Performance of Hybrid MPPT control in PV Grid inverter

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***Abstract*— The world is facing not only the depletion of fossil fuels, but also its rising prices which causes the worldwide economic instability. Numbers of efforts are being undertaken by the Governments around the world to explore alternative energy sources and to achieve pollution reduction. Solar electric or photovoltaic technology is one of the biggest renewable energy resources to generate electrical power and the fastest growing power generation in the world. The main aim of this work is to analyze the interface of photovoltaic system to the load, the power electronics and the method to track the maximum power point (MPP) of the solar panel. There are many methods for maximum power point tracking like on line methods and off line methods. But hybrid methods proved to be more efficient than them. In this work maximum power point tracking is done by bacterial foraging optimized perturbation and observation method. BFO is offline method and P&O is online method, so a combination of both is used in our work to control the duty cycle of boost converter which boosts the dc voltage produced form PV array, to pass to grid..**

***Keywords*— PV Grid inverter MPPT.**

I. INTRODUCTION

To face this challenge, they are striving to put in place regulatory guidelines to aid the adoption of best practices by utilities in terms of the Smart Grid and renewable energy applications. Smart Grid organization provides the consumers with the ability to monitor and control energy consumption. This is crucial because as the world population grows the electricity demand will also increase, but at the same time, we will need to reduce our electricity consumption to fight global warming.

Photovoltaic allow the consumers to generate electricity in a clean, reliable and quiet manner. Photovoltaic are often abbreviated as PV. Photovoltaic cells combine to form photovoltaic systems. Photovoltaic cells are devices that convert light energy or solar energy into electricity. As the source of light is usually the sun, they are often referred to as solar cells. The word photovoltaic is derived from "photo," meaning light, and "voltaic," which refers to production of electricity. Hence photovoltaic means "production of electricity directly from sunlight." Usually, a PV system is composed of one or more solar PV panels, an AC/DC power converter (also known as an inverter), and a rack system that holds the solar panels, and the mountings and connections for the other parts. A small PV system can provide energy to a single consumer, or to isolated devices like a lamp or a weather device. Large grid-connected PV systems can provide the energy needed to serve multiple customers. A single individual solar cell has a very low voltage (usually ca. 0.5V). Hence, several cells are wired together in series giving rise to a "laminate". The laminate is then assembled into a protective weatherproof casing, thus creating a photovoltaic module or a solar panel. Modules may be then strung together to form a photovoltaic array. The electricity generated can either be stored, put into direct use (island/standalone plant), fed into a big electricity grid powered essentially by central generation plants (grid-connected/grid-tied plant), or fed into a small grid after combining with one or many domestic electricity generators (hybrid plant). Depending on the application type, the rest of the system known as balance of system or "BOS" consists of several components. The BOS is dependent on the load profile and the type of system. PV energy conversion systems can either be off-grid (stand-alone) or grid-connected. A description of both types of PV systems follows.

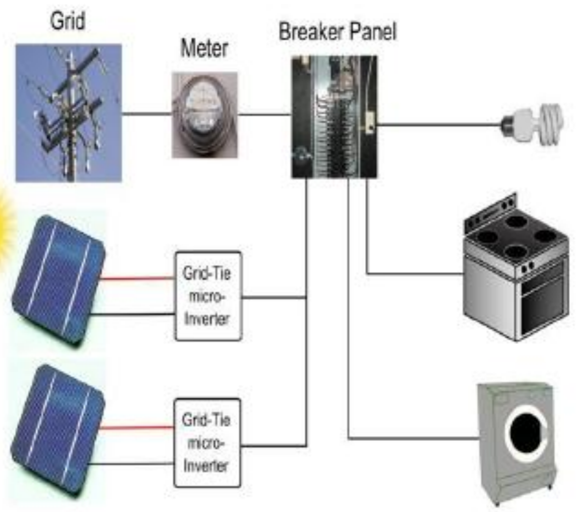


Fig 1.1: Schematic diagram of a simple photovoltaic system

II. RELATED WORK

The modelling and control of grid connected photovoltaic energy conversion system has been proposed by many researchers. The previous paper presents a review of the Modelling of photovoltaic systems include modelling of SPV array, power electronics inverter/converter based on MATLAB/SIMULINK . Maximum power point tracking (MPPT) can effectively improve the solar energy conversion efficiency of PV systems. Maximum power point tracking (MPPT) control system in general is taking care of extraction of maximum power from the sun light whereas current controller is mainly designed to opti- mize the inverter power to feed to power grid.

