Experimental Investigation of Harmonics in a Grid-Tied Solar Photovoltaic System

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Abstract-The power quality issues in the grid tied solar photovoltaic system are important to address to know about the actual power production and consumption in the existing system. This paper investigates the presence of voltage and current harmonics due to the linear, nonlinear loads and the reactive power transferred between plant, grid and load. The digital power analyzers are kept in the system to know the amount of power import and export between the plant and grid, so as to serve the load. In order to control the effect of harmonics a compensator in incorporated in the phase locked loop of the inverter as well as a power quality conditioner is connected at the point of common coupling. It has been found that by switching the conditioner unit, the quality of power and power factor of the system gets improved and it also reduces the export of reactive power to the load so as to obtain the reliable and efficient operation of the grid tied solar photovoltaic system.

Keywords -Total Harmonic Distortions, Power Quality, Solar Inverters, Grid Connected PV.

1. Introduction

Major part of the electrical power system is centralized and suffers different kind of problems such as system stability, congestion and losses in transmission lines that are generally not present in distributed power generation systems. Therefore the trend is shifting from centralized power generation systems to the distributed power generation systems and the usage of renewable energy resources such as wind, solar, biomass as distributed power generation plants seems a viable solution to deal with the mentioned problems.

For fulfilling the customer's energy requirements the low capacity power generating systems can be connected to the local grid, however solar photovoltaic (PV) installations have exponentially growing and supporting the government and utility companies for providing continouse supply to the commercial and residental loads [1]. The solar photovoltaic system is categorized as standalone, grid tied and hybrid distributed power generation systems. The maximum power harnessed of a standalone power system is limited to the load connected. Thus the extra power prduced by the plant remaines unutilized considering the batteries as fully charged and the load has been served, whereas the grid tied systems after fullfilling their needs sell power to the utility or to the local grid. This scheme promotes more and more distributed generation roof top grid tied solar plant installations as it provides opportunities for extra income or cutting in electricity bills, at the same time and overcomes electricity shortage problem. However there is a mechanism to govern the net amount to be paid/ received by user with roof top installation. The net metering system keeps track of power drawn by user from grid and power fed to the grid and it is also known as bidirectional meters/ smart meters.

The main focus is on the grid connected distributed power generation systems besides their low efficiency and complex controllability. If these systems are not properly controlled for injecting power into the grid, then the connection to the utility network can leads to the power outrages, grid instability or sometimes even failure. In this case the synchronization and current control of distributed power system with respect to grid plays an important role. For the synchronization of solar PV power plant with local power grid the voltage, phase and frequency of the system should be matched. Zero Crossing

Detection (ZCD) is simplest way to obtain the frequency information and zero crossing of voltage which can ideally be detected as duration between twoconsecutive zero crossings that is equal to the reciprocal of double the voltage frequency [2]. It is a known fact that there are always the presence of harmonics in the utility voltage/current, which can ultimately result in detection of zero crossing at the rate different than the fundamental frequency. Also it is not possible to get instantaneous phase information. Thus a phased locked loop (PLL) based technique for grid synchronization is fast, efficient and most commonly adopted for capturing the accurate information about the fundamental as well as distorted signal is used. With slight modifications, three phase PLL can be used for single phase system also by converting the three phase voltages/ currents components (a-b-c) into single phase with the help of stationary (i.e. p-q fame) or synchronous (i.e. d-q-o) reference frame theory, that is based on time domain theory.

The objective of this paper is to analyze the performance of the power quality conditioner placed near the load at the point of common coupling in case of power quality issues/problems such as interruptions, voltage sag/swell, harmonics etc. When the distributed generation system is synchronized with the grid and serving the linear as well as nonlinear loads, the existance of harmonics effect the system power factor and overall efficiency has also been observed. This paper is divided into various sections giving an overview of the structure of grid tied distributed power generation system connected with different types of loads. It is continued with a discussion on performance parameters of the system and analyzing the efforts of power quality improvement device in the system for better solutions to these issues.

