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Analysis of power factor correction of PV-Grid interconnected system

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Abstract - *This paper explain about power factor correction topology for a single phase two wire (1ϕ2w) photovoltaic (PV) system. The charge controller techniques (maximum power point tracking) is also proposed here to maintain store energy of the battery set. Boost converter is served as a boost up the voltage according to my output level. The bidirectional inverter is used as a generator, to continuous power to the load. The battery system with inverter is also used to maintain the voltage level when solar system is not capable to deliver energy to the load. A parallel power factor correction (PPFC) scheme can be satisfied with the control scheme of the inverter. A power factor correction algorithm is implemented in a DSP controller with PV system. The simulation result on a 1 KW PV system show the approximately unity power factor (PF) at the utility side.*

Key Words: Photovoltaic System, Boost Converter, MPPT Technique, Inverter, Utility Grid.

1. INTRODUCTION

In recent trend, there has been a lots of demand all over the world might require the construction of new generation plant using the conventional energy sources. Which is motivating a lot of investment in alternative energy solutions. Renewable energy sources like solar energy, wind energy, biomass are good alternatives for power generation. Photovoltaic (PV) system interface with the electric utility grid are rapidly growing in recent year. This scheme includes PV array, MPT charger, battery, inverter and utility grid. A conventional grid-connected PV system is as shown in fig. (1). The maximum power tracker (MPT) is combined with boost converter to obtain as much solar power as possible. The main function of DC/DC converter to store the excessive solar energy in the batteries. Inverter function is to store energy when solar PV system and deliver energy to convert AC when sunlight is insufficient or during the night time. If the grid connection is of voltage-type, then frequency, phase and amplitude of output voltage of the inverter and utility grid must be same. In case of load combined with distribution network inductive load is favored.

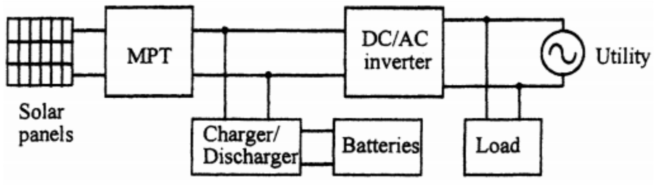


Fig. (1) A conventional grid-connected PV system

Those loads need two types of power, active power for the purpose work performing such as motion and reactive power for providing a magnetic field. Those loads absorb reactive power from the network, reduce the power factor of the network and cause many economic losses. In this paper, a new conventional topology grid-connected PV system with a simpler structure and providing parallel power factor correction is presented. The block diagram of parallel power factor correction is shown in fig. (2).

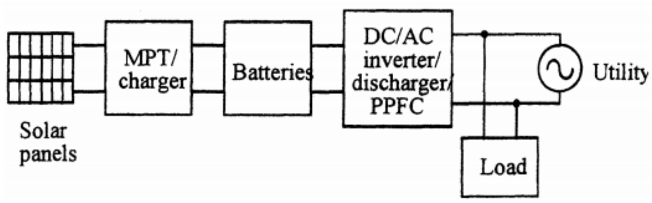


Fig. (2) The schematic of grid-connected PV system

The MPT also served as a charger, tracking the maximum solar power and charging the battery bank at same time. The inductor filter is also connected in between DC/AC inverter and the utility grid. The inverter is capable of bi-directional power transfer. When either the solar power or stored energy of the battery is sufficient, the inverter provides all part of the load power by injecting into the load a fundamental current in-phase with the source voltage. The power transfer from the solar panels to the batteries and from the batteries and from the batteries to the utility grid are achieved through only one stage. A power factor adjustment can improve the efficiency of the overall utility network. The power factor improvement gives the utility greater flexibility to supply the power the power quality required by the load.

2. MATHEMATICAL OPERATION OF PHOTOVOLTAIC SYSTEM

When Sunlight strikes a PV cell, the photons of the observed Sunlight displace the electrons from the atoms of the cell. The free electrons then move through the cell, crating and filling in holes in the cell. It is this movement of electrons and holes that generates electricity. The physical process in which a PV cell coverts Sunlight into electricity is known as the "Photovoltaic effect". This is the single diode based model. The equivalent circuit of a PV cell is shown in fig (1). It includes a current source (photo current), a diode, a series resistance and a shunt resistance. Essentially the photons or the light energy creates this charge carrier or electron's hole pairs and the PN junction collects this charges and separates these. So that the current flow in the external circuit is enable & also by the process of photovoltaic effect also creates the forward biased voltage. This leads to the single diode model as shown in figure. So the photon generated current modelled by a current source I_{ph}. That current is diverted into this forward biased diode and remaining comes out to the external circuit. The Parasitic resistance is also modelled here, which is denoted by R_{sh} represents the leakage current. Where, R_s is the series resistance of the cell.

