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Real and Reactive Power Injection to Grid Connected Hybrid System with Closed-Loop Power Control for Current Harmonic Mitigation

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ABSTRACT:

The proposed system presents power control techniques of a grid connected wind and solar energy generation system with versatile power transfer. This solar and wind energy system allows maximum utilization of freely available renewable energy. This can be achieved by an algorithm called MPPT along with standard perturbs and observes method will be used for the system. Depending on the availability of the energy sources, this configuration allows two sources to supply load separately or concurrently. The rotor speed of the turbine is main determinant of mechanical output from DG energy of wind power, and solar cell operating voltage in the case of output power for solar energy. From the non conventional energy sources, an inverter converts the generated output DC into useful AC power for the connected load. This paper suggests an enhanced current control approach for utilization of solar and wind power generation unit interfacing converter to actively compensate harmonics, which impeccably integrates system harmonic mitigation capabilities with the primary DG power generation function. For controlling of fundamental and harmonic DG currents, the suggested current controller has two well decoupled control branches which are acted independently. To achieve this technique, there is no need of local nonlinear load harmonic current and distribution system harmonic voltage detection. Instead of using any Phased Locked Loops (PLL), a closed loop power control scheme is employed to directly derive the fundamental current reference. The proposed control technique efficiently exterminates the impacts of steady state fundamental current tracking errors in the DG units. Thus a precise power control is comprehend even when the harmonic compensation functions are activated solar and wind energy system operates under normal conditions which include normal room temperature in the case of solar. The simulation results are presented to illustrate the operating principle, viability and consistency of this proposed system.

Index Terms:

Active power filter, hybrid generation, harmonic compensation, harmonic extraction, phase-locked loop (PLL), resonant controller, virtual impedance.

I. INTRODUCTION:

The importance for renewable energy based power generation increasing a large number of power electronics based DG units have been installed at the low voltage power distribution system [1]. It has been reported that the control of interfacing converters can be initiate system resonance issues [2]. Moreover, the loads at the load end are mostly of non linear in nature, such as Variable Speed Drives (VSD), Light Emitting Diode (LED) lamps, Compact Fluorescent Lamps (CFLS),etc., will further humiliate power system quality.A number of active and passive filtering methods have been developed for the compensation of distribution system harmonic distortions [3]. Due to cost concern installing additional filters is not a favorable situation. Alternatively, distribution system power quality augmentation using flexible control of grid connected DG units becoming an interesting topic as described below. A ZSI based flexible DG system for integrating renewable energy source into the grid for power quality in[4]. For industrial implementation, a current control scheme based on Proportional-Integral regulators using Sinusoidal Signal Integrators (SSI) is proposed for shunt type power conditioners [5]. A cooperative harmonic filtering strategy for distributed generation interface converters in an islanding network is proposed [6].

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The combined operation of UPQC with the DG can improve the power quality at the point of installation on power distribution system or industrial system [7]. Single phase DG system with APF capability, derived for grid current harmonic compensation [8]. Single phase H-bridge inverter for DG system requiring power quality features as harmonic and reactive power compensation for grid connected operation based on SSI and IRP theory [9]. A flexible harmonic control approach through voltage controlled DG grid interfacing converters [10], where the ancillary harmonic compensation capability is integrated with the DG primary power generation function through modifying control references. For the local load harmonic compensation methods as discussed [4]-[10], an accurate detection of local load harmonic current is important. Different types of harmonic detection methods [11] have been presented, such as Fourier transformation based detection method [12], detection scheme using instantaneous real and reactive power theory [13], Second Order Generalized Integrator (SOGI)[14] and the delayed signal cancelation based detection in [20]. Islanding detection is also important in operation of distribution system is as seen a viable option in the future to improve the reliability and quality of the supply, for this a fuzzy rule based passive islanding detection is implemented in [21].

Nevertheless, harmonic extraction process considerably increases the computation load of DG units. Complex harmonic extraction methods might not be acceptable on the basis of the cost effective DG unit with limited computation abilities. Harmonic detection less method was proposed in [16] and [17]. The main grid current can be directly controlled to be sinusoidal, instead of regulating DG output current to absorb local load harmonics. At these circumstances, local load current is fundamentally treated as a disturbance in the grid current regulation loop. When the direct control of grid current is employed, the stability margin of the DG system is smaller. For the shunt active harmonic filtering via Point of Connection (PoC) harmonic detection, the control techniques in [16] and [17] cannot be used. Alternatively, recently proposed hybrid voltage and current control method [18] also allows the compensation of the local load harmonics without using any harmonic detection process where the well understood droop control scheme [19] is adopted to regulate the output power of the DG unit. To determine the optimum allocation of multiples DGs in radial system to reduce losses and voltage improvement based on differential evaluation particle swarm Optimization [DEPSO] method [15].