2. Description of Distributed Solar Photovoltaic System

To design a solar photovoltaic system it is essential to know the amount of sunlight available at a particular geographical location at certain time slot because it acts as an input to the power plant. The two common methods which characterize solar radiations are solar irradiance and solar isolation. The solar irradiance is an instantaneous power density in units of kW/m^2, whereas the solar isolation is total amount of solar energy received at a particular location during a specified time period having units kWh / (m^2 day). However we generally take solar irradiance for calculation purpose and the variations in it depends on the power contained in the sun rays and the angle between the modules. The solar irradiance at the earth's surface depends on the parameters such as latitude of the location, season of the year, time of day and atmospheric conditions like fog, cloudy/rainy day and atmospheric pollution. The atmospheric effects have several impacts on the solar radiation at the earth's surface. The problem faced by photovoltaic systems is the reduction in the power due to absorption, scattering and reflection. Due to greater absorption or scattering of some wavelengths there can be change in the spectral contents of visible sunlight, which contains the energy packets known as photons [3]. These energy packets are the source of electricity because only the visible spectrum of light is absorbed by the solar photovoltaic cells. The diffused/indirect components in the solar radiation are due to local variations in the atmosphere, which produces reflection. Thus the solar collector collects the irradiance that is resultant of direct and diffused rays.

Normally, an optimum tilt angle of solar collector is calculated based on the latitude of the location in order to collect the maximum sun rays on the module surface. The block diagram of an experimental setup of 500W distributed grid tied solar power system is shown in the figure 1.

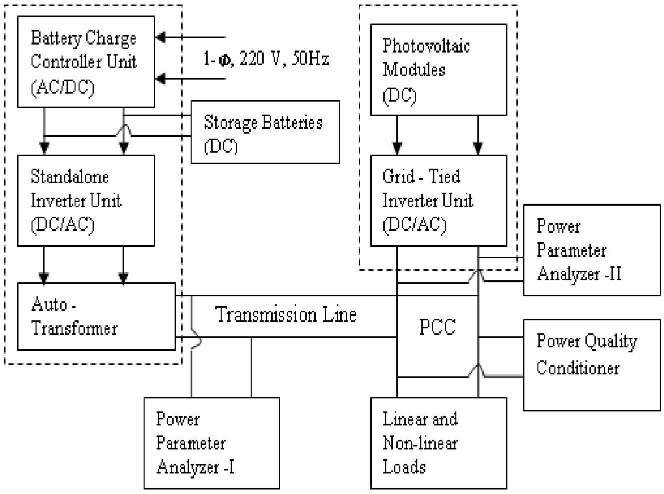

Fig. 1. Prototype Grid Tied System Connected to Load

The dotted blocks represent in the left hand side contains battery charge controller, storage batteries, standalone inverter with an autotransformer collectively is acting as a local grid and the roof top installed photovoltaic modules are connected to the load and the grid at a point of common coupling with the transformerless configured inverter converting direct current to alternating current (DC/AC). [4]. A power quality conditioner is employed at the point of common coupling and digital power analyzers-I and II are measuring the parameters related to the grid tied system from grid and plant side.

2.1. Solar Collectors

The solar collectors can be classified based on their application as solar thermal, solar photovoltaic and solar photovoltaic thermal. For the production of electrical energy the solar photovoltaic collectors/solar modules are used in series and parallel combinations (also known as solar array) in accordance to the maximum load capacity of the customer or load connected to be served. The efficiency of individual solar cell of solar module is the ratio of energy output from the solar cell to input energy from the visible light and determined as the fraction of incident power which is converted to electricity; it is helpful in finding the operational efficiency of the whole system as well [5]. Furthermore the operational efficiency of the solar cells of an array that are flat in structure, relies on the global horizontal irradiance (GHI) i.e. the total amount of radiations with short wavelength received on a surface horizontal to the ground and mathematically expressed in equation (1)

$$GHI = (DNI)*\cos\theta + DHI \quad (1)$$

Where, DNI = Direct Normal Irradiance, which comes in a straight line from the sun at its current position in the sky on the collector , DHI = Diffuse Horizontal Irradiance are the solar radiation that does not arrive on earth directly from the sun i.e. scattered radiations because of molecules and particles in the atmosphere, and θ = solar zenith angle; formally it is defined as the angle through which the earth must turn to bring the meridian of the location of observation under the sun.

However for the concentrating structure of solar arrays only direct normal irradiance (DNI) is an important factor to be known before installing a solar power plant to a particular geographical location to get the maximum efficiency from the solar photovoltaic plant, which is at present around 12-15% at the specified latitude.

2.1.1. Classification of Solar Cells

The structure of solar photovoltaic modules have a top surface made up of toughened glass then an encapsulant of EVA (ethyl vinyl acetate) and the rear layer of module is known as Tedlar, which acts as insulation and provides durability to photovoltaic(PV) modules. The solar cells are mainly classified as mono-crystalline, non-crystalline amorphous and multi-crystalline/ polycrystalline, although silicon is a base material used in various compositions to form different varieties of cells under this broader classification. Polycrystalline or Multi-crystalline solar cells are the most common type of solar cells in the fast-growing PV market and consumes most of the produced polycrystallines worldwide. These are produced from metallurgical grade silicon by a chemical purification process, called Siemens process and an alternative process of refinement uses a fluidized bed reactor [6].