III. PROPOSED WORK

To utilize the photovoltaic array at full efficiency, maximum power point tracking is done so that maximum power generated at PV array can be utilized. But due to the varying environmental condition, namely temperature and solar isolation, the *P–V* characteristic curve exhibits a maximum power point (MPP) that varies nonlinearly with these conditions—thus posing a challenge for the tracking algorithm. To counteract this we have proposed a new technique called BFO optimized P&O. in past various algorithms have been suggested. These have been categorized into three categories: on line method, off line method and hybrid method which is combination of on line and off line method. P&O, incremental and conductance methods are categorized into online methods and MPPT control techniques like artificial intelligence are into offline methods category.

In my work hybrid control technique is used. In this bacterial foraging optimization is used to optimize the initial value of duty cycle input into P&O method. Then by perturbation and observation (P&O) method duty cycle is either increased or decreased depending upon the some boundary conditions which will be discussed later in this chapter. Initially bacterial foraging optimization will be discussed and steps used in to it. The duty cycle observed at the output of P&O will be input to BFO for optimization.

Bacterial Foraging Optimization

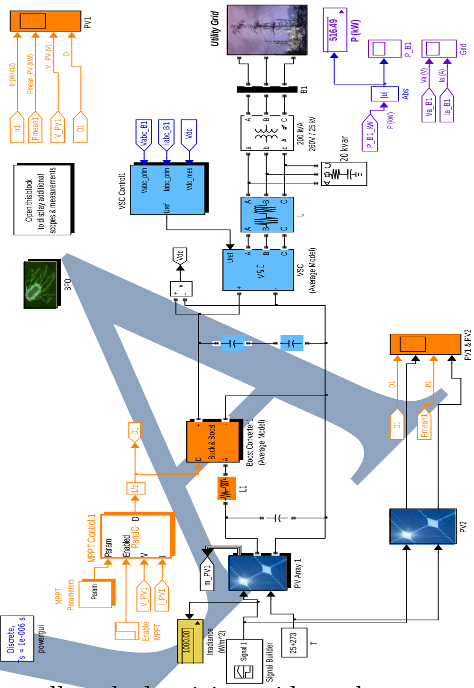
Bacteria Foraging Optimization Algorithm (BFOA), is a new comer to the family of nature-inspired optimization algorithms. For over the last five decades, optimization algorithms like Genetic Algorithms (GAs), Evolutionary Programming (EP), Evolutionary Strategies (ES), which draw their inspiration from evolution and natural genetics, have been dominating the realm of optimization algorithms. Recently natural swarm inspired algorithms like Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) have found their way into this domain and proved their effectiveness. Application of group foraging strategy of a swarm of *E.coli* bacteria in multi-optimal function optimization is the key idea of the new algorithm. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis and key idea of BFOA is mimicking chemotactic movement of virtual bacteria in the problem search space.

IV. MATLAB SIMULINK MODEL DESCRIPTION

In our work MATLAB simulink is used to implement the model. Simulink® is a block diagram environment for multidomain simulation and Model-Based Design.

DISCUSSION OF RESULTS

The implementation of PV grid array using hybrid MPPT control technique is done with the help of simpower system. As discussed above PV grid array is combination of



photovoltaic cell and electricity grid so that extra power generated by PV array can be transferred to grid as power generated can't be stored long. The proposed simulink model consists of four different main blocks PV array, Buck & Boost converter, MPPT contro and electricity grid. Link between MPPT controlled PV array and grid is via voltage source control (VSC), connected in the circuit. The diode model of photovoltaic cell is implemented in simulink.

