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# Effectual GA Optimized PID Control Strategy based MPPT Controller for Extracting Maximum Power from Photo Voltaic system

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**Abstract**

In renewable sources, especially Photo Voltaic (PV) is actively playing an important role in both autonomous and grid-connected applications. A real challenge with any PV system is its dependency on sun's irradiance. Hence, it needs a supporting system for obtaining its maximum output power irrespective of the weather condition. The objective of this paper is to design a Genetic Algorithm (GA) tuned PID controller for a boost converter. Such design will track possible output power from the PV system. In the proposed controller, Perturb and Observe (P&O) methodology has been used for enhancing the system output in presence of varying irradiance. The advantage of discussed control strategy is that it adequately responds with the change in irradiance value and also boosts the conversion operation efficiency. The system performance has been validated both in MATLAB simulation and also in hardware implementation with 18V and 0.5A rated solar panel. The control algorithm has been implemented using low power, low-cost PIC16F877A microcontroller.

**Keywords:** Renewable energy, Solar power, Maximum power point tracking, Genetic algorithm, Control strategy

## Introduction

The energy demand has been increasing every day and mostly it is met out with conventional fossil fuel-based power resources. But, the other problem with this is depleting nature of fossil fuels. Therefore, an alternative approach to meet the increasing energy demand is effective utilization of renewable energy sources and this has become need of the hour [1].

In recent days, wind and solar energy is gaining more importance. It is due to technological advancement and ease of implementation of the system [2]. When compared with wind energy, solar PV based system is attracting more attention because of cost effectiveness. Since, energy from the sun is available round the year; many countries with greater sunshine are opting for this type of technology to meet their energy demand gap [3]. A major problem with the PV system is its low conversion efficiency which depends on temperature and weather condition [4]. Hence, to address this issue and also to obtain maximum output power from the PV system, a suitable Maximum Power Point Tracker (MPPT) has become essential [5].

The MPPT methodology is utilized to track possible output power from PV system by changing proportion among current and voltage to increase the output power. There are several approaches that have been focused on developing a MPPT control strategy for a PV system [6-24]. These methods are adopted to enhance the system performance as well as efficiency. For improving the performance of a PV array various techniques have been proposed such as Perturb & Observe (P&O) technique [6-8], integrated with classical control methodology [9-16], fuzzy logic methodology [17-21], and artificial intelligence methodology [22-24]. These techniques can be imposed on a DC-DC converter to vary the switching pulse of a converter to extract available energy from PV system [25].

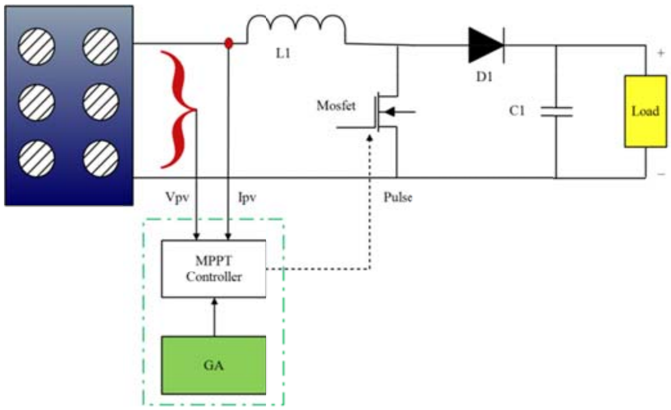



**Figure 1** Schematic of a stand-alone PV system.

**Table 1** PV Panel parameters.

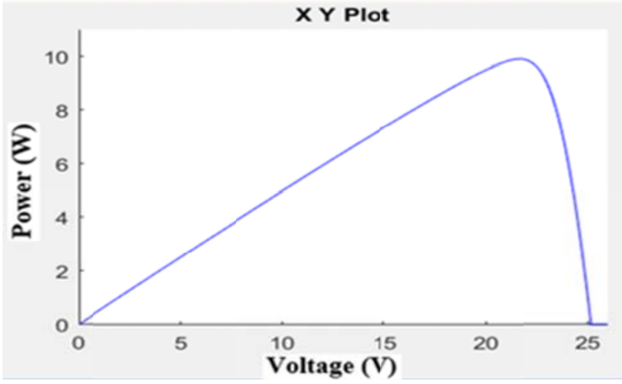
| Panel parameters | Specifications |
|---|---|
| Vmpp | 21.6 V |
| IMPP | 0.462 A |
| (Voc) | 24 V |
| ISC | 0.516 A |