In this experimental setup, two flat plate roof-top solar PV collectors of 36 cells in each module of poly crystalline in nature are connected in series, at optimal tilt angle of 20^0 south facing and the latitude location 28.4595^0 N, 77.0266^0 E (Gurgaon). Each cell produces voltage around 0.6V at STC (standard test conditions: irradiance 1000 W/m^2, temperature 25^0 C, and Air Mass (AM) 1.5) with module specifications shown in table 1.

Table 1. Modules specifications of grid tied system

Electrical Parameters	**Rating**
Peak Power (P_p)	250 KW_p
Maximum Voltage(V_m)	35.0 V
Maximum Current(I_m)	7.14 A
Open Circuit Voltage(V_{oc})	43.2 V
Short Circuit Current (I_{sc})	7.5 A
Fill Factor	0.77

A very common mismatch effect in module cells occur due to the difference in either short circuit current (I_{sc}) or open circuit voltage (V_{oc}) of cells in a module. The cells in module are connected in series string if there is current mismatch; there is reduction in output power. The other condition is shading of module cell in a string, due to this the current in the healthy cell reduces and it produces higher voltage which can reverse bias the shaded cell, the bypass diodes are used to reduce its effect and the overall efficiency of the system can be preserved [1]. Furthermore the installation of this prototype plant is done keeping these factors in mind.

2.2. Inverter Unit

There are three main options of power converters from direct current (DC) to alternating current (AC) that can be installed in solar PV plant are micro, string and central inverters depending upon the application in residential, industrial or commercial purpose. The internal structure of a traditional inverter (single stage, single phase, 50 Hz transformer based string inverter) uses power semiconductors (IGBTs or MOSFETs) to switch the DC on and off very fast in two different directions simulating an AC sine wave. This is filtered by an inductor and then the voltage is boosted with the help of booster or auto-transformer to inject in the grid to obtain AC voltage at the consumer's end.

Table 2. Classification of Solar Power Inverters/Converter

Type of Inverter	**Advantages**	**Disadvantages**
Micro-Inverter or Power Optimizer	▪ Maximum Power Point Tracking at panel/module level ▪ Increases system availability in case of malfunctioning panel of the array ▪ High Safety due to lower DC voltage ▪ High voltage DC cabling is not required	▪ Cost of power per watt is double compared to string inverters ▪ Increases complexity in installation. ▪ Sometimes micro-inverters may have issues in extreme heat. ▪ High maintenance costs because of multiple units in an array
String Inverter	▪ High design flexibility ▪ High efficiency ▪ Robust ▪ Three phase variations available ▪ Low cost ▪ Remote monitoring capabilities	▪ No panel level MPP tracking ▪ Monitoring of electrical parameters is not possible ▪ High voltage levels present a potential safety hazard
Central Inverter	▪ Single unit ▪ Low capital price per watt ▪ High efficiency ▪ Comparatively easy installation	▪ Bulky and Large in Size ▪ Noisy ▪ A single potential point of entire system failure

Typically, the inverter's DC input bus voltage needs to be greater than the peak of the AC voltage (before the transformer) [7], [8]. Because the AC voltage obtained from the inverter is generally of lower root mean square value than the DC input due to the efficiency of inverter which is a multiplication factor for this conversion to take place. Then the capacitors are used to filter ripple currents on the DC lines. Ripples can intrupt maximum power point tracking and can increase DC resistive losses in the system.

Ripples are caused by the power semiconductors switching on and off. Typically, low frequency electrolytic capacitors are used, but these are susceptible to failure (drying out over time and at higher temperatures) and the other option is to use film capacitors which are better but are larger and more expensive [7]. The types, advantages and disadvantages of inverters are explained in Table 2 so that the correct choice can be made at the time of installation of distributed solar PV plant.

2.2.1. Standalone inverter with battery and charging unit

Modern standalone inverters use a range of other complex topologies such as three phase, high frequency (HF), bipolar or transformer-less for the power conversion. The inverters also use a DC boost circuit to boost the variable DC to a constant DC voltage. Finally an inductor is used in the circuit of inverter to smoothen out the AC signal and then it is fed to the grid [9]. The specifications of the standalone inverter with battery unit operating in the grid tied setup are shown in Table 3. The battery capacity for the connected load can be determined using following equation 2a, 2b and 2c.

