International Journal of Applied and Advanced Scientific Research (IJAASR)
Impact Factor: 5.655, ISSN (Online): 2456 - 3080
(www.dvpublication.com) Volume 6, Issue 1, 2021

AN OPTIMIZED BLACK WIDOW OPTIMIZATION BASED DC-DC CONVERTER FOR PHOTOVOLTAIC GRID SYSTEM

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Cite This Article: M. Nithya & Dr. S. Anbarasi, "An Optimized Black Widow Optimization Based DC-DC Converter for Photovoltaic Grid System", International Journal of Applied and Advanced Scientific Research, Volume 6, Issue 1, Page Number 29-34, 2021.

Abstract:

This project presents an approach to efficiency optimization in digitally controlled Busk-Boost DC–DC converters over wide ranges of operating conditions. Efficiency is characterized and optimized based on power loss modeling and multivariable nonlinear constrained optimization over power-stage and controller parameters. A valley switching technique is adopted to reduce MOSFET turn-on switching loss in discontinuous conduction mode. An optimization BWO procedure is formulated to minimize power loss weighted over a range of operating points, under a cost constraint. A lookup table-based digital controller is applied to achieve on-line efficiency optimization by BWO programming switching frequencies and operating modes based on the efficiency optimization processes.Another advantage of the developed algorithm that it could work with fixed and adaptive step-size.Although the superior performance of the proposed BWO-MPPT algorithm, working with variable switching frequency uneased the optimum design of the power converter. Both simulation and experimental results are consistence and agreed with the analytical analysis.

Key Words: Efficiency optimization, Busk-Boost, Stability

1. Introduction:

The goal of this project is to design, build, demonstrate, and evaluate a novel, direct-current (DC) converter for use in for PV power system applications, with several advantages when compared to the current state-of-art. The system designed in this thesis will serve as part of a residential-scale, or small commercial, PV power system. The interface for the PV modules and inverter will be addressed as part of the design process. A provision for including optional energy storage will be considered as well, although the actual incorporation of energy storage is outside of the scope of this project. MPPT capability will be implemented as part of the converter design, in order to maximize energy capture. The design process will include performing mathematical modeling and simulation, with analysis made with simulation software such as PSIM and Matlab-Simulink. After completing the modeling and simulation study, the converter will be implemented in hardware and evaluated.

2. Literature Survey:

[1]This paper discusses a shunt active filter intended for installation on a power distribution system. The active filter has an additional capability to regulate the distribution line voltage by means of adjusting reactive power. Theoretical analysis investigates the dynamic performance of combined harmonic damping and voltage regulation. As a result, harmonic damping makes it possible to improve the stability of the control loop for voltage regulation, and the combined harmonic damping. The system with control scheme is implemented in Matlab/Simulink. The simulation results are shown to verify the effectiveness of the combined harmonic damping and voltage regulation. [2]This article discusses the issue of reactive power and higher harmonic compensation by means of classic systems based on capacitor batteries and modern power electronics dynamic systems of the VSI and EFA type. The author, through the process of evaluating advantages and disadvantages, is strongly in favour of the modern dynamic solutions and underlines their benefits and usability in the attempts aimed at improving the quality and efficiency of electric energy usage.

[3]This Paper discusses power quality gains its importance with the introduction of sophisticated electrical gadgets. The performances of these devices are sensitive to the quality of input power supply. Various power quality problems results in failure or mal-operation of end user equipment. Some of the major power quality issues are voltage sag, voltage swell and harmonics. To solve these problems, capacitors, voltage regulators and filters, are conventionally used. These techniques involve inherent drawbacks. So it is proposed to use Flexible AC Transmission System (FACTS) devices for the mitigation of power quality problems. With the usage of these devices, drawbacks associated with conventional methods can be overcome easily. The application of FACTS devices provides faster control and enhances the way of using the transmission system at their rated thermal capability. In this work, it is proposed to use Static Var Compensator (VSI) for mitigating voltage sag and harmonics by providing proper reactive power support.

3. Proposed Method:

The general idea Control BWO is to create a closed loop controller with parameters that can be updated to change the response of the system. The output of the system is compared to a desired response from a reference model. The control parameters are update based on this error. The goal is for the parameters to converge to ideal values that cause the plant response to match the response of the reference model. For example, you may be trying to control the power factor of a load. You actually want the control output voltage to make quick corrections without power loss. Using BWO, you could choose a reference model that could respond quickly to a step input with a short settling time.