To extract the possible power, MPPT must be operated at its optimal operating point. The control strategy proposed in [9-24], measures the past values of a PV system and alters its voltage and current to maintain the operating point at required level for extracting maximum power from a PV system. The classical Proportional Integral Derivative (PID) control is deployed due to its simple control strategy when compared with Fuzzy and artificial intelligence based controller. Hence, they are implemented for attaining a wide variety of control strategies [26]. The drawback of classical method is that appropriate $K_p$, $K_i$, and $K_d$ values must be tuned for efficient operation of control strategy. Optimization techniques have been proposed to change the parameters of classical control strategy [27].

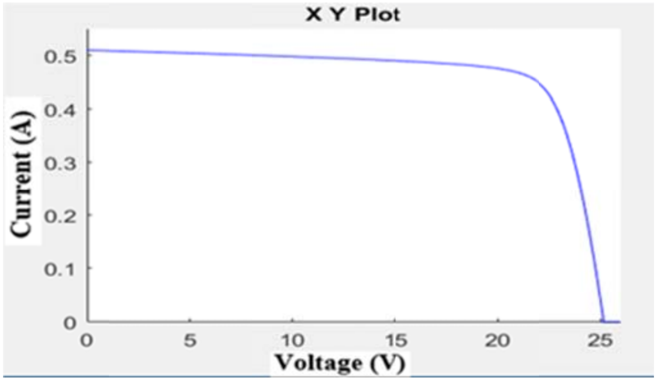
The proposed work deploys genetic algorithm tuned PID controller to a boost converter. Such design can trap the possible output from a PV system. The proposed controller uses Perturb and Observe (P&O) methodology to track the variation and to enhance output power. The advantage of proposed control strategy is that it adequately responds with the change in value and also boosts the conversion operation. The system performance has been validated both in MATLAB simulation and also in hardware implementation with 18V and 0.5A current rating solar panel as mentioned in **Table 1**. The control algorithm has been implemented using low power, low-cost PIC16F877A microcontroller.

**Investigated system modeling and description**

The schematic diagram of proposed system is shown in **Figure 1**. The PV panel generates output power with respect to solar irradiance incident on the panel. The output voltage and current obtained is $V_{pv}$ and $I_{pv}$ respectively. The P-V and V-I characteristics of a PV system are shown in **Figures 2(a)** and **2(b)**, respectively. $V_{pv}$ and $I_{pv}$ are fed to boost converter as inputs which are uncertain in nature. The role of boost converter is to increase the output voltage obtained from PV. To boost the output power, an MPPT controller has been used in this proposed system. The MPPT controller tracks maximum power from PV based on $V_{pv}$ and $I_{pv}$, which is processed by the control strategy. The proposed control strategy uses a PID controller that has been tuned using GA. The developed control strategy generates appropriate switching pulses to operate Metal Oxide Semiconductor Field Effect Transistor (MOSFET) of boost converter for delivering possible output power for the load.




(a)




(b)

**Figure 2** (a) P-V characteristics of PV system, and (b) V-I characteristics of PV system.

**Proposed MPPT control strategy**

The schematic of control approach is shown in **Figure 3**. The measured voltage and current obtained from PV system are $V_{pv}$ and $I_{pv}$. The measurand are further fed as input to MPPT controller. In this study, the P & O algorithm is utilized to generate voltage signal $V^{*}_{pv}$ and is given to a comparator, while the other input to comparator is reference input $V_{pv}$. The output of comparator generates an error signal which is fed to PID controller. The gain parameters of controller are tuned by GA, which generates required gain for PID under supervised technique with respect to error signal from comparator. Consequently, the output of PID block is given to a comparator which is having reference pulses as another input. The output of comparator is a pulse signal that drives the switches of boost converter. Therefore, maximum power is extracted by switching boost converter according to the value of $V_{pv}$ and $I_{pv}$.

