Improvement of Quality of Power at Distribution Level Through Solar Photovoltaic Linking With Grid

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ABSTRACT

Drastic growth in the demand leads to increased tie-in of Renewable energy sources (RES) to distribution systems by power electronics converters. This paper discusses a proposed control strategy for effective utilizing these inverters of grid-interfacing when used in a distribution system which is a 3-phase 3-wire.By adding active power filter functionality, the inverter acts as a device of having multi-function. The given below are the functions of inverter:1)helps in injecting power generated to the grid from RES 2)Provide for harmonics compensation of load current, unbalance, reactive power demand of load.

Keywords— *Renewable energy sources(RES),grid-interfacing inverter, Distributed generation(DG),Power quality(PQ)*

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1. INTRODUCTION

Today 75% of world’s energy demand is met by using of fossil fuels which is having disadvantages of air pollution, global-warming, exhausting fossil fuels; therefore Renewable Energy Sources (RES) are the next alternative in coming days. Modern grid is forced to be integrated with renewable energy sources like solar photo voltaic(SPV) system , wind energy and biomass etc because of increased demand of electrical energy and to minimize the impact of conventional plant on environment [1, 2].By 2022 Ministry of New and Renewable Energy(MNRE)government of India is targeting to complete 2000MW grid interactive power through solar[3]. To meet current demand for electricity RES will aids us ,but its intermittent behavior causes power quality problems[4]. Power quality concerns arises due to the integration. Three important issues are voltage dips, rise in steady state voltage, voltage flicker and harmonics [2]. The increased utilization of non-linear loads also causing power quality problems like unbalance, grid and load current harmonics active and reactive requirements of load[1, 5].Integration of renewable energy sources at distribution level is known as Distributed generation (DG).We should interconnect DG system without compromise safety, reliability and efficient operation of entire network. Intermittent RES can be interfaced with distribution system with the help of current controlled voltage sources. The main idea is to convert under utilization of inverter rating into maximum utilization [1].In order to enhance the system operation besides better power quality at the Point of Common Coupling (PCC), active control of DG is required. The grid interfacing inverter has the following main functions:

- Transfer of active power harvested from the renewable resources
- Supports the load reactive power demand
- Compensates unbalanced current.

Hence interfacing inverter will keep PQ parameters at PCC within the standards of utility [1].

The evaluation of different current controllers with variable input power is employed for grid connected distributed power. This has main aim to set a linear controller such as Proportional Integral, Proportional Resonant and improved deadbeat (DB)and implement these in the [6]. The grid synchronization with RES and consideration of safe running is given with a overview with simulation and experiment result to evaluate the behavior of synchronization method with different grid turbulence as harmonics notches, flickering and voltage dip in [7]. The investigation and comparison of the effects of converter based DG units, synchronous and

asynchronous generator on the retained voltage during voltage dips in low voltage distribution is discussed by B. Renders in [8]. Integration of solar brings changes in the profile of voltage and response of frequency of the system and the transmission and distribution systems of utility grid are affected [2]. Number of DG systems can be Increased and utilized to address the power quality concern raised by increased nonlinear residential loads by using interfacing inverters[9].In the projects having penetration of large photovoltaic (PVs) on rooftops of commercial buildings and houses the problems of quality of power are identified[10]. Various problems associated with interconnection of DG are addressed by Roger C. Dugan in [7]. The key element of PV based system is inverter which controls the power flow between load and dc source. For power Quality improvement Shunt Active Power Filter (SAPF) is used in solar PV integrated grid system[8].Three-phase three-wire SPV system which is supporting the grid utilizing a boost converter at first stage to do the function of MPPT.
Paper is written with well planned pattern. The first section is representing the introduction and literature review of the articles with available techniques. The second section gives the brief description of the system use for the article and methodology applied. The third section is of the conclusion and last section concluded the research followed by the references.

2. SYSTEM DESCRIPTION

The key component of a DG system is voltage source inverter as it interfaces the renewable energy sources to the grid and dispatches the generated power.

