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Research Article

Photovoltaic System Based Interconnection at Distribution Level With Different Loads

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Abstract

In this paper grid is interconnected to Renewable Energy source i.e., Hybrid interconnection of WIND ENERGY & the PV cell. The 3-phase, 4-wire active power filter (APF) which is used as inverter in this paper The inverter is used to act as active power filter (APF), at different voltage i.e., in order to inject the voltage from RES into the grid to reduce the power quality problem to compensate the harmonic content in the total system. The active power filter is of 4-leg in which 3-legs are used to compensate at the 3-phases & the 4th –leg is used to compensate the neutral current. A set of linear and Non-linear loads is used to study the performance of the system with some delay time to study waveforms both in linear & Non-linear loads acting simultaneously or instantaneously. The MATLAB/SIMULATION model of the proposed system & the waveforms is illustrated.

Keywords: *Grid, RES, APF, Linear and Non-Linear loads.*

1. Introduction

Renewable energy sources such as Photo Voltaic cell and the wing energy is integrated at the distribution level for the distribution generation. The use of renewable energy sources plays important role on the present generation as it play important role in the power system. The need to use the renewable energy sources like wind energy and the photo voltaic power to integrate into power system is to make it possible to minimize the environmental impact on conventional plant. The integration of wind energy and solar energy into existing power system presents technical challenges and that requires consideration of power quality problems like voltage instability and harmonic distortions etc.

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard **IEEE1100** defines power quality as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment. As appropriate as this description might seem, the limitation of power quality to Sensitive electronic equipment might be subject to disagreement.

The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters (APF) are extensively used to compensate the load current harmonics and load unbalance at distribution level. This results in an additional hardware cost. However, in this paper authors have incorporated the features of APF in the, conventional inverter interfacing renewable with the grid, without any additional hardware cost. Here, the main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES. It is shown in this paper that the grid-interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the renewable resources (wind, solar, etc.); 2) load reactive power demand support; 3) current harmonics compensation at PCC; and 4) current unbalance and neutral current compensation in case of 3-phase 4-wire system.

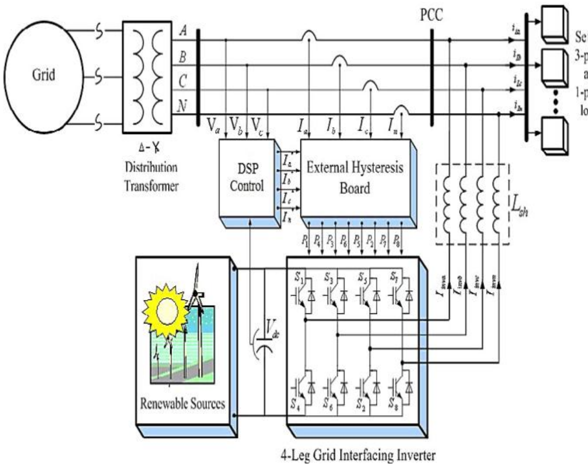

Fig: 1 Schematic of the proposed renewable energy system.

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Moreover, with adequate control of grid-interfacing inverter, all the four objectives can be accomplished either individually or simultaneously. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost. The paper is arranged as follows: Section II describes the system under consideration and the controller for grid-interfacing inverter. RES study is presented in Section III. Control circuit is discussed in Section IV, MATLAB/SIMULATION results are shown in Section V and, finally, Section VI concludes the paper.The block diagram of the proposed renewable energy system is given below:

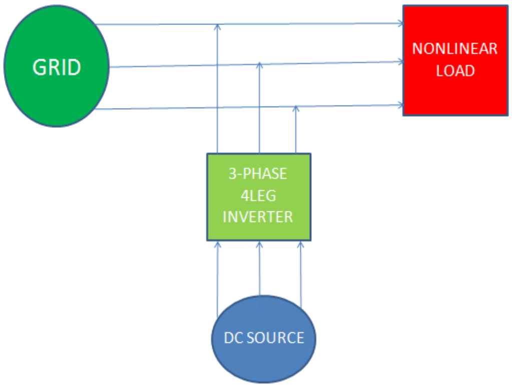

Fig: 2 Block diagram of the proposed Renewable energy system.

System Description

The above Fig.1 shows the schematic of the proposed RES interconnected to the grid, in which Grid, Distribution transformer, set of loads (Linear & Non-Linear), Control Circuit (DSP control & Hysteresis controller), RES & 4-leg inverter are connected as shown. The Voltage is supplied from the grid is connected to the Delta-Star distribution transformer in order to distribute to different loads connected to it i.e., Commercial loads, Industrial loads & House hold loads. A capacitor is placed across the renewable energy sources to regulate the DC voltage. As the voltage from the RES may not be constant throughout the day so, in order to maintain the voltage constant a capacitor is used and acts as voltage regulator.