Table 5.1: Parameters considered for PV array module

Number of series-connected cells	96
Open circuit voltage	64.2 Volt
Short Circuit Current	5.96 A
Voltage and current at maximum power	Vmp =54.7 V, Imp= 5.58 A

The VI and PV characteristics of PV array used in our work are shown in figure 5.1. The above curve is for VI characteristic. It shows the current generated for various irradiation intensities over solar array. As the intensity of radiations is increased, current is also increased and vice versa. Second curve is for power vs voltage. The red circle over each curve represents maximum power point. This will be the maximum power for voltage at that instant and after that power decreases. Maximum power points have different locations for different irradiation intensity. If a curve is drawn meeting these points then that will be a parabolic curve.

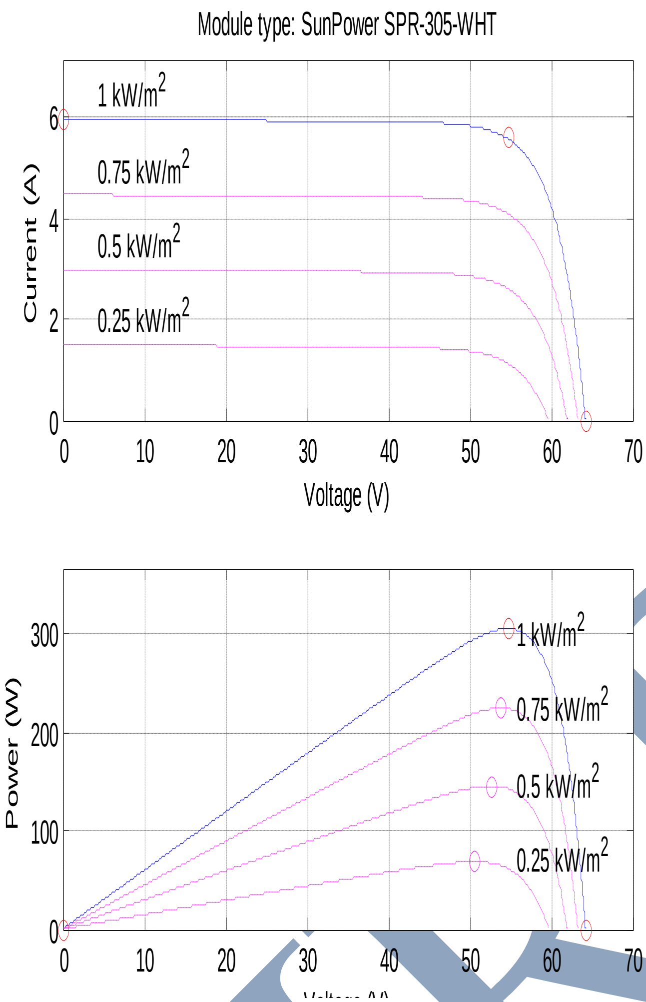


Figure 5.1: IV and PV characteristics for a single PV cell

For the array used the characteristics curve is shown in figure 5.2. it is for 5 series module and 66 cells in parallel inn each module. Observe the current produced for this array. Maximum current produced is 400 A as compared to single cell which is having 6A only. Thus almost 66.6 times increase into current is obtained in an array used here. Boost converter is used for DC/DC conversion of PV array output. It boosts the DC voltage output of PV array. The boost converter used for our work boosts the PV array output to 500 V from 273.5 V. the implementation of boost converter into simulink is shown in figure 5.5. This converter uses a MPPT system which automatically varies the duty cycle in order to generate the required voltage to extract maximum power. In our case the MPPT technique used is hybrid of online and offline method i.e. Perturbation and Observation (P&O) and bacterial foraging optimization (BFO) is used collectively. Initially P&O sets the duty cycle of boost converter and then BFO optimized P&O sets the duty cycle. For P&O implementation, a MATLAB script is written. The last major component is electricity grid whose implementation in simulink model is shown in figure 5.6. But before that an important block voltage source converter is used for interfacing of PV array and grid.