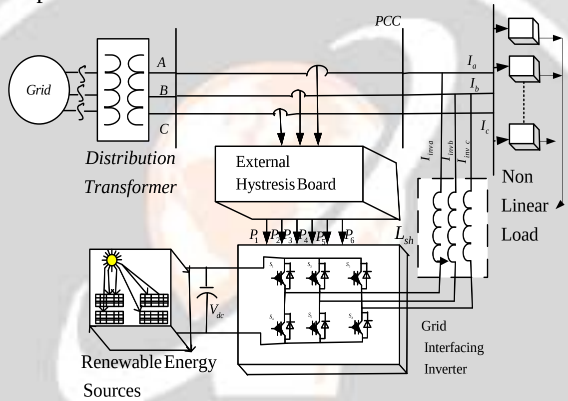

Fig 1 - *Schematic of proposed solar PV based distribution generation system*

The RES coupled to dc link may be a DC/AC source with rectifier. Generally photovoltaic energy sources produce power at changing low dc voltages, while variable ac voltages is generated by variable speed wind turbines. Thus power conditioning (*i.e* AC/DC or DC/AC) is required for power produced from these renewable sources ahead of connecting to dc-link[1].In this paper ,with a simple three-leg three-wire system, it is possible to compensate disturbances like THD, voltage unbalance and others. The topology of grid interconnected active power filter(APF) is presented in fig.1.[7].

2.1 Voltage of DC Link and Operation of Power Control

The power produced is of changing nature in RES, because of its intermittent nature. Grid-interfacing inverter's DC-link connected with RES which is represented by current source. Power delivery from the solar PV via DC-link to grid is shown in the fig.2.Renewable injects current into dc-link at V_{DC} voltage level can be represented as

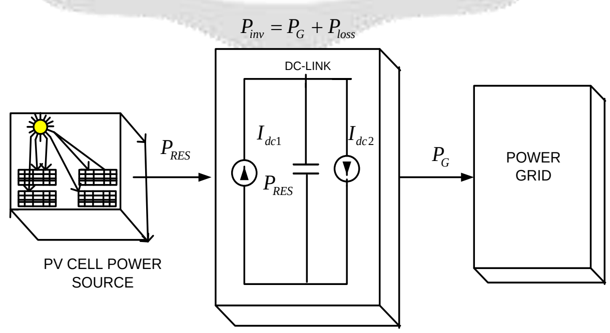

Fig: 2 : DC - Link equivalent diagram

$$I_{DC1} = \frac{P_{RES}}{V_{DC}} \quad (1)$$

The dc-link current flow on the remaining side can be represented as

$$I_{dc2} = \frac{P_{inv}}{V_{dc}} = \frac{P_G + P_{loss}}{V_{dc}} \quad (2)$$

Where P_{inv}, P_G and P_{loss} are grid-interfacing inverter side's total power available, grid received power, losses of inverter correspondingly .If the losses of inverter are omitted, then $P_{RES}=P_G$

For a 3-phase 3-wire system ,grid-interfacing inverter's control diagram is shown in Fig.3.

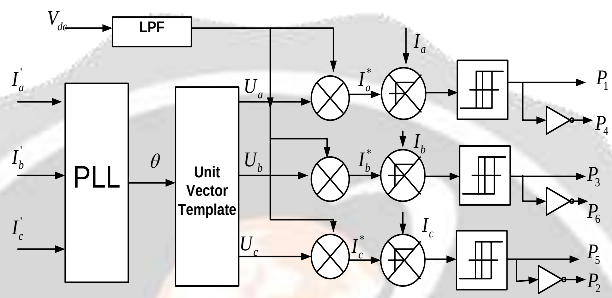

Fig 3:- Block diagram representation of grid-interfacing inverter control.

The inverter is actively managed in such a way that takes/gives fundamental active power from/to the grid. Combined appearance of load and inverter injected power looks like a balanced resistive load by changing duty ratio of inverter switches in a power cycle. The data related to the exchange of active power in between grid and renewable sources is carried by regulation of dc-link voltage.Active current(Im) is the result of regulation of dc-link's output voltage. Reference grid currents (Ia*,Ib*and Ic*) are obtained by multiplying active current component(Im) and vector templates of grid voltages(Ua,Ub and Uc).Phase locked loop(PLL)gives unity vector template with the help of synchronizing angle(Ө) of the grid.

