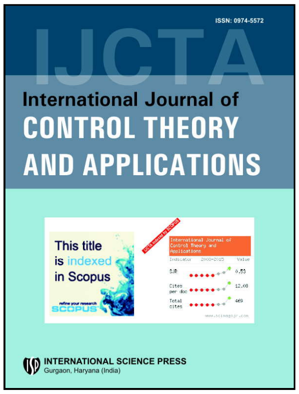

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Maximum Power Point Tracking Control Method for a Hybrid PV/WT/FC Renewable Energy System

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Abstract: The non-conventional energy sources possess a major problem of power reliability due to their dependencies on environment. Advance research and development in solar, wind, and other renewable energy sources are needed to solve the problem of power demand and reliability. The proposed hybrid system incorporates three renewable energy sources like photo-voltaic (PV), Wind Turbine (WT) and Fuel Cell (FC) systems working together to provide maximum power at dc-link. A vast deal of novel research is done for improving the efficiency of overall system using maximum power point tracking (MPPT) method. The perturb and observe (P&O) MPPT method have been used to analyse PV, WT and FC with dc-dc converters. The MPPT control method optimizes the output of proposed hybrid system with variable inputs to extract maximum power.

Keywords: MPPT, Perturb and Observe (P&O) Technique, PV, Wind Generator (WG), Fuel Cell (FC), DC-Link.

1. INTRODUCTION

Several types of non-conventional energy sources such as solar photo-voltaic (PV) and wind turbine (WT) are established in last decade. They are not only clean and abundant in nature but also well developed, cost effective and widely used. Apart from these sources, fuel cells (FC) are also been used to handle increasing power demand [1, 2]. The hybrid renewable energy system (HRES) provides an outstanding opportunity for distributed power generation. In the literature, there are a few studies related to energy management of hybrid power system [3]. Among them, Wang and Nehrir [4] proposed a power management strategy for an AC-linked hybrid wind/PV/FC energy system, Ahmed et al. [5] presented a power management strategy which studied power fluctuations in a hybrid PV/wind turbine/FC power system and Onar et al. [6] proposed a power management strategy algorithm which dealt with a hybrid PV/wind/FC power system containing an ultra-capacitor bank.

MPPT not only just empowers an expansion in the power conveyed from the PV module to the heap but also additionally upgrades the working lifetime of the PV framework [7]. A few MPPT strategies have been created and executed in references [8, 9].

The rest of the paper is organized as follows. Overview of Maximum Power Point Tracking is explained in section II. Proposed Hybrid Renewable Energy System is described in section III. Simulation Analysis of Proposed Hybrid Renewable Energy System in section IV. Results and Discussion in section V. Concluding remarks are given in section VI.

2. OVERVIEW OF MAXIMUM POWER POINT TRACKING

MPPT techniques are usually integrated with an electric power converter system, that provide voltage or current conversion, filtering and regulation, for driving various loads including power grids, batteries and motors. MPPT provides the I-V characteristics of a solar PV, WT and FC systems. The HRES provides maximum power only at one point. For extracting the maximum power from the cell, the operating voltage or the current should corresponds to the maximum power point (P_{max}) projecting V_m and I_m, respectively, under a given temperature and solar radiation [10, 11]. The dc-to-dc converter can be used for this purpose where resistance can be matched by changing the duty-ratio. Performance indices of MPPT technique for a specific application should be based on the efficiency of the MPP tracker, response time, peak overshoot, static and dynamic error, sensors needed and implementation complexity. All these parameters of the MPPT system are analysed in order to compare various renewable energy system. Efficiency is the most important parameter of an HRES.

3. PROPOSED HYBRID RENEWABLE ENERGY SYSTEM

A major importance in the theoretical study of hybrid system is the availability of models which can be used to understand the behaviour of the hybrid system and software environment. The hybrid system is more advantageous as compared to the individual power generation systems which are not completely reliable. When any one of the system is shutdown, the other can supply power. It is well known that renewable energy sources are attractive options for providing power to the locations where a connection to the utility grid is either impossible or unduly expensive. In the developing era of technology, demand for more energy makes one seek new energy sources. The most important application field of this search is the renewable energy resources. The Wind and solar energy are the popular ones because of abundance, ease of availability and convertibility to the electric energy. Block diagram of a hybrid power generation system is shown in Fig. 1. The HRES consists of eight accessories mentioned below:

(i) PV panels, to convert the sunlight into electricity (direct current). (ii) Wind turbine, to convert the kinetic energy from the wind into mechanical energy. (iii) DC generator, to convert the mechanical energy from

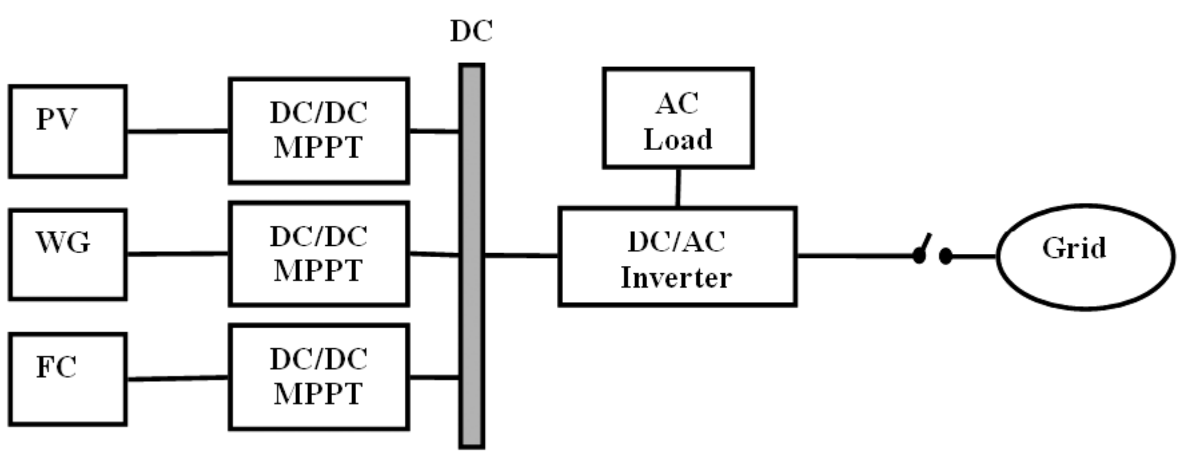

Figure 1: Block Diagram of a Proposed Hybrid Power Generation System

the turbine into electrical energy. (iv) Fuel cells, to act as a backup power source. (v) DC/DC converters, to step-up the dc voltage to a higher level dc voltage. (vi) DC/AC inverters, to generate ac waveform from the dc signal. (vii) The main controller, to ensure continuous power supply for the load demand.

4. SIMULATION ANALYSIS OF PROPOSED HYBRID RENEWABLE ENERGY SYSTEM

Simulation model using MATLAB/ SIMULINK™ of the proposed hybrid system consists of a wind turbine induction generator (WTIG), dc-dc buck, boost converters, PV, FC, P&O based MPPT technique, and resistive load. Table 1 shows the parameters of photovoltaic, fuel cell wind turbine, rectifier and buck converter, boost converter, induction generator and dc-link. Fig. 2 to Fig. 5 show the simulation diagram of hybrid system, PV model with boost converter, WTIG model with buck converter and FC model with boost converter using P&O based MPPT method and Fig. 6 shows the subsystem of proposed P&O technique.