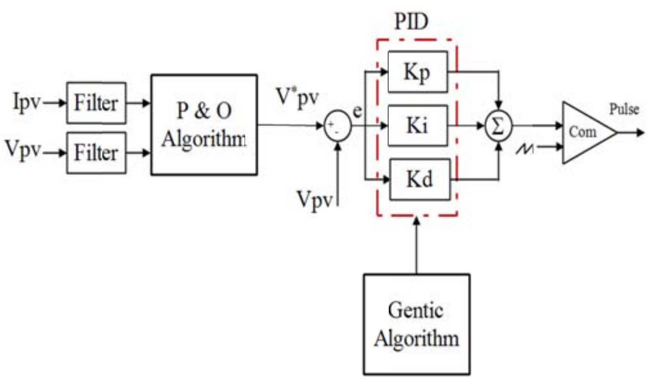



**Figure 3** Schematic of the proposed MPPT control strategy.

**PID tuning process using GA**

The GA tuning process is shown in **Figure 4**, where the algorithm adjusts the $K_p$, $K_i$, and $K_d$ parameters of PID controller. The GA method utilizes population of particles to decide the best possible solution [27]. In this, every particle signifies an optimistic result to the system. Thus, an objective function is generated through progression to update $K_p$, $K_{i,}$ and $K_d$ parameters of PID controller. Initializing the population is carried in subsequent progression. At this point, the population signifies cluster of random values that are chosen at random. In subsequent progression, a new hybrid population has been formed through roulette wheel selection, where by picking out the survival of fittest values. A healthy population has been formed in the following stage through crossover mechanism in which survived population undergoes binary crossover progression. The efficiency of selected binary digits is boosted by polynomial mutation in final stage. The crossover probability of GA is set to 1000 and 0.9 for estimating the function and thereby controller parameter is tuned by GA.

