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FOUR-PHASE INTERLEAVED BOOST CONVERTER FOR MAXIMUM POWER EXTRACTION IN PV SYSTEM

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ABSTRACT

The use of renewable energy is increasing, thus affecting the rapid use of DC-DC converter technology. The use of a conventional boost converter has a weakness, namely high current ripple. This input current ripple will enter the voltage source, so that the switching noise will spread to other circuits. This problem can be overcome by using a multiphase converter topology that can suppress current ripple. But the conventional multiphase topology has large power losses, because the value of the inductor used tends to be large. Ripple currents will also reduce the efficiency of solar power plants. This study aims to design a four-phase interleaved boost converter that is applied to PV (photovoltaic) with maximum power extraction. The topology method of this circuit is to assemble a conventional boost converter in parallel up to 4 levels, so that it can suppress the input current ripple. This topology modification series also uses the interleaved scaling method in order to reduce heat distribution on each switch. The test method in this study uses a standard boost converter circuit as a comparison, and observes its characteristics and performance through simulation. The converter system is also operated as Maximum Power Point Tracking (MPPT) using the PSO and P&O algorithm controls as a comparison. Based on the simulation results, the MPPT tracking speed has the same speed, which is 2 ms, but the speed to achieve ripple stability in the standard circuit and four-phase interleaved boost converter is 4.5 ms and 6.1 ms, respectively.

KEYWORDS *Four-phase interleaved boost converter; current ripple input; solar power plant; MPPT; Particle Swarm Optimization*

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INTRODUCTION

The output power generated from renewable energy is generally difficult to control, a power electronic converter capable of implementing high-speed and high-accuracy control is required for renewable energy in power plants (Bayoumi, 2015). In addition, the output voltage of the solar cell is limited, so a boost converter circuit is needed to increase the voltage from the solar cell (Ikawanty et al., 2019). The main factor of the solar cell itself is the existence of a power supply capable of producing a continuous voltage. Currently the power supply works in switching mode, because it has a much higher efficiency compared to a linear power supply system. One of the main components of a switching mode power supply system is the DC-DC converter (Lopa et al., 2016). In general, DC-DC converters function to convert direct current (DC) electric power to other forms of DC electric power that are controlled by current, or voltage, or both (Midya et al., 1997). A boost converter is a switching DC-DC converter that uses a solid-state switch to perform its function. While the switching technique makes the boost converter generally very efficient, it introduces noise. The noise is mainly caused by the rapid switching on and off of the current through the switch, which results in a pulsating interrupted current. This generated noise affects the input and output terminals of the converter. On the input side, switching noise appears as input current ripples, and if not suppressed properly, will travel back to the DC bus and will propagate to other converters connected to the same bus (Ikawanty et al., 2022; Lentz, 2017). In PV systems using Maximum Power Point Tracking (MPPT), input current ripple from the boost converter will worsen MPPT performance and reduce PV system transfer efficiency (Ikawanty et al., 2022; Schofield et al., 2012). Therefore, minimizing the input current ripple from the boost converter in a PV system becomes an important goal. But using a conventional boost converter result in limited voltage gain and operating duty cycle close to 100% (Rosas-Caro et al., 2010). In addition, a very large component value is needed, a large inductor value will affect the magnitude of the input current ripple (Valdez-Resendiz et al., 2013).

Some of the problems that arise in the use of conventional boost converters resulting in large input current ripples are switching noise. The use of switching mode in the boost converter further adds AC ripple to the input or output signal (Ikawanty et al., 2022). Likewise, a mistake in designing the boost converter will cause the switching noise to spread to the circuit, and result in electromagnetic interference (EMI). EMI is an electromagnetic radiation signal that damages the performance of electrical systems (Geetha et al., 2009). The next problem is the discontinuous current caused by the switching mode of the converter. When the input current ripple enters the voltage source, the switching noise will spread to other circuits, which use the same voltage source. Current ripple will also worsen the maximum power point tracking (MPPT) performance and reduce the transfer efficiency of photovoltaic systems (Schofield et al., 2012). So, by reducing the current ripple in the converter will have a good impact on all systems.

The next obstacle to the solar power system is weather changes and the cloud cover factor for solar panels. In addition, solar cell energy is a non-linear source, highly dependent on load and weather conditions such as solar cell temperature and variations in solar irradiance (Faizal & Setyaji, 2016; Salah & Ouali, 2011). Under these conditions, the efficiency becomes low. In addition, in the case of a solar cell array under partial shade conditions, hotspot problems will occur which can damage the solar cells. Partial shading causes a change in the peak of the P-V characteristic curve, in other words, more than 80% of solar energy is not converted into useful electrical energy but is lost in the environment (Ngan & Tan, 2011). There are various ways to overcome power optimization in solar power systems, including non-physical and physical-electrical engineering mechanisms. Non-physical engineering is carried out through the Maximum Power Point Tracking (MPPT) mechanism, or a method based on Artificial Intelligent Control (AIC). MPPT is used to extract the maximum available power from the PV array to maximize the utilization efficiency of the solar cell array (Ji et al., 2010).

