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Solar Energy Grid Integration System with IcosΦ Controlled Shunt Active Filter for Efficient Power Sharing

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Abstract

Within the Indian electricity system, greening the grid through the use of Renewable Energy Sources (RES), particularly wind and solar energy, is expected to develop dramatically. The RES is said to be the future for powering the whole world. The solar PV, the natural teeming power source is playing a decisive role in RES integration. Even if the PV is an ambiguous power source, the astute integration of PV with grid will results in a prompt, reliable powering system. The PV integrated grid system will be more impressive, if we could eliminate the power quality issues while connecting the PV integrated grid to a non-linear load. For that aspiration, the converter used for the PV integration itself can act as a shunt active filter with proper controlling. The most efficient IcosΦ method of controlling is adopted here. For the maximum power tracking of solar PV, P&O MPPT is utilized. Hence a better active power sharing along with the reactive power compensation is incorporated and analysed in terms of THD.

Keywords: MPPT, IcosΦ, Solar PV,THD

1. INTRODUCTION

The economic prosperity of a country is determined by its energy resources and how they are used. When compared to other emerging countries, highly developed countries such as the United States and China consume a lot of energy. According to reports, India’s absolute primary energy consumption is just 1/29 of that of the rest of the globe, 1/7 of that of the United States, and 1/1.6 of that of Japan.However, given the growing threat posed by pollution, it is critical to shift away from polluting conventional energy sources and toward environmentally friendly alternatives such as renewable energy supplies. In terms of renewable energy programs, including biofuels, solar energy, wind energy, hydropower, and other emerging technologies, India has catapulted to the top of the globe. The most significant of these is solar.

Solar energy has several advantages: it produces pollution- free electricity and emits no greenhouse gases; it requires little maintenance because solar panels survive for over 30 years; it can be deployed almost anyplace; and it may be combined with batteries for dependable operation. The performance of a PV panel is highly dependent on the ambient cell temperature and solar insolation. Any change in the aforementioned parameters has an impact on the system’s overall performance, resulting

In low conversion efficiency and non-linear I-V characteristics. Maximum Power Point Tracking (MPPT) methods are used to track the maximum power from a PV panel. Perturb and Observe (P&O), Fractional Open Circuit Voltage (FOCV), Incremental Conductance (IC), Artificial Neural Network (ANN) and Particle Swarm Optimization (PSO), Fuzzy controlled MPPT are some of the MPPT methods. So what if we integrate a PV to the conventional grid, we can form a reliable cost effective powering system [1].

The quality of electricity has been decreased due to harmonic pollution of the power system network by modern power electronic equipment. Rectifiers, power electronic converters, controllers for adjustable speed motor drives, electronic power supplies, DC motor drives, battery chargers, and electronic ballasts are examples of non-linear loads that are often utilized today. Harmonic currents generated by Non-linear loads are causing an increase in power quality issues. Harmonic distortion in a power distribution system is mostly caused by these loads. The point of common coupling sends the harmonic current created by these nonlinear loads back into the power system. The distorted supply current changes the supply voltage profile. The distorted voltage has an impact on the micro grid that is connected to the main grid. A decent active shunt filter could be used to eliminate the harmonic issues. [2].

The choice of control algorithm decides accuracy and response time of the filter [3].In harmonic, reactive power, and imbalance compensation, the Icos Phi algorithm has been found to be useful. It also aids in the achievement of unity power factor at the source end. The source only provides the active fraction of the load current, according to this algorithm. The harmonic components required by the load are provided by the filter. [4].A converter use to integrate the PV with grid can itself be used as a shunt active filter.

1.1. ICOSΦ CONTROLLER

The Icos Phi controller is one of the most reliable controllers for ensuring optimum harmonic, reactive power, and imbalance management [2]. When both reactive power and harmonic compensations are supplied in a micro grid to grid integration, the source only has to supply the active portion of the load current, i.e. Icos Phi component of the source current, where I is the amplitude of the basic load current and cos Phi is the load's power factor. The IcosΦ By obtaining unit power factor at the source, the algorithm could offer harmonic reactive power as well as imbalance compensation. [5]. The algorithm works both in balanced as well as unbalanced and distorted source voltages feeding both balanced and unbalanced non- linear reactive loads.