Fig. 7 and Fig. 8 show the input power and input voltage characteristics before boost converter without MPPT controller, Fig. 9 and Fig. 10 show the output power and output voltage characteristics after boost converter

Table 1
Parameter used for Proposed Hybrid Renewable Energy System

Parameter	*Value*	*Parameter*	*Value*
PV Module		*Fuel Cell*	
Irradiations	1000 W/m^2	Number of cells	42
Temperature	27^{o}C	Nominal stack efficiency	46%
Series-connected modules per string	3	Operating temperature	55^o C
Parallel strings	1	Nominal air flow rate	2400 (lpm)
Wind Turbine		Nominal supply pressure	1.5 (bar)
Wind Turbine nominal Power	1.2e3 Watt	Nominal composition	99.95 H_2, 21 O_2 and 1 H_2O in (%)
Base wind speed	Ramp (1-12) m/s	Buck Converter	
Base rotation speed	1 (pu of base generator speed)	MOSFET Switch	1 No.
Maximum pitch angle	45 deg.	Diode	1 No.
Rectifier		Input Resistance	0.005 Ohm
Number of Bridge arm	3	Inductor	3mH
Carrier frequency	1080 Hz	Input Capacitor	0.02μF
Modulation index	0.4	Output Capacitor	470μF
Output capacitor	1000 μF	Boost Converter	
Frequency of output voltage	50 Hz	Inductor	3mH
Phase of output voltage	0 degrees	Output Capacitor	470μF
Induction Generator		MOSFET Switch	1 No.
Nominal power	1.2e3(VA)	Diode	1 No.
Line-to-line voltage	415 (V_{rms})	Input Resistance	0.005 Ohm
Frequency	60 Hz	Input Capacitor	0.02μF
Pairs of poles	3	Others	
Inertia constant	5.04	DC link	1000 μF
Friction factor	0.01	Load resistance	15 Ohm
Maximum rate of change of pitch angle	2 deg./s	PWM (carrier frequency)	10,000 Hz

with MPPT controller respectively for PV system. Fig. 11 and Fig. 12 show the input power and input voltage characteristics before buck converter without MPPT controller, Fig. 13 and Fig. 14 show the output power and output voltage characteristics after buck converter with MPPT controller respectively for WT system. Fig. 15 and Fig. 16 show the input power and input voltage characteristics before buck converter without MPPT controller, Fig. 17 and Fig. 18 show the output power and output voltage characteristics after buck converter with MPPT controller respectively for FC system. Fig. 19 and Fig. 20 show the output power and output voltage characteristics of hybrid system connected to resistive load.