The Digital signal processing control (DSP) is used to generate the reference currents (I_a^*, I_b^*, I_c^*) from the voltages from the source &propotional integral controller is used to generate the imaginary current from the DC voltage by comparing with the same voltage of the DC voltage, which in turn connected to the external hysteresis control board which will compare the reference currents & actual currents i.e., source currents (I_a, I_b, I_c).

The figure: 2 shows the block diagram of the proposed renewable energy system in which grid is fed to the Non-Linear load. The 3-phase 4-leg inverter connected to the PV & Wind energy system in order to supply the DC source gird to compensate the current harmonics at the Point of Common Coupling (PCC). At the point of common coupling the voltage s maintained constant in this scheme & the current behavior is changing with respect to the linear & nonlinear loads. The harmonics present in the current is reduced at the PCC, to maintain the source unaffected at the source side.

Renewable Energy Source

A PV cell is the basic structural unit of the PV module that generates current carriers when sunlight falls on it. The power generated by these PV cell is very small. To increase the output power the PV cells are connected in series or parallel to form PV module. The equivalent circuit of the PV cell is shown in fig: 3.

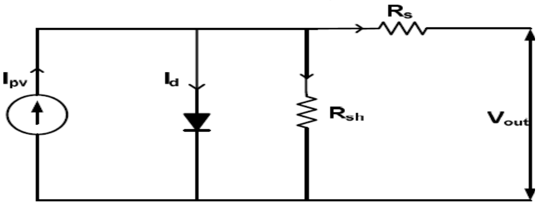

Fig: 3 Equivalent circuit of the PV cell.

The main characteristics of the PV cell are given by:

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

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 exp\left[\frac{qE_g}{\alpha K}\right]\left(\frac{1}{T_n} - \frac{1}{T}\right)$$

$$I_{pv} = [I_{sc} + K_i(T - T_n)]\frac{G}{G_n}$$

Where,
I and *V*- Cell output current and voltage;
Io- Cell reverse saturation current;
T- Cell temperature in Celsius;
K- Boltzmann's constant;
q- Electronic charge;
Ki- short circuit current/temperature coefficient;
G- Solar radiation in W/m2;
Gn- nominal solar radiation in W/m2;
Eg- energy gap of silicon;
Io,n- nominal saturation current;
Tn- nominal temperature in Celsius;
Rs- series resistance;
Rsh- shunt resistance;
α- ideality factor between 1.0 to 1.5;
Ipv- light generated current;

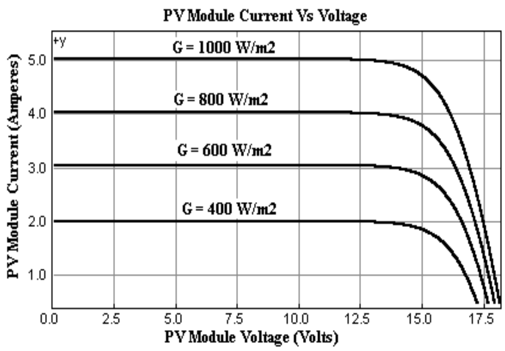

Fig: 4 Current versus voltage at constant cell temperature T=25^0.

The I-V characteristic of a PV module is highly non-linear in nature. This characteristics drastically changes with respect to changes in the solar radiation and cell temperature. Whereas the solar radiation mainly affects the output current, the temperature affects the terminal voltage. The IV characteristics of the PV module under varying solar radiation at temperature $T=25^0$ is shown in fig 4

Fig.5 shows the I-V characteristics of the PV module under varying cell temperature at constant solar radiation ($1000\ W/m^2$).

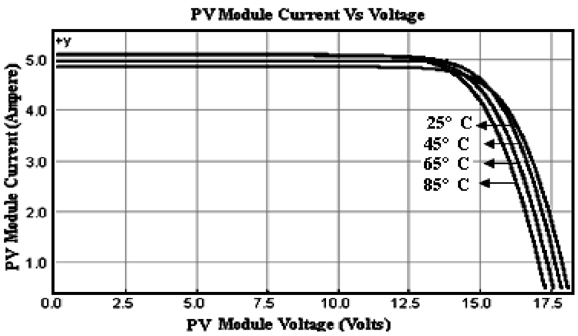

Fig. 5 Current versus voltage at constant solar radiation G = $1000\ W/m^2$.