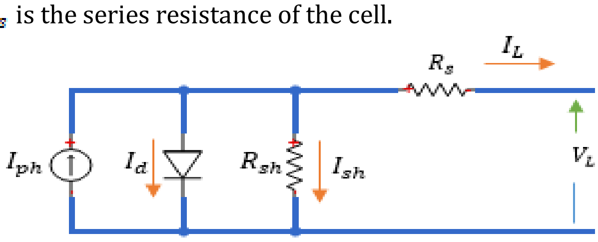


Fig. (3) The PV cell equivalent circuit

Now, on applying KCL in the PV circuit cell of fig. 3, we have,

$$I_{ph} = I_d + I_{sh} + I_L \qquad (1)$$

$$where, \; I_d = I_o\left(e^{\frac{qV_d}{\gamma kT}} - 1\right) \qquad (2)$$

Using eq_n (2) on eq_n (1), we get,

$$I_L = I_{ph} - I_o\left(e^{\frac{qV_d}{\gamma kT}} - 1\right) - \left(\frac{V_L + I_L R_s}{R_{sh}}\right) \qquad (3)$$

The eq_n (3) so obtained represents the load current in PV cell irrespective of photo current (I_{ph}) and reverse saturation current (I_o) as function of temperature, but it does depend on it, which are given below as,

$$I_0(T) = I_0\left(\frac{T}{T_{nom}}\right)^3 exp.\left[\left(\frac{T}{T_{nom}} - 1\right)\frac{E_g}{\gamma V_t}\right] \qquad (4)$$

$$I_{ph}(T) = [I_{sc} + K_i(T - 298)].\frac{\alpha}{1000} \qquad (5)$$

Again, on applying KVL, we have the required relation for voltage drop across the diode as, $V_d = V_L + R_s I_L$. Using this voltage drop equation on eq_n (1) with the consideration of shunt resistance open-circuited.

$$\frac{I_{ph} - I_L}{I_o} + 1 = e^{q(V_L + R_s I_L)/\gamma kT} \qquad (6)$$

Taking logarithm both side of the eq_n (6) which further yields to give the load voltage across the PV circuit as,

$$V_L = \frac{\gamma kT}{q} ln\left(\frac{I_{ph} - I_L}{I_o} + 1\right) - R_s I_L \qquad (7)$$

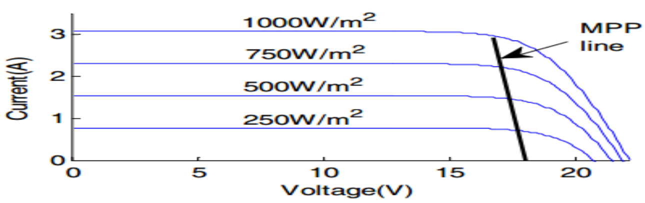
In case of open load condition $(i.e. I_L = 0)$, we have open circuit voltage relation as,

$$V_{oc} = \frac{\gamma kT}{q} \ln\left(\frac{I_{ph}}{I_o} + 1\right) \qquad (8)$$

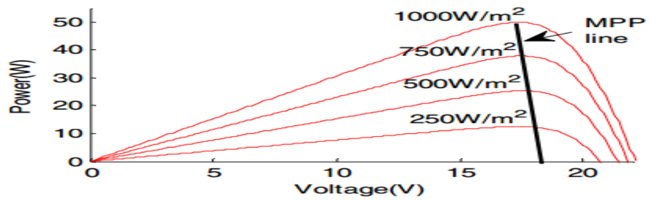
Where,

I_d	*Diode current*
V_d	*Diode voltage*
V_{oc}	*Open circuit voltage*
I_{sc}	*Short circuit current*
R_{sh}	*Shunt resistance*
γ	*Cascading constant*
K	*Boltzmann's constant*
T	*Absolute temperature*
q	*Charge on an electron*
T_{nom}	*Nominal temperature*
E_g	*Band gap energy of the semiconductor*
V_t	*Thermal voltage*
K_i	*Short circuit current temperature coeff. of PV cell*
α	*Solar irradiance*

The characteristics curve of PV cell so possible by this is nonlinear, which vary with the level of solar irradiation and temperature, which make the extraction of maximum power a complex task, considering load variations. To overcome this problem, several methods of extracting power have proposed up till, but here, perturb & observe (P&O) are explained. By 2003, the best efficiency of solar cell so discovered was less than 40 %. The PV characteristics for various irradiance is shown below in fig. (4).