Droop control based DG unit often feature slow power control dynamics [22] and current controlled DG units are more widely installed in the distribution system, developing a robust current control based harmonic compensation method without using any system harmonic detection is very necessary. It is observed that during the harmonic compensation the DG real and reactive power performance shall not be affected. To satisfy the above requirement, the fundamental current reference shall calculate according to power references. For synchronization of fundamental current references with main grid Phased Locked Loops (PLL) is used. This fundamental current reference can be determined by the ripple free grid voltage with the fixed magnitude.

The power flow fluctuations in the distribution system may varies the PoC voltage magnitude from the above concern, this method may cause non trivial power control errors. The fundamental current reference can be deliberated from the “Power - Current transformation” in [5], where the detected PoC voltage fundamental component used in the calculation. To ensure a precise power tracking performance, a closed loop DG power control is needed because for a DG unit with the ancillary harmonic compensation capability, the interaction between distorted DG current and PoC power bias, and this power bias cannot be directly deals with the control method in [5].

This paper poses an improved current controller with two parallel branches for abridge the operation of DG unit with ancillary harmonic compensation capability by maintaining an accurate power control. The first control branch is responsible for DG unit fundamental current control, and the second one is employed to compensate local load harmonic current or feeder resonance voltage.

In disparity to the conventional control methods with the harmonic detection, the PoC voltage and local load current can be directly used as the input of the proposed current controller, without affecting the harmonic compensation accuracy of the DG unit. The proposed DG unit achieves zero steady state power tracking errors even when the fundamental current tracking has some steady state error, because of implementation of simple PI regulation at the outer power control loop.

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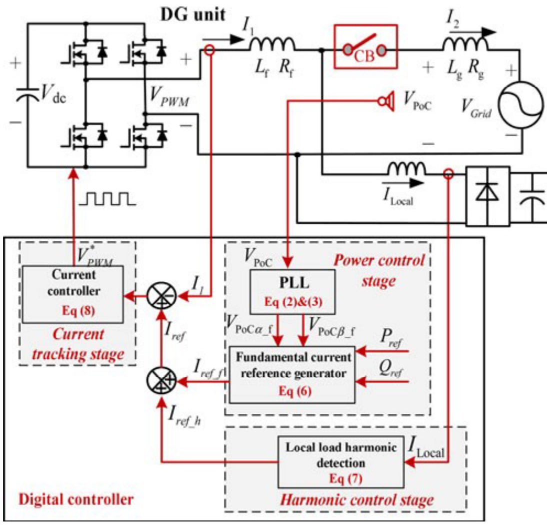

Fig. 1. DG unit with local load harmonic current compensation capability. synchronized with PoC voltage.

(V_{PoC}) as

$$I_{ref\_f} = \frac{\cos(\theta)P_{ref} - \sin(\theta)Q_{ref}}{E^*} \quad (1)$$

Where θ is the PoC voltage stage point recognized by PLL, Pref and Qref are the genuine and responsive force references, and E□ is the evident voltage size of the framework. Notwithstanding, the present reference generator in (1) is not right in controlling DG power, in perspective of blends of the PoC voltage size. To defeat this disadvantage, an overhauled force control system with considered PoC voltage monstrosity vacillations [9] was made as shown in Section II-B. Regardless, the boss PoC voltage VPoC α-f and its orthogonal part VPoC β-f (quarter cycle surrendered significant admiration to VPoC α-f) are acquired by utilizing SOGI[14]as Validate the effectiveness of the proposed DG control method.

II. MODELING OF DG UNIT WITH THE PROPOSED CURRENT CONTROL SCHEME:

Around there, the consonant compensation execution using the proposed flow controller is explored.