Therefore, this research will correct some of the deficiencies with the MPPT method using a four-phase interleaved boost converter with Particle Swarm Optimization (PSO), with this combination it is hoped that it can improve tracking speed. The second is a modification of the four-phase interleaved boost converter, so you will get low input current ripple. Moreover, the study aims to design a four-phase interleaved boost converter that is applied to PV (photovoltaic) with maximum power extraction.

RESEARCH METHOD

The method used in this study to reduce current ripple is to modify the boost converter, with parallel method or in other words is multiphase. Multiphase converters offer various benefits over phase converters conventional single. The use of two phases effectively doubles the operation converter frequency. The two-phase implementation provides the benefit of higher frequency switching without many of the drawbacks and disadvantages of switching associated with increase the switching frequency of a single-phase converter.

The use of multiple phases improves the input and output characteristics of converter. The input current ripple shows lower amplitude and harmonics. Because the total input ripple represents the combination of the four inductor inputs charging and discharging is out of phase, ripple cancellation occurs. This effect produces a peak ripple to the input peak the current is equal to quarter of the inductor per phase. Operation multiphase also increases the quality of the output voltage. Output voltage ripple frequency effectively multiplied, reducing filter requirements. Ripple reduction significantly reduces the stress applied to the capacitor, which it generally has shortest life of all components. While most of the components generally operating in tens or hundreds of thousands of hours, electrolytic capacitors show a period life under ten thousand hours when operated at full load. The circuit in Figure 1 is the result of a four-phase interleaved boost converter.

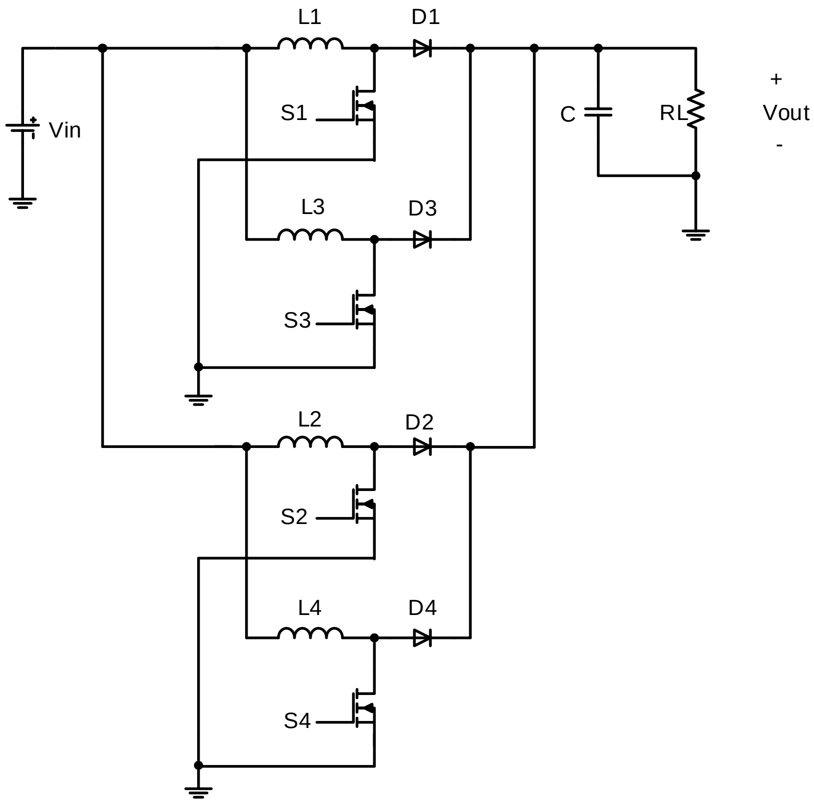

Figure 1. Four-phase Interleaved Boost Converter

Solar cells will not automatically work at their maximum working point, but must be controlled. Maximum Power Point Tracking (MPPT) is a method used to find the maximum working point of solar cells and maintain the solar cells working at that point. By getting the optimal voltage and current values so that the maximum output power is obtained from the solar cell. This maximum output power will result in high efficiency and reduce power loss in the system.