(a)



(b)

Fig. (4) PV cell characteristics (a) current versus voltage (b) power versus voltage

3. Boost Converter

Boost converter is power electronic device that convert one dc voltage to different (boost) dc voltage up to a desired level. Maximum power point techniques (MPPT) uses for different purposes, regulating the input voltage of PV at optimum value of power and providing load matching for maximum power transfer (MPT). Boost converter circuit is the combination of inductor, diode and switch. If switch is closed, then inductor gets charged through the battery and stores the energy. In this case inductor current rises exponentially. The diode blocks the current flowing, thus current remains constant which is being possible due to the discharging capacitor.

4. MPPT Technique

In general, solar panel converts only 30 to 40% of the incident solar radiation into the electrical energy. In order to achieve the maximal efficiency of such MPPT technique as introduce in the earlier section is employed. From the Maximum Power Transfer Theorem (MPTT), we know that the output power of a circuit is maximum only when the Thevnin impedance of the circuit matches with that of its load impedance. In similar way, the objective of the solar irradiance tracking is to meet the point of power maximality in MPPT technique, which must need to be done in such a way that it also matches the impedance of corresponding as stated in MPTT technique. Thus, one can loosely say that MPPT technique based on the problem of impedance matching. For the purpose of such (i.e. matching) in PV grid the element which must need to be introduce is the boost converter at the input side which may regard as Transformer of step-up type for the tracking of optimal one, so that the voltage at the output side get enhanced which can be employed for the application of different types like to drive the motor as load, for lightning etc. By changing the duty cycle of such converter appropriately we can able to match the intrinsic (or Thevenin) impedance with that of the load impedance. If we have variable input, for instance, solar irradiance, the current and voltage will be found to vary correspondingly as shown in fig. (4). Where, the output power (i.e. simply the product of $V \& I$) is zero at V_{oc} (because $I = 0$) and zero again at I_{sc} (because $V = 0$). In between these two crispy points it rises and then falls, so that there is one point at which the cell delivers maximum power.

4.1 Perturb-and-Observe Method of MPPT

Perturb & Observe algorithm works when voltage and current across PV array are used at any instant in each switching cycle. Same process is repeated periodically until the maximum power point is reached. Oscillations of the system can be minimized by reducing the step size of perturbation. Even perturbation step size is small then the point of maximal power point is also slow from fig. (5). Thus overall response of perturb and observe is slow. The new topology has developed to achieve maximum power point faster compared to that of conventional one. The overall efficiency of P& O is good but common problem is that load side voltage of PV is perturbed every MPPT cycle even when MPP is reached, resulting loss of power.

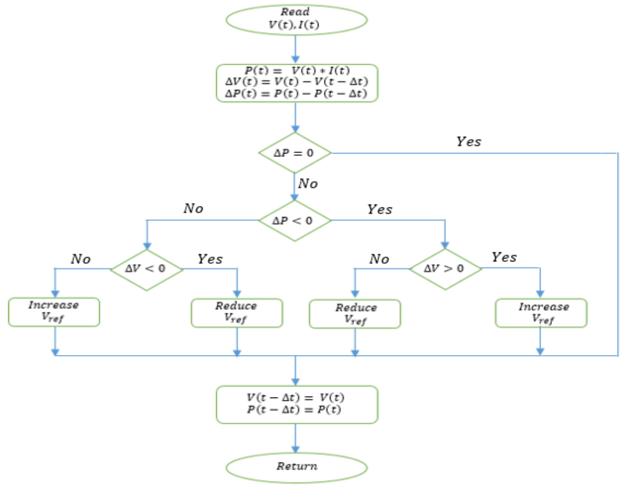


Fig. (5) Flowchart of P & O Algorithm

5. SYSTEM DESCRIPTION:

The maximum power tracker (MPT) is a boost DC/DC converter as shown in fig. (2). The perturbation and observation (P&O) method is used to draw the maximum solar power. According to the obtained solar energy and the stored battery energy, the controller determines the ratio between the amounts of the power supplied to the batteries and the inverter. One simple criterion is to detect the voltage level of the battery bank. The upper limit of the battery voltage is recommended by the battery manufacturer and the lower bound is set depending on the performance of the PPFC. The DC/AC inverter is a full-bridge type as shown in fig. (6).