A. Modeling of the Proposed Current Control Method :

It is clearly realized that the current-controlled inverter ought to be depicted as a close circle Norton corresponding circuit [24], [25]

$$I_1 = H_c(s)I_{ref} - Y_c(s)V_{PoC} \quad (2)$$

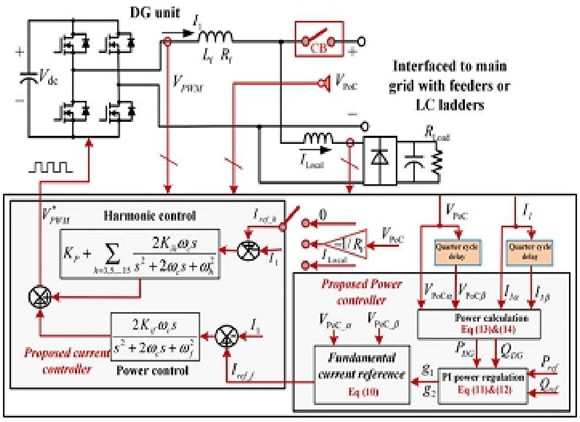

Fig.2 DG unit with the proposed control scheme

B. Grid Operation:

The DG Grid can work in two modes. In lattice tied mode, the essential converter is to give stable dc transport voltage and obliged responsive power and to exchange power between the AC and DC transports. The help converters are controlled to give the most great power. Exactly when the yield power of the DC sources is more essential than the dc loads, the converter goes about as an inverter and mixes power from DC to AC side. Right when the total power period is not precisely the total weight at the dc side, the converter imbues power from the AC to DC side. Right when the total power time is more noticeable than the total load in the DG Grid, it will mix vitality to the utility cross section. Something else, the DG Grid will get power from the utility grid. In the lattice tied mode, the battery converter is not discriminating in system operation in light of the way that power is balanced by the utility system. In self-administering mode, the battery expects a crucial part for both power counterbalance and voltage quality. Control destinations for distinctive converters are dispatched by essentialness organization structure. DC transport voltage is kept up stable by a battery converter or bolster converter according to unmistakable working conditions. The rule converter is controlled to give a consistent and awesome cooling transport voltage. Both PV can take a shot at most compelling power point taking after (MPPT) or off-MPPT mode in light of structure working requirements. Variable wind speed and sun controlled brightening are joined with the PV displays separately to reproduce mixed bag of power of cooling and dc sources and test the MPPT control count.

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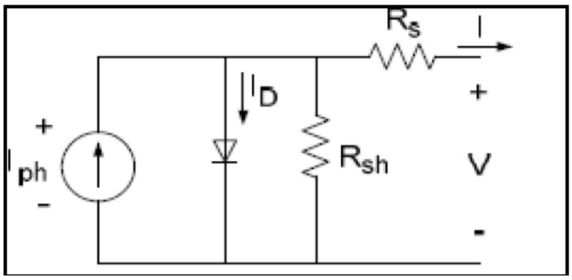

Fig. 3. Equivalent circuit of a solar cell.

C. Modeling of PV Panel:

A solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel. Considering only a single solar cell It can be modeled by utilizing a current source, a current source, a diode, and two resistors, this model is known as a single diode model of solar cell. Two diode models are also available. The same modeling techniques is also applicable for modeling a PV module[23] the equivalent circuit diagram PV is shown in Fig.3.

$$I_{PV} = n_p I_{ph} - n_p I_{sat} \times \left[\exp\left(\left(\frac{q}{AkT} \right) \left(\frac{V_{pv}}{n_s} + I_{pv} R_s \right) \right) - 1 \right] \quad (3)$$

$$I_{ph} = \left(I_{sso} + K_i (T - T_r) \right) \times \frac{S}{1000} \quad (4)$$

$$I_{sat} = I_{rr} \left(\frac{T}{T_r} \right)^3 \exp\left(\left(\frac{qE_{gap}}{kA} \right) \left(\frac{1}{T_r} - \frac{1}{T} \right) \right) \quad (5)$$

D. Wind Power:

Wind turbines are utilized to change over the wind power into electric force. Electric generator inside the turbine changes over the mechanical force into the electric force. Wind turbine structures are accessible extending from 50W to 2-3 MW. The importance creation by wind turbines relies on upon the wind rate making up for lost time with the turbine. Wind force is utilized to backing both criticalness creation and use pastime, and transmission lines in the regular compasses Wind turbines can be portrayed regarding the physical parts (estimations, tomahawks, number of edge), made constrain et cetera. For instance, wind turbines with respect to focus structure: level rotor plane found turbines, turbines with vertical or level turning headings concerning the wind. Turbines with sharpened steel numbers: 3-amazingly sharp edge, 2-very much honed sharp edge and 1-front line turbines.