3.1 Block Diagram of the Proposed System:

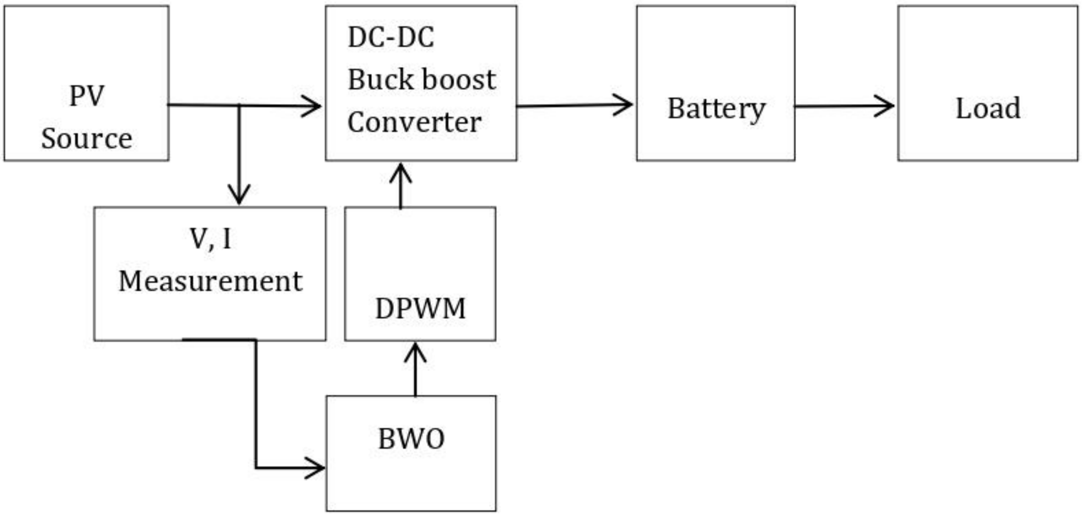

Figure 1: BWO Flow Chart

3.2 Pv Panel:

The solar panel is the power source of all photovoltaic installation. It is the result of a set of photovoltaic cells in series and parallel. In order to undertake its analysis, we begin from the study of a photovoltaic cell, main nucleus of the conversion of light to electrical current. Beginning from the electrical circuit that describes a cell, problems due to its association are analyzed.

3.3 Solar Off Grid & Cabin System:

A PVS consists of many components. These include solar cells, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

Due to the low voltage of an individual solar cell, several cells are combined into photovoltaic modules (commonly called solar panels), which are then connected together into a photovoltaic array.