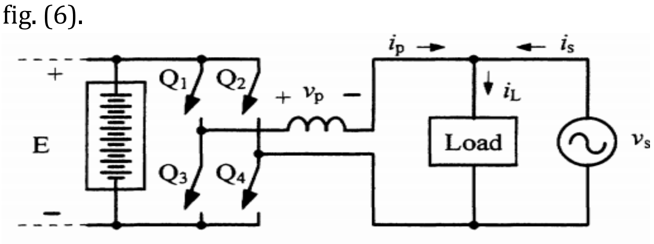


Fig. (6) The full-bridge inverter as a PPFC

The output current of the inverter, i_p, must contain all the harmonics (i_{Lh}) and the out of phase fundamental component (i_{Lfo}) of the load current, i_L. when the PPFC also supplies powr to the load, i_p may carry part of the in-phase fundamental component (i_{Lfi}) of i_L. from the above descriptions and the KCL equations, it leads to:

$$i_L = i_p + i_s \quad (9)$$

After rearranging the eq_n (9),

$$i_p = i_L - i_s \quad (10)$$

or, $$i_p = (i_{Lfi} - i_s) + i_{Lfo} + i_{Lh} \quad (11)$$

The magnitude of the in-phase fundamental part of i_p, which equals to $(i_{Lfi} - i_s)$, represents the power level sent from the PPFC to the load. The waveform of i_p determines the quality of i_s. Usually i_p is sensed to follow its command $i_{p,com}$, which is the difference between actual load current i_L and the command of i_s and the command of i_s, $i_{s,com}$. To overcome the complexity of the control circuit, i_s is instead sensed to track , $i_{s,com}$ to produce the gate signals. After conlusion it said that the voltage level of the battery bank, E, must be high enough for i_p to perfactly resemble its command. However, a higher E will result in a larger swtching loss. Thus, the lower limit of the battery volatge can be determined according to the heaviest load. The block diagram of the controller for the proposed PPFC is in fig. (7),

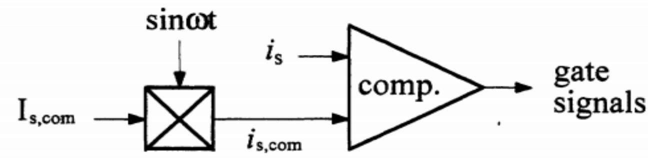


Fig. (7) Block diagram of PPFC controller

where $I_{s,com}$ is the amplitude of $i_{s,com}$. As stated earlier, $I_{s,com}$ determines the required amount of power supplied from utilty grid. There are four operating stages of the proposed grid-connected PV system are discussed as follows. It is assumed that the system has been in the nighttime for long enough, and the battery bank has been discharge to its lowest allowble voltage level. The flow chart descibes the four operating stages as a case, is shown in fig. (8).

Case 1: The MPT is shut down. To prevent i_p and i_s from distortion, the lowest voltage level of the battery bank is first set to be E_L. since each battery is specifed with a lowest discharging volatge, the required number of the series batteries can thus be caculated. Also $I_{s,com}$ is determined to maintain the battery voltage at E_L.

Case 2: When the sun begins to shine, the MPT produce the maximum available solar power. As long as the charging current, i_C, does not exceed its maximum limit, $i_{C,max}$, all the solar power is supplied to charge the batteries. E increases towards its upper bound, E_H. Since the load power is still supplied the utility solely, $I_{s,com}$ remains the same as in case 1. Once the charging current is too high, some of the output power of the MPT must be transferred accordingly. It is therefore concluded that, $I_{s,com}$ is dependent on the voltage level and the charging current of the battery bank.