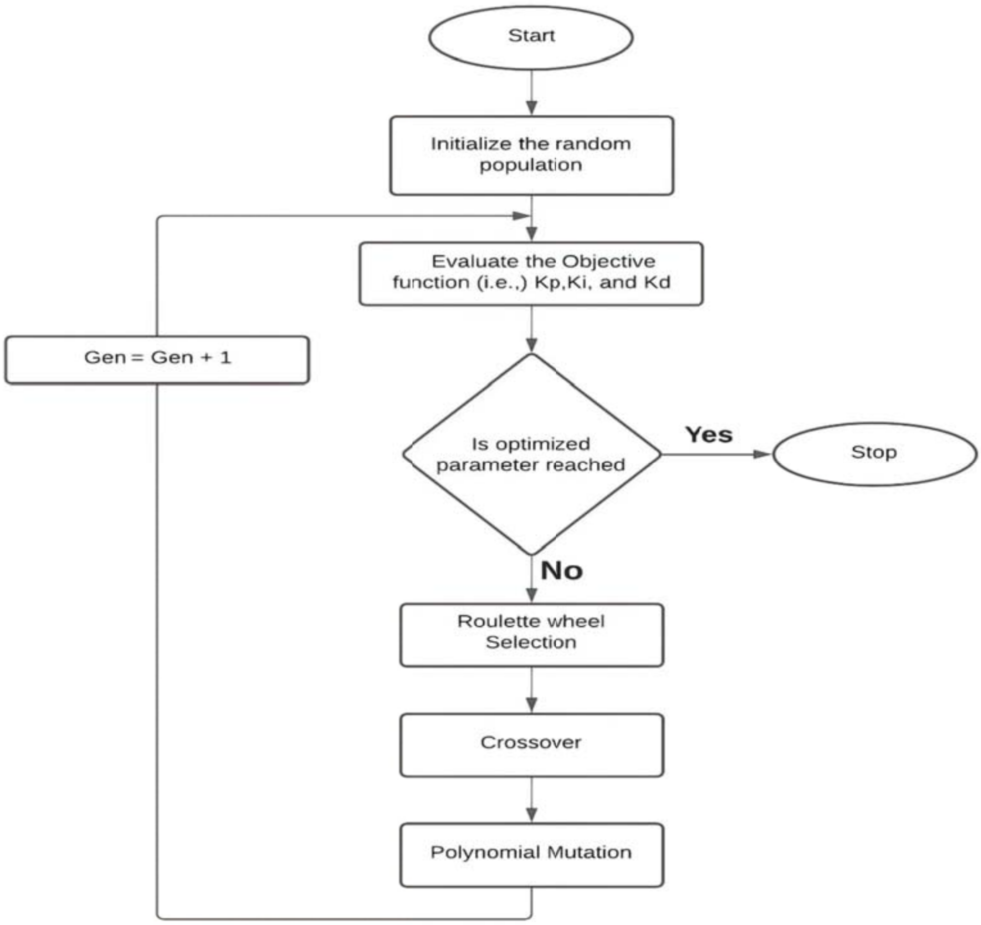



**Figure 4** Flow chart of PID tuning process using GA.

**MPPT algorithm**

The MPPT algorithm for tracking possible power from PV systems is shown in **Figure 5**. The working principle of this method is to increase or decrease the PV terminal parameters in reference to the output power of the PV with that of the preceding perturbation sequence. During this operation, if the working voltage of the array alters, it also makes corresponding changes in power. Then the controller used in the system will move the operating point in identical direction, else it will be moved in opposite direction. In this way, the operation continues for the next cycle. The P & O control algorithm fine-tunes the process on its own, in adjusting the reference array voltage and voltage step size to attain the MPPT [8-11].

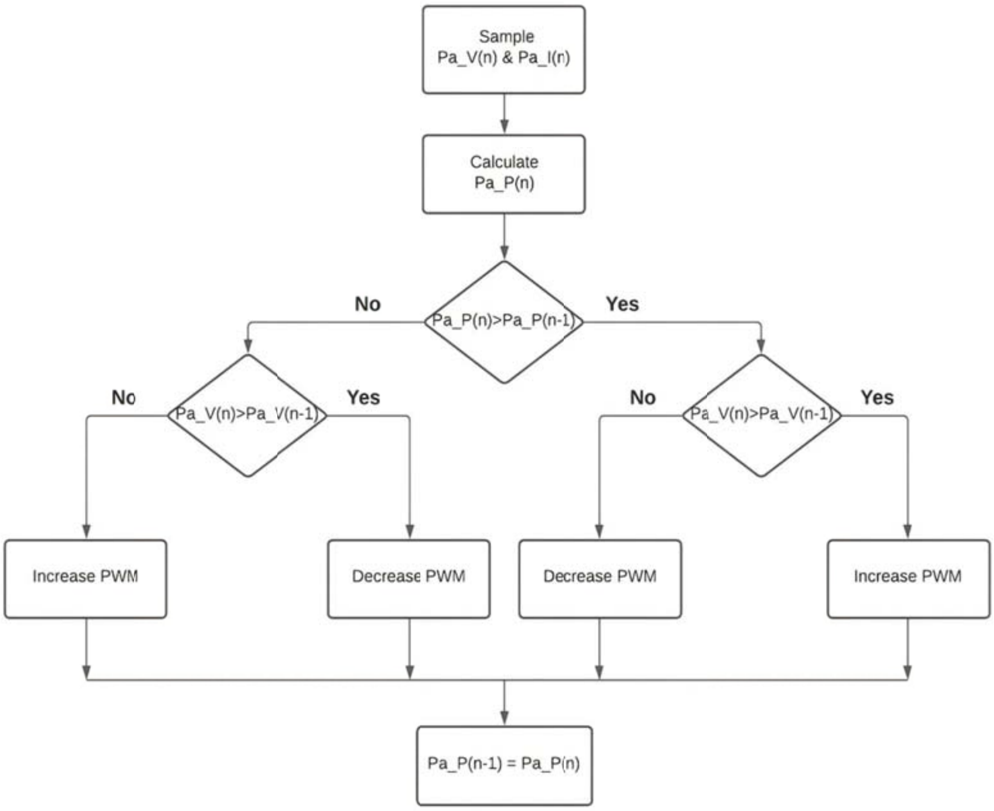



**Figure 5** Flow chart of the P & O algorithm.

**Results and discussion**

The evaluation of the MPPT control strategy has been carried out with Proteus software and validated using experimental analysis. Before designing the hardware setup of the system, a simulation analysis is carried out in the system as shown in **Figure 6**. The controller is designed using Proteus software for validating the results. In this study, the microcontroller is used as a controller in the main hardware design that is selected in the Proteus software. Further, the microcontroller is programmed to generate gate pulse with Proteus software for tracking MPP using P & O with GA tuned the PID controller. The schematic diagram of 16F877A coded with embedded C code is shown in **Figure 6**. The generated gate pulse output observed from the internal scope is shown in **Figure 7**.