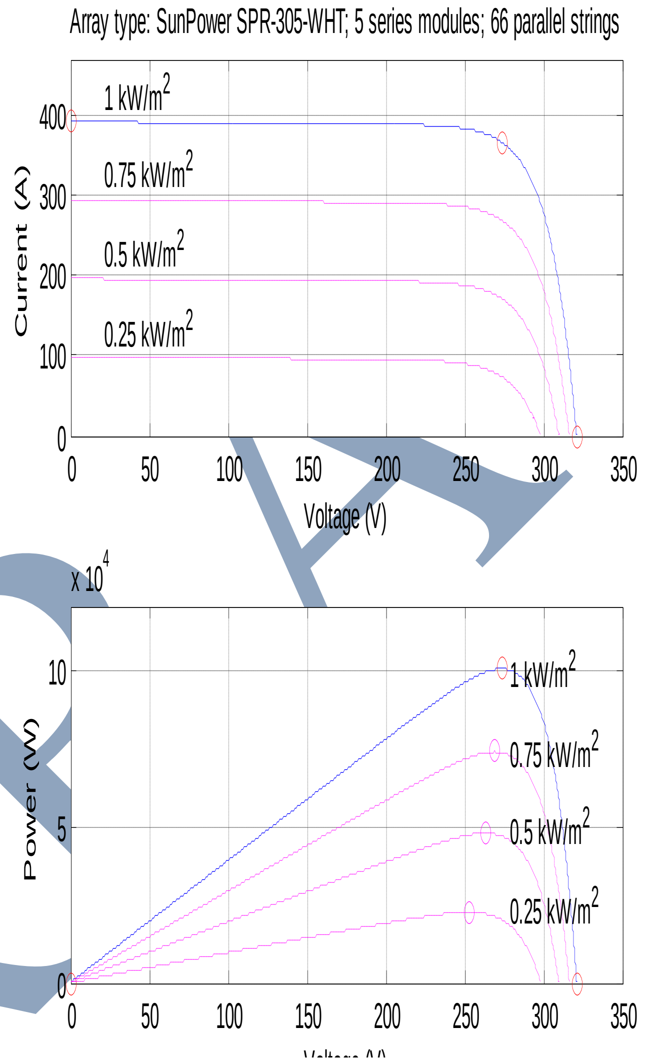


Figure 5.2: IV and PV characteristics for a complete PV array

The utility grid designed is having 25-kV distribution feeder + 120 kV equivalent transmission system. The complete model is shown in figure 5.7. This model implements the proposed hybrid MPPT control technique which varies the duty cycle of boost converter. For bacterial foraging optimization implementation, coding is used. This MATLAB script file for BFO is called by a block named BFO in main simulink model by just double clicking on that block. It will execute BFO script and results will be saved into initial value of duty cycle of P&O automatically, once execution is completed. The initial temperature into PV array is taken as 25^{o}C. Here twp PV arrays are implemented, amongst that PV1 give optimized P&O controlled MPPT output whereas other PV2 will give unoptimized P&O MPPT output. Comparison in output is shown in scope just after PV2 named as PV1 & PV2. The whole model is run for 3 seconds and initially unoptimised outputs are observed.Initially without optimization system model is run. The output of PV1 is shown in figure 5.3.

