PV-WIND Hybrid System Based Cuckoo Search Maximum Power Point Tracking Algorithm

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Abstract. The main goal of this project is to find a PV-Wind hybrid system's Maximum Power Point using Cuckoo search MPPT. The PV system and wind turbine based on a permanent magnet synchronous generator are both part of the proposal. Particle swarm optimization (PSO) and traditional MPPT algorithms (incremental conductance, P and O, and particle swarms) fail to keep up with rapidly changing environmental conditions. For this reason, an evolutionary algorithmic technique known as the Cuckoo Search Algorithm (CSA) is used to track down the optimal amount of power. The DC-DC step-up boost converters are utilized to apply to WIND and PV, with CS artificial intelligence method being used for each. The DC/DC converters increase the voltage of the 2 source after maximum power point tracking method suggested to the DC link or DC loads. The simulation results indicate the PV/WIND with CSA MPPT with constant irradiance and step changes in the irradiance.

Keywords: Incremental conductance · Perturb and Observe · PSO · Cuckoo Search Algorithm · Incremental conductance (IC) · PV · Wind · DC-DC boost converter

1 Introduction

It's no longer a possibility to generate all of your electricity from coal or nuclear power plants. There has been a rise in the usage of solar photovoltaic's (PV) for electricity generation due to depletion of fossil fuel supplies and growing concern about the environmental impact of fossil fuel consumption. The electricity generated by photovoltaic (PV) systems is a low-maintenance, environmentally friendly option. PV modules' ability to generate electricity is dependent on a variety of variables, including temperature, solar irradiation, and amount of shade [1]. The voltage-current (V-I) characteristics of PV modules are non-linear. PV modules have a voltage-power characteristic curve (V-P) with a single maximum power point (Pmax). MMP fluctuates in response to changes in the surrounding environment. As a result, the power given to the load is reduced to its highest possible level. "In order to match the characteristics of the PV module with the

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load and minimize power loss, MPPT is utilized" [1, 2]. When a DC-DC converter is used between the load and the PV modules in a PV system, the MPPT controller comes in useful. Several MPPT strategies are documented in the literature for use in various photovoltaic applications to extract the maximum power from the PV modules. There are a number of MPPT approaches that are routinely utilized, including Perturb and Observe, Fractional Short Circuit Current, and Incremental Conductance. Fuzzy logic, Artificial Neural Networks (ANN), and Particle Swarm Optimization (PSO) are some of the more advanced soft computing-based MPPT algorithms. "MPPT algorithms differ in a variety of ways, including: effectiveness, complexity, the number of sensors required, the ease of hardware implementation, and the speed of convergence, among others" [3]. Since it's simple, easy to apply, and reliable, the P&O MPPT method is the most commonly utilized MPPT method. However, there are two fundamental drawbacks to this approach: To begin with, when one gets closer to the MPP, the output power oscillates endlessly, resulting in a drop in energy yield. It also loses energy because it can't keep up with rapidly changing irradiance, leading the operating point to move farther from the Maximum power point and lose efficiency Soft computing-based MPPT approaches are becoming prominent as a solution to these issues [4]. It is possible to track MPP using two simple meta-heuristic algorithms, such as Particle Swarm Optimization (PSO) or Cuckoo Search (CS). GMPP can be extracted using MPPT algorithms even when there is some shade (PSC). GMPP location does not have to be identified using these approaches [5].