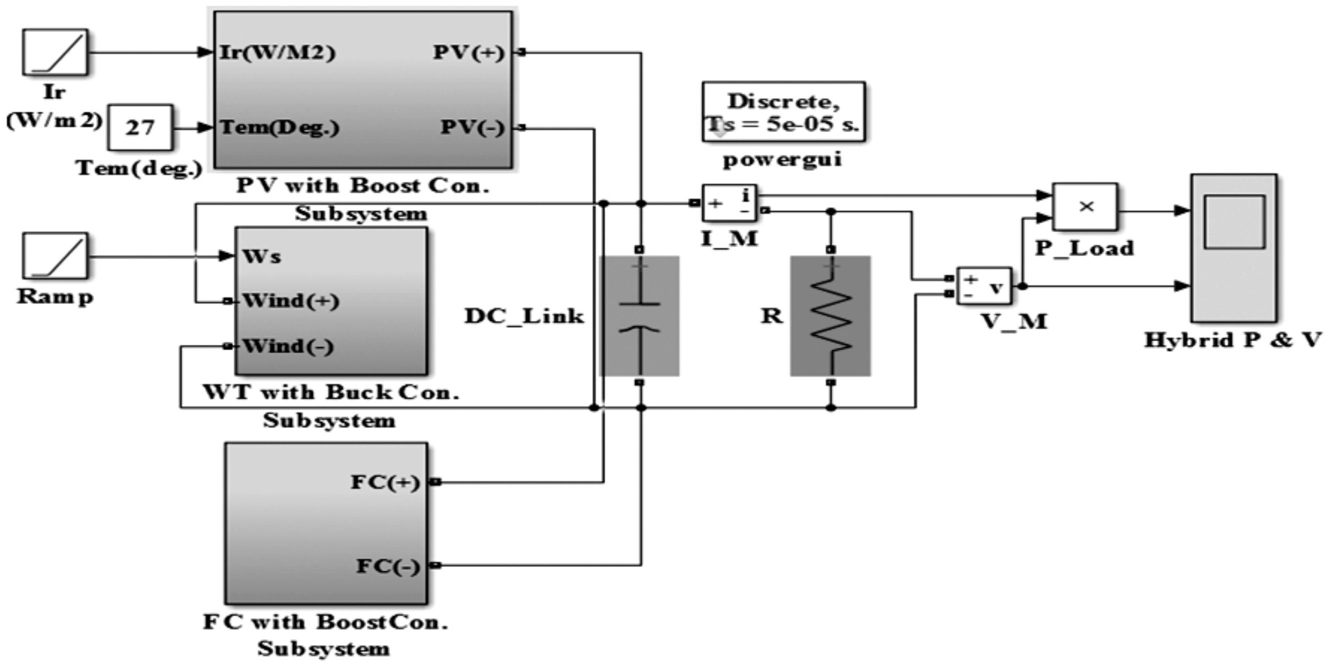

Figure 2: Simulation Diagram for Hybrid Wind-PV-FC System

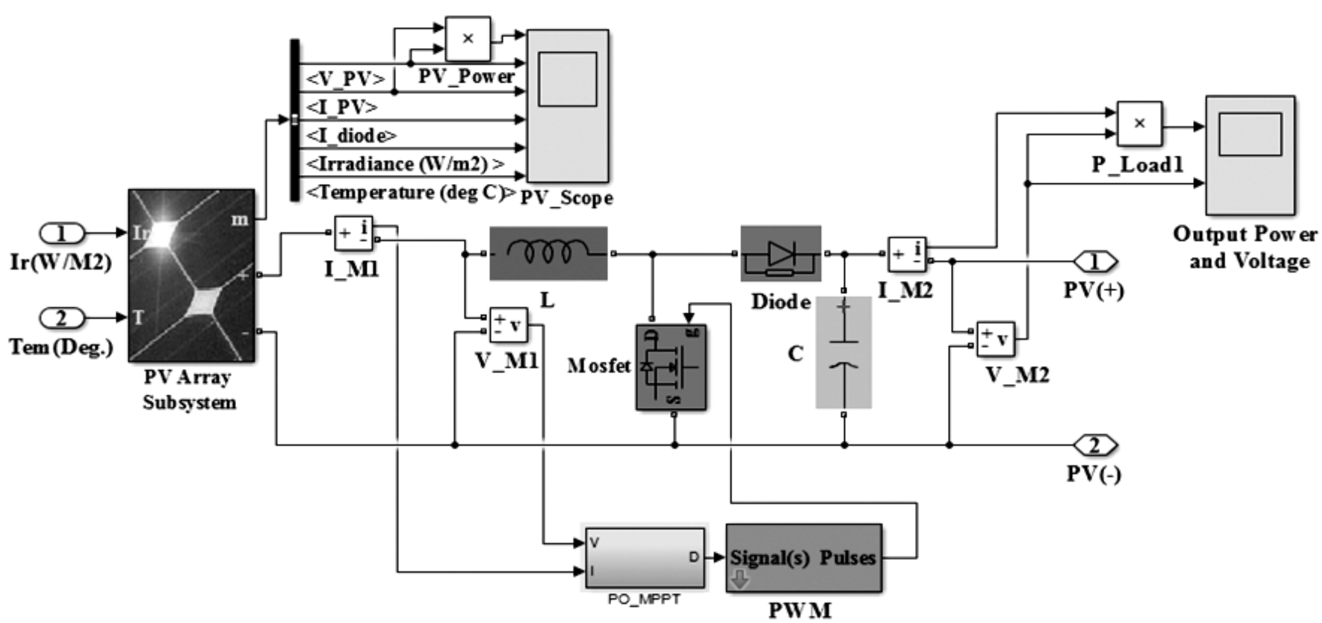

Figure 3: PV Model with Boost Converter and P&O Technique

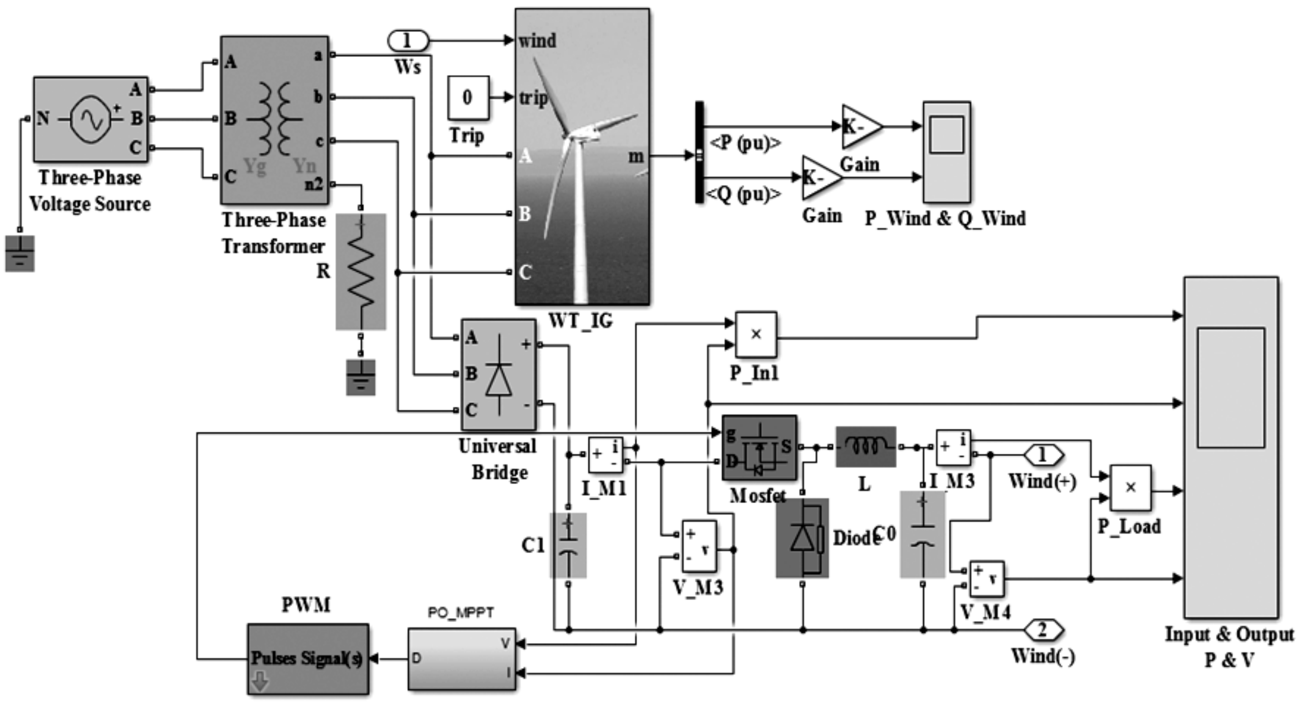

Figure 4: WTIG Model with Buck Converter and P&O technique

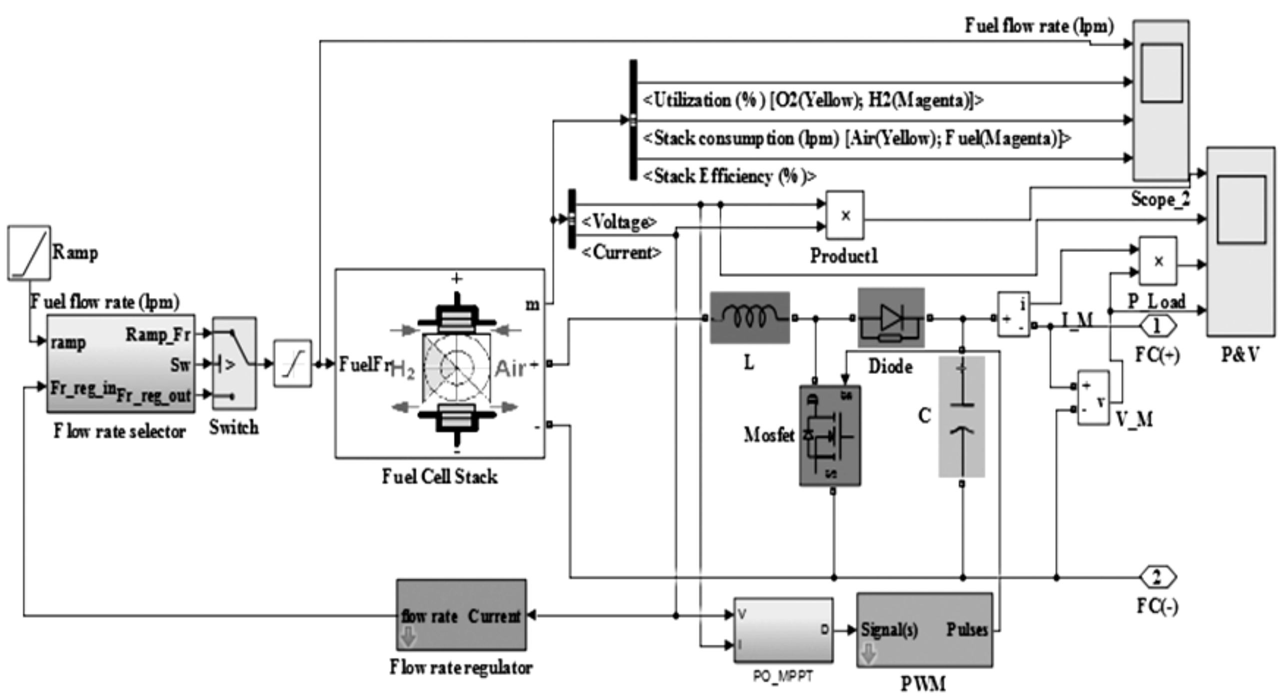

Figure 5: FC Model with Boost Converter and P&O technique

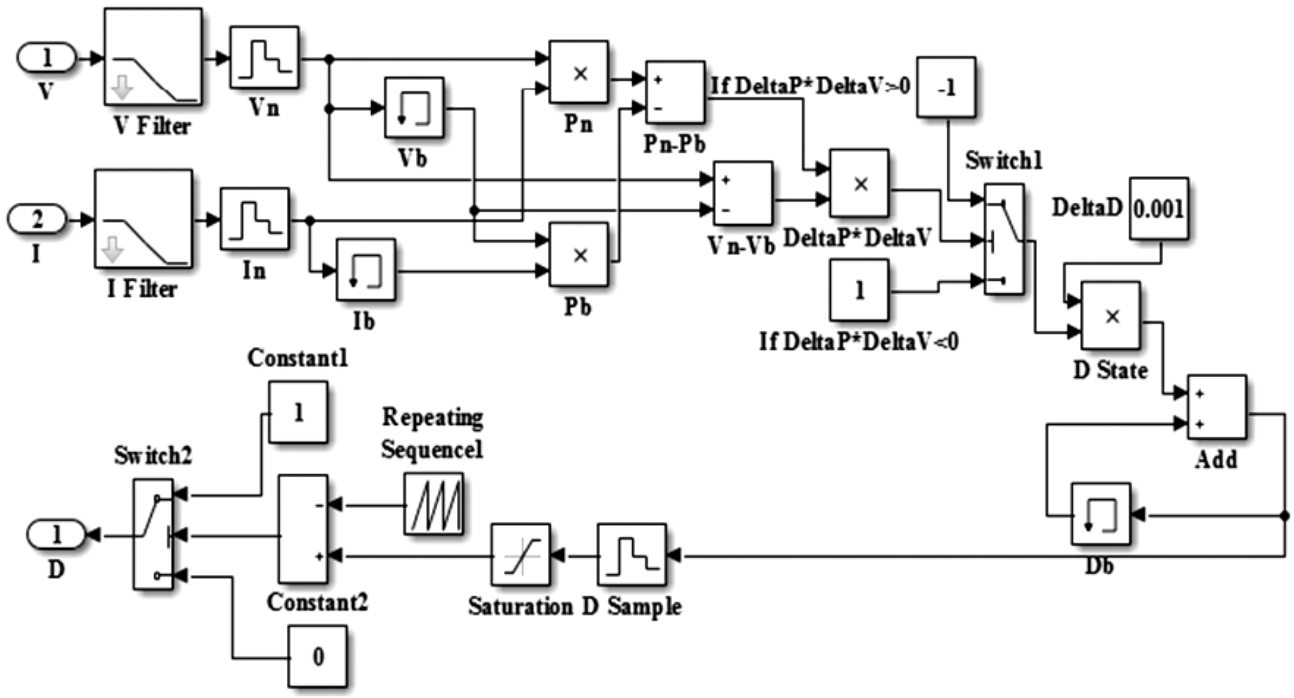

Figure 6: Subsystem of P&O Technique

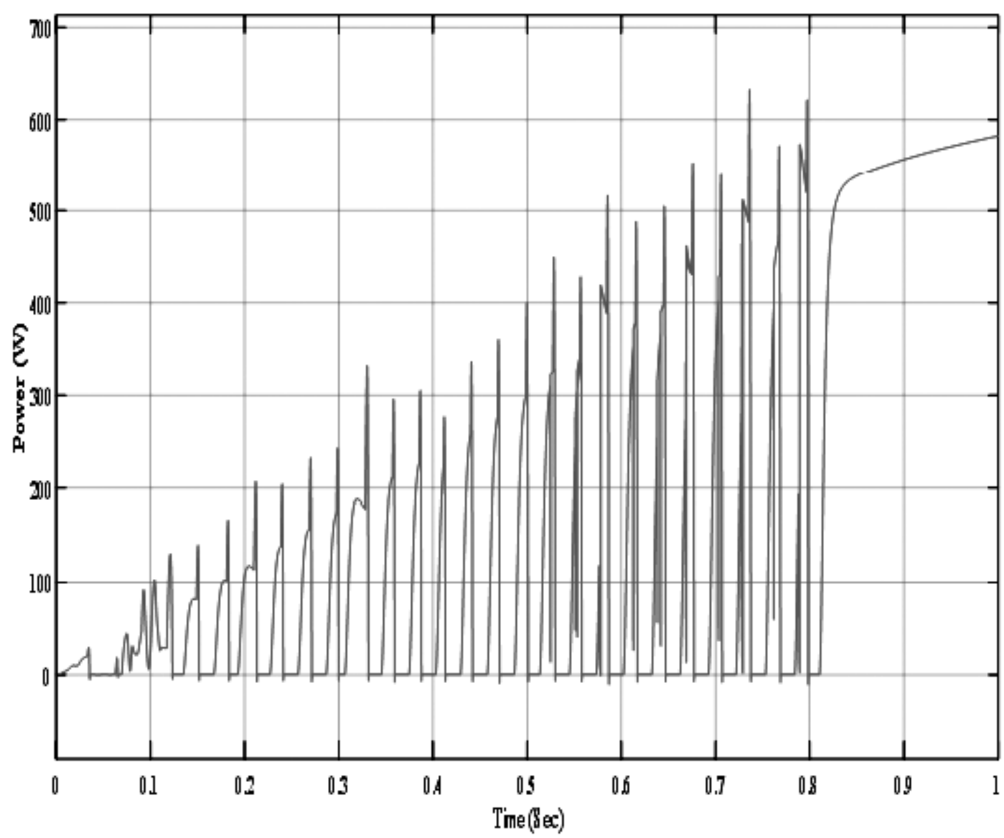

Figure 7: Input Power before Boost Converter without MPPT Controller

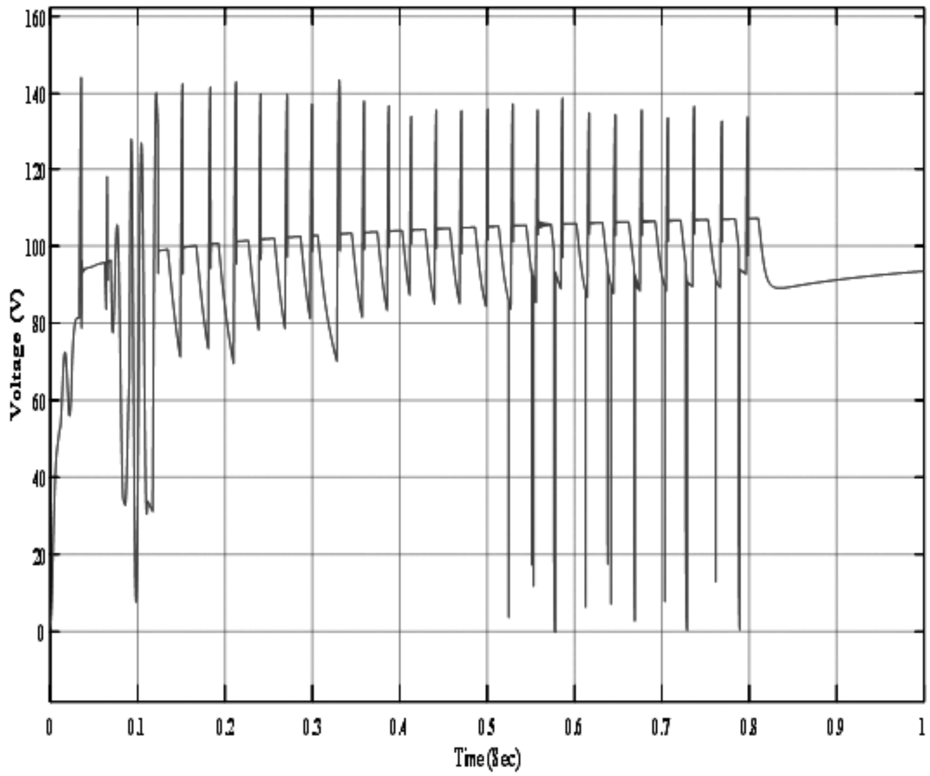

Figure 8: Input Voltage before Boost Converter without MPPT Controller

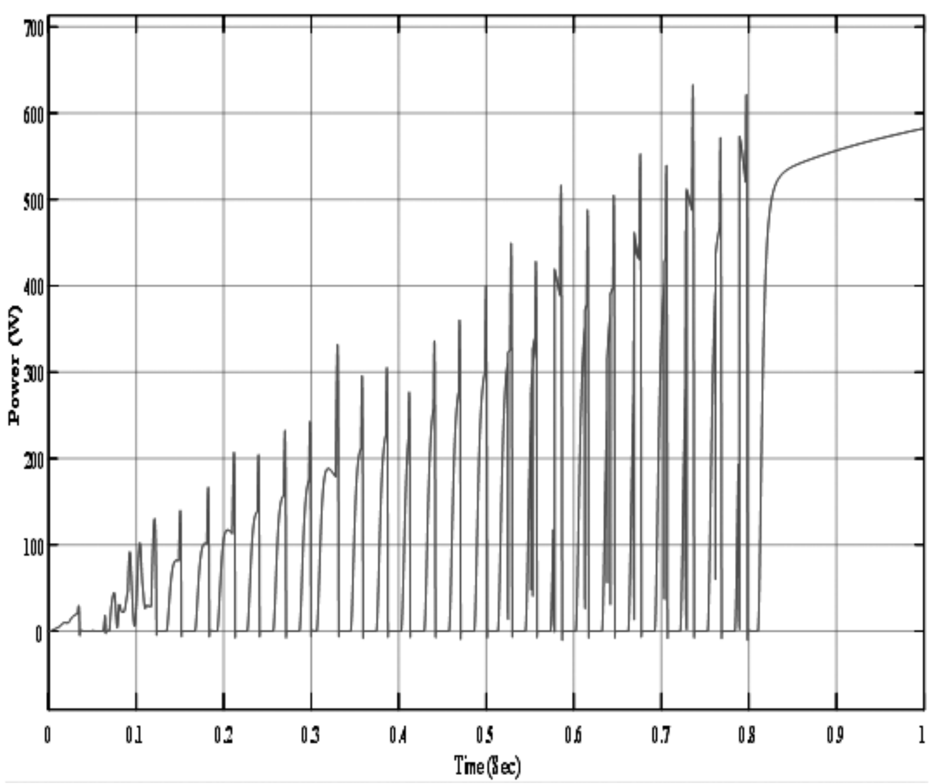