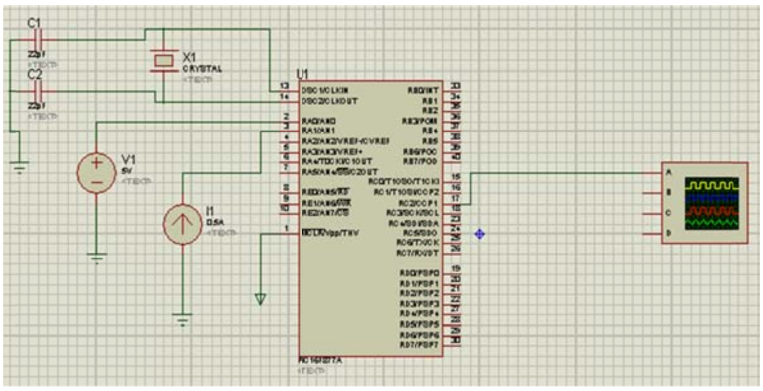



**Figure 6** Schematic diagram of 16F877 micro controller.

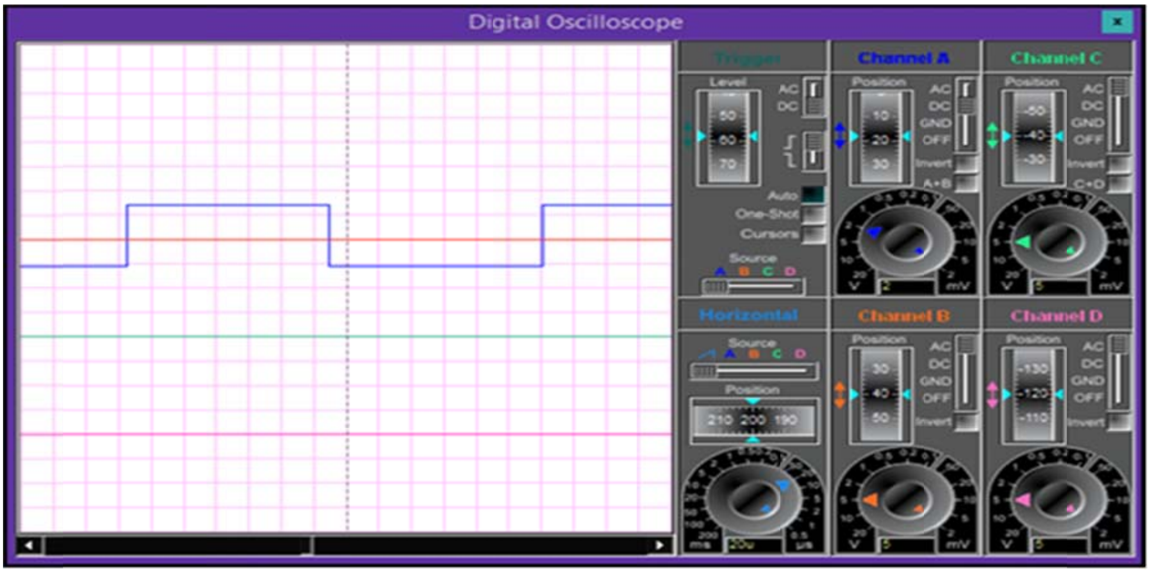



**Figure 7**Gate pulse output for P & O method captured from internal scope.

Initially, the study system with PID controller is given a disturbance in the form of variation in solar parameters at time t = 4s as shown in **Figure 8** which cause a change in output. The PID controller is tuned with the disturbance and it fails to track the operating point of solar PV, which results in low output voltage. Therefore, to achieve the desired DC voltage, the system is again tested through same PID controller but at this time the PID parameters are tuned with GA. Similar kind of disturbance in again given to the system but, at this time the PID controller is able to track the necessary power and it is being reflected in the output voltage as revealed in **Figure 9**.