WIND ENERGY: The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

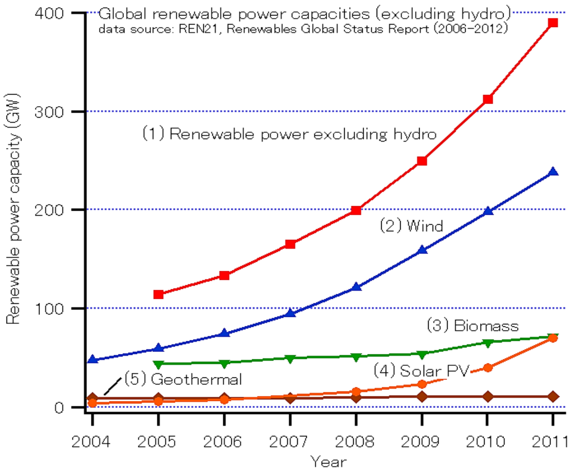

Fig: 6 Shows the Wind Energy and Wind Power generated per year.

Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators. Although wind power plants have relatively little impact on the environment compared to fossil fuel power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and birds and bats having been killed (avian/bat mortality) by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly sitting wind plants.

Control Circuit

The control circuit is used to generate the triggering pulses for the 4-leg inverter to compensate the harmonic currents at the PCC. In the control circuit the DSP control, PI controller & the External hysteresis controller is placed. The multiplication of active current component (I_m) with unity grid voltagevector templates (U_a, U_b and U_c) generates the reference grid currents (I_a^*, $I_b^*$and I_c^*). The reference grid neutral current is set to zero, being the instantaneous sum of balanced grid currents. The grid synchronizing angle obtained from phase locked loop (PLL) is used to generate unity vector template as.

$U_a= \text{Sin}(\theta)$ (1)

$U_b= \text{Sin}(\theta-120)$ (2)

$U_c= \text{Sin}(\theta-240)$ (3)

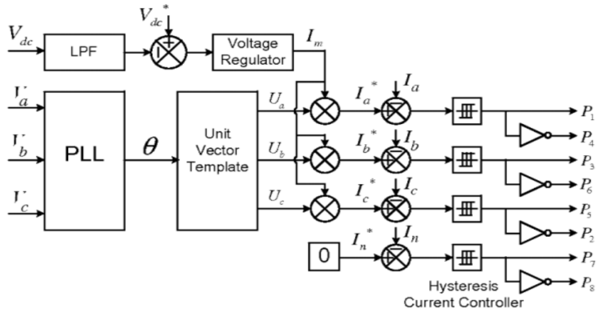

Fig: 7 Block diagram representation of grid-interfacing inverter control.

The instantaneous values of reference three phase grid currents are computed as

$Ia^*= I_m.U_a$ (4)

$I_b^*= I_m.U_b$ (5)

$I_c^*= I_m.U_c$ (6)

The neutral current, present if any, due to the loads connected to the neutral conductor should be compensated by forth leg of grid-interfacing inverter and thus should not be drawn from the grid. In other words, the reference current for the grid neutral current is considered as zero and can be expressed as

$I_n^*=0$ (7)

The reference grid currents (I_a^*, I_b^* and I_c^*) are compared with actual grid currents (I_a, I_b and I_c) to compute the current errors as:

$I_{aerr}= I_a^*-I_a$ (8)

$I_{berr} = I_b^* - I_b$ (9)

$I_{cerr} = I_c^* - I_c$ (10)

$I_{nerr} = I_n^* - I_n$ (11)

The difference between the reference current & the actual current give the resultant gating pulses to the inverter & it is given for the 8 switches using NOT gate so that the 8 switches act simultaneously for the Positive cycle & Negative cycle.

Matlab/Simulation Circuits

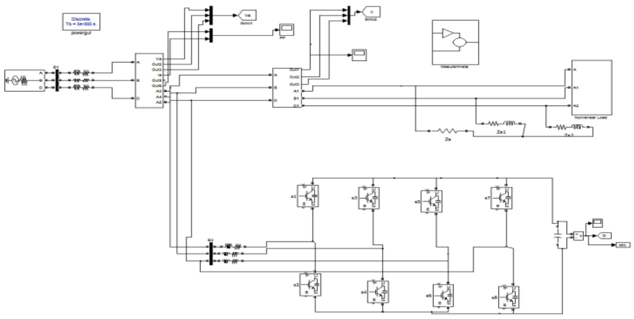

Fig: 8 The simulation model of the grid interfacing circuit without control circuit.