Watt Hour Storage = {(daily watt hr consumption)*(days of Autonomy) / (Inverter Efficiency* Depth of discharge)} (2a)

Battery Capacity (in Ampere hours) = (Watt Hour Storage / Battery voltage / Battery efficiency) (2b)

No. of Batteries = (Total ampere hour) / Amp hour per battery (2c)

If the power produced by the distributed PV plant is higher than the power required for load then the extra power can be stored into the batteries. However in this prototyp the batteries are the part of grid not the plant. It has been observed that the negative reading in DC ammeter shows that the batteries are getting charged and the positive readings means the batteries are getting discharged. The specifications of standalone inverter with battery unit which is acting as local grid are shown in Table 3.

Table 3: Specifications of Prototype Grid

Electrical Parameters	Rating
Output Waveform Type	Pure Sinusoidal
Output Power	750 KVA/500 W
Nominal Output Voltage	230V-AC
Input Voltage for Battery Charging	160-286 V
Two Batteries(each with rating)	12 V, 7.5 Ah

A battery charger limits the rate of current being delivered to the battery bank and protect the batteries from overcharging. For the battery-based inverter, integration of the charge controller is mandatory. The charge controllers are crucial for keeping the batteries healthy, which ensures the lifetime of a battery bank is maximized. The battery charging unit installed in this prototype has specifications discussed in Table 4.

Table 4. Specification of Battery Charging Unit

Electrical Parameters	Rating
Maximum Input Voltage	150 V
Max. Output Battery Charging Current	10 A
Mode of Operation	Auto and Manual
Output Voltage in Automatic Mode	78 V
Gate Voltage for Manual Mode	5 V_{peak}

2.2.2. Grid-Tied Inverter

The responsibility of grid tied inverter is to maintain an instantaneous power balance between the generation and transmission. A grid tied inverter control unit regulates the output current and ensures that it is sinusoidal in nature and in phase with the grid electrical parameters. In this prototype grid tied inverter a transformer-less configuration is used with specifications in table 5. The grid tied inverters are designed to shut down automatically upon loss of utility supply, for safety reasons and also they do not provide backup power during utility outages [8], [9].

Table 5: Specifications of Solar Photovoltaic Plant

Electrical Parameters	Rating
Maximum Recommended Power	375W_P
Maximum Power Point Voltage	45-100V
AC output Grid Voltage	207-253 V
Maximum Output Current	1.5A
Maximum Power	300 W
Night time power loss	Less than0.1W
Feeding Single Phase at Max. Efficiency	94.8%
MPP Efficiency	99%
Switch on Power	2W

The safety disconnects AC and DC switches are purposely provided for all solar systems so as to protect the system. For the off-grid operation of solar systems, one additional DC disconnect is installed between the battery bank and the standalone inverter, which is used to switch off the current flowing between these components to maintain the system protection. This is important for maintenance, troubleshooting and protection against the unexpected internal and external problems in the system.

2.2.2.1. Operational Analysis of Inverter

It is important for a grid tied inverter and conditioner connected in the system at point of common coupling (PCC) to control the quality of power delivered to the load. The harmonic content in voltage and current i.e. total harmonic distortions (THD) can be maintained by the pulse width modulated sine wave grid tied inverters and typically kept less than 3%. It shows that the degradation of power with regard to harmonics in the system is hardly because of modern inverters, whereas it is mostly because of the type of load and some contribution has been made by transmission line parameters such as line inductance and capacitance for the increase in harmonics in the system[10]. Thus the applied controlling loop of a grid tied inverter for the stable operation of inverter is explained with the help of figure 2.

