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Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power-Quality Improvement Features

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ABSTRACT

Renewable energy resources (RES) are being progressively connected in distribution systems utilizing power electronic converters. This paper presents a completely unique management strategy for achieving most advantages from these grid-interfacing inverters once put in in 3-phase 4-wire distribution systems. The electrical converter is controlled to perform as a multi-function device by incorporating active power filter practicality. The inverter will therefore be used as: 1) power converter to inject power generated from RES to the grid, and 2) shunt APF to compensate current unbalance, load current harmonics, load reactive power demand and load neutral current. All of those functions could also be accomplished either singly or at the same time. With such a bearing, the mix of grid-interfacing electrical converter and therefore the 3-phase 4-wire linear/non-linear unbalanced load at purpose of common coupling seems as balanced linear load to the grid. This new management construct is incontestable with in depth MATLAB/Simulink simulation studies.

INTRODUCTION

Electric utilities and final users of electrical power have become more and more involved concerning meeting the growing energy demand. Seventy 5 percent of total world energy demand is equipped by the burning of fossil fuels. However increasing pollution, warming considerations, decreasing fossil fuels and their increasing price have created it necessary to seem towards renewable sources as a future energy answer. Since the past decade, there has been a colossal interest in several countries on renewable energy for power generation. The market liberalization and government's incentives have more accelerated the renewable energy sector growth.

Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility worries because of the high penetration level of intermittent RES in distribution systems because it might cause a threat to network in terms of stability, voltage regulation and power-quality (PQ) problems. Therefore, the decigram systems area unit needed to fits strict technical and regulative frameworks to confirm safe, reliable and economical operation of overall network.

With the advancement in power physical science and digital management technology, the decigram systems will currently be actively controlled to boost the system operation with improved PQ at PCC. However, the in depth use of power physical science based mostly instrumentation and non-linear masses at PCC generate harmonic currents, which can deteriorate the standard of power.

Generally, current controlled voltage supply inverters area unit wont to interface the intermittent RES in distributed system. Recently, a couple of management methods for grid connected inverters incorporating PQ answer are projected. In associate electrical converter operates as active electrical device at an exact frequency to soak up the harmonic current. however the precise calculation of network inductance in period is troublesome and should deteriorate the management performance. an analogous approach during which a shunt active filter acts as active electrical phenomenon to damp out the harmonics in distribution network is projected. a sway strategy for renewable interfacing electrical converter supported – theory is projected. during this strategy each load and electrical converter current sensing is needed to compensate the load current harmonics.

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The non-linear load current harmonics might lead to voltage harmonics and may produce a heavy PQ drawback within the grid network. Active power filters (APF) area unit extensively wont to compensate the load current harmonics and cargo unbalance at distribution level. This ends up in an extra hardware price. However, during this paper authors have incorporated the options of APF within the, standard electrical converter interfacing renewable with the grid, with none further hardware price. Here, the most plan is that the most utilization of electrical converter rating that is most of the time underutilized because of intermittent nature of RES. it's shown during this paper that the grid-interfacing electrical converter will effectively be utilised to perform following vital 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 just in case of 3-phase 4-wire system. Moreover, with adequate management of grid-interfacing electrical converter, all the four objectives is accomplished either separately or at the same time. The PQ constraints at the PCC will thus be strictly maintained inside the utility standards while not further hardware price.

The main aim of the paper is to realize the utmost edges with the interfacing inverters once connected in 3-phase 4-wire distributed systems. The electrical converter used conjointly improve the standard of power at PCC.

The grid-interfacing electrical converter with the projected approach is utilised to:

i. inject real power generated from RES to the grid,

ii. operate as a shunt Active Power Filter (APF).

Moreover, the load neutral current is prevented from flowing into the grid facet by compensating it domestically from the fourth leg of electrical converter.

LITERATURE SURVEY

The following literature survey for the current report consists of various papers on Photovoltaic system published in the IEEE conferences and the journals.

Carl Ngai-Man Ho, Victor S. P. Cheung, and Henry Shu-Hung Chung, [1] presented a paper about implementation of a constant frequency hysteresis current control for grid-connected voltage source inverter (VSI). This is based on predicting the current reference, system dynamic behavior, and past time to formulate the switching function for dictating the switching times of the switches in the inverter within a predefined switching period.