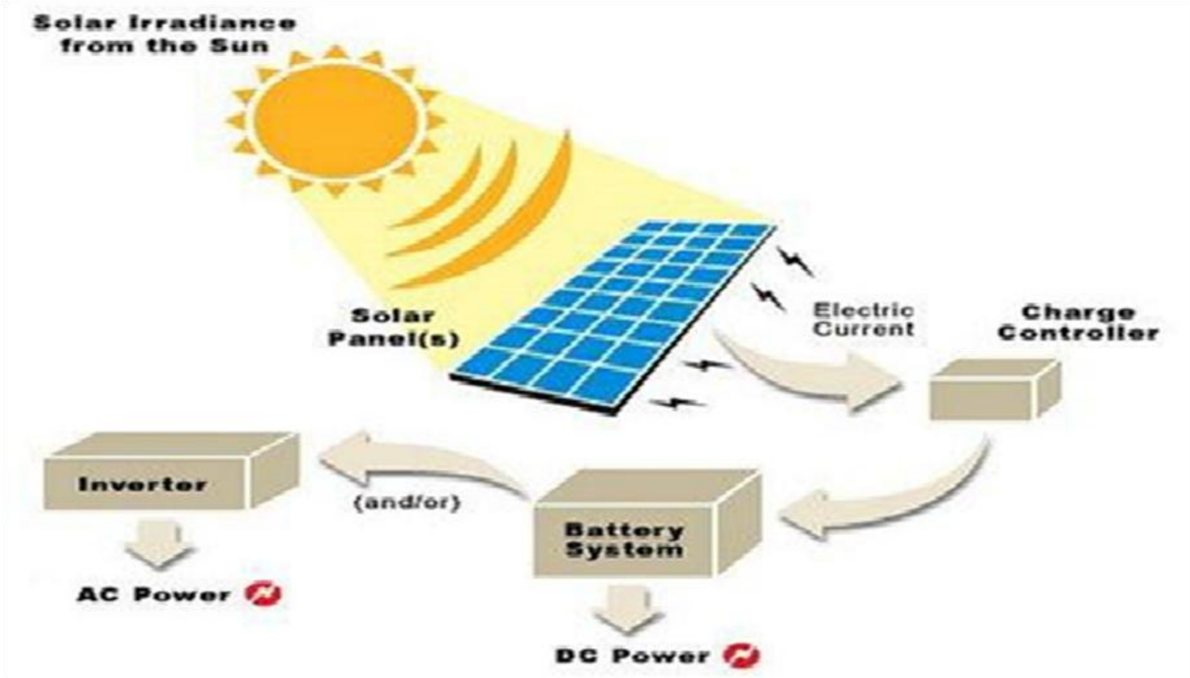

Figure 2: Simple PV System

The electricity generated can be used directly, stored or fed into a large electricity grid. A PVS may also be combined with domestic electricity generators to create a hybrid system. A photovoltaic system is generally designed in order to ensure the highest energy yield for a given investment.

3.4 Pv Modeling:

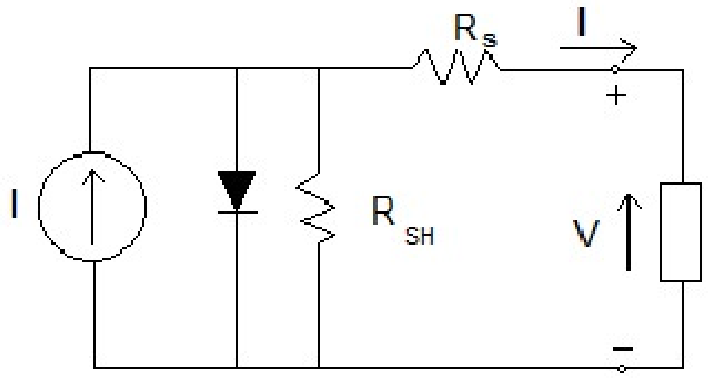

Figure 3: Single Diode Model of a PV Cell

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected into it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n top junction and parallel resistance is due to the leakage current.

In this model we consider a current source (I) along with a diode and series resistance (Rs). The resistance (RSH) in parallel is very high, has a negligible effect and can be neglected.

The output current from the photovoltaic array is

$$I = Isc - Id \quad (3.1)$$

$$Id = Io\,(eqVd/kT - 1) \quad (3.2)$$

Where Io is the reverse saturation current of the diode, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin.

From eq. 3.1 and 3.2

$$I = Isc - Io\,(eqVd/kT - 1) \quad (3.3)$$

Using suitable approximations,

$$I = Isc - Io\,(eq((V+IRs)/nkT) - 1) \quad (3.4)$$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor.

In order to model the solar panel accurately we can use two diode models but in our project our scope of study is limited to the single diode model. Also, the shunt resistance is very high and can be neglected during the course of our study.