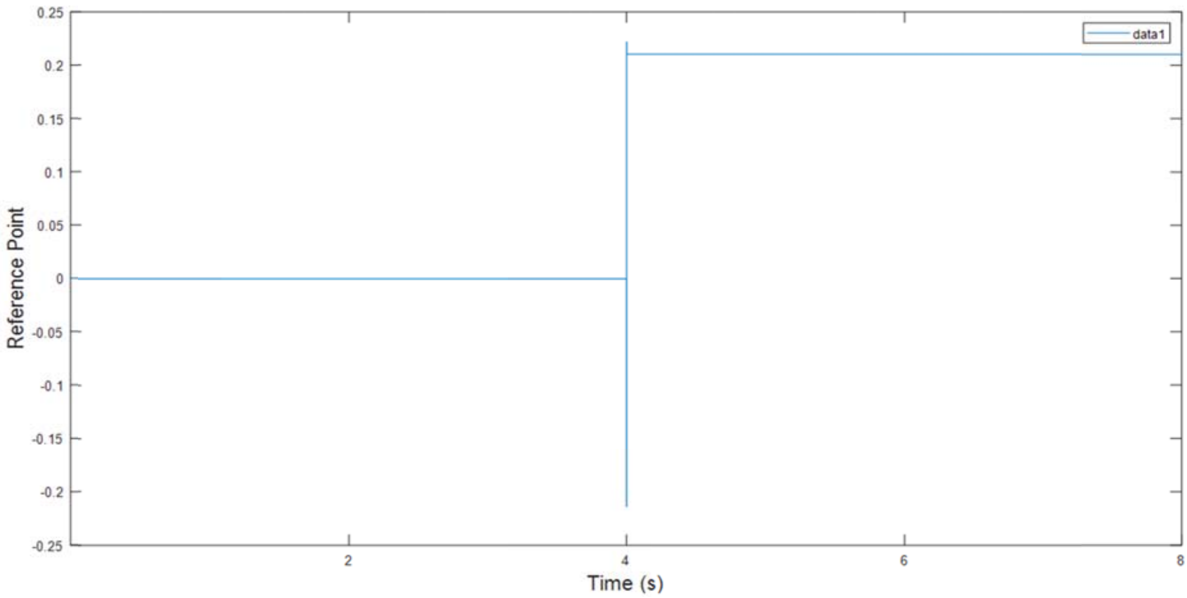



**Figure 8**Simulation output voltage of PID controller with disturbance.

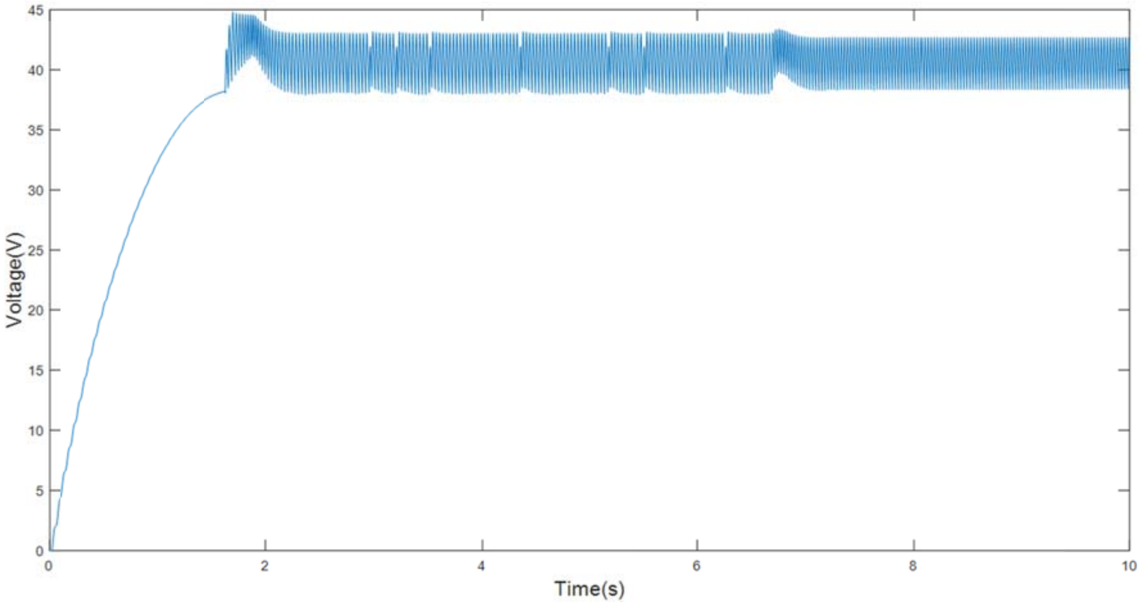


**Figure 9**Simulation output voltage of GA-PID controller under normal irradiation.

**Experimental validation**

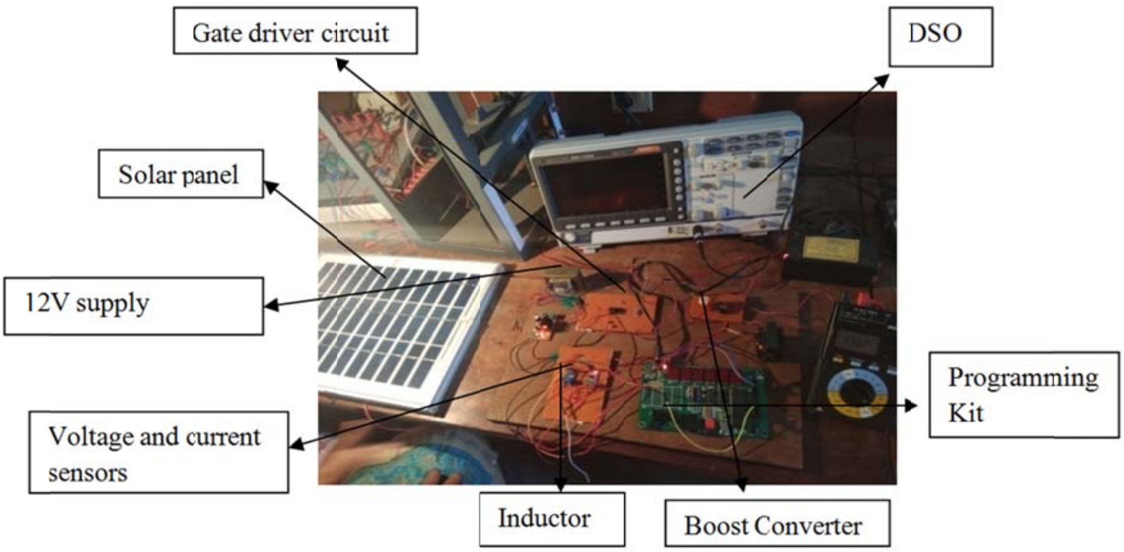


**Figure 10** Complete hardware setup.

The validation has been carried out using the experimental system shown in **Figure 10**. Initially, input supply has been given through Regulated Power Supply (RPS) which is then connected to sensors and a 5V supply is given to the microcontroller. The boost converter is also coupled with the circuit. Inductance for boost converter is given from the decade induction box. The generated gate pulse is given to the converter by means of a