"Rezk et al." [6] Looked at PSO and CS data. MPP tracking strategies were evaluated in MATLAB with and without partial shading. In comparison to incremental resistance, the convergence of PSO and CS to MPP was much rapid. Because it required less time to track, the CS-based tracker beat out the PSO. To compare the MPPT technique's findings with those of other MPPT methods, Mosaad et al. [7] used computer simulations (CS). With different conditions, it was discovered that CS had the most power when compared to IC and ANN. Upon approaching MPP, the output power remained stable. Traditional MPPT approaches (IC, P&O) in PV systems were compared to PSO by Koad and Zobaa [8], who found that the former was superior. Cuk converter in MATLAB is used to implement these MPPT algorithms in order to compare their accurateness, speed of tracking, price. In simulations, it was discovered that PSO has the ability to precisely track MPP regardless of the situation. In comparison to other approaches, it has a higher tracking efficiency. Comparing it to IC and P&O, it also has a faster convergence time and is easier to implement. Cuckoo search for MPP tracking in a photovoltaic scheme were carried out by Ahmed and Salam [9]. The outcomes were compared to those of the standard P&O procedure. Simulated results revealed that even in altering atmospheric conditions with no steady-state oscillations in progress, the CS technique follows the MPP fast and accurately. Despite the fact that renewable energy is a new concept, it has unpredictable results. Its erratic supply necessitates the use of backup power sources like batteries [10]. Renewable energy resources are intermittent, therefore adopting just one result in larger components, additional operational and lifetime costs, and other drawbacks [11]. A hybrid energy system compensates for the shortcomings of each particular energy resource by combining two or more types of energy resources. Consequently, the design objectives for a hybrid power system are to minimize the cost of power production, minimize the cost of obtaining electrical energy from the grid and to reduce emissions while also lowering total life cycle costs [2, 10, 11]. The "hybrid renewable energy system" (HRES), which combine two or more RESs to produce more stable and higher-quality power, is becoming more popular because the sources complement one another. This study proposes and tests a hybrid PV-WIND system based on Cuckoo Search MPPT in the Simulink environment.

2 Proposed System

The suggested system consists PV model with boost converter and wind model with boost converter and these DC/DC converters controlled by use CSA-based maximum power point tracking the overall block diagram shown in Fig. 1. Finally, use artificial intelligence-based approaches like the CSA-based maximum power point tracking control algorithm to determine the maximum power point from all the individual modules. Better results and less variation around the maximum power point are obtained using this method (MPP).

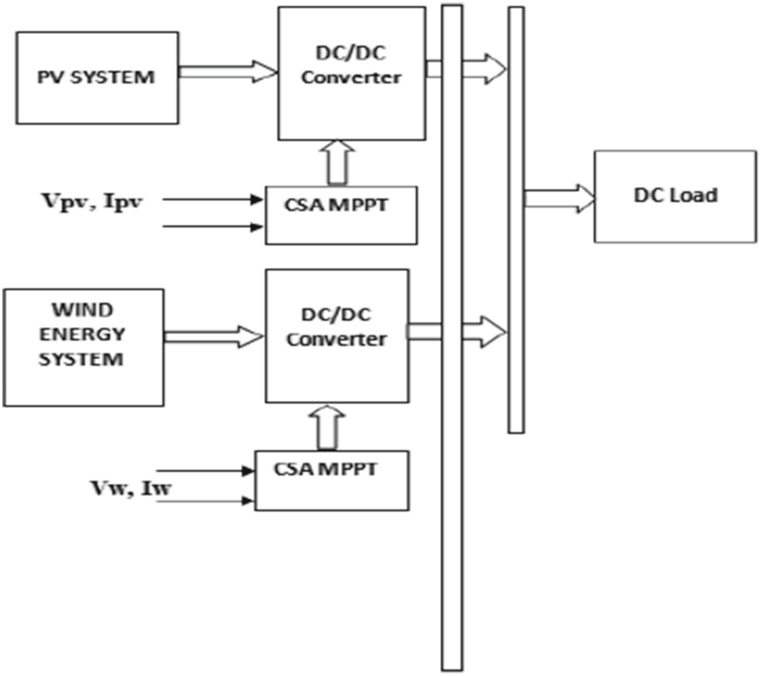

Fig. 1. Block diagram of a suggested hybrid system

2.1 Modeling of PV Panel

The PV (Photo Voltaic) cell equivalent circuit is shown below. The solar cell is treated with the current source and diode in parallel connected.

