Peripheral interface controller-based maximum power point tracking algorithm for photovoltaic DC to DC boost controller

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ABSTRACT

A method of developing a maximum power point tracking (MPPT) algorithm for photovoltaic (PV) utilizing a peripheral interface controller (PIC) is presented in this paper. The efficiency and adequacy of a PV depend on the temperature and the exposed position to the sun. Thus, there is an optimum point at which the operating power is at maximum. The goal is to operate the PV module at this point (MPP). It can be accomplished by using the MPPT algorithm designed with a DC-DC boost converter. The boost converter, MPPT circuit, PIC18F4550 microcontroller and PV panel are the main components used in this design. The current and voltage produced by the solar panel are observed continuously by a closed-loop control system. The microcontroller-based control system adjusts the duty cycle of the converter to extract the maximum power. With a DC input voltage of 15 V, the boost converter is capable of generating an output voltage of an approximately 60 Vdc at a maximum power of 213.42 W with minimum voltage ripple as compared to 84 W without the MPPT. It proved the effectiveness of the developed algorithm.

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1. INTRODUCTION

Lately, the exploratory and open mindfulness on ecological and energy problems has acquired real attention to the examination of cutting-edge innovations, especially in very useful innovation [1]. Energy is an essential component for the society and monetary advancement of social orders. The usage scale of energy means that the financial flourishing of a country.

In Malaysia, the developing industrialization and expanding way of life have extensively expanded the use of energy. Malaysian energy utilization has risen significantly in recent years due to the joined requests of industrialization and urbanization [1]. Due to the expansion of energy utilization, there are growing concerns about energy use and its effects that are not friendly to the earth. Normal and productive use of energy assets bears exceptional significance too. The point of the exploration is to examine the energy request, supply, utilization, ecological effect and also audit the future energy assets.

Energy is a fundamental requirement for the development, commercial development, modernization and mechanization [2]. Therefore, energy demand throughout the world is expanding rapidly, and this global demand must be considered to meet energy concerns for the future. The world promoted power request is demonstrated in Figure 1. Politically influential nation request ascends from 145 billion MW in 2007 and expected to be 218 billion MW in 2035, which means 49 per cent increment. That leads to more installation of power plants [3].

The Intergovernmental Climate Change Panel has reported that the main hazardous issue is global warming [4]. Since then, many governments, institutions and the responsive public in general, have set a clear mission to save the earth from all severe issues caused by the conventional power generation stations [5-9]. Since emanations are depending on the utilization of fossil fuel, so the efforts are focused on the projects of developing efficient renewable energy generation stations such as solar fields [10].

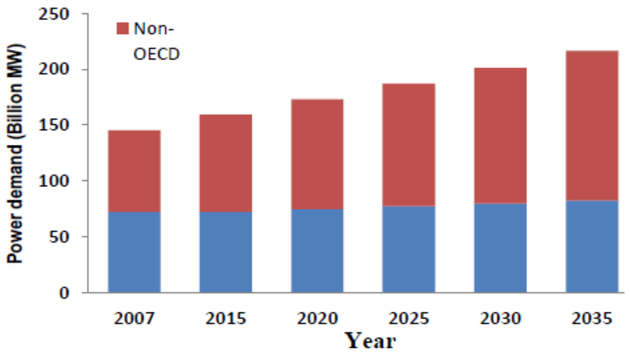

Figure 1. World power demand [1]

a. Renewable energy potentiality in Malaysia

The conventional energy sources are being depleted aggressively because of the high consumption of energy for the various applications in our daily life. Therefore, alternative renewable sources are particularly essential for future energy requests. At the same time, the governments and research institutes are under pressure to meet the goal of supplying all humanity demands with the alternative sources.

Recently, utilizing a renewable source of energy is getting more popular, especially solar energy, which is the most potent source of alternative energy in this country and also in some other countries. Catching sunlight and transforming it into electricity for everyday utilization is a smart plan, and the photovoltaic systems have been used in Malaysia since the 1980s [10]. PV technology is developing quickly because of the increased attention and awareness to climate changes, thinner ozone layer and carbon pollution. The average solar radiation is 400 to 600 MJ/m2 in Malaysia [11]. It was aimed by the Malaysian government from the tenth plan from 2011-2015 to have fields that contribute by 5.5 per cent of the total power generation mix [12]. As indicated by the Malaysian government report. There will been around 50-80 per cent in the first project (residential areas) will been provided by solar PV [13].

b. Challenges of using MPPT algorithm for PV generators

As people are anxious about the fossil fuel contaminations and the fundamental issues brought by using it for power generation, renewable energy sources, especially photovoltaic (PV) are currently utilized. The solar board is utilized, which comprises PV cells. These cells retain the energy from sunlight. PV generators are being used as a part of numerous applications, for example, battery charging, light sources, water pumping, space stations powering. The solar board has the advantages of requiring less maintenance and being contamination free. However, they have some drawbacks as they are manufactured with the high cost and low energy conversion efficiency [14-16]. Therefore, the PV system must deliver the maximum available power to the load, thus increasing the PV efficiency [17-21].

Since the PV modules still have generally low change effectiveness, the overall system cost can be lessened by utilizing high productivity power trackers that are intended to extract the most extreme conceivable power from the PV module. The process of extracting the most powerpoint itself is challenging and always remains a significant challenge in the literature [22]. Different MPPT algorithms have been proposed to maximize PV power. Designing PV systems need to consider the power flow such that the power transfer from the source to the load is of the highest possible and most stable [23]. One must take into account that the power generated by these panels depends on the weather conditions such as irradiance and temperature [23]. A PV system without the integration of an MPPT function exposes the connected load at risk due to the voltage fluctuation [24]. It also leads to waste in PV power as the PV system is unable to extract maximum power from the PV module. Hence, the need for the MPPT controller is deemed necessary [24-25].