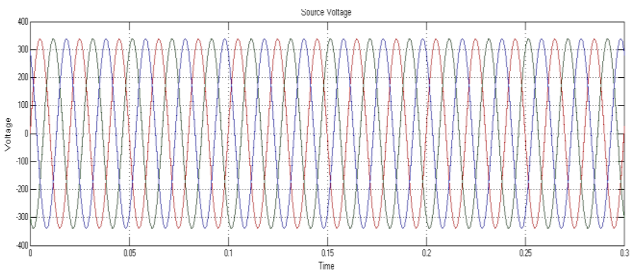

Fig: 9 Shows the waveform for the source voltage for the APF without control circuit.

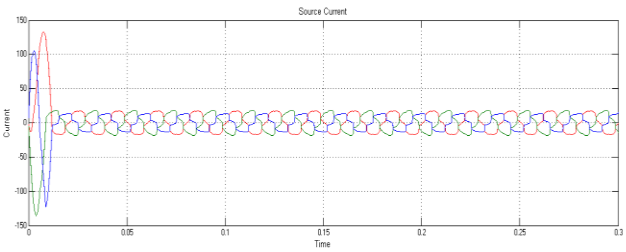

Fig: 10 Figure shows the waveform for the source current for the APF without control circuit.

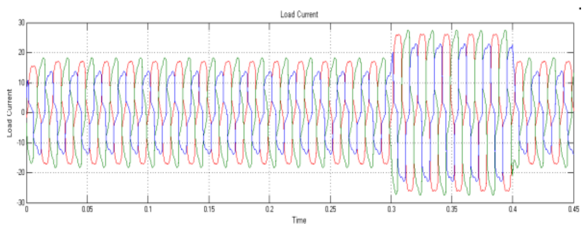

Fig: 11 Figure shows the waveform for the load current for the APF without control circuit

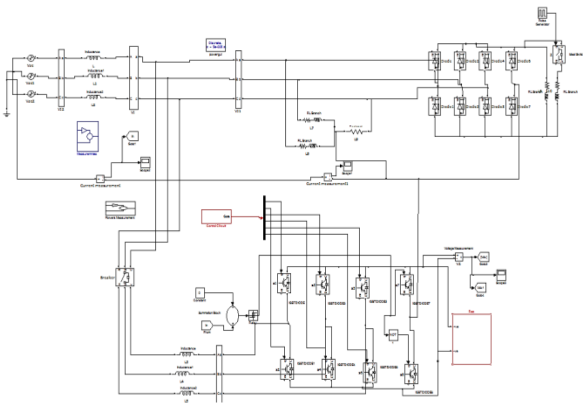

Fig: 12 Shows the MATLAB/SIMULATION model of the grid with control circuit with linear & Non-linear loads acting simultaneously

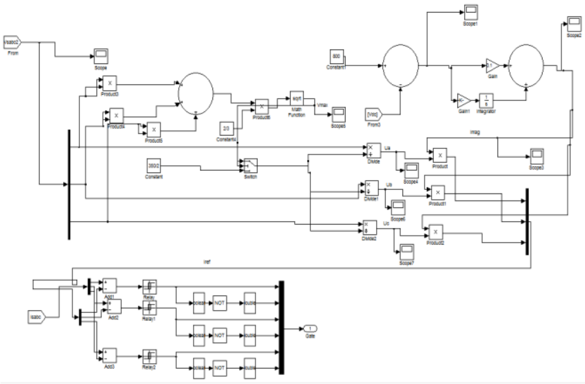

Fig: 13 Shows the control circuit to give triggering pulses to the inverter

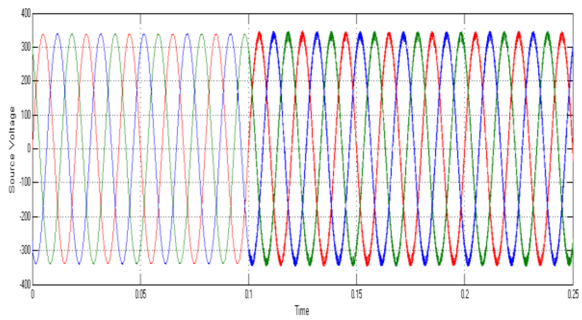

Fig: 14. Shows the waveform for the source voltage for the grid interfacing inverter which acts after time interval of 0.1 seconds

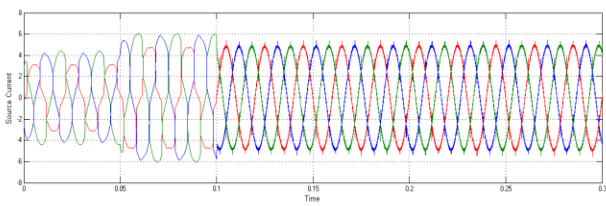

Fig: 15 Shows the waveform for the source current for the grid interfacing inverter & inverter acts after 0.1 seconds.