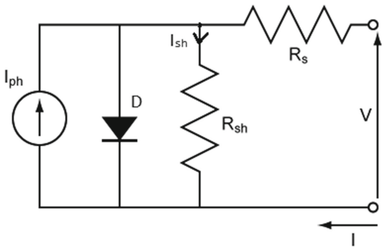

Fig. 2. Solar PV module equivalent circuit

From Fig. 2, apply KCL (Kirchhoff's Current Law), then

$$I_{ph} = I_d + I_{sh} + I \tag{1}$$

$$I = I_{ph} - (I_{sh} + I_d) \tag{2}$$

We have [6] following equation for Solar cell current,

$$I = I_{ph} - I_o[e^{q(V+I.Rs)/nkT)} - 1(V + IR_s)/R_{sh} \tag{3}$$

where V_T represents Terminal Voltage
I_{ph} denotes isolation current
V represents the cell voltage
I represent cell current
I_o denotes reverse saturation current
R_{sh} is Shunt Resistance
R_s denotes Series Resistance
q represents elementary charge
n denotes diode ideality factor
T represents absolute Temperature
K denotes Boltzmann's constant

2.2 Wind Turbine Modeling

Wind generator turbine rotates which is coupled to an alternator generates electrical energy. Electric power magnitude [6] of speed changes with a given turbine is described as:

$$p_w = \frac{1}{2}\frac{m.v_w^3}{t} = \frac{\frac{1}{2}\rho.A.d.v_w^3}{t} = \frac{1}{2}\rho.A.v_w^3 \tag{4}$$

where V_w = wind speed (distance/time) (m/s)

P_w = Wind Power (W)

ρ = Air density (kg/m^3)

A = Area swept by the turbine blades (m^2)

d = radius of the swept area of blades (m)

m = mass of the air

m = air density X volume = ρ.A.d (Kg)

The generated mechanical power is expressed by [5]

$$p_m = p_w.c_p(\lambda, \beta) = \frac{1}{2}\rho.A.v_w^3.c_p(\lambda, \beta) \tag{5}$$

Here C_p denotes power coefficient

λ represents tip speed ratio of the rotor blade

tip speed to wind speed

β represents the pitch angle

The power coefficient of the turbine is expressed by

$$c_p = c_1(\frac{c_2}{\lambda_i} - c_3\beta - c_4)e^{\frac{-c_5}{\lambda_i}} + c_6\lambda \tag{6}$$

where,

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \tag{7}$$

And also

$$C_p = \frac{P_m}{P_w}; C_p < 1 \tag{8}$$

$$P_m = C_p.\frac{\rho.A}{2}v_w^3 \tag{9}$$

The power produced P_m depends on the magnitude of C_p. The C_p is defined as a ratio of electric power generated by wind generator turbine to mathematical wind generator power.

TSR denotes relation among wind speed angular speed which is expressed by

$$\lambda = \frac{\omega \cdot d}{V_w} \tag{10}$$

Here ω is the rotor speed expressed in rpm.

For a gearless wind turbine, the mechanical torque is expressed as

$$T_m = P_m\frac{d}{\lambda V_w} = 1/2 \text{ p. A. Cp } (\lambda,\ \beta)\frac{R}{V_w} = \frac{P_m}{W} \tag{11}$$

3 Boost Converter

Boost converter is also known as step-up DC/DC converter. The boost converter contains inductor, MOSFET, diode and capacitor and circuit of boost converter as indicated in Fig. 3.

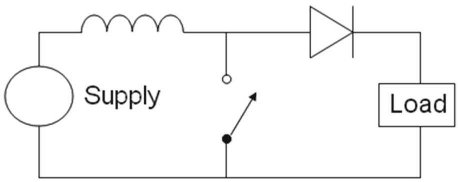

Fig. 3. DC/DC step-up (Boost) converter

There are 2 operating condition.