$$U_a = \sin(\theta)$$
$$U_b = \sin(\theta - \frac{2\pi}{3})$$
$$U_c = \sin(\theta + \frac{2\pi}{3})$$

The actual dc-link voltage (Vdc) is subtracted from the reference dc-link voltage(Vdc*) and the difference is supplied to a discrete PI regulator to have fixed dc-link voltage even though load and generation conditions are changing. At the point of nth sampling, the voltage error of dc-link Vdcerr(n)

$$V_{dceer(n)} = V^*_{dc(n)} - V_{dc(n)}$$

At the point of nth sampling ,discrete-PI regulator's output is expressed as

$$I_{m(n)} = I_{m(n-1)} + K_{PV_{dc}}(V_{dcerr(n)} - V_{dcerr(n-1)}) + K_{IV_{dc}} V_{dceer(n)}$$

Where K_{PVdc}=10 and K_{IVdc}=0.05

The three phase grid currents have the following computation formulas

$$I_a^* = I_m.U_a$$
$$I_b^* = I_m.U_b$$
$$I_c^* = I_m.U_c$$

To obtained the current errors, the reference currents of grid (Ia*, Ib*, Ic*) are compared with original currents of grid (Ia, Ib, Ic).

$$I_{aerr} = I_a^* - I_a$$
$$I_{beer} = I_b^* - I_b$$
$$I_{cerr} = I_c^* - I_c$$

The hysteresis current controller is given by the errors of current. Switching pulses are generated by hysteresis current controller for grid interfacing inverter's gate drives which are (P1 to P6).

State space equations of 3-leg inverter's average model are

$$\frac{dI_{Inva}}{dt} = \frac{(V_{INVa} - V_a)}{L_{sh}}$$
$$\frac{dI_{Invb}}{dt} = \frac{(V_{INVb} - V_b)}{L_{sh}}$$
$$\frac{dI_{Invc}}{dt} = \frac{(V_{INVc} - V_c)}{L_{sh}}$$
$$\frac{dV_{dc}}{dt} = \frac{(I_{Invad} + I_{Invbd} + I_{Invcd})}{C_{dc}}$$

Where V_{Inva}, V_{Invb}, V_{Invc} and V_{Invn} are generated on the inverter's output terminal as ac three-phase switching voltages. Output voltages of the inverter can be represented as a combination of instantaneous dc bus voltage and inverter's switching pulses as below

$$V_{Inva} = \left(\frac{P_1 - P_4}{2}\right)V_{dc}$$
$$V_{Inva} = \left(\frac{P_3 - P_6}{2}\right)V_{dc}$$
$$V_{Inva} = \left(\frac{P_5 - P_2}{2}\right)V_{dc}$$

Each leg of inverter having charging current I_{Invad}, I_{Invbd}, I_{Invcd} can be represented as

$$I_{Invad} = I_{Inva}(P_1 - P_4)$$
$$I_{Invbd} = I_{Invb}(P_3 - P_6)$$
$$I_{Invcd} = I_{Invc}(P_5 - P_2)$$

The inverter is having IGBTs whose switching pattern is decided based on the difference between actual and reference current of inverter, which are given below

If $I_{Inva} < (I^*_{Inva-hb})$ gives switch off of upper switch S1

(P1=0) and switch on for lower switch S4(P4=1)in the inverter's phase a leg

If $I_{Inva} > (I^*_{Inva-hb})$ gives switch on of upper switch S1.

(P1=1) and switch off for lower switch S4(P4=0)in the inverter's phase a leg.

h_b =width of hysteresis band.

Remaining three firing pulses of the three legs can be derived in the similar manner

3. CONCLUSION

This paper has described a new control strategy for 3-phase 3-wire DG system's grid-interfacing inverter to improve the power quality at PCC. Without changing operation of real power transfer, the effectiveness of grid-interfacing inverter for power conditioning is discussed. The presented approach of grid-interfacing inverter is useful to

1. Injection of generated real power from RES to the grid.
2. Behaves as a shunt Active Power Filter (APF)
3. Improves the power quality.

The power quality at PCC is improved without using extra equipment for conditioning of power. Here it is discussed that grid-inter facing inverter is having multi-functions.

4. REFERENCE

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BIOGRAPHIES

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