Soeren Baekhoej Kjaer, John K. Pedersen, and Frede Blaabjerg[13] discussed about different types of inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid. In this Various inverter topologies are presented, compared, and evaluated against demands, lifetime, component ratings, and cost**.**

K.Punitha, Dr. D. Devaraj, Dr. S. Sakthivel[5] presented a paper about Adaptive Hysteresis Current Controller to control the inverter, used in the solar photovoltaic cell. This paper also discuuses about how To control the Inverters. There are several current control strategies proposed, namely, PI control , Average Current Mode Control (ACMC), Sliding Mode Control (SMC) and hysteresis control . Among the various current control techniques, hysteresis control is the most popular one for voltage source inverter .

FOUR-LEG CONVERTER MODEL

The following figure shows configuration of a typical power distribution system with renewable power generation. It consists of various types of power generation units and different types of loads. Renewable sources, such as wind and sunlight, are typically used to generate electricity for residential users and small industries. Both types of power generation use ac/ac and dc/ac static PWM converters for voltage conversion and battery banks for longterm energy storage. These converters perform maximum power point tracking to extract the maximum energy possible from wind and sun. The electrical energy consumption behavior is random and unpredictable, and therefore, it may be single- or three-phase, balanced or unbalanced, and linear or nonlinear. An active power filter is connected in parallel at the point of common coupling to compensate current harmonics, current unbalance, and reactive power. It is composed by an electrolytic capacitor, a four-leg PWM converter, and a firstorder output ripple filter, as shown in Figure. This circuit considers the power system equivalent impedance *Zs* , the converter output ripple filter impedance *Zf* , and the load impedance *ZL* . The four-legPWMconverter topology is shown in Fig. 3. This converter topology is similar to the conventional three-phase converter with the fourth leg connected to the neutral bus of the system., improving control flexibility and output voltage quality and is suitable for current unbalanced compensation.