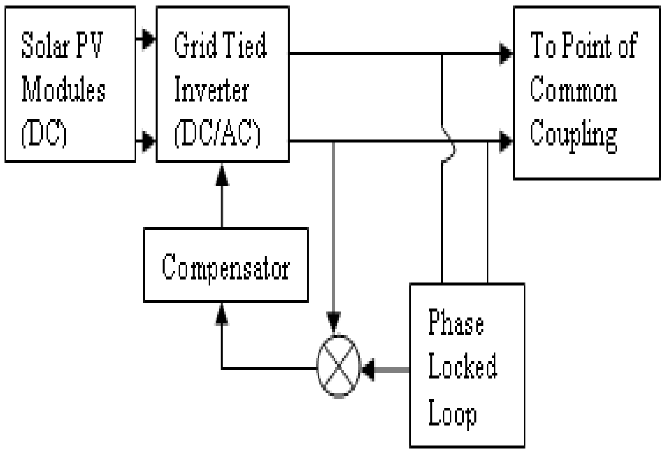

Fig. 2. Power Quality Control Loop of Solar PV Plant

3. Experimental Analysis

In this prototype unit, the harmonics in voltage andcurrent are addressed at the PCC. The short transmission lines having inductance 6mH serves as a link between the grid and a unit containing distribution generation system in this experiment. Due to the transformers and the transmission line collectively a system has finite amount of inductive reactance in it. There are several power quality issues associated with inductance like excessive reactive power flow, voltagesag and increased THD in voltage at PCC when a non-linear load is connected to the system [1] and the voltage at PCC is represented in equation (3).

$$V_{PCC} = V_S - I_L*Z_{TX} \quad (3)$$

Let us consider the fundamental source voltage generated as V_S = 210sinwt, transmission line inductance Z_{TX} = 2coswt and the voltage profile at PCC changes i.e. after loading with nonlinear load (let say the load current I_L = 10sinwt + 2 sin5wt + 0.8sin7wt), higher order components appear at PCC voltage given in equation (4).

$$V_{PCC} = V_S - I_L*Z_{TX} = \{210\sin wt - (2\cos wt) * (10\sin wt + 2\sin 5wt + 0.8\sin 7wt) \quad (4)$$

From this it is concluded that with the nonlinear loading, higher order harmonics appear at the PCC and it also depends upon the transmission line inductance. However Inductor offers higher impedance to higher order frequencies. So higher is the inductance, higher will be the impedance seen by higher order harmonics, consequently THD in current decreases. Whereas the power factor lags and leads based on the load such as if the load is capacitive like over excited synchronous motor, phase of current leads the phase of source voltage and if the load is inductive like arc furnace in nature then the phase of current lags the phase of source voltage. Therefore for the non linear loads, a power factor (cos θ) is product of Distortion Factor and Displacement Factor [1], where the total harmonic distortions can be calculated using equation (5) and the distortion factor (D.F.) can be calculated theoretically using the current total harmonic distortions as given in equation (6).

$$THD = \frac{\sqrt{V_2^2+V_3^2+V_4^2+V_5^2+\ldots\ldots}}{V_{rms}} \quad (5)$$

Where, $V_{rms} = \sqrt{V_1^2 + V_2^2 + V_3^2 + V_4^2 + V_5^2 + \cdots}$

$$D.F. = \frac{V_1}{V_{rms}} = \frac{V_1}{\sqrt{V_1^2+V_2^2+V_3^2+V_4^2+V_5^2+\cdots}} = \sqrt{1 - THD^2} \quad (6)$$

A poor power factor affects the utility's costs, and one that they pass to customers by imposing an increased tariff for customers with low power factor loads. There are lot of technical issues associated with operating at poor power factor like increased losses in transmission, transformers etc . As the compensator is switched on to improve the power factor, though the displacement factor (cos δ) improves but the THD in both voltage and current increases which leads to degradation in distortion factor. Reason behind increased THD in current is low impedance path offered by compensator of phase locked loop to the lower as well as higher order currents [5], [11]. Since the impedance offered by conditioner is inversely proportional to frequency, therefore small impedance path offered to the voltage harmonics appeared because of grid inductance and nonlinear load at PCC. Therefore the conditioner almost sinks high frequency currents which were causing THD in voltage and line current and improves the power factor of the system. The fundamental voltage and current of the system can be calculated using equation (4) and (5).

$$\text{Fundamental Voltage } (V_{fund}) = V_{rms}\sqrt{1 - THD_V^2} \quad (7)$$

$$\text{Fundamental Current } (I_{fund}) = I_{rms}\sqrt{1 - THD_I^2} \quad (8)$$

The table 6 shown is representing the change in voltage and current harmonics, with and without power quality conditioner unit in the grid tied solar photovoltaic system.