gate driving circuit. Now, the RPS is replaced by the solar panel, and the induction box is replaced by the induction coil. The final output is captured in a digital oscilloscope. The parameter used for designing the boost converter is calculated using the Eqs. (1) - (10) and is given as;

$$V_s = 18 \text{ V} \quad (1)$$

$$V_O = 45\text{ V} \tag{2}$$

$$F_s = 25\text{ KHz} \tag{3}$$

$$\Delta V_O = 0.01\text{ V} \tag{4}$$

$$I = \frac{100}{45} = 2.3\text{ A} \tag{5}$$

$$R = \frac{V}{I} = \frac{45}{2} = 22.5\ \Omega \tag{6}$$

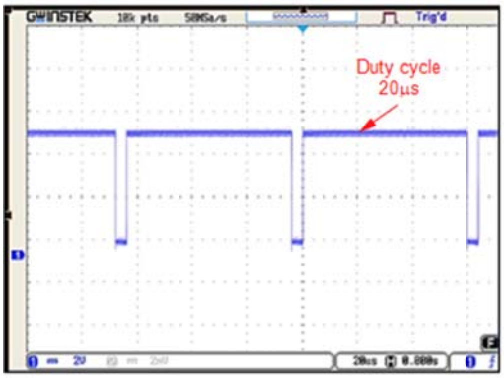
$$A = 1 - \left(\frac{V_s}{V_0}\right) = 1 - \left(\frac{18}{45}\right) = 0.6 \tag{7}$$

$$L_{min} = \left[\frac{[D(1-D)^2 2R]}{2f}\right] = \left[\frac{[0.6(1-0.6)^2 2*22.5]}{2*25000}\right] = 4.32 * 10^{-5}\text{mH} \tag{8}$$