Figure 9: Output Power after Boost Converter with MPPT Controller

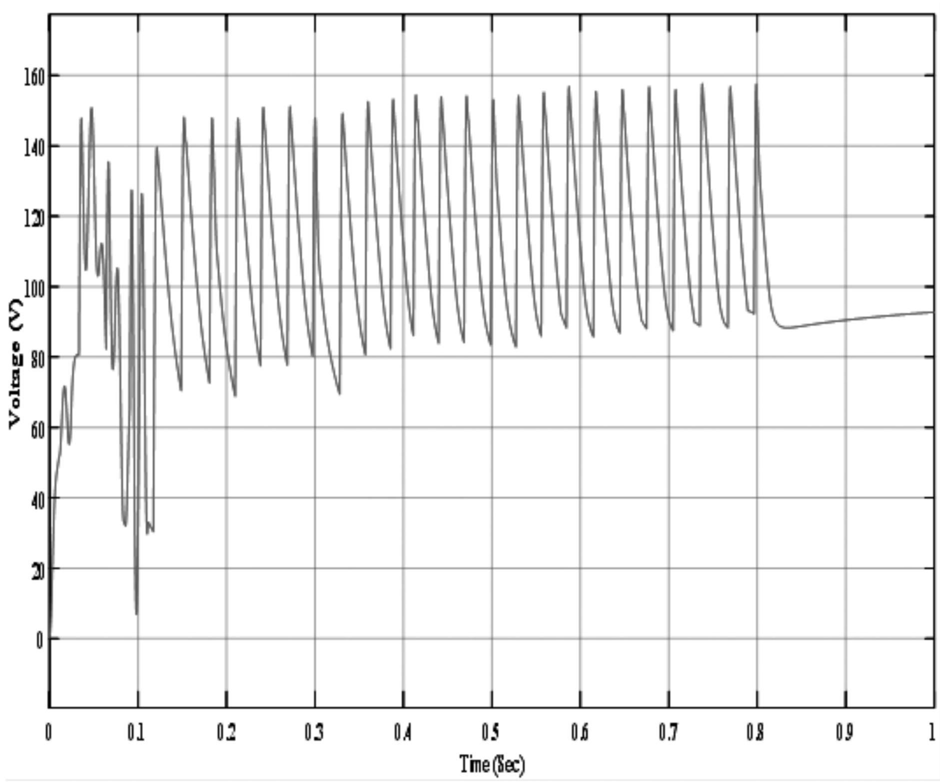

Figure 10: Output Voltage after Boost Converter with MPPT Controller

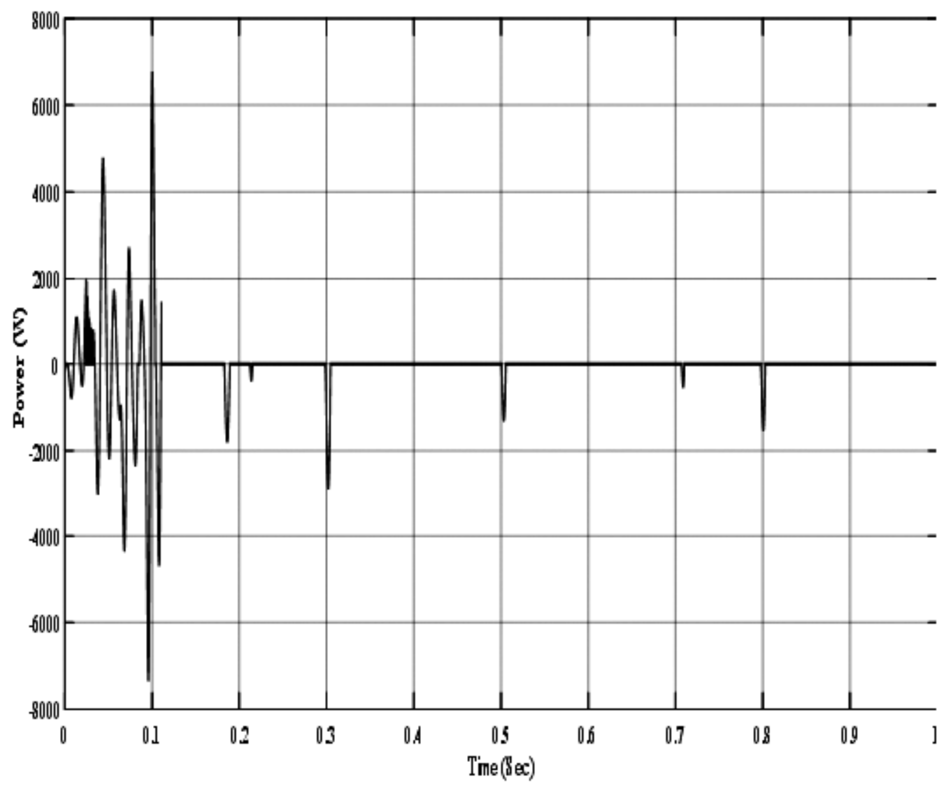

Figure 11: Input Power before Buck Converter without MPPT Controller

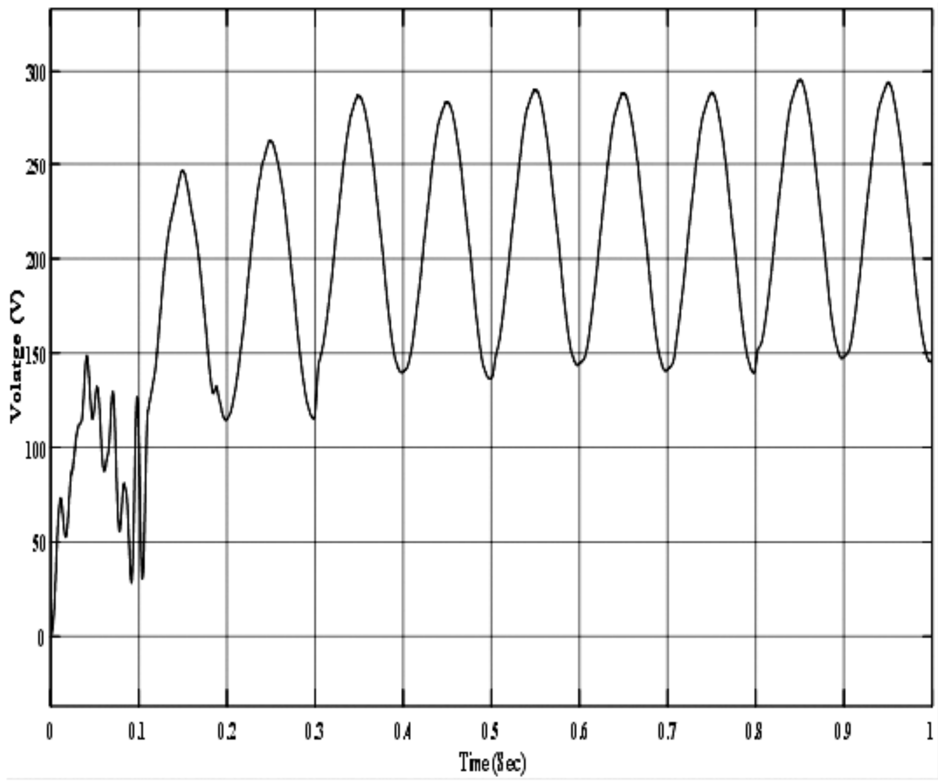

Figure 12: Input Voltage before Buck Converter without MPPT Controller

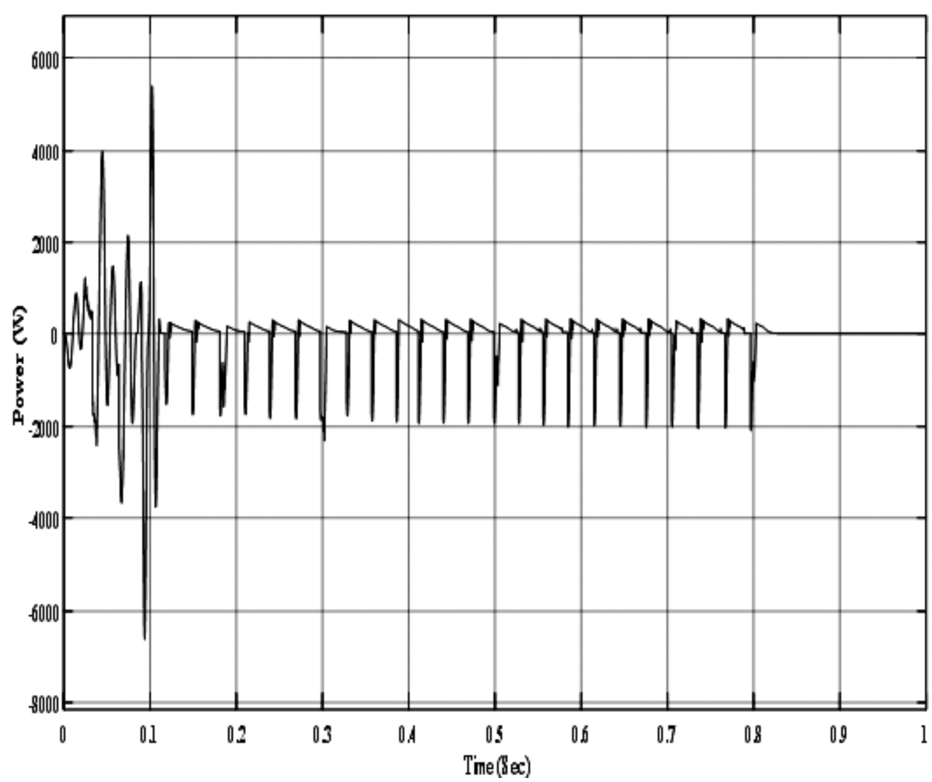

Figure 13: Output Power after Buck Converter with MPPT Controller

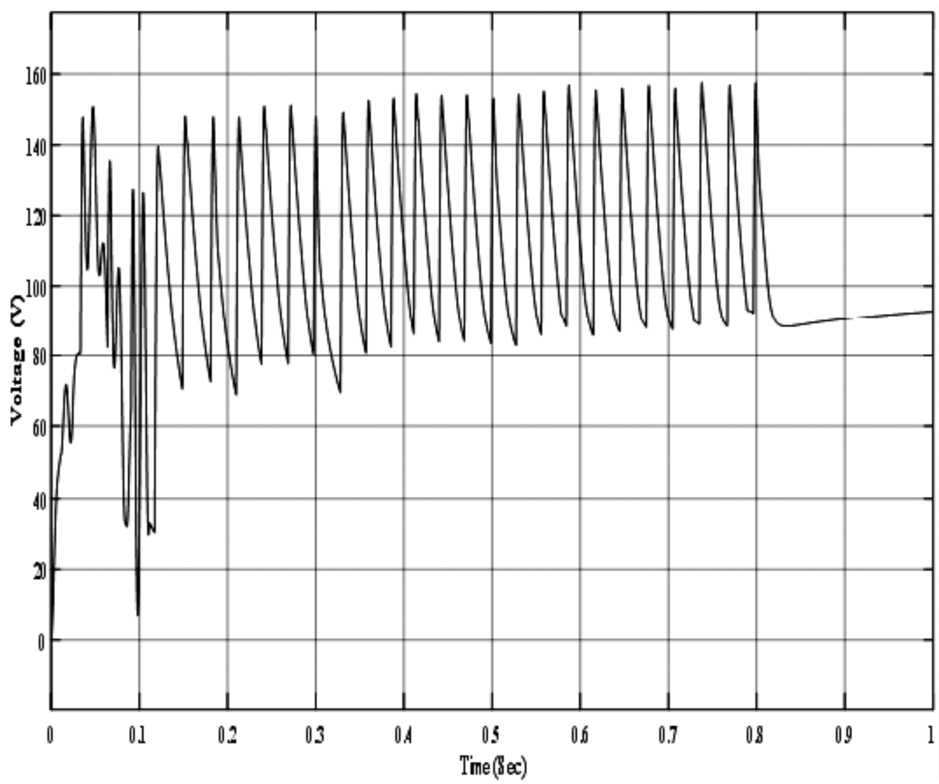

Figure 14: Output Voltage after Buck Converter with MPPT Controller

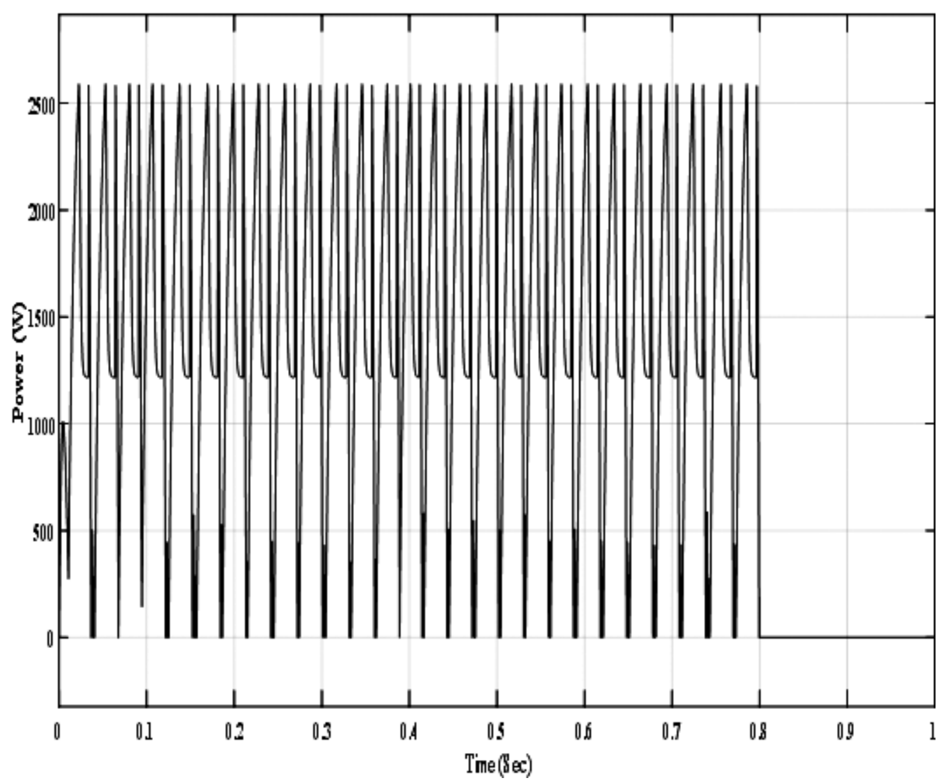

Figure 15: Input Power before Boost Converter without MPPT Controller

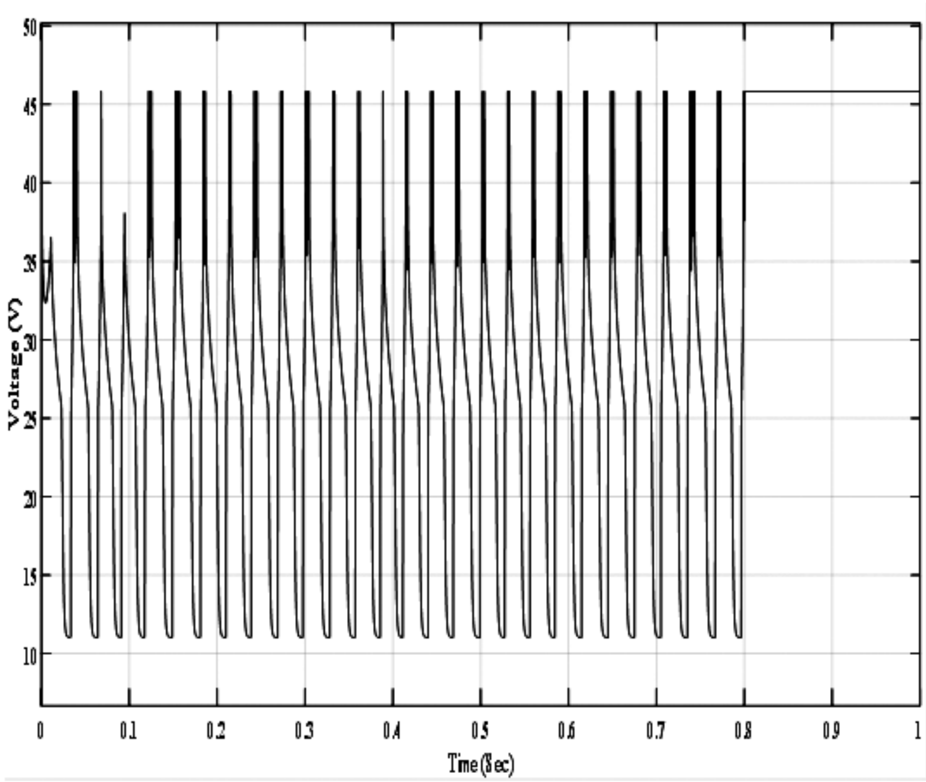

Figure 16: Input Voltage before Boost Converter without MPPT Controller