When Switch is "ON" Position the current at the inductor can be written as Eq. (12).

$$\Delta i_L(ON) \overset{0<t<DT}{=} \frac{V_S}{L} DT \tag{12}$$

When Switch is "OFF" Position the inductor current can be wrote as (13).

$$\Delta i_L(OFF) \overset{DT<t<T}{=} \frac{V_S - V_O}{L} DT \tag{13}$$

Obtaining the output voltage is Eq. (12) is equal to Eq. (13) i.e.

$$\frac{V_S}{L} DT + \frac{V_S - V_O}{L} DT \overset{\Delta i_L(ON)+\Delta i_L(OFF)=0}{=} 0 \tag{14}$$

By solving the Eq. (15) we can get the output voltage

$$V_O = \frac{1}{1-D} V_s \tag{15}$$

4 CSA (Cuckoo Search Algorithm) MPPT

It is based on the Cuckoo bird's method of brood parasitism (laying eggs in another bird's nest). For the most part, CS is governed by three simple principles: A single egg will be laid by each individual cuckoo, and it will be placed in a nest that is chosen at random. As a result, the best nests with the best eggs will be passed on to future generations. If the statistic of appropriate nests is known in advance, the host bird has a probability of discovering a cuckoo-laid egg in one of those known nests of Pa, where Pa [0, 1]. Cuckoo birds symbolize particles tasked with finding a solution, while cuckoo bird eggs represent the current iteration process's solution. "To produce local maxima points, the CS algorithm uses the Lévy distribution, which reduces the amount of time it takes to reach the global maximum power point" [15]. Figure 4 depicts the CS [16] flow chart.

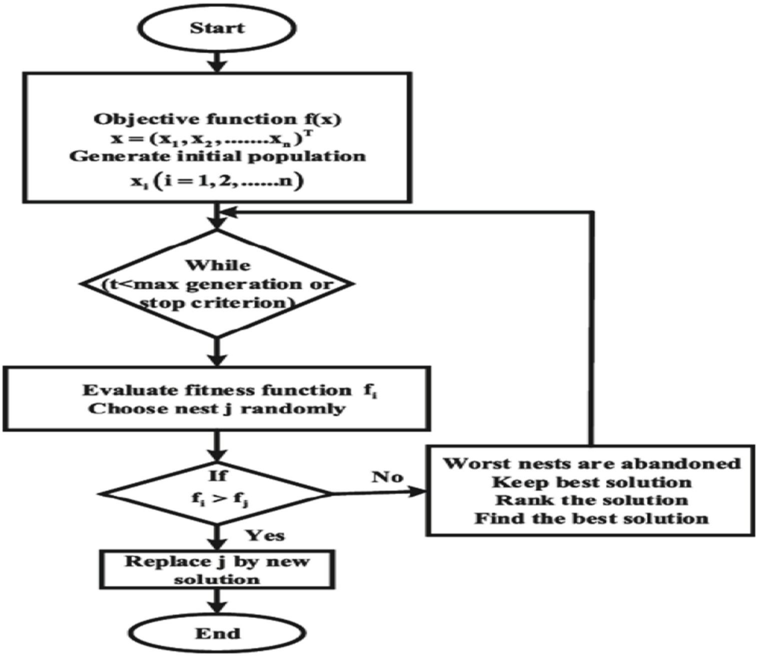

Fig. 4. Cuckoo search method flow chart

5 Simulation Results

5.1 PV with CS MPPT

Solar PV array parameters	Value
M_{aximum}	100 V
I_{Sc}	2.5 A
Optimum current (I)	5.75 A
Power is used by system (W)	250 W

Constant Irradiance

The below Fig. 7 shows the output power of PV system using Cuckoo MPPT at constant irradiance conditions Fig. 5 and 6 shows the PV voltage and PV step-up voltages.