$$Z_{\text{eq}} = \frac{Z_s Z_L}{Z_s + Z_L} + Z_f \approx Z_s + Z_f.$$

MATLAB DESIGN OF CASE STUDY AND RESULTS

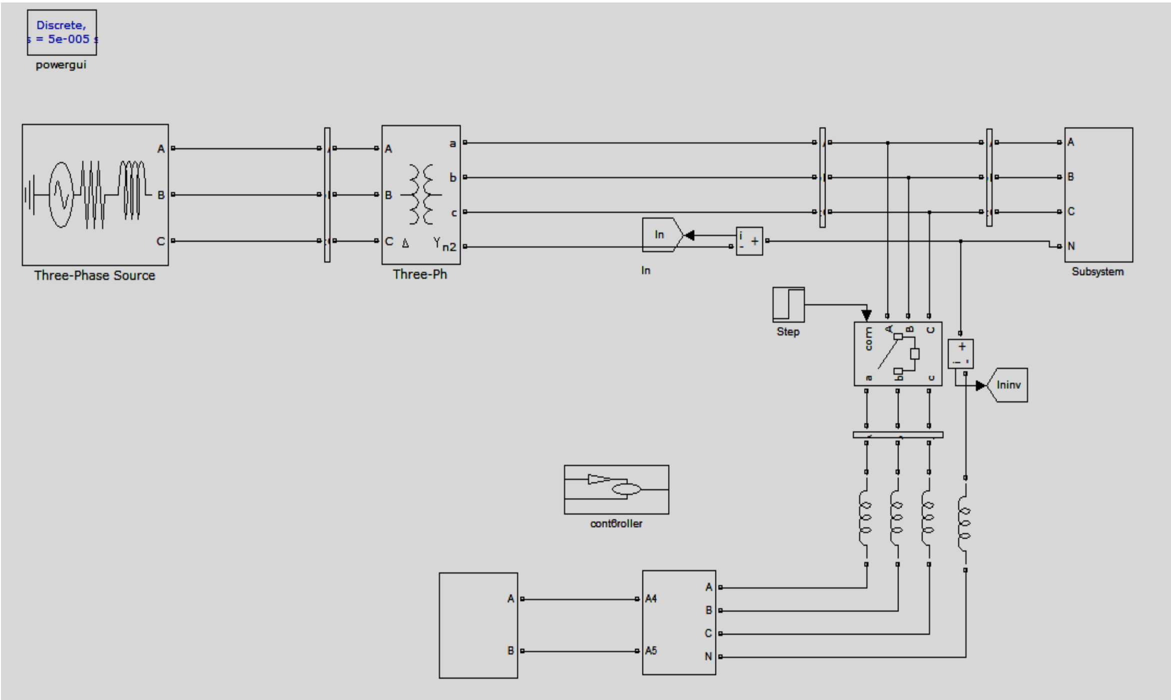

Fig8.4. *Block Diagram of Base Circuit*