The shunt active filter should compensate for the harmonic and reactive portions of the three-phase load current, as well as any three-phase load current imbalances. This guarantees that the balanced current drawn from the mains is completely sinusoidal and in phase with the mains voltage. [6]. As a result, the mains must only supply the active portion of the load current. The targeted mains current is thus considered to be the product of the magnitude IcosPhi and a unit amplitude sine wave in phase with the mains voltage in the IcosPhi method. For a balanced three-phase source. The ideal source current will equal the average of the magnitudes of real components of fundamental load current in three phases to create balanced sinusoidal currents at unity power factor.

The basic block diagram of IcosΦ algorithm is shown in Fig. 1. I cosΦ controller is very effective under symmetric and asymmetric load conditions as well as for all the source conditions

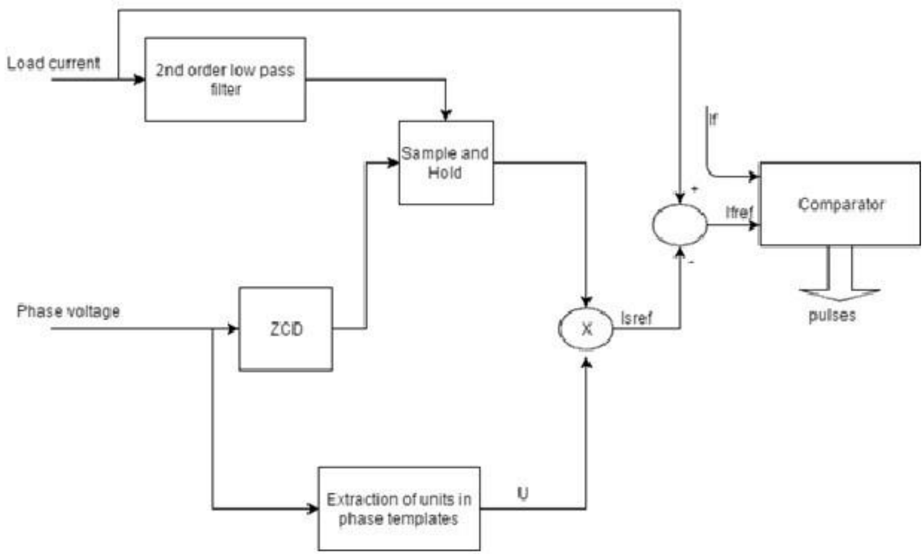

Fig. 1. Block Diagram of IcosΦ algorithm

2. POWER SHARING

This deals with the switching of PV into the grid. The switching of the PV is based on the availability of power of the PV. Under standard testing condition (STC), the PV is designed to provide 1400 W power. Three loads are considered having power rating of 1 kW, 2 kW,1 kW. At 0.3sec second load with power rating 2 kW is connected to the system, at 0.5 sec third load having power rating 1 kW is connected to the system. So during the heavy loaded condition ie, after 0.3 sec, the PV is connected to the system. PV is designed to provide maximum power of 1400 W at STC condition. So when the PV is connected to the grid, the power that the loads are drawing from the grid is shared and is reduced. Table I gives an insight about the control logic.

A connected diode bridge rectifier fed R loads are considered as the loads. After 0.3 sec the load power.

Requirement surges, but the PV integration helps to reduce the grid burden during the high peak demands. Fig. 2 shows the MATLAB model of the proposed system.. The switching table of the grid connected system is tabulated in the table 1

Table I. PV and Grid Switch Status

Load	Source	PV
Load 1 is active	ON	OFF
Load 2 is active	ON	ON
Load 3 is active	ON	ON

3. MATLAB SIMULINK MODEL AND RESULT VERIFICATION

A 3Φ The principal energy source is a three-phase AC grid with 415 V and 50 Hz.. A solar PV module TP310LBZ is considered as the secondary source.