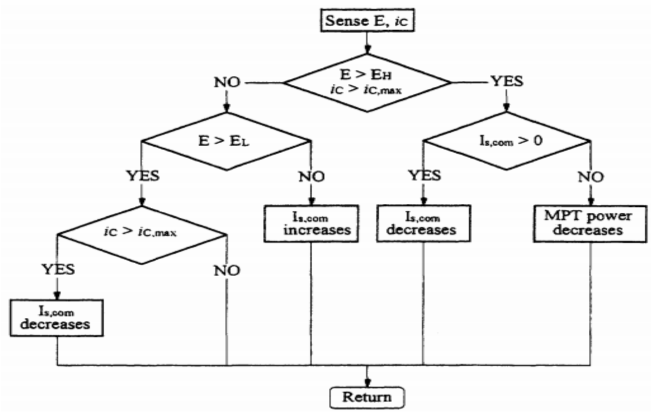


Fig. (8) The flowchart of operating cases (stages) for the proposed PV system

Case 3: When the battery bank is fully cahrged, E reaches E_H. If the sunlight is still sufficient, then $I_{s,com}$ decreases to maintain the voltage level of the battery bank at E_H. The ratio of the load power supplyined by the PPFC untill E begins to fall below E_H. In some cases, the availible solar power may be more than required. The operating point of the MPT will then be adjusted to be from the optimum to output less solar power.

Case 4: In the nighttime, the MPT is shut down. Battery bank begins to discharge through the PPFC untill E falls below E_L. Then the operation returns to case 1.

6. SIMULATION & RESULT

A prototype system is built to perform simulation result, modelling parameters are listed as follows: $V_s = 155\ V_{rms}$, load power $P_L = 1\ KW$, $E_L = 190\ V$ and $E_H = 220\ V$, shown in fig. (9-16) are the power factor waveform of different load 1000 W and 750 W.

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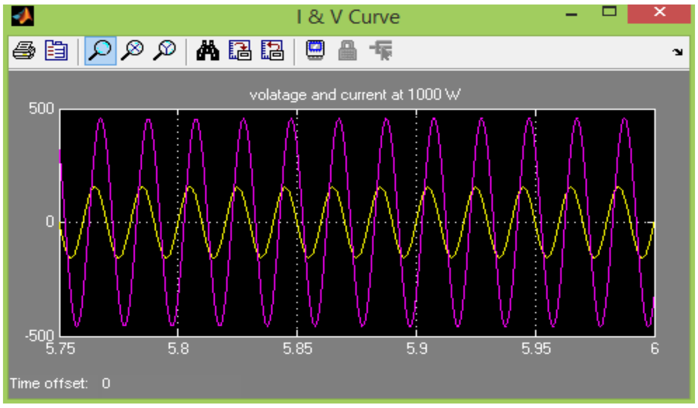

