4 wire system are showed below by using MATLAB/SIMULINK tool. This system contains three phase non linear load, single phase non linear load and linear load at each phase. The non linear load is bridge rectifier feeding a RL load. The non linear loads connected to source that inject current harmonics, which distorts the source current. And it may deteriorate the quality of power. Finally the current harmonics are suppressed by injecting the compensating current by using SAPF.

Grid voltage will be constant at before and after compensation in system will be shown in Figure 4. And grid current for the three phase A, B, C as shown in Figure 5. The unbalanced load current will be represented in Figure 6. That which indicates loads current harmonics in the system.

At time t = 0.752s the grid interface inverter is connected to the system as shown in Figure 7. At this moment the inverter starts injecting current to grid from the RES. In such a way the grid current starts changing unbalanced non linear to balanced sinusoidal current. Grid neutral current will be zero that inverter supplies load neutral current. And active power will goes down to negative this means RES supply power to grid. Reactive power will supplied to grid normally by grid interface inverter.

At time t = 0.825s the excess flow active power from RES to grid that indicates increased in magnitude of grid current. And time t = 0.925s the power will reduced and the changes in grid current, inverter current will observed clearly. The increasing and decreasing of active power in this will be noticed in Figure 8. The DC-link voltage will be remains constant at each and every instant of time in the system. THD value of source current before compensation will be 28.36%. After compensation THD value of source current will be 3.18%.

By this simulation results the grid interface inverter will compensate unbalanced current, harmonic current and load reactive power support respectively.

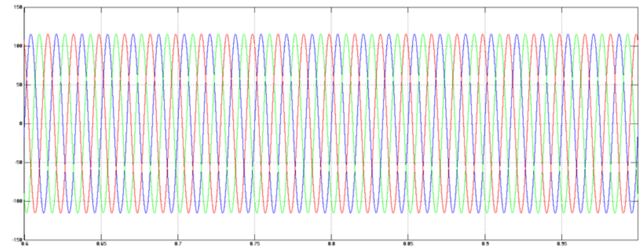


Figure 4. Grid voltage.

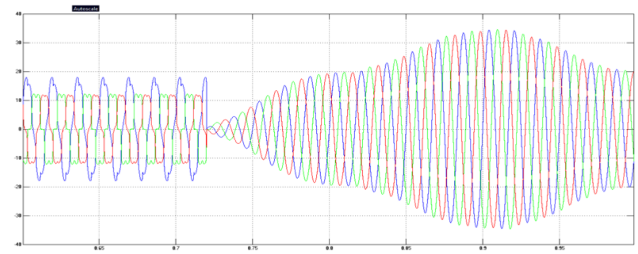


Figure 5. Grid Current.

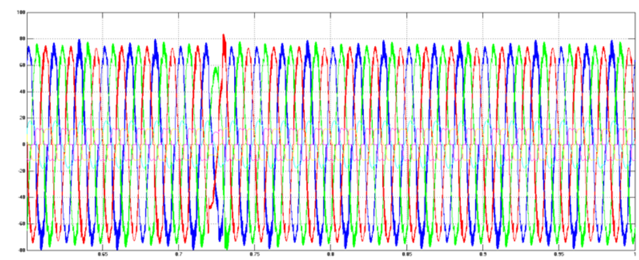


Figure 6. Unbalanced load current.

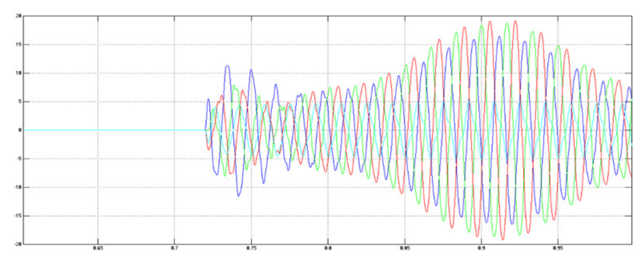


Figure 7. Inverter Currents.

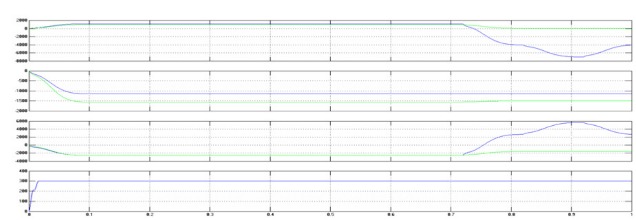


Figure 8. (a) PQ-Grid, (b) PQ-Load, (c) PQ-Inverter, (d) dc-link voltage.

4. Conclusion

This paper suggests the use of shunt active filter as interface between RES and to electrical grid. Simulation results are showed by the proposed control strategy. SAPF capability to inject the sinusoidal current with low THD and compensated harmonic and unbalanced problems. In this paper the authors are use PV system used as RES and different switching techniques of inverters for to reduced the power quality problems. And the future work we can use hybrid sources instead PV system and different logic techniques of inverter for to improve power quality in the system.

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