Continuous estimations of PV board open-circuit voltage are utilized to recognize the most extreme power outcome of the solar board. The battery charge rate is persistently balanced in a way that the system working point is powered close to the identified most extreme power outcome of the solar board. Hypothetical and exploratory investigations are utilized to show the steady quality and feasibility of the proposed method.

2. MPPT METHODS

As mentioned earlier, using solar energy is an active topic which has been discussed by many researchers throughout the world. In-state of the art, it is agreed upon that the solar cells operate with low efficiency. Therefore, the challenge is to find the best possible technique to improve the efficiency of those cells. A maximum power point tracking (MPPT) is an appreciated development in this field. Many methods have been utilized for MPP tracking. Several methods are discussed in details and benchmarked in this section. For example, perturb and observe method [26], incremental conductance method [27], constant voltage method [28] and short-current pulse method [29]. An alternative method in the extracting of the maximum possible power from the PV panel is through the integration of the MPPT circuit into the system. The concept of the circuit simplicity which integrates the programmable interface controller (PIC) microcontroller is the main sign of this method.

2.1. Perturb and observe method

This method is widely used for MPPT as it requires less number of sensors and has been discussed by many researchers. The idea behind this method is to modify the converter's duty cycle. It will being indicate a change in the panel voltage. In this method, the voltage on both sides of the maximum power point will being developed increasingly and decreasingly with observing the generated power until the optimum value is gained with repeating this process each tracking step till the MPP is reached.

Once the MPP is reached, the algorithm oscillates about the right value. The step used for increasing and decreasing the voltage is a fixed step as it should not be small so that the tracking process is not slow, albeit it helps to reduce oscillation. On the other hand, it also should not be a big step to reduce power losses, albeit doing that fastens reaching MPP. It has been stated that this method is not suitable if the variation in solar irradiation is high [26].

2.2. Incremental conductance method

This algorithm uses the fact that the voltage is zero at maximum power point (MPP) in panel power slope. Unlike the previous method, the operating voltage is either decreased or increased and stop when the MPP is reached. MPP tracking is restarted according to the change in panel current depending on the surrounding conditions. Also, in this method, two sensors are required to get voltage and current values. Same as in the previous algorithm, the size of the step is fixed [27].

2.3. Constant voltage method

This algorithm is not widely used due to some disadvantages. The relation is shown in (1) where the maximum power point voltage VMPP is directly proportional to the open-circuit voltage VOC. VOC is obtained experimentally, and VMPP is obtained by multiplying it with the solar cell constant KV, which is about 0.76.

$$V_{MPP} = K_v V_{oc} \tag{1}$$

This algorithm is robust and simple, but it has disadvantages of losing power when the system disconnects temporarily to measure the open-circuit voltage and calculate the operating voltage [28].

2.4. Short-current pulse method

This method has the same concept as in the constant voltage method. The MPP is obtained by using (2). The MPP current IMPP is directly proportional to the short circuit current Isc. The constant KI is roughly around 0.95. Therefore, the operating current is 95% of the experimentally obtained short-circuit current. But in this method, determining the value of Isc is more difficult as it needs additional current sensor and switch. Besides, obtaining its value from time to time increase heat dissipation and power losses [29].

$$\mathrm{I_{MPP}} = \mathrm{K_I I_{sc}} \tag{2}$$

2.5. Proposed method

The main idea is to use a boost converter for the MPPT with a controller circuit that contains the PIC18F4550 microcontroller, which adjusts and control the duty cycle of the converter. PIC microcontrollers are electronic circuits that can be modified to do a limitless scope of tasks. In this study, the DC-DC boost converter circuit is simulated, as it is a more natural way to utilize the PV panel for power supply adequately. A DC-DC converter is utilized to step up from 15 V to 60 V. The PV panel supplies the 15 V input voltage, and the 60 V is the output voltage of the converter. The relationship of the generated output voltage, duty cycle and the input voltage is explained in (3).

$$\text{Vout} = \frac{V_{in}}{1-D} \tag{3}$$

3. SYSTEM CONFIGURATION

The objective of the system is to develop an algorithm that increases the efficiency of the PV panels in various conditions by using a boost converter. The proposed system's circuit is simulated in Proteus environment. This system configuration is shown in Figure 2, comprises of an MPPT controller, solar panel, load and DC-DC power converter. Figure 3 shows the system simulation. The input voltage supply provides a voltage signal to the microcontroller. As a result, the DC-DC manages to boost the voltage from 15 Vdc to 60 Vdc. The PV output voltage fluctuates because of the changes in climate condition. Hence, the DC output changes constantly. The microcontroller monitors the output of PV module, then provides the best power so that PV panel delivers and keep adjusting until the maximum current value is obtained. The circuit involves the voltage measurement signal to be used by the PIC18F4550 microcontroller. The changes of voltage are suitable to be nourished into analog to digital converter (ADC) port of the PIC18F4550 microcontroller to create a relative duty percentage of PWM signal reaction.