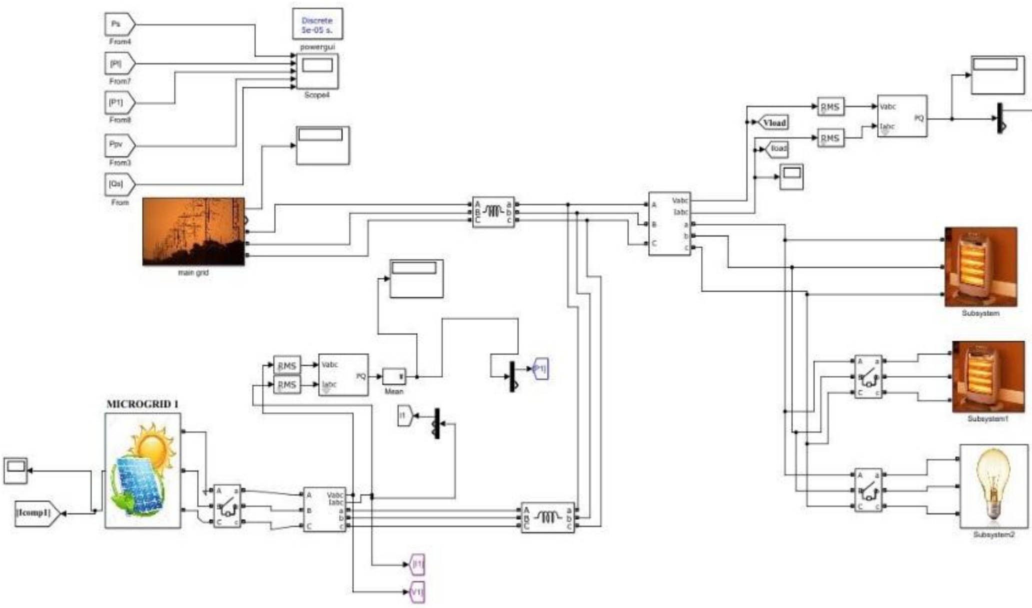

Figure : 2

Table II. PV System Description

Description	Rating
MP	309.856 W
M(i)	8.42 A
M(v)	36.8 V
Short circuit current(Isc)	8.85 A
T	25°
Voc	44.6 V
Number of parallel strings	2
Number of series strings	2
Irradiation(R)	700,1000 W/m^2

The converter for PV integration (inverter) is appropriately controlled by using IcosΦ algorithm so that the source current remains undistorted even under the case of nonlinear load. As the solar PV is getting integrated with the main grid, power electronic converters are required for the better implementation. A DC/DC Boost converter is used to maintain and balance the output from the solar source, the power, voltage current and physical parameters of the selected solar panel is described in table II and the design parameters of the Boost converter in the proposed model is described in the table III [7][8]

Table III. Boost converter description

Description	Rating
Inductor	5 mH
Capacitor	200 uF

4. RESULT ANALYSIS

The result can be verified under different cases in terms of efficient active power sharing, reactive power compensation and THD analysis. Figure 3 shows the load requirement. The connected load is a non-linear

Residential load. The load is 1kw until 0.3 seconds, then a power shoot occurs, and the load increases to 3kw; similarly, the load value increases to 5kw at 0.5 seconds.

Figure 4 shows the source power in relation to the

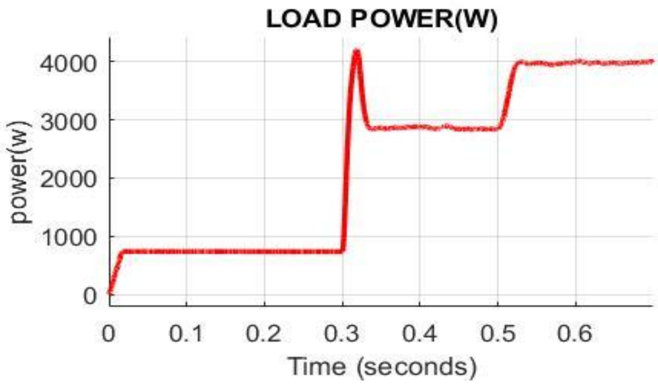

Figure: 3

Load demand. The grid is the source of this power. The connected solar power sharing is shown in Figure 5 is used to meet the load requirement.