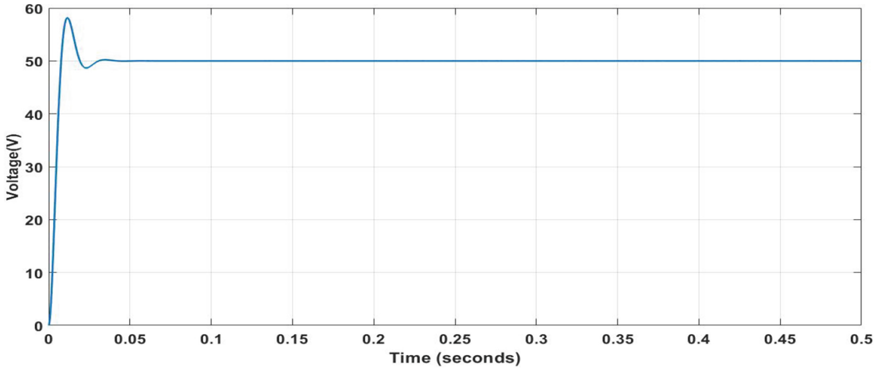

Fig. 5. PV voltage

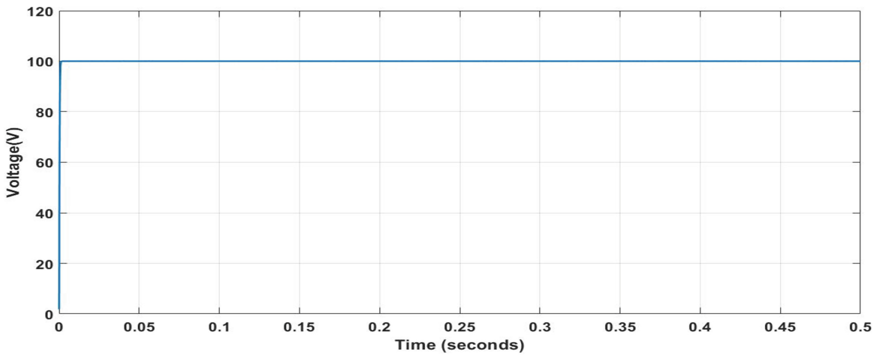

Fig. 6. PV boost voltage

Step Change in Irradiance

In this section, as the irradiation changes in steps, the recommended controller is evaluated to show its validity in tracking MPPs for PV, the Cuckoo Search controller able to track the maximum power of a PV as shown in Figs. 8 and 9.