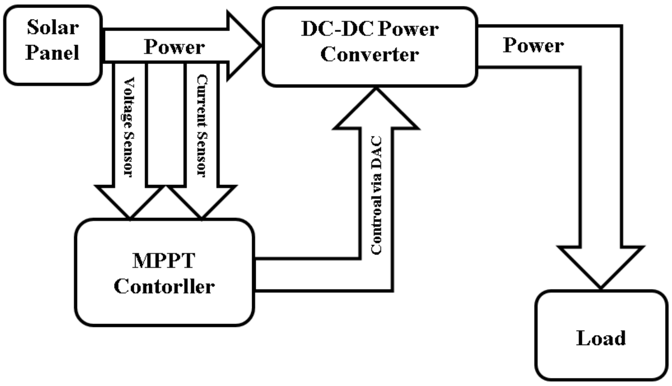

Figure 2. System configuration [30]

4. SIMULATION RESULTS AND DISCUSSION

For the DC to DC boost converter simulation, the input of 15 Vdc was supplied, and it was found out that the output voltage at the load is overshoot until maximum 75 Vdc, then it dropped until 52 Vdc and then fluctuated and remained constant at 58.62 Vdc after 23.420 ms, as shown in Figure 4. The magnification of this output voltage can be seen in Figure 5. A voltage ripple of 0.438 V can be seen in the figure, which is equal to 0.75% voltage ripple.

The output current flows through R4 reach steady state after 32.66 milliseconds is equal to 1.468 A, as shown in Figure 6. The average current flowing through R4 is 1.4621 A, as shown in Figure 7. In terms of the voltage in diode D1, it reaches a steady-state after 23.42 milliseconds with a magnitude of 59.45 V, as shown in Figure 8.

The current flows through the Inductor L1 reached steady state after 31.074 milliseconds with a maximum value of 5.9134 A as shown in Figure 9. The current in D1 reached steady state after 31.0748 milliseconds with a maximum value of 5.9134 A as illustrated in Figure 10. For the capacitor C3, the current reaches steady state after 34.9748 milliseconds with a magnification equal to 4.461 A and 4.324 A maximum and minimum are shown in Figure 11 and Figure 12, respectively.

Figure 13 shows the plotting of both the input and output voltage and current at the load. Figure 14 compares the output of the step-up converter to its input power. In the other part of the circuit for the 60 V output, the output voltage at resistor R2 and capacitor C4 is shown in Figure 15 and Figure 16. The load current in R2 is 1.778 A, which reaches steady state at 51.94 ms, as shown in Figure 17. The final plot that compares the power when using this technique to normal situations is shown in Figure 18. With MPPT, the system is able to achieve a maximum power of approximately 213.42 W as compared to 84 W without MPPT.