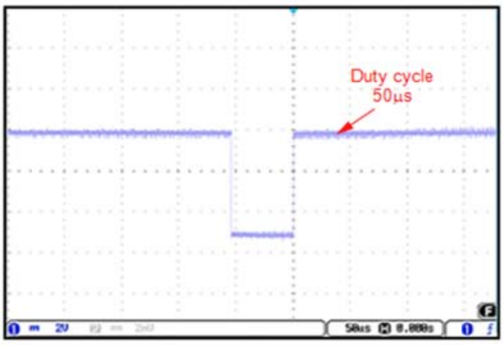
$$I_1 = \frac{V_S}{(1-D)^2 * 2R} = = \frac{18}{(1-0.6)^2 * 2 * 22.5} = 5\text{ A} \tag{9}$$

$$A = \frac{D}{R}\left(\frac{\Delta V_0}{V_0}\right) f = \frac{0.6}{22.5} * \left(\frac{0.01}{45}\right) * 25000 = 0.0048\text{ F} \tag{10}$$

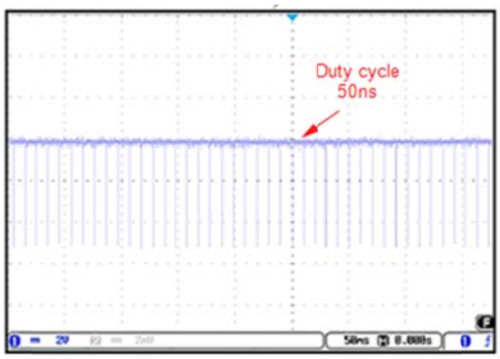
**Figures 11(a) - 11(d)** the gate pulse fed to boost converter for different irradiation 800, 1000, 600,500 W/m$^2$, respectively. The developed converter tries to track the optimal point for change in irradiation to extract the possible power. **Figure 12** shows the output voltage. It has been verified that the converter is capable of boosting the output voltage to 42.4 V as seen from the oscilloscope and shows the capable conversion efficiency to 94.2 %. The obtained result shows the effectiveness of the proposed GA tuned PID based MPPT controller.



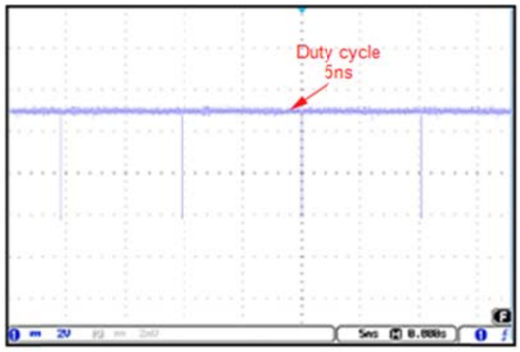

(a)




(b)




(c)




(d)

**Figure 11** (a) - (d) Gate pulse fed to boost converter for different irradiation800, 1000, 600,500 W/m$^2$, respectively

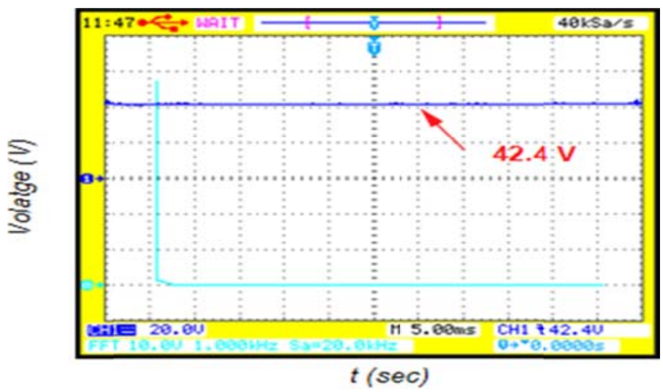



**Figure 12** Optimal output voltage from the developed system.

## Conclusions

The MPPT control is an essential tool for extracting optimal output power from the PV system for uneven irradiations. Therefore, an efficient MPPT controller has been developed to track the optimal point adequately. The developed MPPT controller uses P & O methodology and is loaded in a PIC16F877A microcontroller. The corresponding pulse has been generated by the GA optimized PID control strategy based on the measured voltage and current from the PV panel. By varying the duty cycle with the microcontroller, the boost converter tracks the optimal output power from the PV panel and delivers the extracted output power. The advantage of GA optimized PID control strategy is that it reduces the complexity of the system, reduced cost and also operates effectively with increased efficiency. The obtained results prove that the developed control strategy has an efficiency of 93% and has the capability to track the optimal power at all sorts of varying irradiance conditions. The developed MPPT controller could play a significant role in solar energy to extract maximum possible power and further by adopting an advanced DC-DC converter topology, the maximum power tracking can be enhanced.

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