i. **CASE 1: From 0 to 0.3sec Load analysis**

1kw is the comparable load demand. Because the source power contribution is 700w and the remaining 300w is supplied by the solar source, the required load is split between the grid and the grid connected solar source (by referring figures 4 and 5)

ii. **CASE 2: From 0.3 to 0.5sec Load analysis**

3kw is the comparable load demand. Because the source power contribution is 1.5kw and the remaining 1.5kw is supplied by the solar source, the required load is split between the grid and the grid connected solar source (by referring figures 4 and 5)

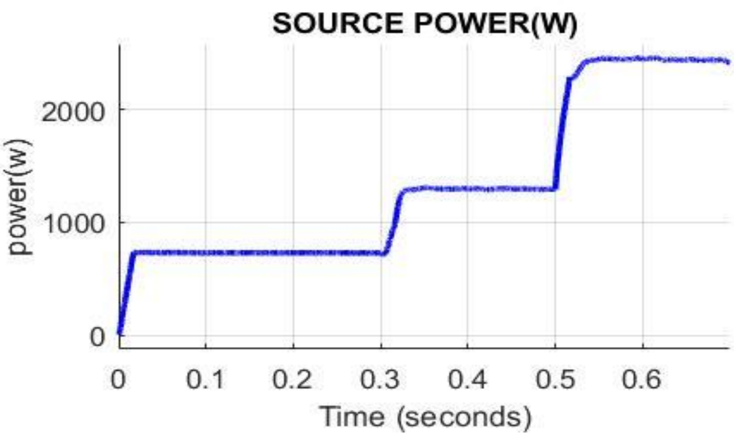

Figure 4

iii. CASE 3: From 0.5 to 0.7sec Load analysis

5kw is the comparable load demand. Because the source power contribution is 4kw and the remaining 1.5kw is supplied by the solar source, the required load is split between the grid and the grid connected solar source (by referring figures 4 and 5)

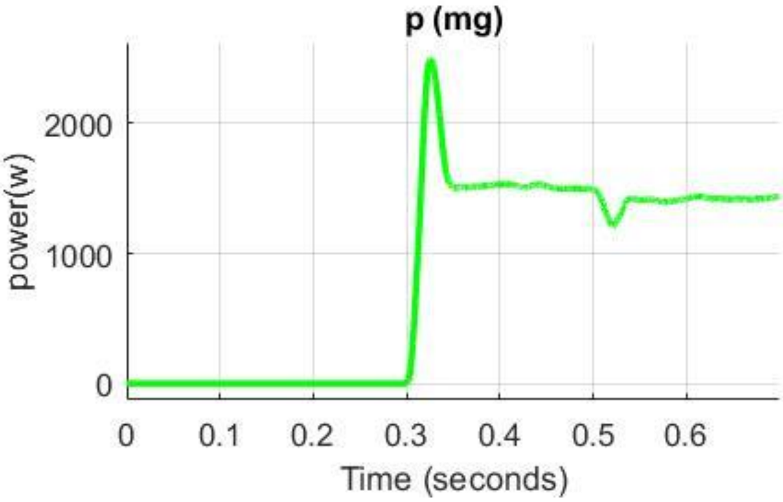

Figure 5

As the connected load is a non-linear residential load, the load will draw non-linear source current from the main grid, which intern injects harmonics to the system. In order to rectify the effect of harmonics Icos phi controller is used at the inverter controlling side. Figure 6 shows the source current nature. The load shoots at