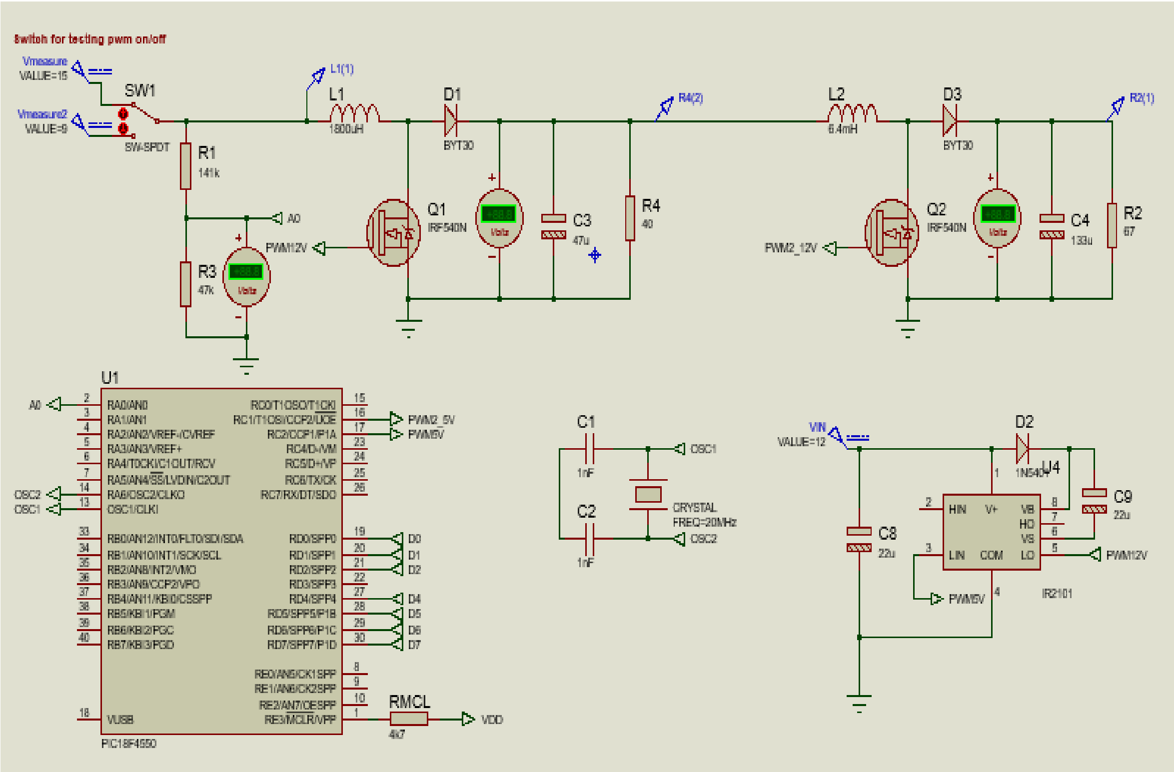

Figure 3. System simulation

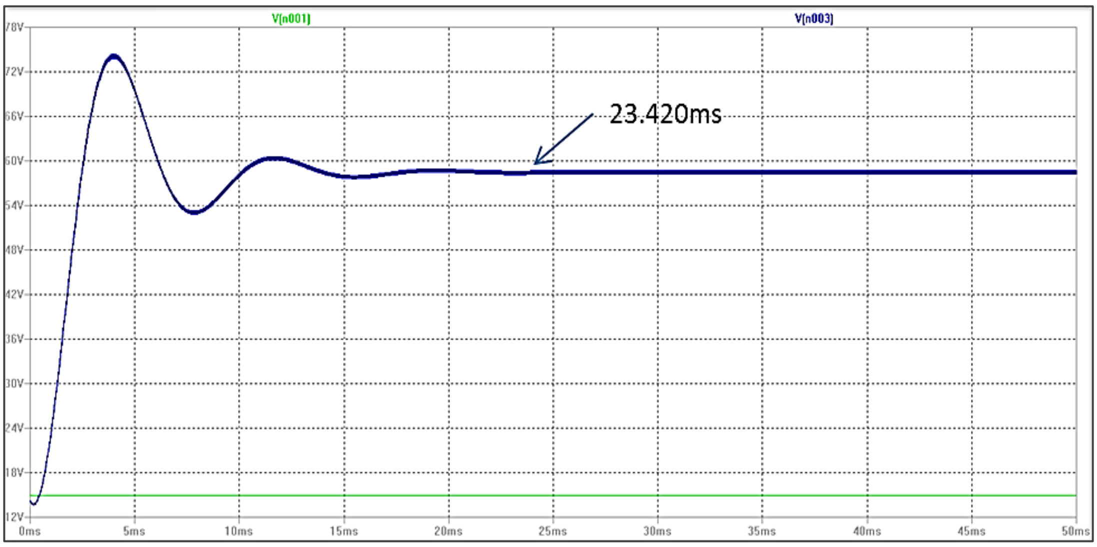

Figure 4. Output voltage across the load resistor R4

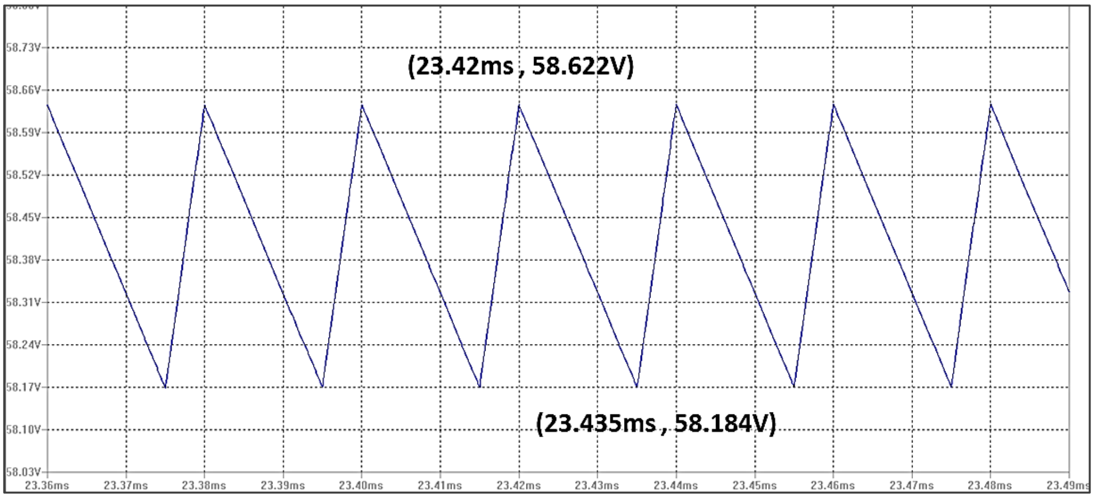

Figure 5. Magnification of output voltage across load resistor R4