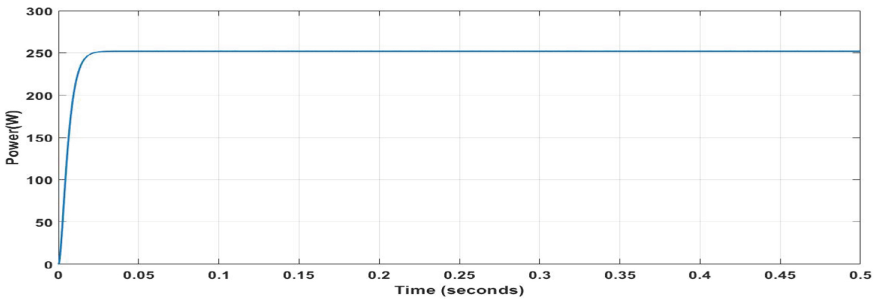

Fig. 7. PV power

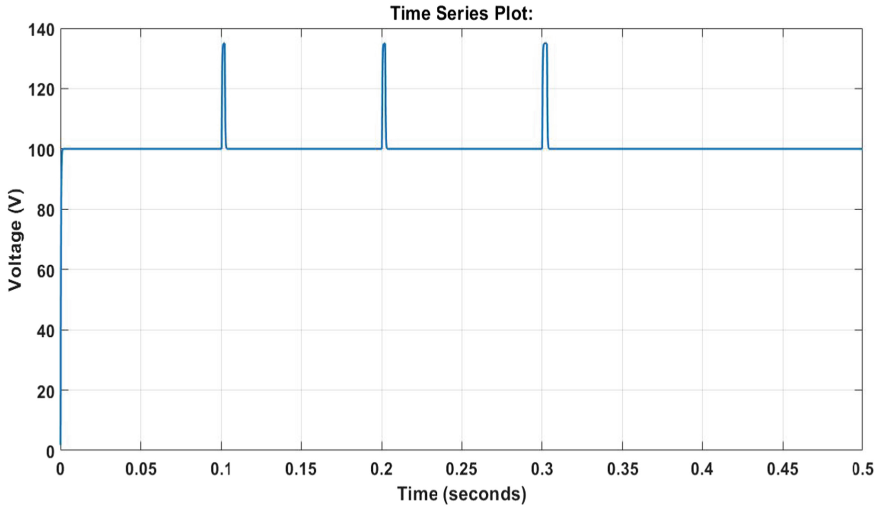

Fig. 8. PV boost voltage.

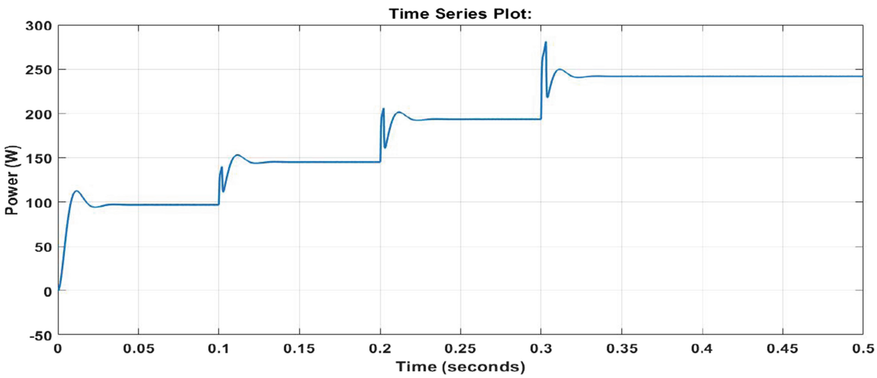

Fig. 9. PV power

5.2 WIND with CS MPPT

PMSG parameters	Value
Rated voltage(V)	100
No. of poles	2
Rated current (I)	3.5
Rated power (W)	275
Stator frequency (Hz)	12.15

The below Fig. 11 shows the output power of WIND system using Cuckoo MPPT (Fig. 10).