Then again, control creation most distant point based solicitation has four subclasses [5].

- Small Power Systems
- Moderate Power Systems
- Big Power Systems
- Megawatt

IMPLEMENTATION OF DOMESTIC SOLAR-WIND HYBRID ENERGY SYSTEM:

Mix structures are the ones that utilization more than one noteworthiness assets. Joining of systems(wind and sun arranged) has more impact as to electric force period. Such frameworks are called as “cross breed structures”. Cross breed sun orchestrated wind applications are executed in the field, where all-year vitality is to be eaten up with no chance for an interloper. It is conceivable to have any blend of hugeness assets for supply the vitality request in the mix structures, for example, oil, sun orchestrated and wind. This try is comparative with sun based force board and wind turbine power. In a shocking manner, it is just an extra in the framework.Photovoltaic sunlight based sheets and little wind turbines rely on upon air and environment conditions. Along these lines, neither sun arranged nor wind force is adequate alone. Distinctive renewable criticalness master cases to have an engaging mix centrality asset if both wind and sun based force are intertwined inside of an amazing body.In the mid year, when sun shafts are sufficiently solid, wind pace is bearably little. In the winter time, when sunny days are sensibly shorter, wind speed is high on the partition.Feasibility of these renewable frameworks display comparably separates as the year progressed. As being what is shown, it is obliged to backing these two frameworks with one another to keep up the congruity of the centrality period in the framework.

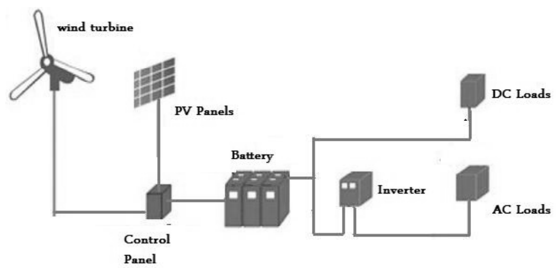

Fig. 4. Hybrid system

In the perceived framework, a part of the obliged noteworthiness for a customary home has been gotten from power that is acquired from the wind and sun based force.

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Exploratory setup for the family unit cross breed structure contains a low power wind turbine and two PV board. Subordinate upon the basic conditions, obliged centrality for the framework can be supplied either unreservedly from the wind or universes or utilizing these two advantages in the mean time is in show Figure 4. Control unit picks which source to use for rebuking the battery for thankfulness to state of the moving closer importance as found in Figure 5.Wind turbine first changes over the motor importance to mechanical vitality and a while later changes over it to the power. The wind turbine in the framework incorporates tower, alternator, speed converters (gadget box), and propeller. Likewise, a photo of the gathered cream framework is show in Figure 4. The dynamic vitality of the wind is changed over to the mechanical I-30 criticalness in the rotor. The rotor shaft speed, 1/18, is restored in the diminishment mechanical gathering and after that transmitted to alternator. The power that starts from the alternator can be especially transmitted to DC beneficiaries and it can be set away in the batteries. The sun energized sheets in the framework change over the light especially into power.

IV.COORDINATION CURRENT CONTROL OF THE CONVERTERS:

There are five sorts of converters in the DG Grid. Those converters must be coordinately controlled with the utility system to supply a persistent, high capability, and astounding vitality to variable DC and AC stacks under variable sun based light and wind speed when the DG Grid lives up to expectations in both separated and framework tied modes. The control counts for those converters are displayed around there.

A. Grid-Connected Mode:

Exactly when the DG Grid meets expectations in this mode, the control focus of the help converter is to track the MPPT of the PV display by controlling its terminal voltage. The sequential ventilating/dc/aerating and cooling converter of the DFIG is controlled to oversee rotor side mutt rent to perform MPPT and to synchronize with ventilating structure. The imperativeness overabundance of the DG Grid can be sent to the utility system. The piece of the battery as the essentialness stockpiling ends up being less basic in light of the fact that the power is balanced by the utility system. For this circumstance, the principle limit of the battery is to take out customary power trade between the dc and ventilating association. The dc/dc converter of the battery can be controlled as the imperativeness bolster using the procedure [14]. The essential converter is proposed to work bi-directionally to circuit relating typical for wind and sun based sources [16], [17].