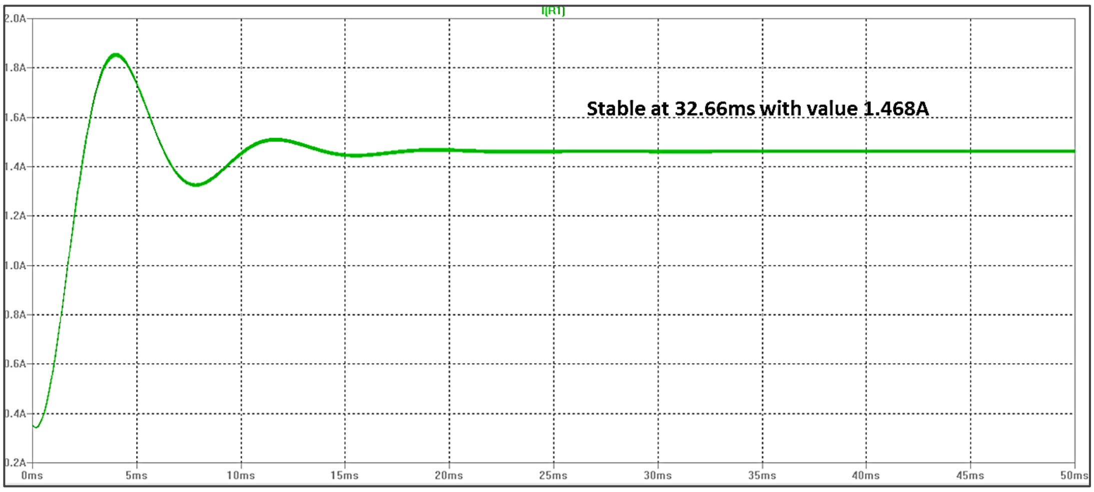

Figure 6. Output current

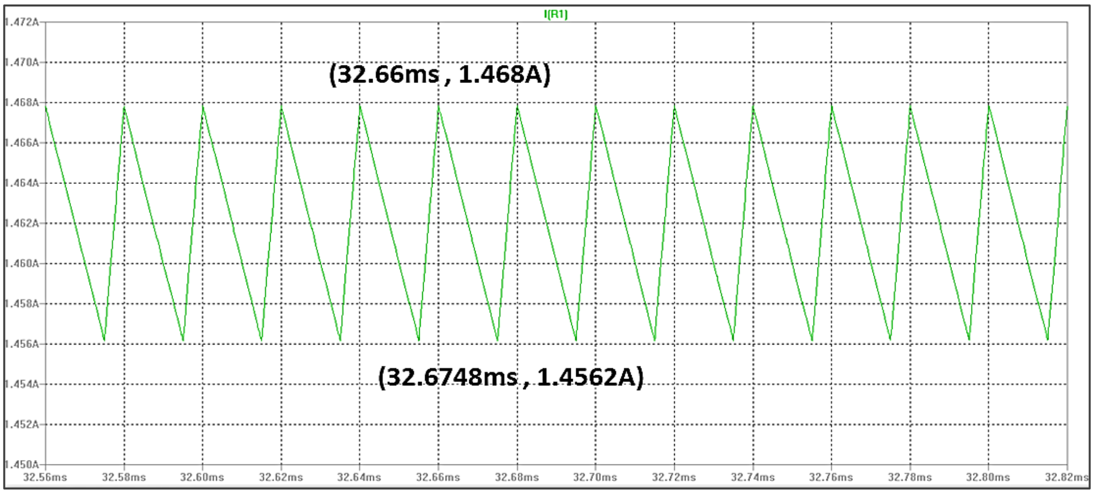

Figure 7. The average current flowing through R4

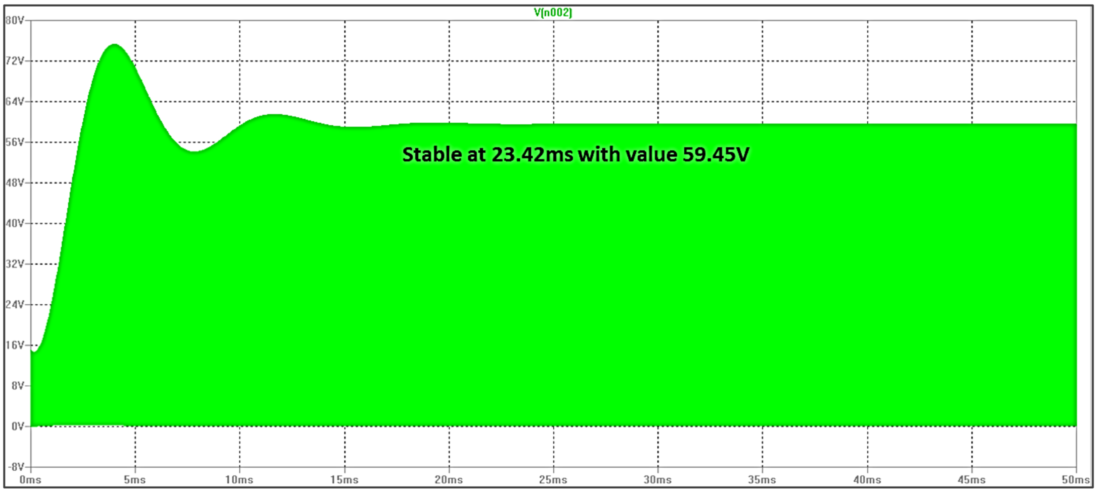

Figure 8. Voltage at diode D1

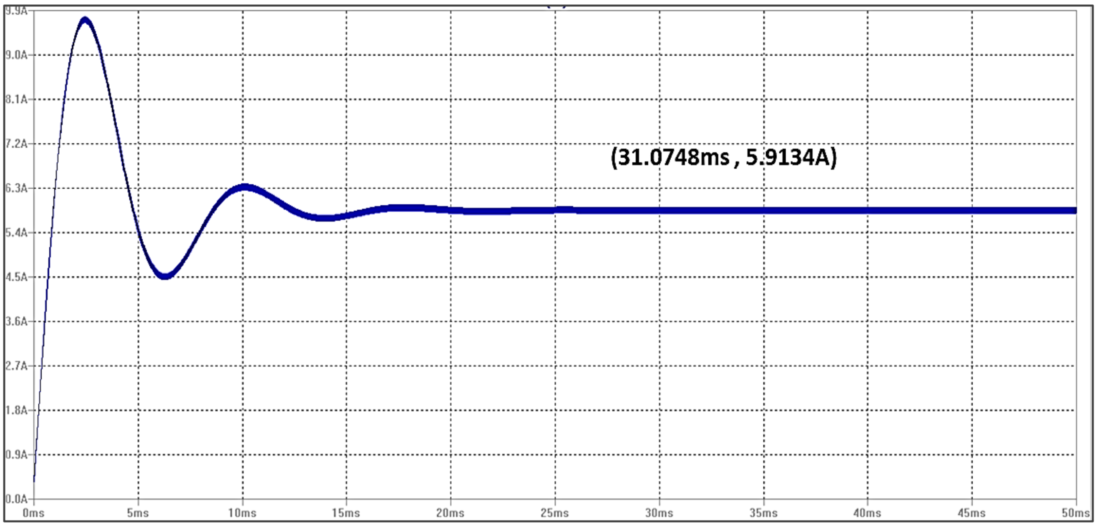

Figure 9. Current at inductor (L1)