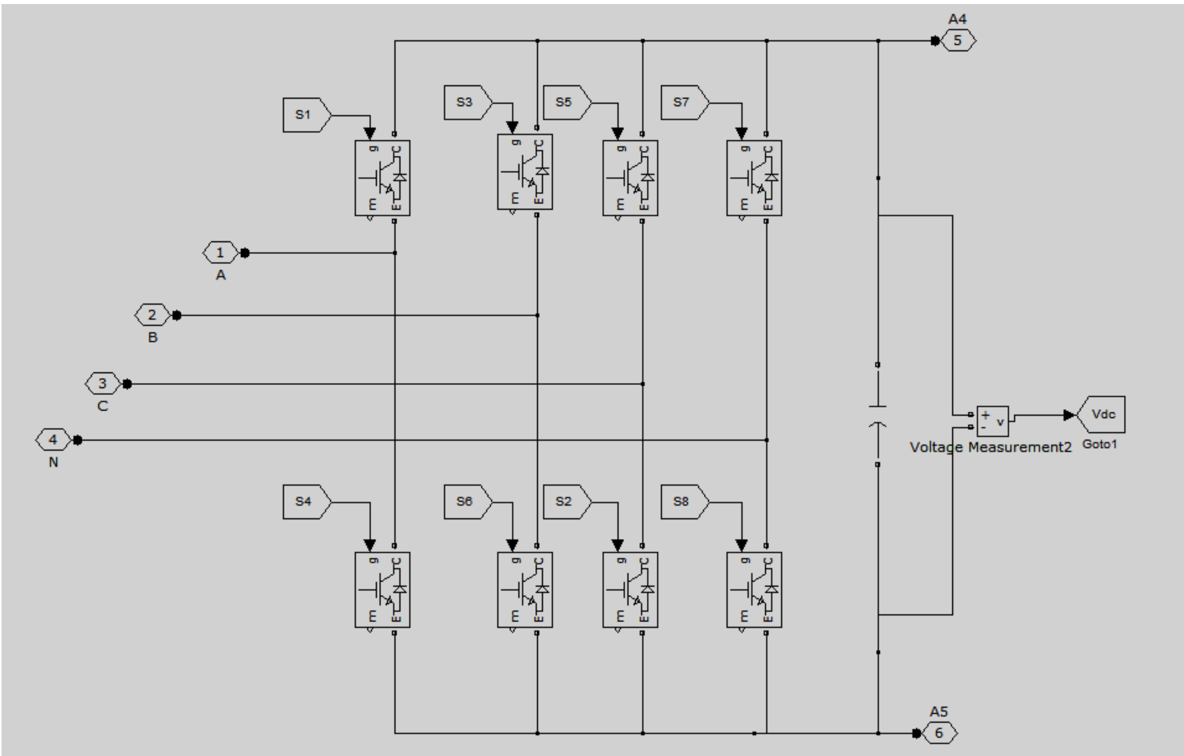

Fig8.5. *Inverter Subsystem*

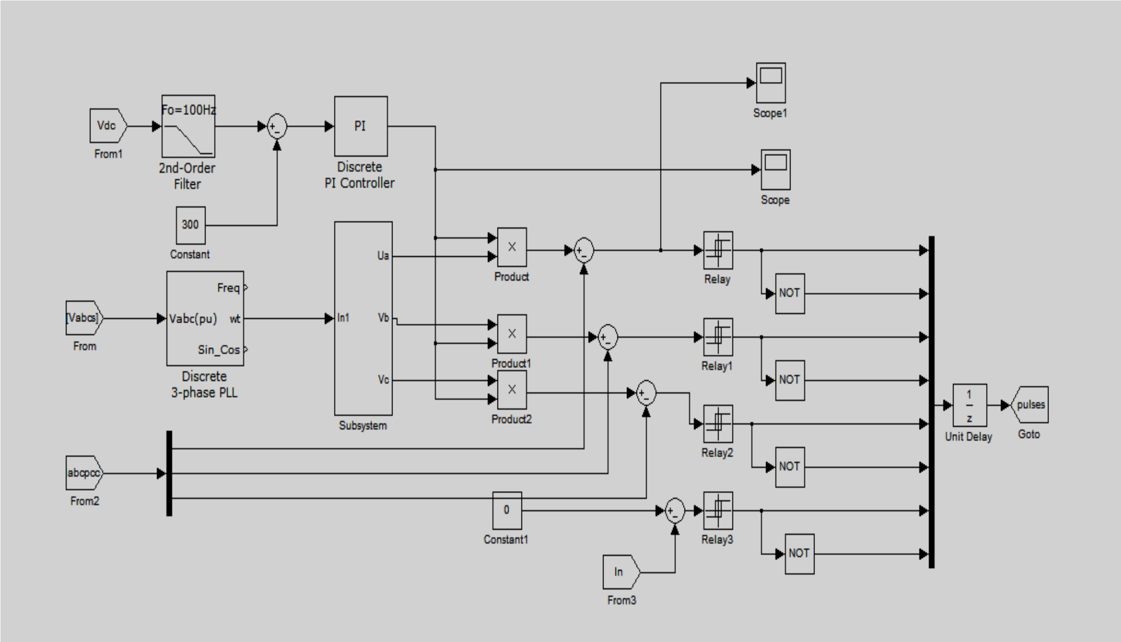

Fig8.6. *Controller Subsystem*

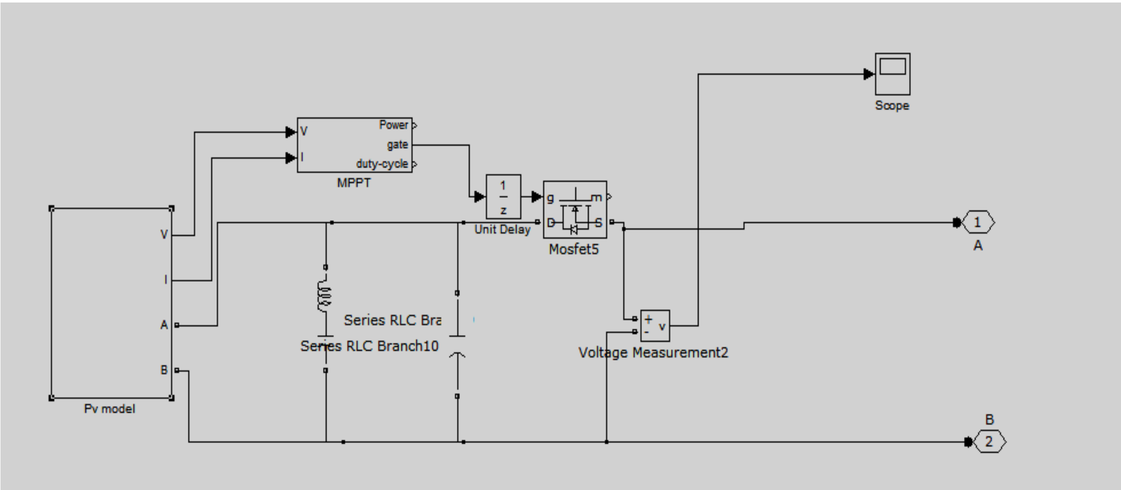

Fig8.7. *PV Cell Subsystem*