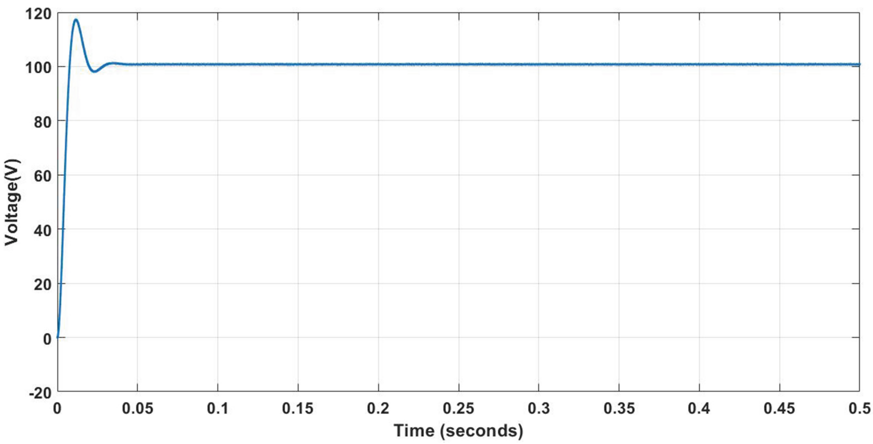

Fig. 10. WIND boost voltage

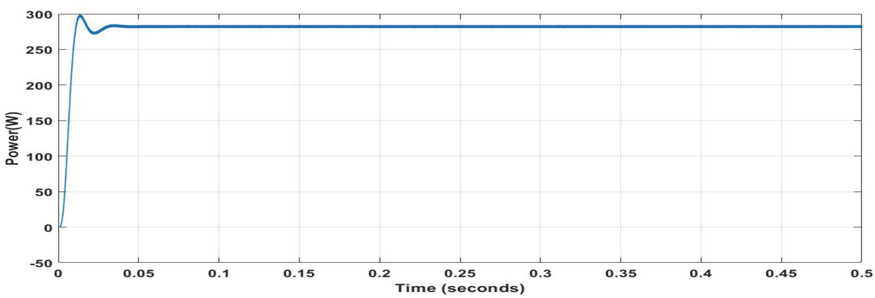

Fig. 11. WIND power

The Fig. 12 shows load voltage and Fig. 13 indicates the load power of hybrid scheme.

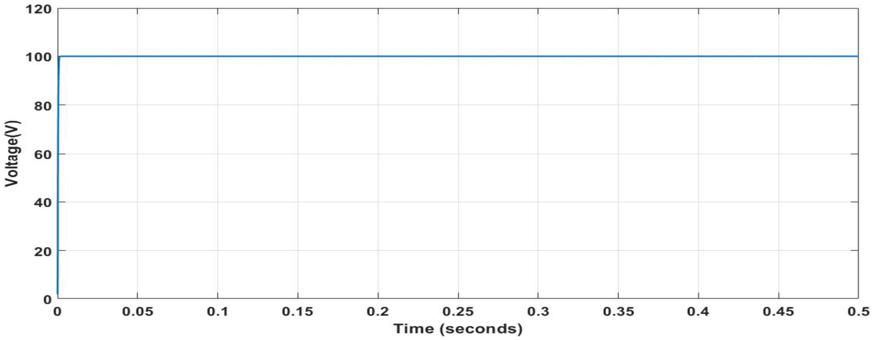

Fig. 12. Load voltage

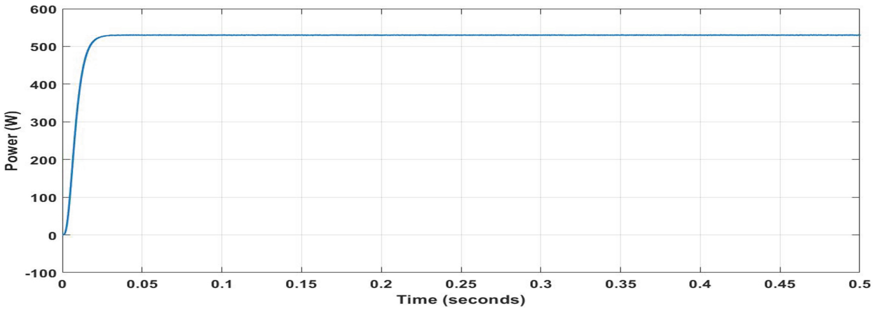

Fig. 13. Load power

6 Conclusion

In this chapter, a stand-alone Photovoltaic hybrid power system for remote power applications is constructed and modeled. The MATLAB/SIMULINK software package was utilized to implement the model, and a dialogue box similar to those found in SIMULINK block libraries was employed in its design. The amount of solar radiation a PV system can generate determines how much power is available. It was decided to connect the PV module with the wind turbine system in order to make up for the PV system's shortcomings. PV panels with 72 cells and a PMSG wind energy conversion system were used to test the dynamic behavior of the suggested model. In the proposed system the combined power from both sources (PVA and WF with Cuckoo MPPT) is 525 W. The DC link voltage is kept at 100 V in both systems. Further stabilization of the system is possible using adaptive circuit controllers, which improve system efficiency by reducing ripple and harmonics.

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