Table 6 : Total Harmonic Distortion Analysis

Load Type	Total Harmonic Distortion		Root Mean Square Value		Power Factor (cosθ)	Fundamental Voltage (V_{fund})	Fundamental Current (I_{fund})
	Voltage (V_{THD})	Current (I_{THD})	Voltage (V_{rms})	Current (I_{rms})			
Linear	4.72	14.39	101.6	0.285	0.99	101.3	0.279
Nonlinear	4.67	87.40	247.2	0.275	0.80	246.6	0.133
Linear + Nonlinear	5.88	46.35	98.68	0.707	0.83	98.33	0.626
System Parameters with Compensation							
Nonlinear	4.65	13.32	246.06	0.277	0.98	245.7	0.274
Linear + Nonlinear	4.74	14.20	97.46	0.417	0.99	95.12	0.412

Table 7: Power Components of Grid Tied System

Load Type	Apparent Power 'S' (KVA)	Active Power 'P' (KW)	Reactive Power 'Q' (KVAr)	Angle (δ)	Output AC Voltage (Volts)	AC Load Current (Amp.)
Linear	0.028	0.028	0.005	346.2	101	0.74
Nonlinear	0.481	0.004	0.048	268.8	250	0.13
Linear +Nonlinear	0.056	0.054	0.013	332.8	98	0.54

Conclusion

In order to identify the harmonics which are the major cause of low quality of power obtained at the customer end, a prototype of grid tied system with and without quality conditioner unit has been analyzed. The experimental results shown above depicts that due to the presence of voltage and current harmonics the power factor of the system gets affected and also the reactive power is highest in the presence of nonlinear load, which in turns affect the power flow in the system i.e. from plant to grid and grid to the load. Thus the overall system performance in terms of power output can be increased by compensating the harmonics at the point of common coupling and improving power factor of the system. With the help of this experiment, the source of harmonics, their effect on the system and removal from the system can beanalyzed. As the grid tied solar photovoltaic plants are increasing, the use of compensator/conditoner units is a vital to obtain the maximum power output at consumers' endwithout affecting the system stability. However the pulse width modulation control based conditioner used is this experiment validate the removal of harmonics from the system.

The harmonic reactive power maintained at the load end is 0.03 KVArh in all the conditions including transmission line inductance. The array voltage and current keeps on varying in the range 85.4 - 58.6V and 6.98 - 0.058A respectively and the maximum voltage obtained at PCC from the plant is less than 250 Volts. The apparent, active and reactive power delivered to the linear, nonlinear and combined loads is shown in the table 7. It has been observed that when there is presence of linear load the active power decreases with the increase in phase angle, while it is not applicable for the nonlinear load.

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References

[1] M. A. Eltawil and Z. Zhao, "Grid-connected photovoltaic power systems: Technical and potential problems- A review", Renewable and Sustainable Energy Reviews, vol. 14, pp. 112–129, 2010.

[2] A. Kalbat, "PSCAD Simulation of Grid-Tied Photovoltaic Systems and Total Harmonic Distortion Analysis", 3rd International Conference on Electric Power and Enegy Conversion Systems, pp. 1-6, Oct 2013.

[3] Danny Li *et al.*, "A study of grid-connected photovoltaic PV system in Hong Kong", Applied Energy, vol. 90, pp. 222-227, 2012.

[4] N. W. A. Lidula and A. D. Rajapakse, "Microgrids research: a review of experimental microgrids and test systems", Renewable and Sustainable Energy Reviews, vol. 15, no. 1, pp. 186–202, 2011.

[5] M. I. Azim, M. F. Rahman, T. Sarkar, “Hysteresis Current Control and Filtration”, International Journal of Applied Information Systems, vol. 7, no. 2, pp. 1-4, April, 2014.

[6] T. Nacer et al., “Feasibility study and electric power flow of grid connected photovoltaic dairy farm in Mitidja (Algeria)”, Energy Procedia, vol. 50, pp. 581-588, 2014.

[7] J. M. Espi Huerta, J. Castello, J. R. Fischer and R. Garcia-Gil, “A synchronous reference frame robust predictive current control for three phase grid connected inverter”, IEEE Trans. Ind. Electron., vol. 57, no. 3,pp. 954-962, March 2010.

[8] L. R. Limongi, R. Bojoi, C. Pica, F. Profumo, and A. Tenconi, “Analysis and comparison of phase locked loop techniques for grid utility applications”, Proceeding PCC APOS, Nagoya, Japan, pp. 674-681, 2007.

[9] H.B. Hu, S. Harb, N. Kutkut, I. Batarseh and Z.J. Shen, “A Review of Power Decoupling Techniques for Microinverters with Three Different Decoupling Capacitor Locations in PV Ststem”, *IEEE Power Electronics*, vol. 28, no. 3, pp. 2711-2726, June 2013.

[10] U. Jahn and W. Nasse, “Operation performance of grid-connected PV systems on buildings in Germany”, Progress in Photo-voltaics Research and Applications, vol. 12, pp. 441-448, 2004.