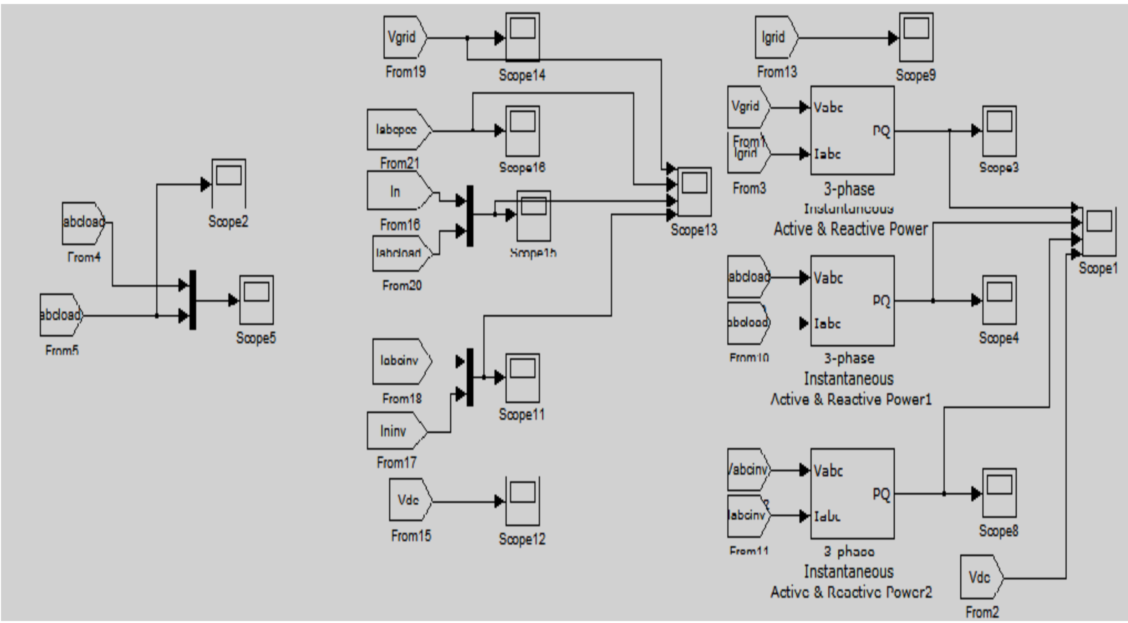

Fig8.8. *Measurements*

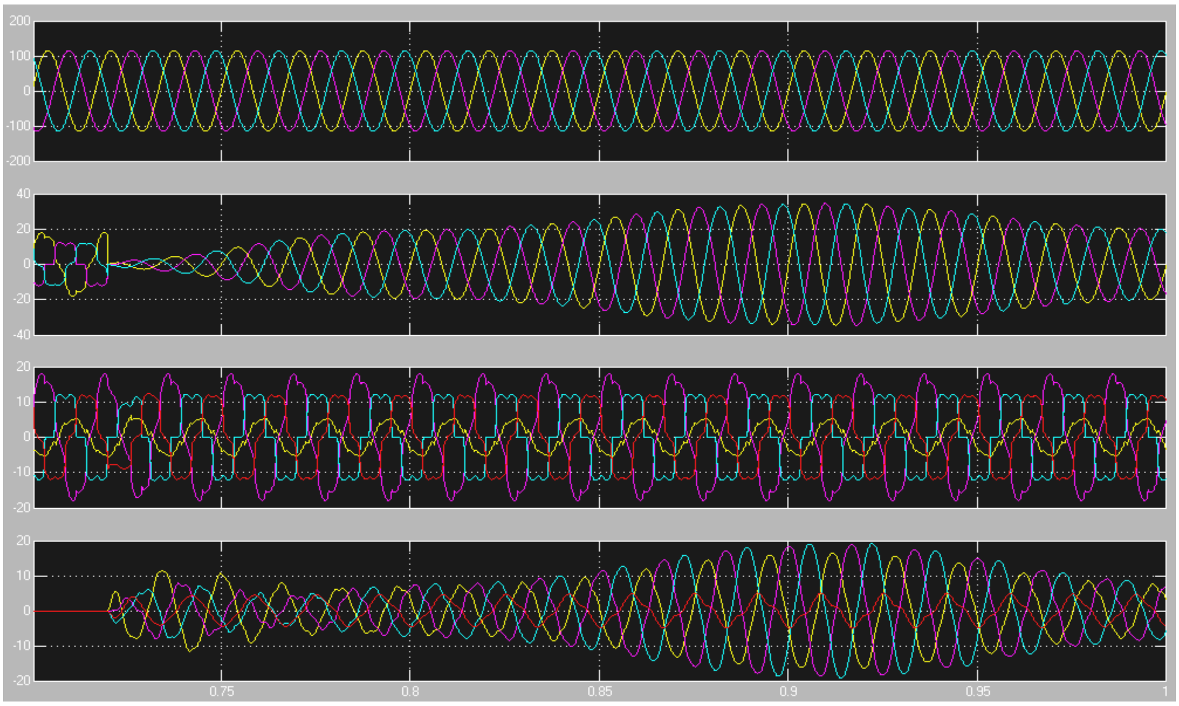

Fig8.9(A). *Simulation results: (a) Grid voltages, (b) Grid Currents (c) Unbalancedload currents, (d) Inverter Currents*