The control focuses of the essential converter are to keep up a stable dc-join voltage for variable dc load and to synchronize with the aeration and cooling system association and utility structure. The joined time typical equivalent circuit model of the backer and standard converter is demonstrated in Fig. 4 in light of the key norms and depictions in [16] and [17] for backer and inverter independently. Power stream scientific proclamations at the dc and aerating and cooling associations are according to the accompanying:

$$P_{pv} + P_{ac} = P_{dc} L + P_b \qquad (6)$$

$$P_s = P_W - P_{ac} L - P_{ac} \qquad (7)$$

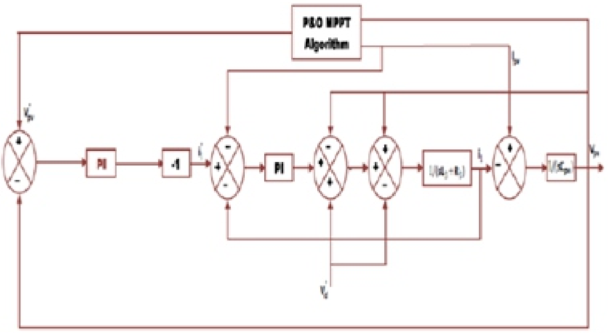

Fig.5. Time average model for the booster and main converter.

where real power and are made by PV separately, and are certifiable power weights connected with cooling and dc transports independently, is the power exchange the center of ventilating and dc associations, is power implantation to battery, and is power mixture from the DG system to the utility. The current and voltage examinations at dc transport are according to the accompanying:

$$V_{pv} - V_T = L_i \frac{di_1}{dt} + Ri_1 \qquad (8)$$

Where d1 is the commitment extent of switch ST. Numerical articulations (9) and (10) exhibit the aeration and cooling system side voltage examinations of the standard converter in ABC and - organizes exclusively [20].

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$$L_2 \frac{d\begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix}}{d} + R_2 \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} V_{CA} \\ V_{CB} \\ V_{CC} \end{bmatrix} - \begin{bmatrix} V_{SA} \\ V_{SB} \\ V_{SC} \end{bmatrix} \quad (9)$$

$$L_2 \frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -R_2 & \omega L_2 \\ -\omega L_2 & -R_2 \end{bmatrix}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} v_d \\ e \\ v_{cq} \end{bmatrix} - \begin{bmatrix} v_d \\ e \\ v_{sq} \end{bmatrix} \quad (10)$$

Where (VCA, VCB, VCC) ac side voltages of the essential converter are, (VSA, VSB, VSC) are voltages transversely over in Fig. 2, and , and are the looking at - co- with a particular finished objective to keep up stable operation of the DG Grid under diverse supply and interest conditions, a coordination control count for supporter and crucial converter is proposed in perspective of key control computations of the system canny inverter in [17]. The control piece layout is shown in Fig. 6.The reference estimation of the sun based board terminal voltage is controlled by the principal inconvenience and discernment (P&O) count in perspective of sun fueled light and temperature to handle the best compel [22]. Twofold circle control for the dc/dc bolster converter is portrayed in [22], where the control target is to give a splendid dc voltage with incredible component response.

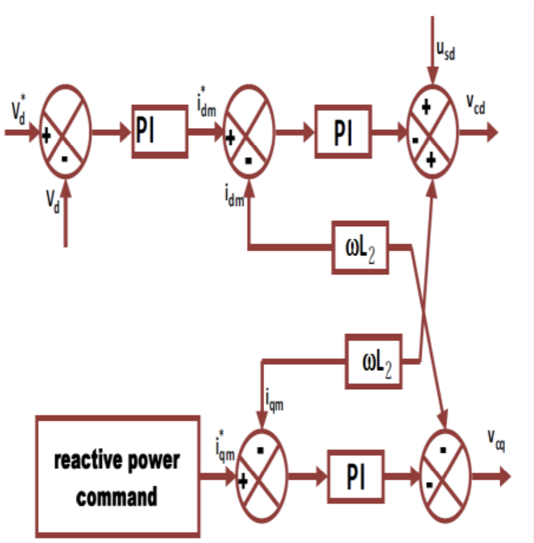

Fig. 6.The simulation control block diagram.

IV. SIMULATION RESULTS:

Simulation is performed using MATLAB/SIMULINK software. Simulink liabrary files include inbuilt models of many electrical and electronics components and devices such as diodes, MOSFETS, capacitors, inductors, motors, power supplies and so on. The circuit components are connected as per design without error, parameters of all components are configured as per requirement and simulation is performed.