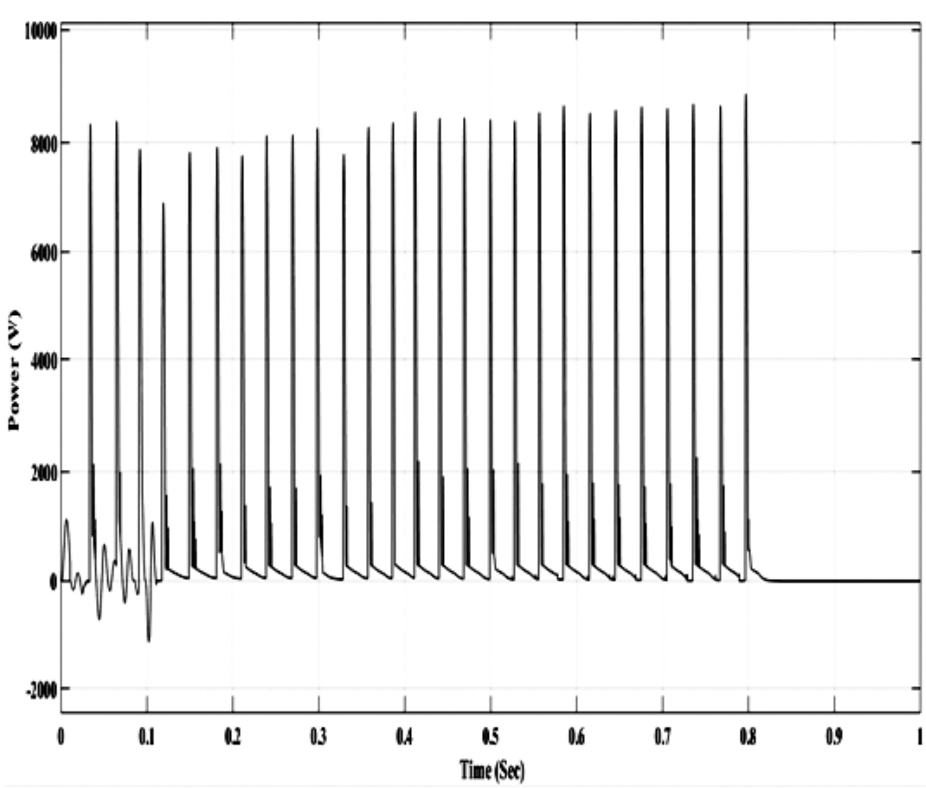

Figure 17: Output Power after Boost Converter with MPPT Controller

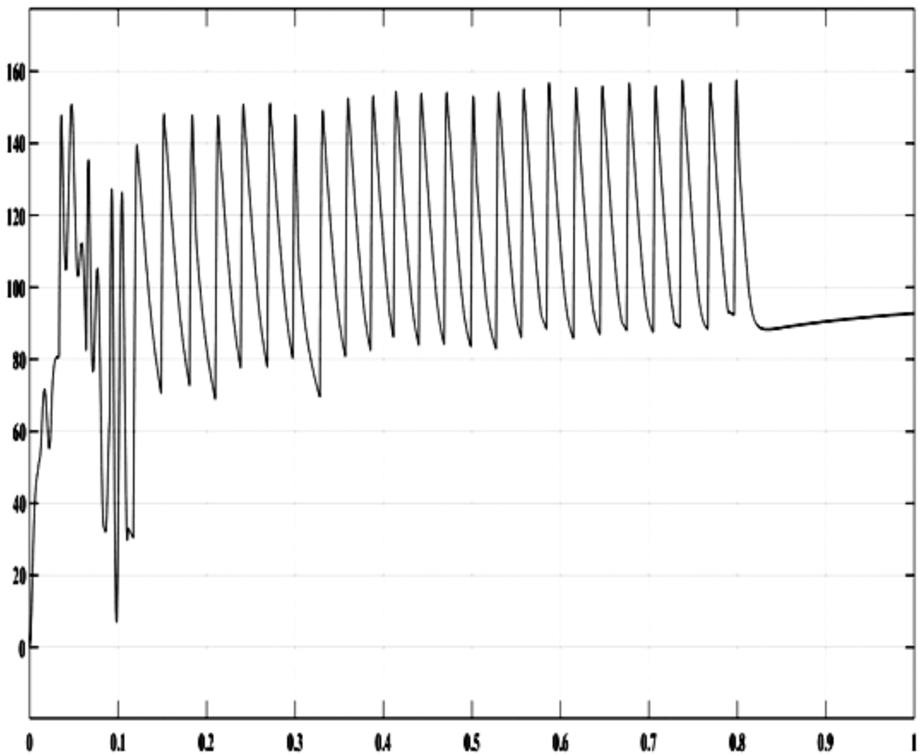

Figure 18: Output Voltage after Boost Converter with MPPT Controller

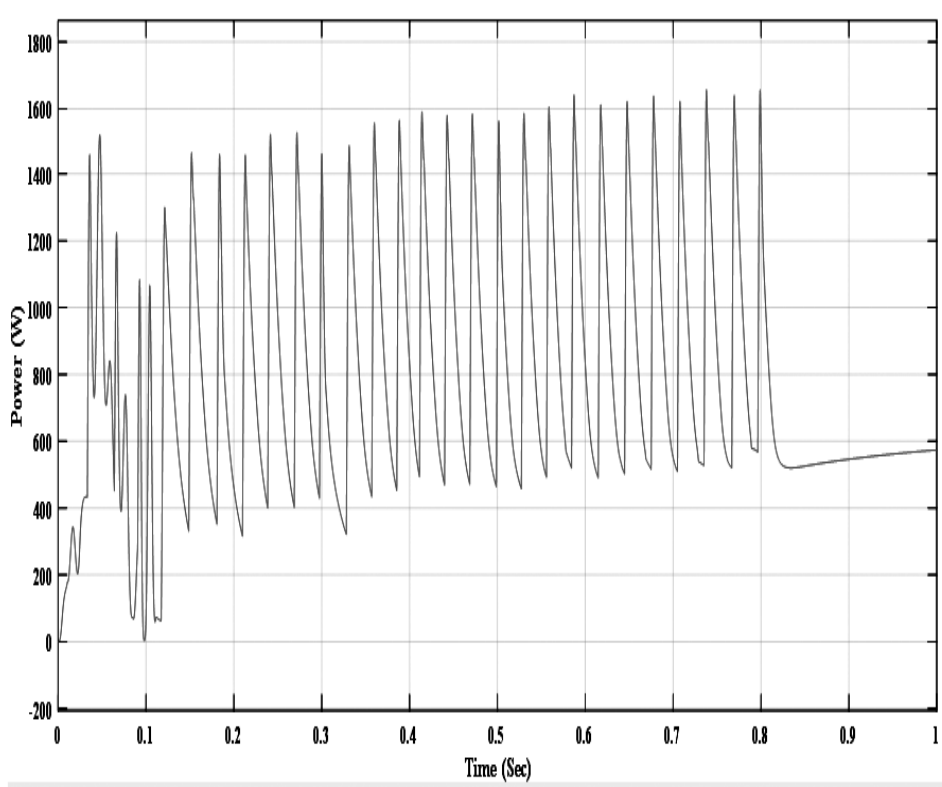

Figure 19: Output Power of Hybrid System

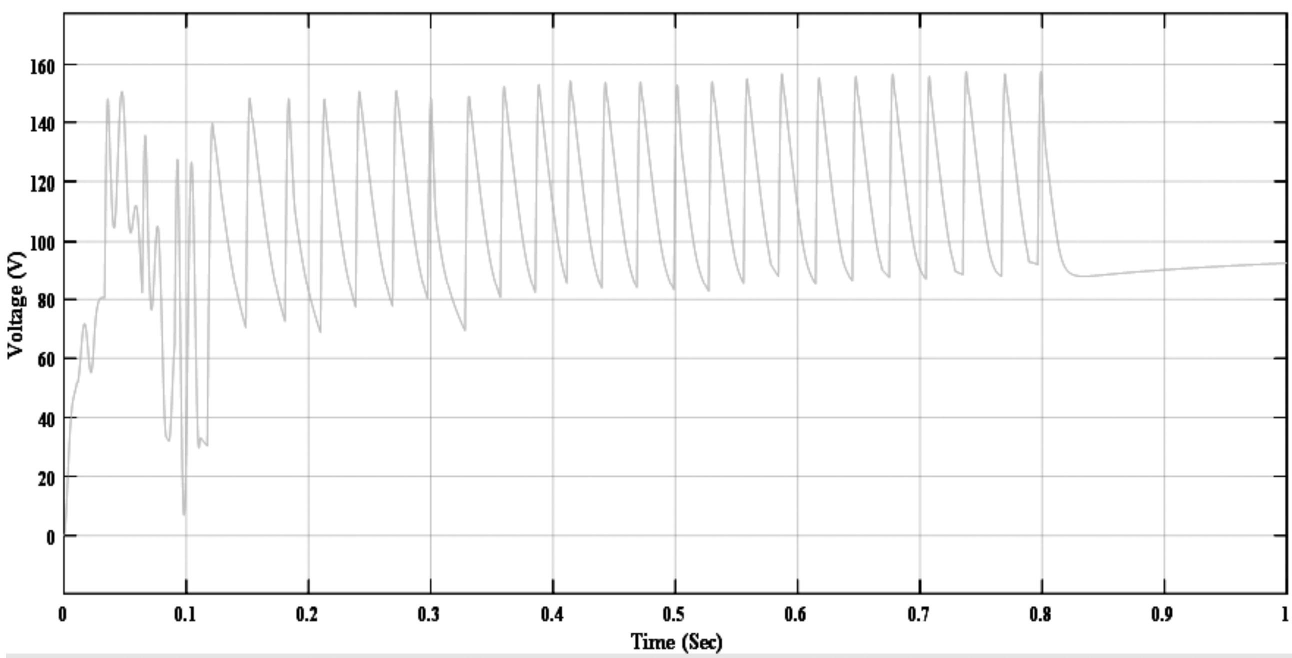

Figure 20: Output Voltage of Hybrid System

Table 2
Comparative Analysis of Renewable Energy Systems

Systems	*Input Power and input voltage before Boost Converter without MPPT Controller*	*Output Power and output voltage after Boost Converter with MPPT Controller*
PV	350W / 100V	500W / 120V
WT	500W / 275V	600W / 120V
FC	600W / 45V	650W / 120V
Hybrid	–	1600W / 120V

5. RESULTS AND DISCUSSION