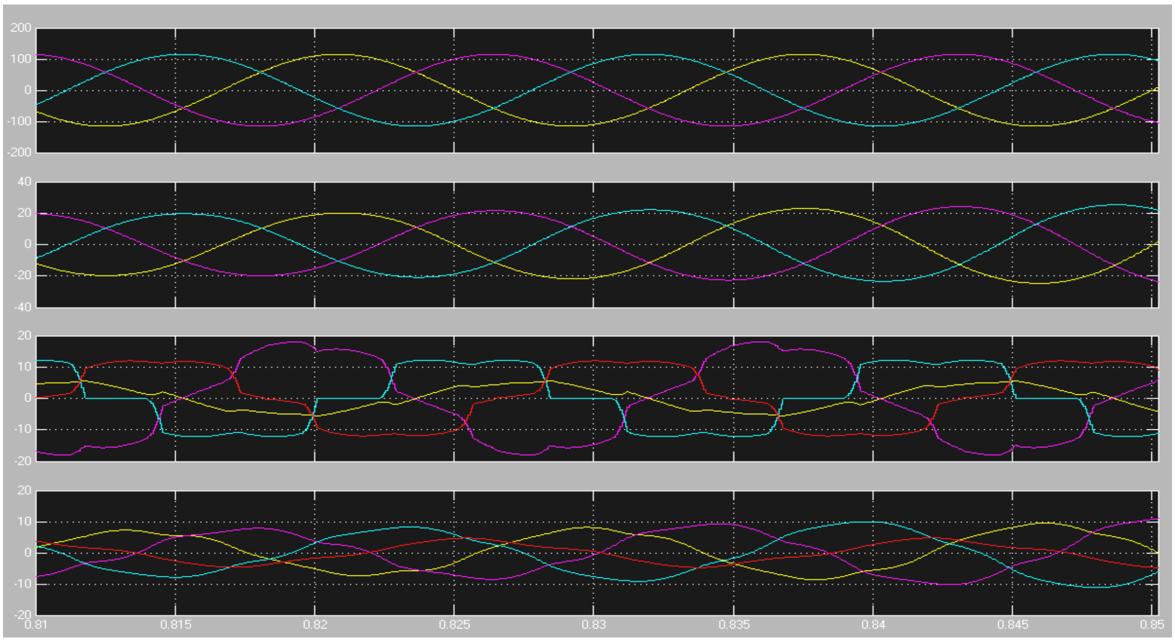

Fig8.9(B). *Simulation results: (a) Grid voltages, (b) Grid Currents (c) Unbalancedload currents, (d) Inverter Currents*

Initially, the grid-interfacing inverter is not connected to the network (i.e., the load power demand is totally supplied by the grid alone). Therefore, before time t=0.72 s, the grid current profile in. Fig. 8.9(b) is identical to the load current profile of Fig. 8.9(c). At t=0.72 s, the grid-interfacing inverter is connected to the network . At this instant the inverter starts injecting the current in such a way that the profile of grid current starts changing from unbalanced non linear to balanced sinusoidal current as shown in Fig. 8.9(b). As the inverter also supplies the load neutral current demand, the grid neutral current becomes zero after t=0.72 s. At t=0.72 s, the inverter starts injecting active power generated from RES ($P_{res} \approx P_{inv}$) . Since the generated power is more than the load power demand the additional power is fed back to the grid. The negative sign of P_{grid} , after time 0.72 s suggests that the grid is now receiving power from RES. Moreover, the grid-interfacing inverter also supplies the load reactive power demand locally. Thus, once the inverter is in operation the grid only supplies/receives fundamental active power.

At t=0.82 s, the active power from RES is increased to evaluate the performance of system under variable power generation from RES. This results in increased agnitude of inverter current. As the load power demand is considered as constant, this additional power generated from RES flows towards grid, which can be noticed from the increased magnitude of grid current as indicated by its profile.