Fig. (9) voltage & current at 1000 W

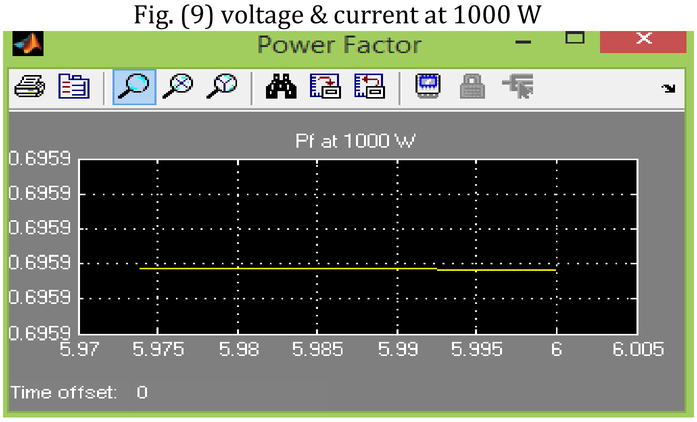

Fig. (10) Power Factor at 1000 W

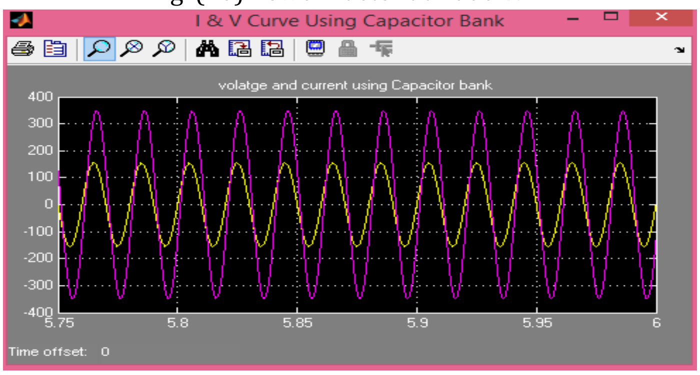

Fig. (11) voltage & current at 1000 W after correction

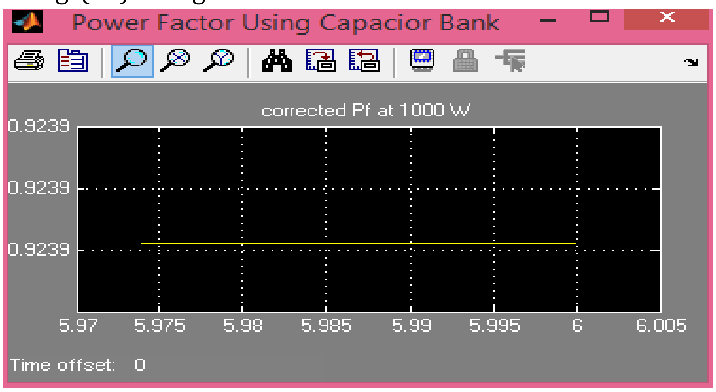

Fig. (12) Power Factor at 1000 W after correction

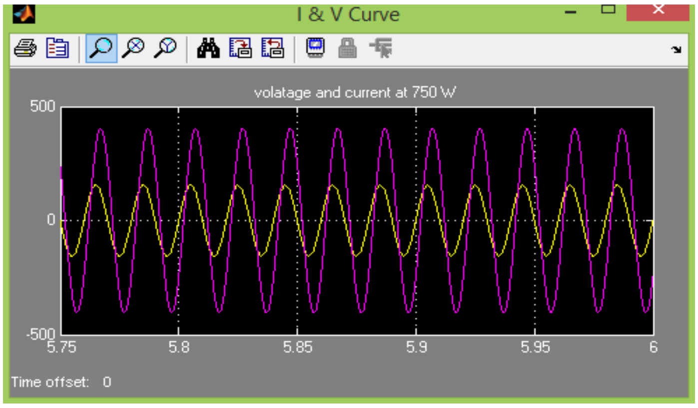

Fig. (13) Voltage & Current at 750 W

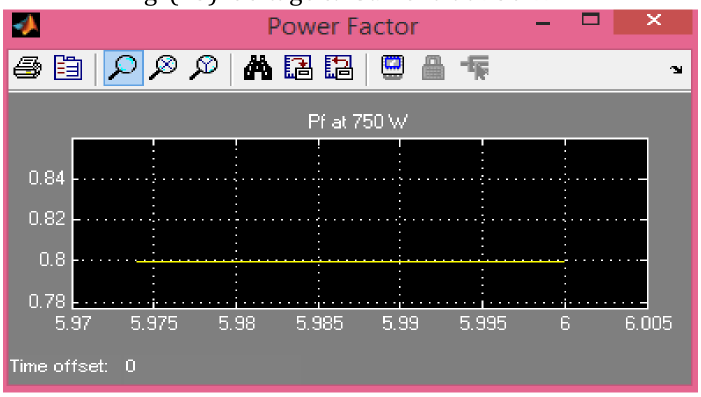

Fig. (14) Power Factor at 750 W

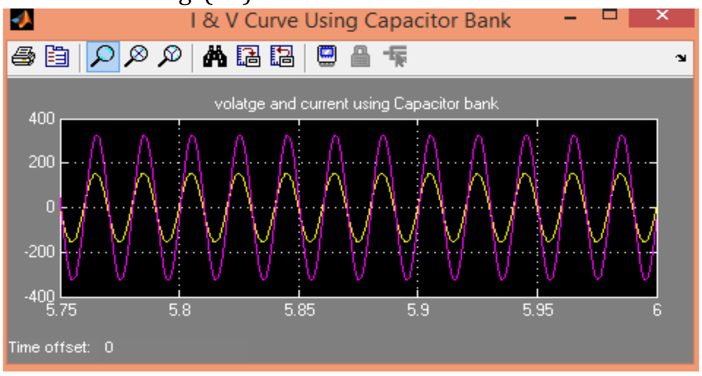

Fig. (15) voltage & current at 750 W after correction

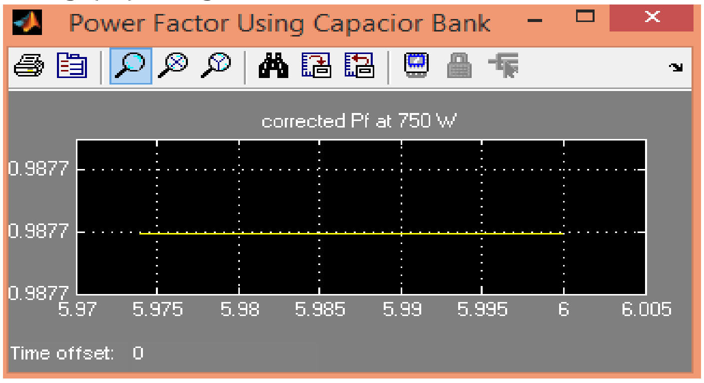

Fig. (16) Power Factor at 750 W after correction

7. CONCLUSION

A single-phase photovoltaic system simulation model is built in this paper. It combines with the voltage and current closed loops control and puts forward a tracking method of maximum power fast interpolation. It recognise two main task: (1) it achieves MPPT of the photovoltaic system. (2) it sends to the grid a sine wave current with the same frequency, phase and amplitude with the grid voltage. The power factor of 1000 W and 750 W load is 0.6959 and 0.7997 respectively which is from fig (10 & 14). Power factor is the phase angle between applied voltage and current under the consideration of load variation. Using capacitor bank topology means that after improvement of power factor for 1000 W and 750 W load bacame 0.9239 and 0.9877 respectively which is shown in fig (12 & 16). In future one can use as a industrial aspect for the purpose of reduction in harmonics and less settling time with the variation of load.

REFERENCES

[1] Yu-Kang Lo, Jin-Yuan and Tin-Yuan wu, "Grid-Connection Technique for a Photovoltaic System with Power Factor Correction" IEEE PEDS (2005) pp. 522-525