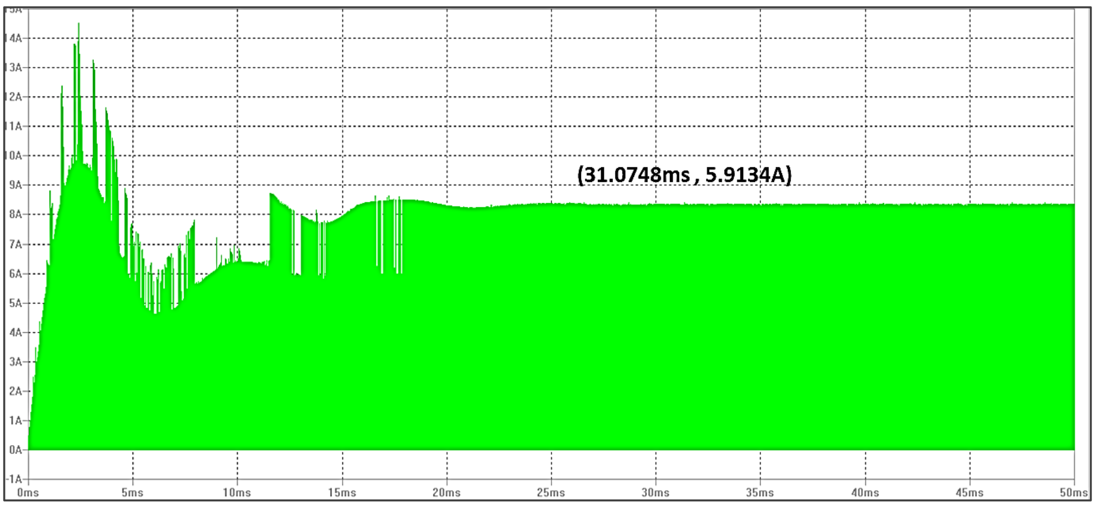

Figure 10. Current at diode D1

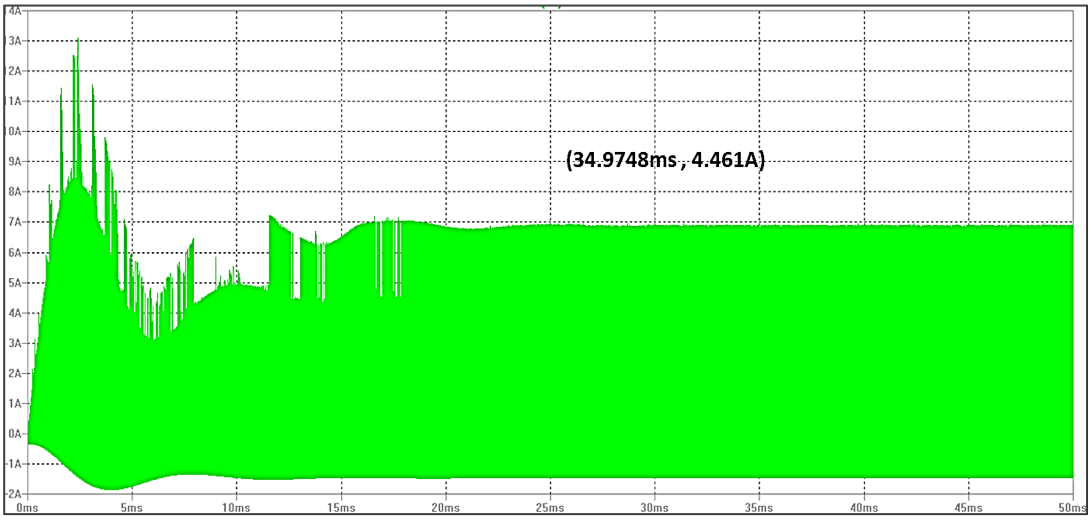

Figure 11. Current at capacitor C3

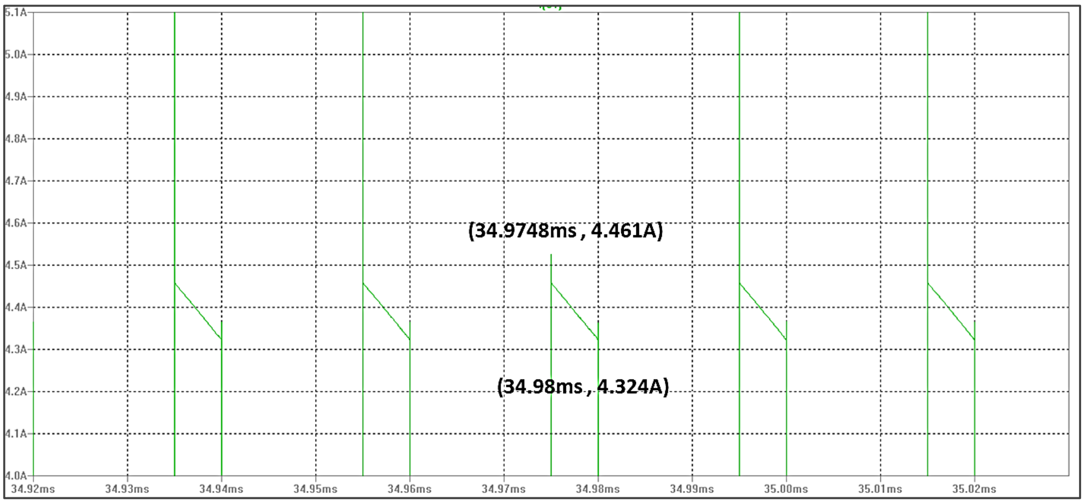

Figure 12. Current magnification at capacitor C3

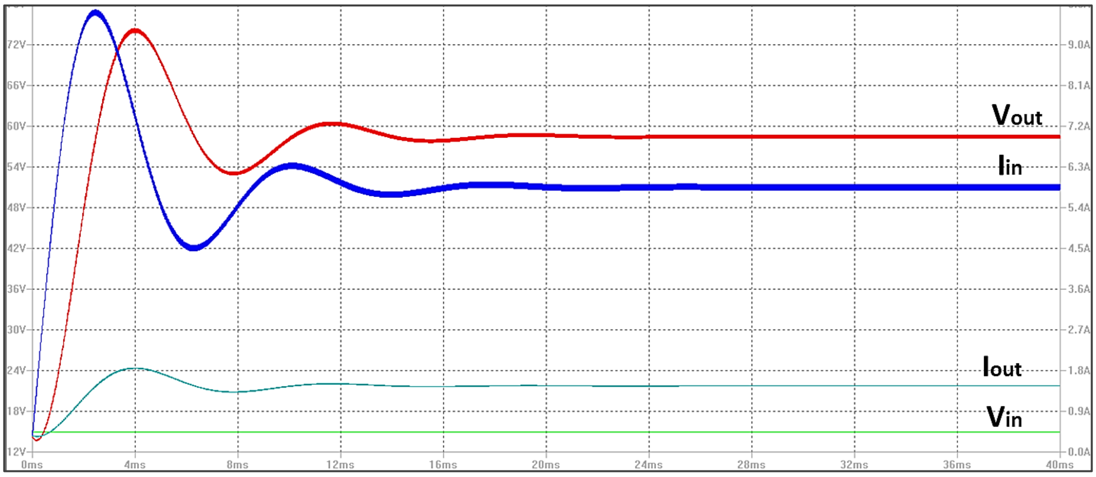

Figure 13. Voltage and current magnification at the load R4

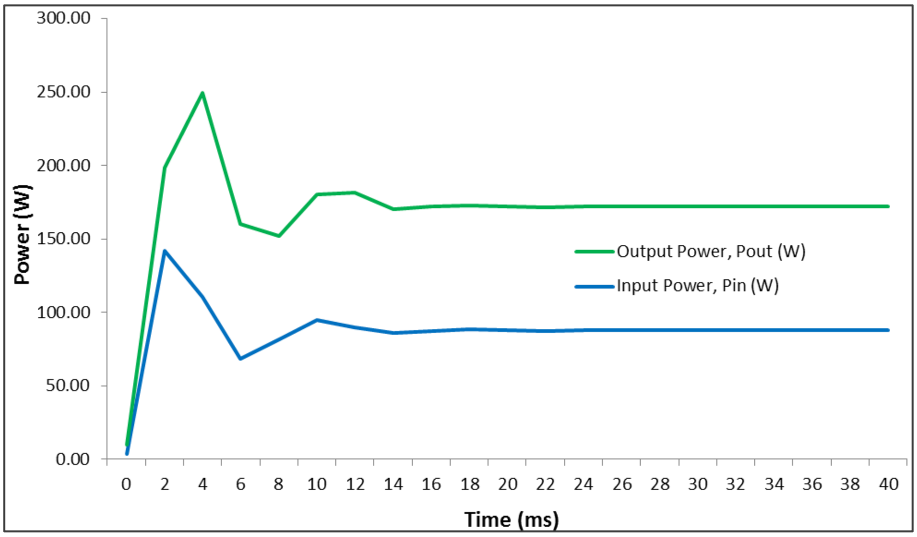

Figure 14. Input and output power of DC to DC boost converter

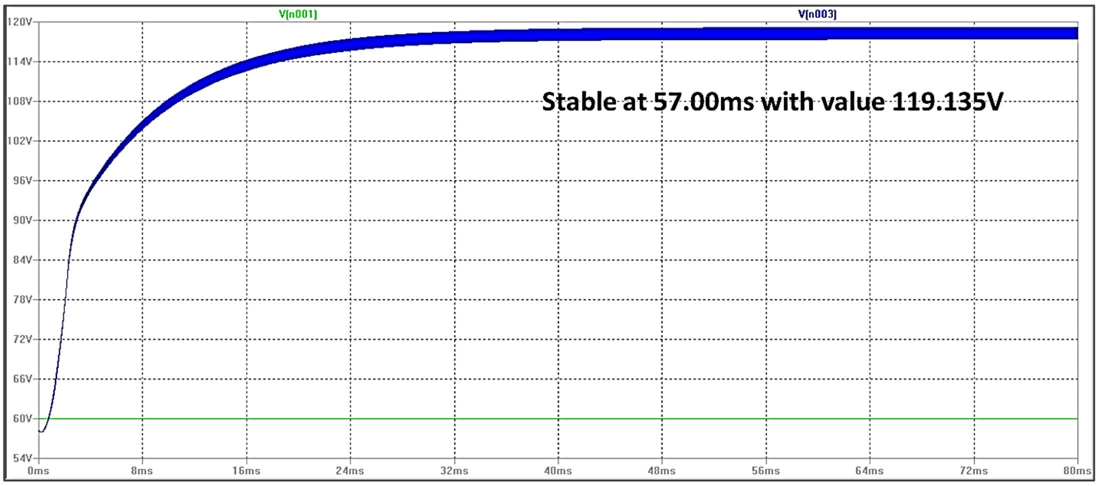