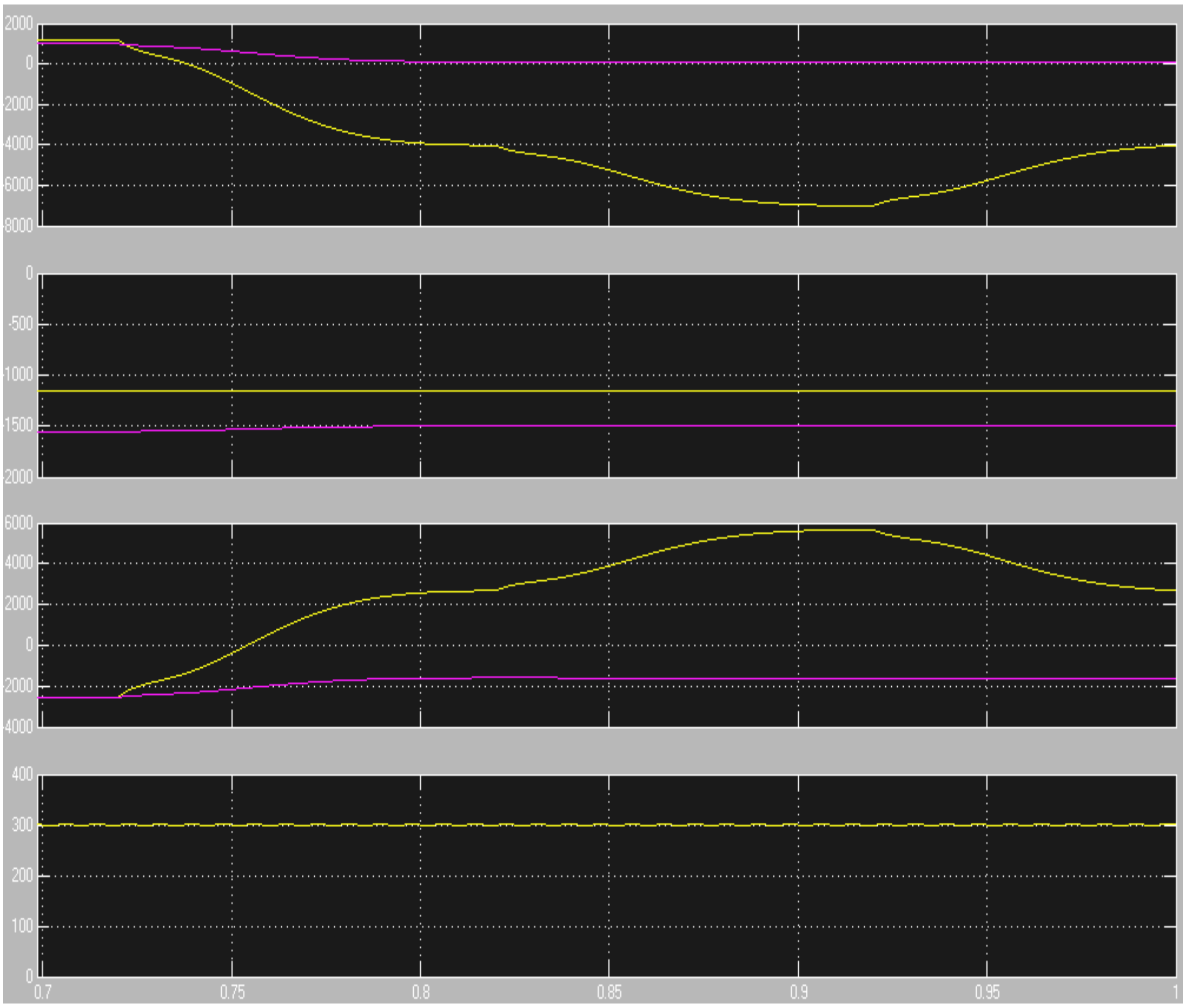

Fig8.10. *Simulation results: (a) PQ-Grid, (b) PQ-Load, (c) PQ-Inverter, (d) dc-link voltage.*

In order to verify the proposed control approach to achieve multi-objectives for grid interfaced DG systems connected to a 3-phase 4-wire network, an extensive simulation study is carried out using MATLAB/Simulink. A 4-leg current controlled voltage source inverter is actively controlled to achieve balanced sinusoidal grid currents at unity power factor (UPF) despite of highly unbalanced nonlinear load at PCC under varying renewable generating conditions.