[2] Jinhui Xue, Zhongdong Y in, Qipeng song, and Renzhong Shan, "Analyze and Research of the inverter for Grid-connected photovoltaic system", IEEE (2008) pp. 2530-2535

[3] Aslain Ovono Zue, Ambrish Chandra, "Simulation and Stability Analysis of a 100 KW Grid Connected LCL Photovoltaic Inverter for Industry", IEEE (2006) pp. 1-6

[4] T.-F. Wu, C.-H. Chang and Y.-K. Chen, "A Multi-Function Photovoltaic Power system with Grid-Connection and Power Factor Correction Features ", IEEE-2000, pp. 1185-1190

[5] Ioan Viorel BANU, Razvan BENIUGA, Marcel ISTRATE, "Comparative Analysis of the Perturb-and-Observe and Incremental Conductance MMPT methods" ATEE, IEEE (2013) 1-4

[6] Moacyr A.G. de Brito, Leonardo P Sampaio, Luigi G. Jr., Guilherme A.e Melo, Carlos A. Canesin, "Comparative Analysis of MPPT Techniques for PV applications", IEEE, (2011) 99-104

[7] Shihong Q in, Min Wang, Teng Chen, Xiangling Yao, "Comparative analysis of Incremental Conductance and Perturb-and-Observation Methods to Implement MPPT in Photovoltaic System", IEEE (2011) 5792-5795

[8] G. Dileep, S.N.Singh, "Maximum power point tracking of solar photovoltaic system using modified perturbation and observation method" ELSEVIER (2015) 109-129

[9] Tarak Salmi, Mounir Bouzguenda, Adel Gastli, ahmed Masmoudi, "MATLAB/Simulink Based Modelling of Solar Photovoltaic Cell", IJRER (2012) 213-218

[10] Bikram Das, Anindita Jamatia, Abanishwar Charaborti Prabir Rn. Kasari & Manik Bhowmik, "New perturb & observe MPPT and its validation using data from PV module" IJAET (2012) 579-591

[11] Ahmed M. Atallah, Almoataz Y. Abdela Ziz, and Raihan S. Jumaah, "Implementation of Perturb and Observe MPPT of PV system with Direct control method using Buck and Buck-Boost Converter, EEIEJ, (2014) 31-44

[12] A. Fezzani, I. Hadj Mahammed, and S. Said, "MTALAB-Based Modeling of Shading Effects in Photovoltaic arrays", STA IEEE (2014) pg.781-787.