There are several MPPT techniques to get the maximum power point. P&O has advantages over other algorithms, namely easy and fast computation. The P&O algorithm can be illustrated in Figure 2 as a flow chart explaining the P&O algorithm. The operation of the MPPT P&O algorithm depends on the dP/dV perturbation term. When dP/dV is positive, the algorithm will automatically increase the voltage magnitude to the maximum dP/dV point. Conversely, when dP/dV is negative, the algorithm will automatically reduce the amount of voltage to a maximum dP/dV. This condition will continue until the maximum point is reached.

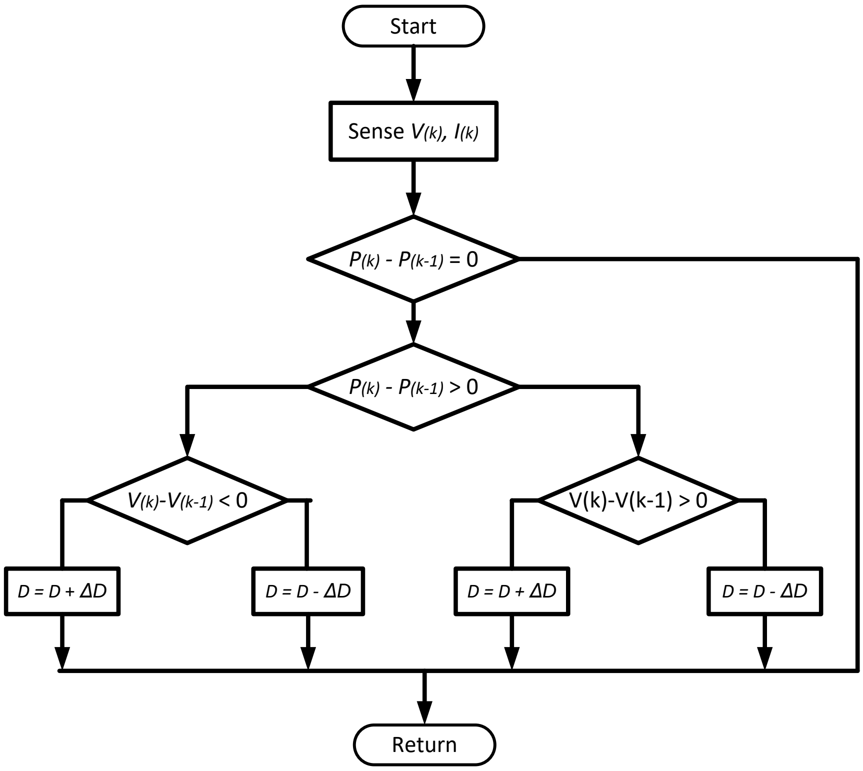

Figure 2. Flowchart of P&O algorithm

The PSO algorithm can be illustrated in Figure 3, begins by determining the particle swarm size of N. After that, degenerate the initial solution value population, for each particle with a value of x. The objective function of each particle is calculated: f(x). In this step, the iteration value is set equal to 1. And the value 0 is assigned to the velocity value of each particle in this iteration (1st iteration). In the next iteration, the parameters for each particle j are calculated, namely Pbest and Gbest. Pbest is the value of the optimum objective function encountered by a particle j.