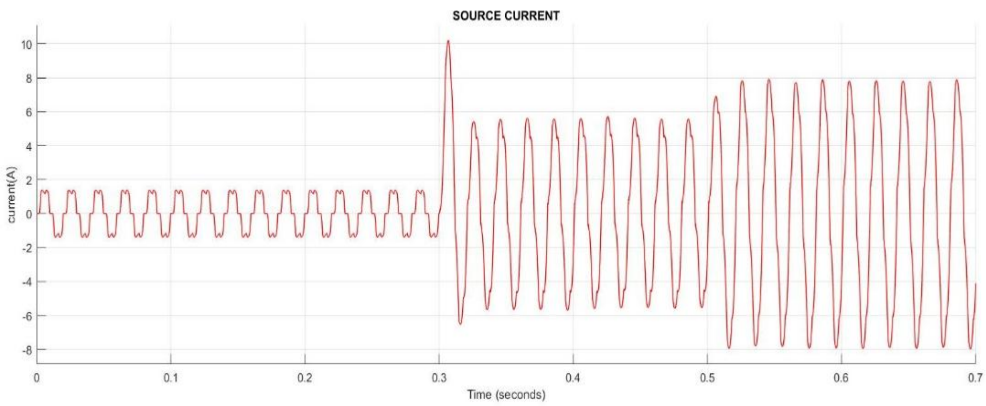

Figure 6

0.3 sec, 0.5 sec reflects on the source current, and the source current's non-linearity is corrected using the active shunt filtering Icos phi algorithm. The non-linearity of the source current can be identified and analyzed by the analysis of THD value. As we are analyzing the source current THD as well the load current THD, the load non-linearity is 23.97% . This non-linearity is due to the non-linear nature of the connected residential loads as well as the incorporation of the power electronic converters.

After the successful implantation of the active shunt filtering using ICOS phi algorithm the effect of non-linearity at the source current is reduced to 8%. Figure 7 and figure 8 shows the load THD and source THD analysis

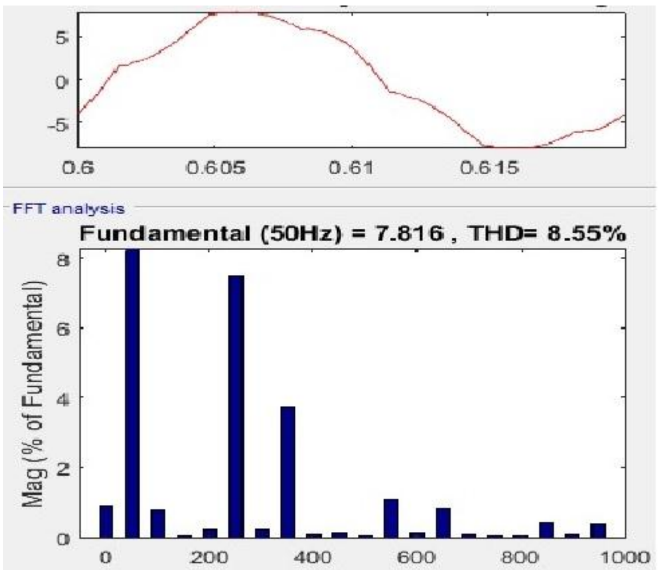

Figure 7

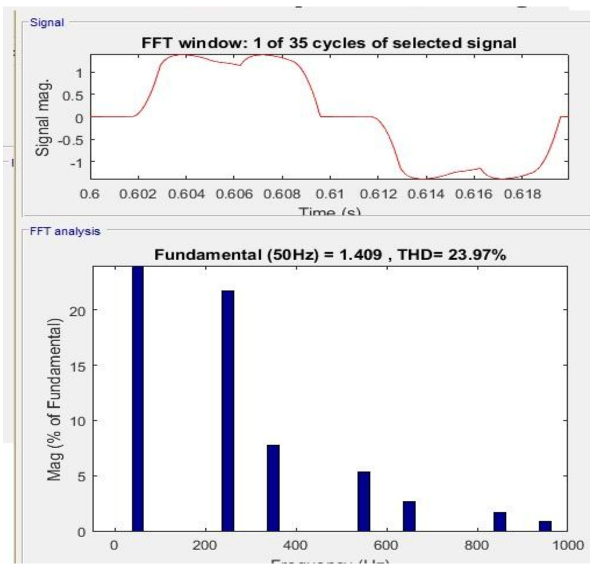

Figure 8

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