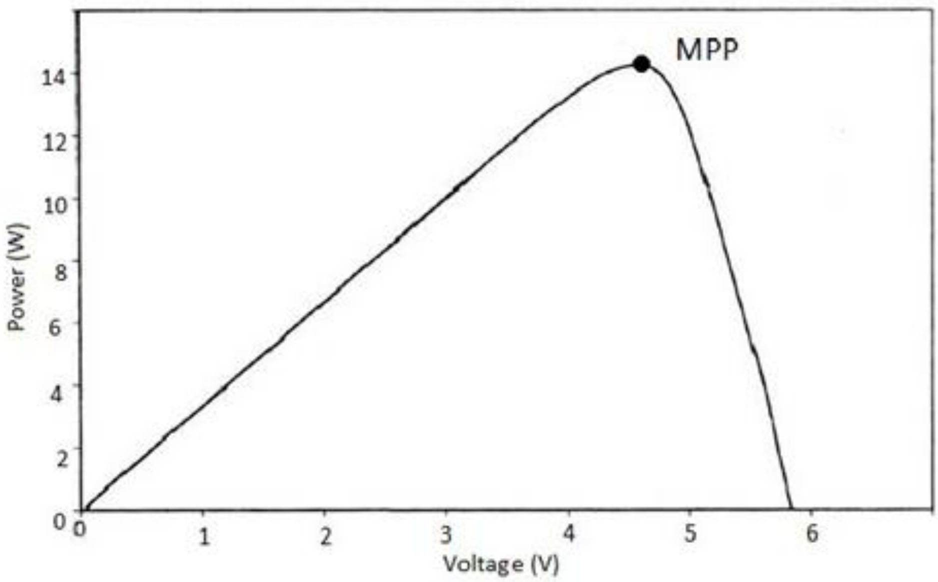

Figure 4: I-V Characteristics of a Solar Panel

When the voltage and the current characteristics are multiplied we get the P-V characteristics as shown in

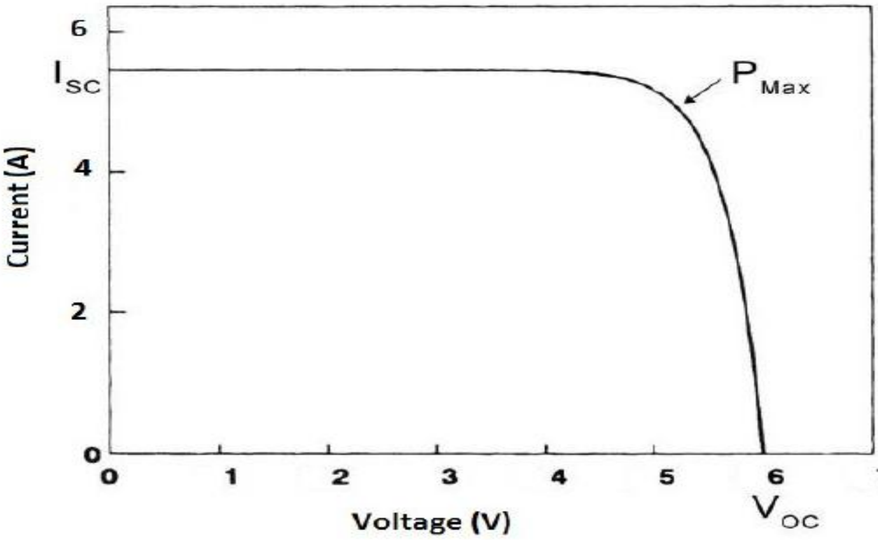

Figure 5: P-V Characteristics Curve of Photovoltaic Cell

3.5 Black Widow Optimization (BWO):

A new met heuristic optimization algorithm based on mating behavior of the black widow spiders, first proposed by V. Hayyolalam and A. Pourhaji Kazem in 2020, and has been used to solve different engineering and scientific problems owing to their easiness and flexibility. The Black Widow Optimization Algorithm (BWO) is inspired by the unique mating behavior of black widow spiders. This method includes an exclusive stage, namely, cannibalism. Due to this stage, species with inappropriate fitness are omitted from the circle, thus leading to early convergence. BWO algorithm is evaluated on 51 various benchmark functions and three real-world engineering optimization problems to verify its efficiency in obtaining the optimal solutions for the problems. The BWO algorithm has various main differences compared to other methods. Providing a good performance in exploitation and exploration stages, the BWO algorithm delivers fast convergence speed and avoids local optima problem. Moreover, it should be mentioned that BWO has the ability to maintain the balance between exploitation and exploration. In other words, it is able to inspect a large area to obtain the best global solution; hence, BWO will be a good choice for solving different optimization problems with several local optima

3.6 Stages of Black Widows' Life Style:

- Matting Process of black widow Spider
- Reproduction Style and Cannibalism
- Sibling Cannibalism