Figure 15. Output voltage at R2 and C4

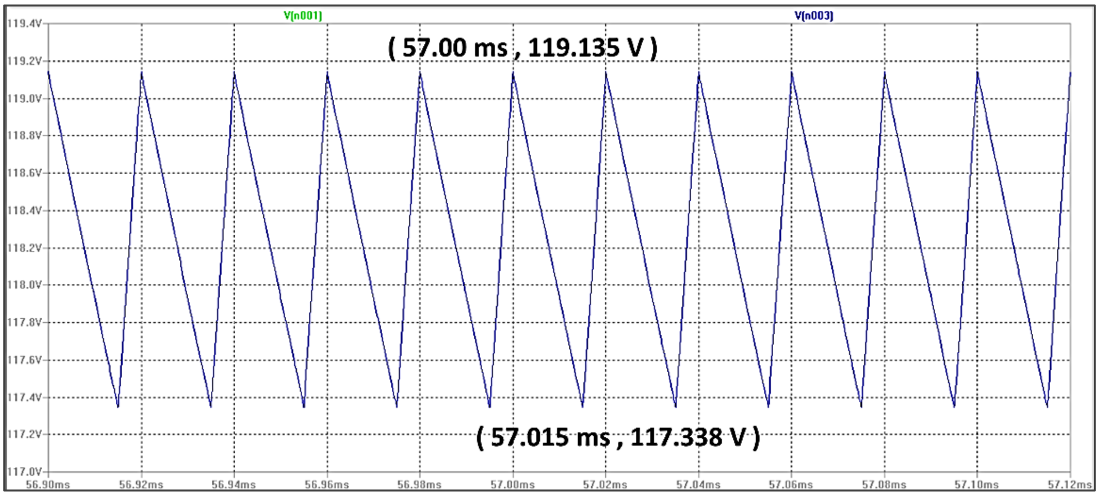

Figure 16. Magnification of voltage at R2 and C4

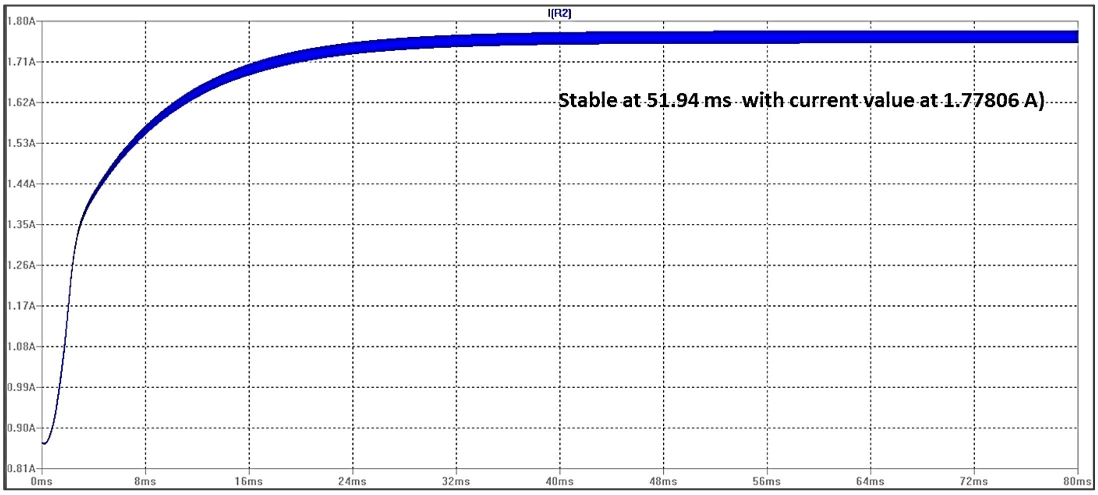

Figure 17. Load current at R2

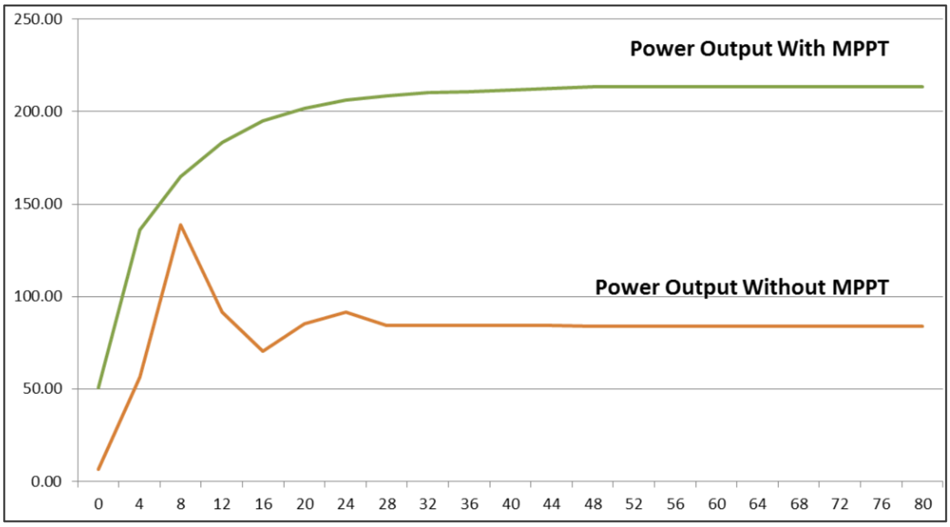

Figure 18. Output power with and without MPPT

5. CONCLUSION

In this work, the method of developing the MPPT algorithm for PV utilizing the Peripheral Interface Controller has been successfully implemented with the integration of the DC-DC boost converter. The developed control system adjusts the duty cycle of the converter to extract the maximum power. With a DC input voltage of 15 V, the boost converter is capable of generating an output voltage of an approximately 60 Vdc at a maximum power of 213.42 W with minimum voltage ripple as compared to 84 W without the MPPT. This proved the effectiveness and adequacy of the developed algorithm.

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