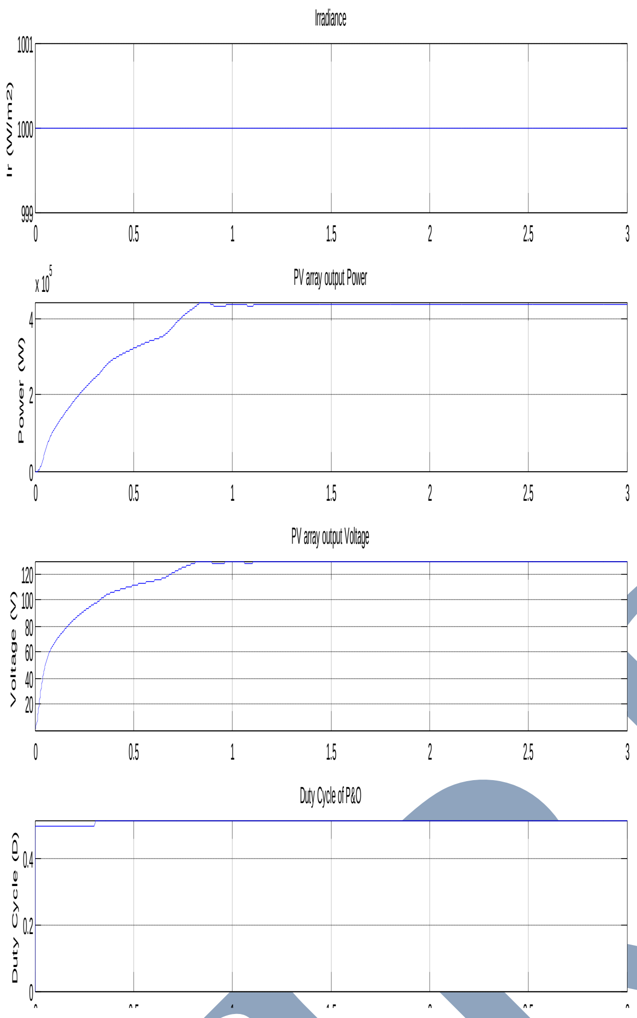


Figure 5.3: PV array output in case of unoptimised P&O

The maximum power generated in this case is 445kw and voltage is 130 volt. The voltage and power curve becomes steady after 0.7 sec and prior to that their values are increasing for irradiance of 1000 w/m2. Now BFO optimization is done after double clicking on NFO block in the model. It will optimize the objective function defined and set the optimum duty cycle value. After that again model is run and optimized output of PV1 array is shown in figure 5.4. here in this case the maximum power is 513kw as compared to 445kw of unoptimised duty cycle case and maximum voltage in this case is 139.72 volt. A comparison of maximum power is shown in figure 5.5 which clearly shows the difference in both cases. In optimized case the settling time of power is also increased (from 0.7 in case of unoptimised) to 1sec. Initialization parameters used for BFO are shown in figure table 5.2. If maximum power is increased then power reached to grid is also increased. A comparison of gird power is shown in figure 5.7 and figure 5.6 shows the voltage and current at bus B1 of grid. First 400 samples of voltages and currents are shown in figure 5.6 for better reader's clarity as high number of samples will make visibility analysis zero.