SIMULATION PARAMETRERS

PV input:
Silicon cells
Radiation: 1000 W/m^2
Temperature: 25C
Voltage=50V

Wind:
Wind speed=4.5m/s
2-Pole, PMSG

Grid parameter
230V, 50Hz

IGBT SW ratings:
R_ON=1mOhm
Snubber parameters
Rs=0.1MOhm
Snubber capacitance=1MF

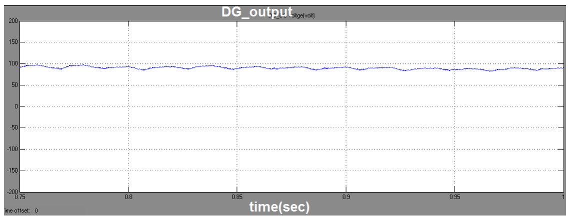

Fig.7. DG output voltage DC

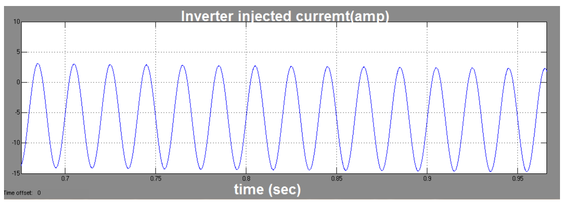

Fig.8. Injected current from inverter

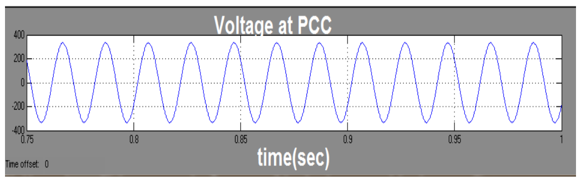

Fig.9. Voltage at point of common connection

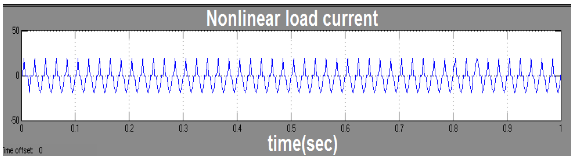

Fig.10. Nonlinear load current

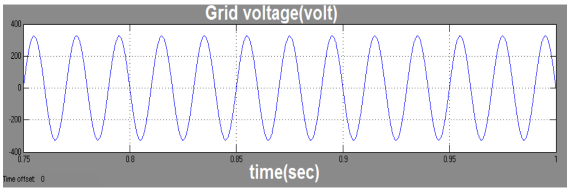

Fig.11. Grid voltage

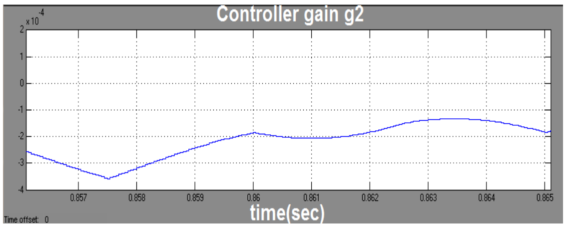

Fig.12. Controller gain g2

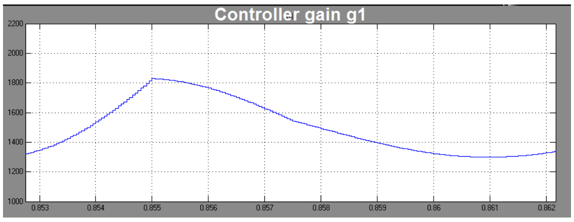

Fig.13. Controller gain g1

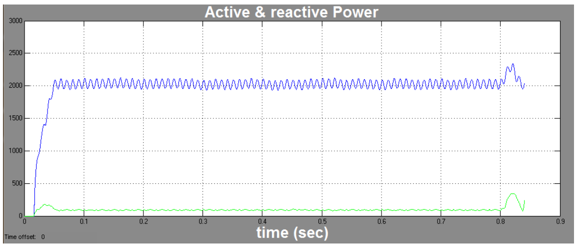

Fig.14. Active and Reactive power from DG

The performance of the system after the local load harmonic compensation is stimulated, under the local load harmonic compensation mode, its fundamental current reference is shown in fig. (8). It can be observed that the fundamental current reference is slightly lagging of the PoC voltage. For the compensation of feeder resonance voltage, the DG unit is connected to the stiff main grid with five cascaded filters, when the feeder resonance voltage compensation enabled at the selected harmonic frequency, the corresponding responses are shown in fig.(10). The measured local load harmonic current is compensated and the real and reactive power are improved in fig.(14). It is seen that the proposed technique maintains an accurate power tracking even the main grid voltage may varies.