4. Results-Matlab Model:

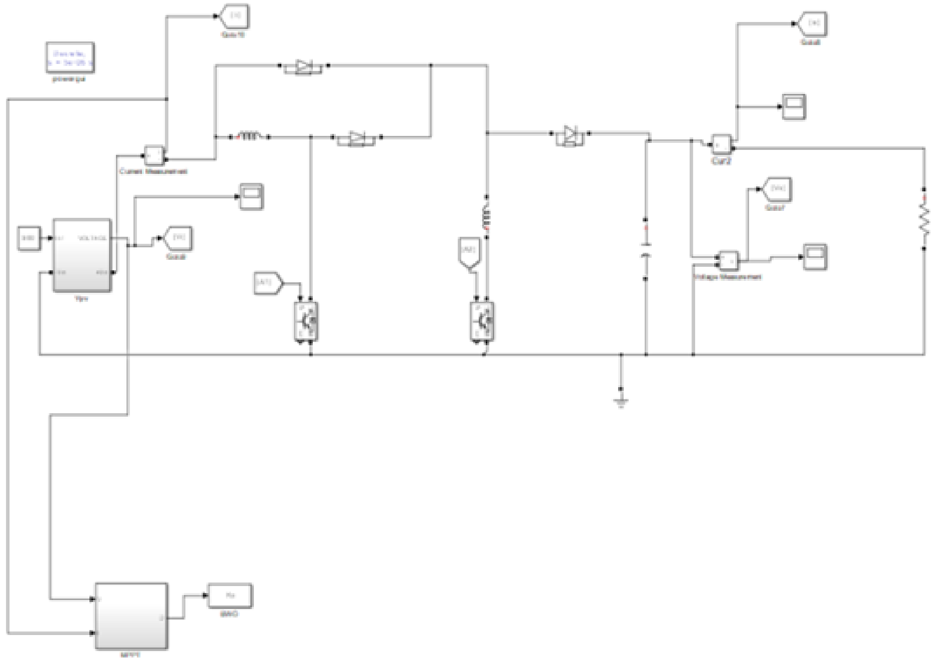

Figure 6: Operation Analysis of the Proposed DC-DC Converter

The obtained values are validated only through official data received from the producer of the PV Panel, and through data obtained from testing. The results of the other sources were obtained only through computerized simulation, of a model validated based on real data, without being validated through experimental measuring.