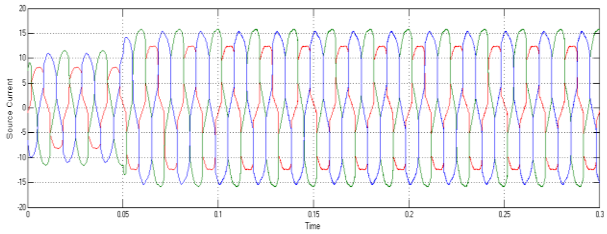

Fig: 16 Shows the load current waveform for the grid interfacing inverter which acts after 0.1 seconds

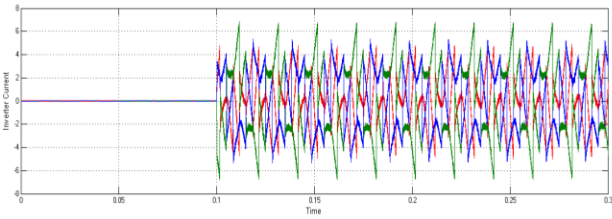

Fig: 17 Shows the waveform for the inverter current which will acts after 0.1 seconds

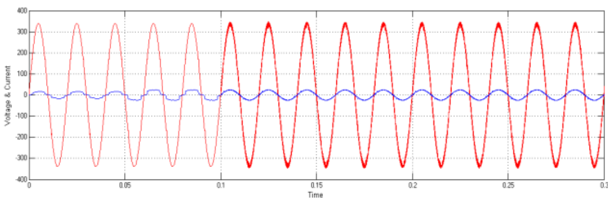

Fig: 18 Shows the power factor waveform for the grid interfacing inverter which attains unity power factor after 0.1 seconds

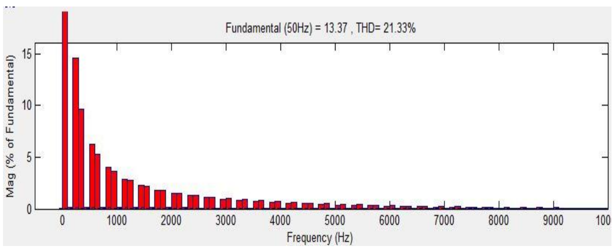

Fig: 19 Shows the total harmonic distortion for the

grid interfacing inverter when the triggering pulses is not given to the inverter & the THD= 21.33%

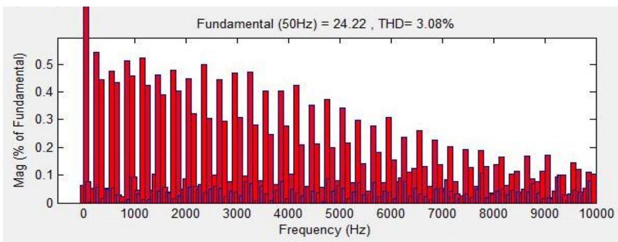

Fig: 20 Shows the total harmonic distortion for the APF when the triggering pulses are given to the inverter & the THD is reduced to 3.08%.

Conclusion

This paper presents a novel control strategy for the existing system grid interfacing inverter to improve the power quality at point of common coupling (PCC) with 3-phase 4-leg inverter system. The grid interfacing inverter can be effectively utilized for power conditioning without affecting its normal operating of real power transfer. The grid-interfacing inverter with the proposed approach can be utilized to: i) inject real power generated from RES to the grid, and/or, ii) operate as a shunt Active Power Filter (APF). This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. The MATLAB/SIMULINK simulation model of the proposed system with hybrid connection of renewable energy sources (RES) is shown and validated. The control circuit is operated with phase lock loop (PLL), proportional integral controller (PI) and hysteresis controller which is used to generate the gating pulses for the 4-leg inverter. The proposed model is carried out for four different cases at load side, (i). Linear balanced load. (ii). Linear unbalanced load. (iii). Nonlinear balanced load. (iv). Nonlinear unbalanced load. When the power generated from RES is more than the total load power demand, the grid-interfacing inverter with the proposed control approach not only fulfills the total load active and reactive power demand (with harmonic compensation) but also delivers the excess generated sinusoidal active power to the grid at unity power factor. The total harmonic distortion (THD) is reduced to 3.08% from 21.33%.

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