Simulation analysis using MATLAB/SIMULINK™ is performed in order to find the maximum power of the resistive load. In this paper, hybrid renewable energy system has been simulated and evaluated. Fig. 7 and Fig. 8 show simulation results of input power and input voltage before boost converter without P&O technique based MPPT, Fig. 9 and Fig. 10 show off-line simulation results of input power and input voltage after boost converter with P&O technique based MPPT using MATLAB/SIMULINK™ It is clearly seen that the input power, input voltage, output power and output voltage values are 350W, 100V, 500W and 120V respectively having simulation time of 1s.

Fig. 11 and Fig. 12 show simulation results of input power and input voltage before buck converter without P&O technique based MPPT, Fig. 13 and Fig. 14 show simulation results of input power and input voltage after buck converter with P&O technique based MPPT using MATLAB/SIMULINK™ for WT system It is clearly seen that the input power, input voltage, output power and output voltage values of 500W, 275V, 600W and 120V respectively having simulation time of 1s.

Fig. 15 and Fig. 16 show simulation results of input power and input voltage before boost converter without P&O technique based MPPT, Fig. 17 and Fig. 18 show simulation results of input power and input voltage after boost converter with P&O technique based MPPT using MATLAB/SIMULINK™ for FC system It is clearly seen that the input power, input voltage, output power and output voltage values of 600W, 45V, 650W and 120V respectively having simulation time of 1s.

Fig. 19 and Fig. 20 show simulation results of output power and the output voltage of HRES. Finally, it is clearly seen that the output power and output voltage values of 1600W and 120V respectively having simulation time of 1s

6. CONCLUSION

Different systems to obtain MPP in solar PV, WT and FC have been discussed in this paper. The result shows that MPPT technique improves the efficiency of the proposed hybrid system. The analysis of the hybrid system provides higher power as compare to PV, WT and FC. In this, review of MPPT system helps to choose particular MPPT method for a specific application and also for further research in the area of MPPT and hybrid MPPT, use of this method may improve the output.

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