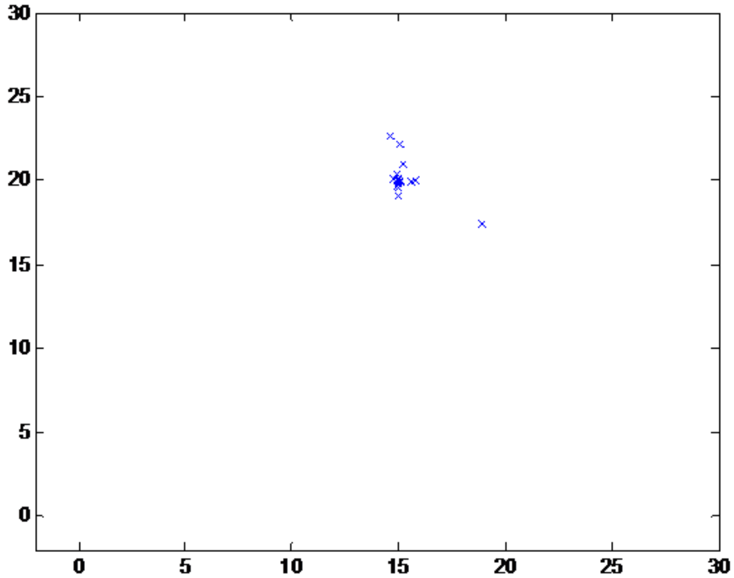

Figure 7: BWO Waveform

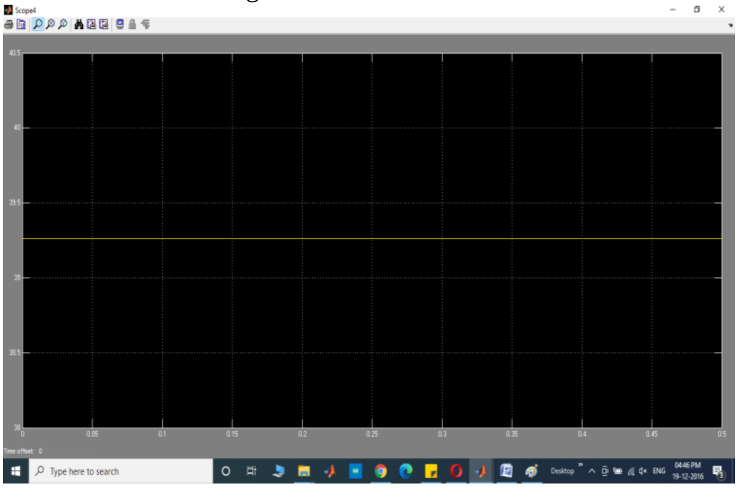

Figure 8: Input Voltage

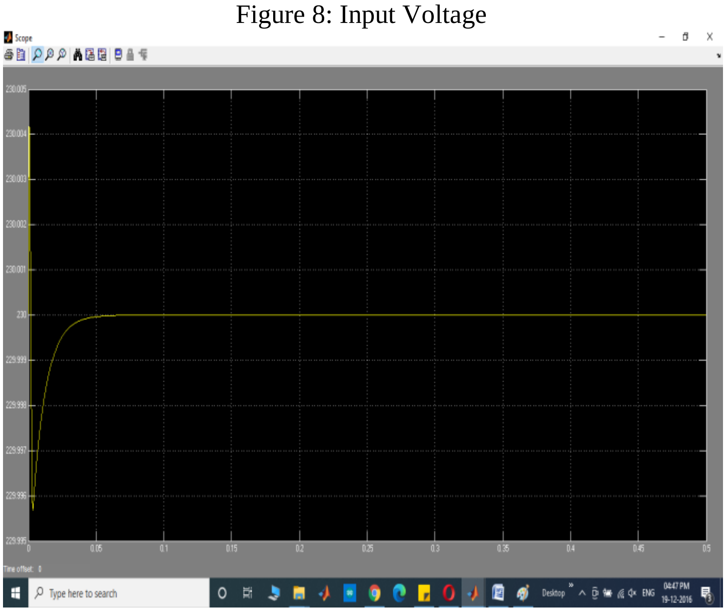

Figure 9: Output Voltage

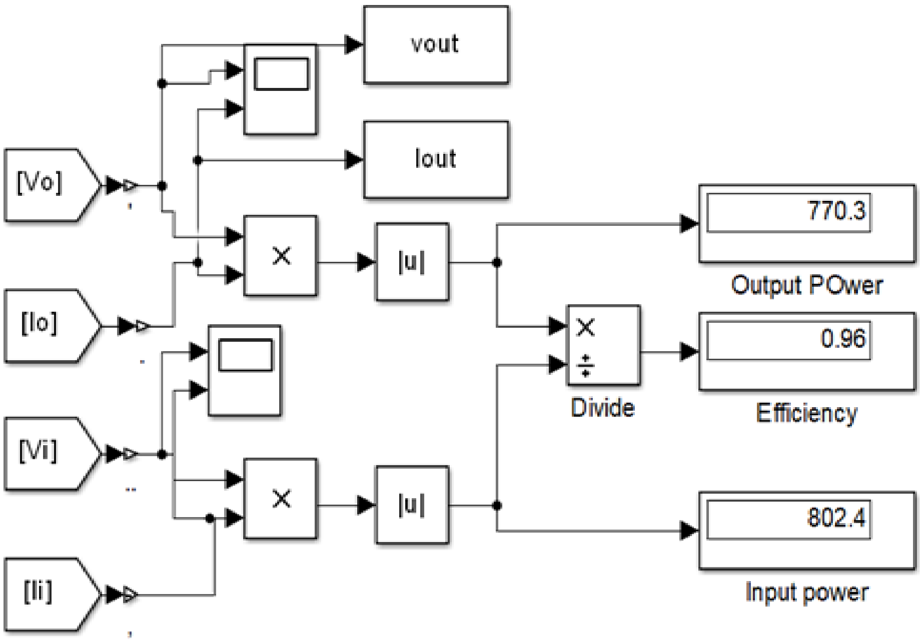

Figure 10: Output Efficiency

5. Conclusion:

The contribution of this project could be summarized as follows: Proposing and implementing a new high gain DC-DC converter for PV applications; Developing and implementing MPPT-BWO algorithm with optimum number of sensors for PV applications. The developed DC-DC converter was having superior advantaged over its transformer less counterparts as demonstrated through the manuscript. The developed BWO-MPPT algorithm, output voltage sensor has replaced by an observer to optimize the system cost and at the same time preserve the same performance. Another advantage of the developed algorithm that it could work with fixed and adaptive step-size.Although the superior performance of the proposed BWO-MPPT algorithm, working with variable switching frequency uneased the optimum design of the power converter. Both simulation and experimental results are consistence and agreed with the analytical analysis.

6. References:

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