A RES with variable output power is connected on the dc-link of grid-interfacing inverter. An unbalanced 3-phase 4-wire nonlinear load, whose unbalance, harmonics, and reactive power need to be compensated, is connected on PCC. The waveforms of grid voltage($V_{a,}$,V_b,V_c) grid currents (I_a,I_b,$I_{c,}$$I_n$), unbalanced load current (I_{la},I_{lb},I_{lc},I_{ln}) and inverter currents($I_{inva,}$$I_{invb}$,$I_{invc}$,$I_{invn}$) are shown in Fig. 8.9. The corresponding active-reactive powers of grid($P_{grid,}$$Q_{grid)}$, load(P_{load},$Q_{load)}$ and inverter(P_{inv},Q_{inv}) are shown in Fig. 810. Positive values of grid active-reactive powers and inverter active-reactive powers imply that these powers flow from grid side towards PCC and from inverter towards PCC, respectively. The active and reactive powers absorbed by the load are denoted by positive signs.

At t=0.92 s, the power available from RES is reduced. The corresponding change in the inverter and grid currents can be seen from Fig. 8.9. The active and reactive power flows between the inverter, load and grid during increase and decrease of energy generation from RES can be noticed from Fig. 8.10. The dc-link voltage across the grid- interfacing inverter (Fig. 8.10(d)) during different operating condition is maintained at constant level in order to facilitate the active and reactive power flow. Thus from the simulation results, it is evident that the grid-interfacing inverter can be effectively used to compensate the load reactive power, current unbalance and current harmonics in addition to active power injection from RES. This enables the grid to supply/ receive sinusoidal and balanced power at UPF.

CONCLUSION

This Thesis has given a unique control of associate degree existing grid interfacing electrical converter to boost the standard of power at PCC for a 3-phase 4-wireDGsystem. it's been shown that the grid-interfacing electrical converter will be effectively used for power learning while not touching its traditional operation of real power transfer. The grid-interfacing electrical converter with the planned approach will be used to:

i. Inject real power generated from RES to the grid, and/or,

ii. Operate as a shunt Active Power Filter (APF). This approach therefore eliminates the necessity for added power learning instrumentality to boost the standard of power at PCC. in depth MATLAB/Simulink simulation results have valid the planned approach and have shown that the grid-interfacing electrical converter will be used as a multi-function device.

It is more incontestible that the PQ sweetening will be achieved beneath 3 completely different scenarios: 1) PRES=0, 2) PRES PLoad, and 3) PRES PLoad. the present unbalance, current harmonics and cargo reactive power, attributable to unbalanced and non-linear load connected to the PCC, square measure remunerated effectively such the grid facet currents square measure perpetually maintained as balanced and curving at unity power issue. Moreover, the load neutral current is prevented from flowing into the grid facet by compensating it domestically from the fourth leg of electrical converter. once the facility generated from RES is quite the entire load power demand, the grid-interfacing electrical converter with the planned management approach not solely fulfills the entire load active and reactive power demand (with harmonic compensation) however conjointly delivers the surplus generated curving active power to the grid at unity power issue.

FUTURE SCOPE

Renewable energy represents only 9 percent of the nation's electricity production, roughly 75 percent of this production comes from conventional hydropower. However, in recent years, federal and state regulatory committees demand for greater renewable energy production. Due to a variety of economic and environmental barriers, development of large scale hydroelectric production facilities has almost stopped. As a consequence, solar, wind and biomass energy are currently the fastest growing renewable energy segments.

This growth in solar and wind is aided by technology improvements which have significantly reduced their cost, assisted by regulatory incentives, such as renewable portfolio standards and production tax credits.

In this project I have used hysteresis current controller to control the interfaced inverter, but with advances in power electronics we can control the interfaced inverter more precisely and efficiently with other controlling techniques(SVPWM, DSP, selection of harmonic filter, Fuzzy logic controllers).

If we reduce the cost of this set-up, we can install in local areas so that we can make use of the renewable energy sources. In future we may expect that every locality installs this setup and produce power that serves their own needs.

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