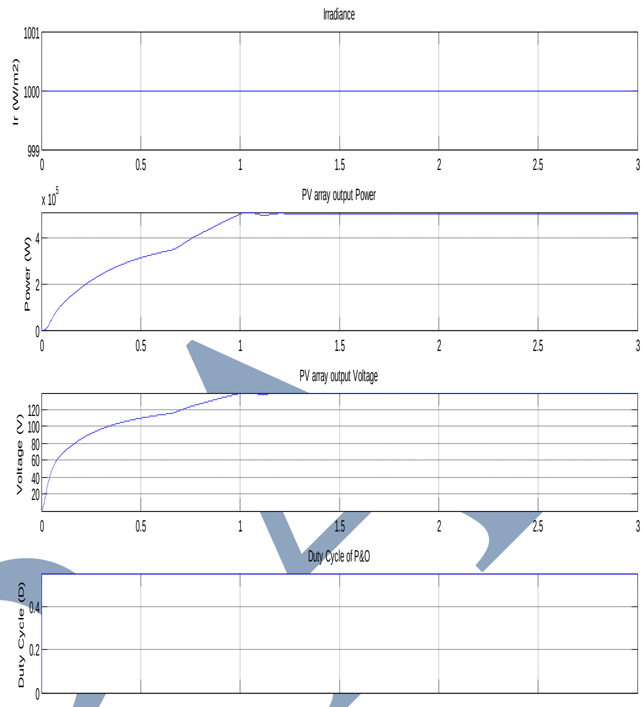


Figure 5.4: Optimized duty cycle output of PV1 array

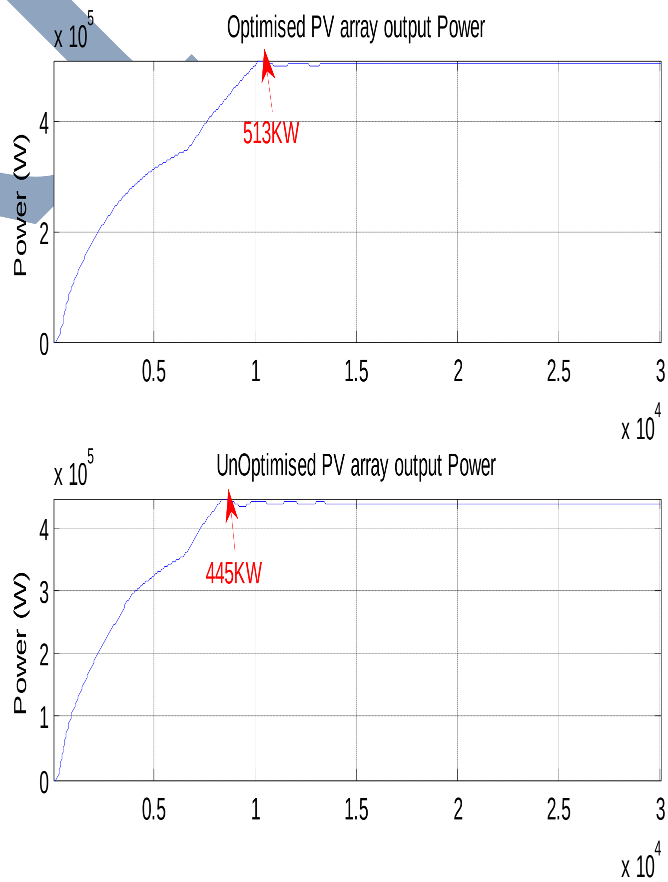
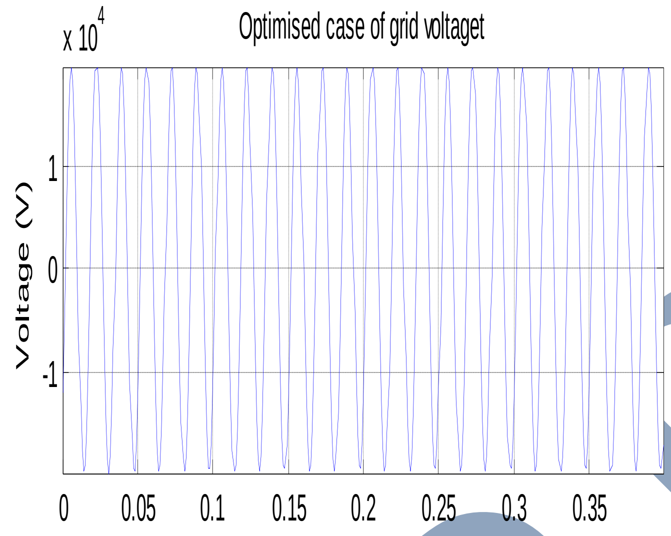


Figure 5.5: Comparison of Optimized and unoptimised power

Table 5.2: BFO parameters used for optimisation

No of bacteria	26
No of chemotactic steps	50
Searching dimension	2
Length of swim	4