SIMULATION CIRCUITS:

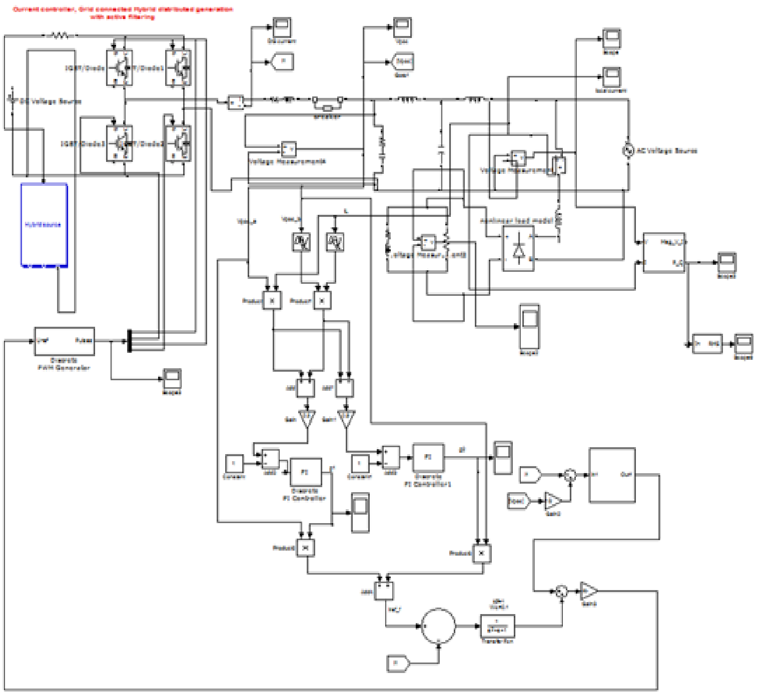

Fig.15. Current controller Grid connected Hybrid Distributed Generation with Active Filtering

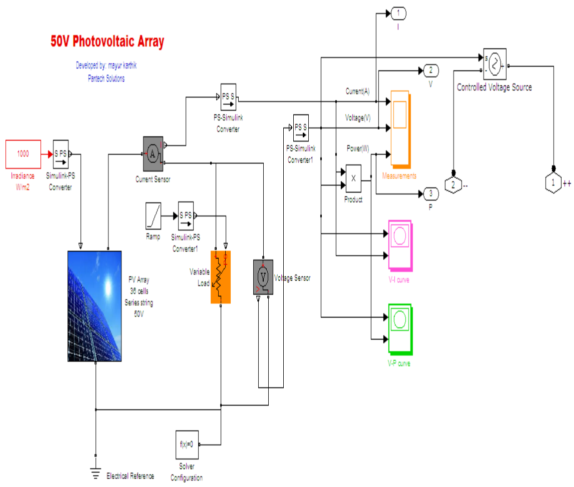

Fig.16. Simulation Circuit for 50V Photovoltoic Array

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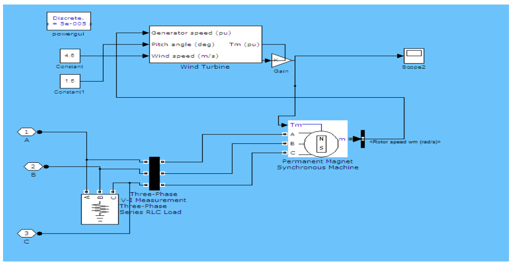

Fig.17. Simulation Circuit for Wind System

V. CONCLUSION:

This paper presents a power-control strategy of a grid-connected solar and wind generation system with variable power transfer. This hybrid system allows maximum utilization of freely available renewable energy sources like wind and photovoltaic energies. In order to get hybrid generation unit interfacing converters to actively compensate harmonics, this paper proposes an enhanced current control approach, which seamlessly integrates system harmonic mitigation capabilities with the primary DG power generation function. It is seen that the proposed technique maintains an accurate power tracking even the main grid voltage may varies. The local load harmonic current is compensated and the real and reactive power is improved. Simulation study is carried out using MATLAB/SIMULINK software.

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