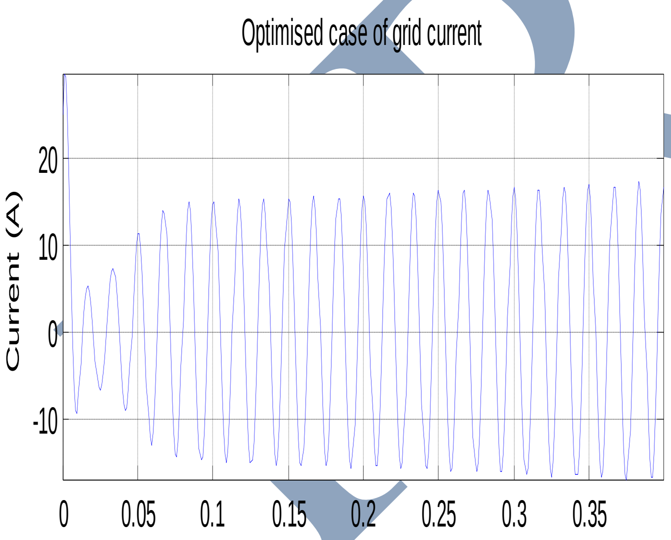


Figure 5.6: voltage and current at utility grid in case of optimized duty cycle.

Figure 5.7 clearly shows that the power reached at grid is also increased once optimization of duty cycle is done. Scale of figure 5.7 along Y axis proves above said. Before optimization the duty cycle was settled to 0.5 unit but after optimization it has changed to 0.5466 as shown in figure 5.4 and 5.5. Thus maximum power is always tracked by P&O algorithm which is online method and efficiency of P&O is increased by bacterial foraging optimization (BFO) which is offline MPPT control technique.

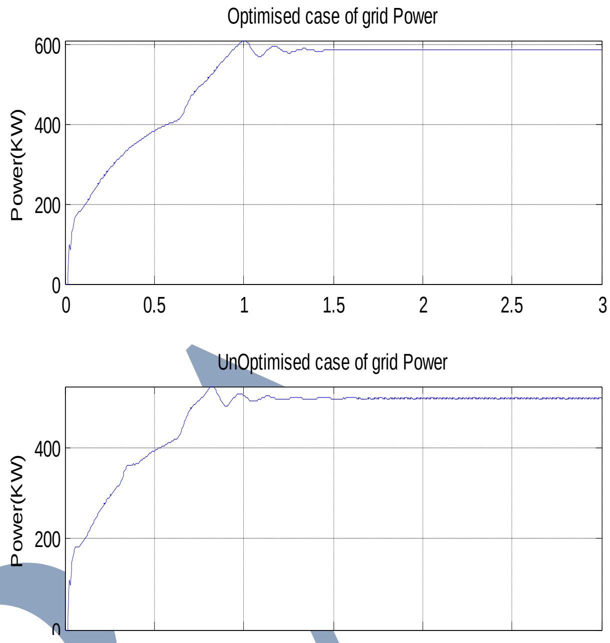


Figure 5.7: Power at utility grid in both cases

V. CONCLUSION

In this paper, the study of the photovoltaic system with maximum power point controller has been developed. From the theory of the photovoltaic, a mathematic model of the PV has been presented. Then, the photovoltaic system with DC-DC boost converter, maximum power point controller and utility grid has been designed. Finally, the system has been simulated with Simulink MATLAB. First, the simulations of the PV panels showed that the simulated models were accurate to determine the characteristics voltage current because the current voltage characteristics are the same as the characteristics given from the data sheet. In addition, when the irradiance or temperature varies, the PV models output voltage current change. Then, the simulation showed that Perturb and observe algorithm can track the maximum power point of the PV, it always runs at maximum power no matter what the operation condition is. The efficiency of P&O algorithm is increased by bacterial foraging optimization (BFO). It optimize the output duty cycle of P&O which is further used as input to the boost converter. Finally, the PV performance and the maximum power point were analyzed. The results showed that the maximum power generated by PV array can be tracked more efficiently by using bacterial foraging optimized perturbation and observation algorithm which is used to control the duty cycle of boost converter.

Further work

Extensive simulation of the PV system should be done. A voltage control can be implemented to keep the boost converter output voltage constant. The simulation of the PV with three-phase inverter and current control can be performed. The current control will regulate the current that will be injected to the load. In case of grid connected PV system, synchronization to the grid can be added. Adding a phase locked loop to the system is an intriguing study to determine the performance of the grid connected PV.

Finally, a laboratory setup should be made to verify the simulation results with the experimental tests. Further studies can still be done with PV system for research purposes and the detailed PV simulator can be used for educational purposes.

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