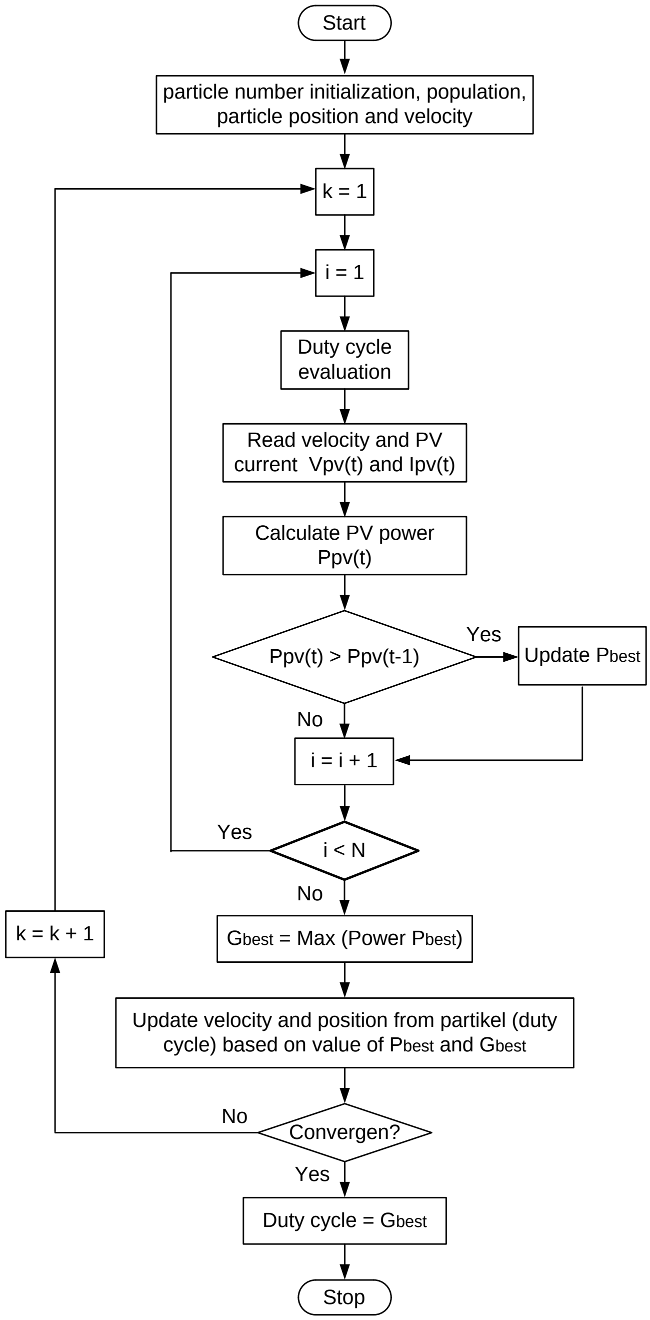

Figure 3. PSO MPPT Algorithm Flow Chart

RESULT AND DISCUSSION

The simulation of maximum power extraction in the four-phase interleaved boost converter uses 2 algorithms, namely the P&O and PSO algorithms. The next step is to combine four-phase interleaved boost converters with PV arrays and MPPT. This simulation aims to select the appropriate algorithm for the four-phase boost converter modification circuit. The simulation results were carried out with different irradiation values between 600 to 1000 W/m2 at a constant temperature of 25°C. Changes in the irradiation step at 700 W/m2 occurred at t = 0.4 s, 600 W/m2 at t = 0.5 s, 900 W/m2 at t = 0.6 s, 1000 W/m2 at t = 0.7 s, 800 W/m2 at t = 0.8 s, and 700 W/m2 at t = 0.9 s.

Figure 4 shows a graph of the voltage, current and power of the PV array in a four-phase interleaved boost converter with the P&O algorithm. In the figure, it can be seen that the PV current is unstable at 0.4 s when the irradiation changes from 0 to 700 W/m2, which affects the graph of PV power.

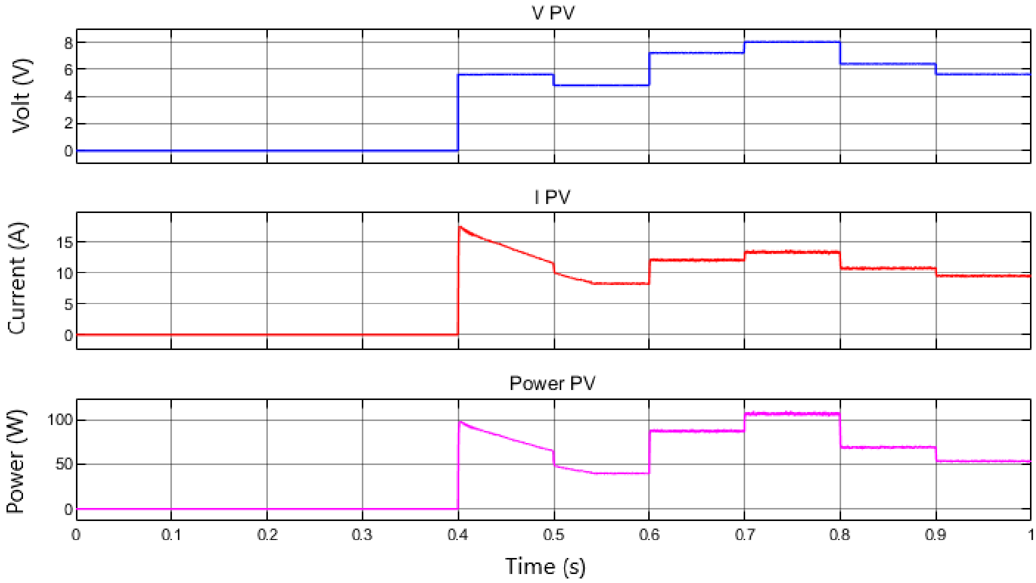

Figure 4. Voltage, current and power of PV array in four-phase interleaved boost converter with P&O algorithm

Figure 5 is a graph of voltage, current and load power in a four-phase interleaved boost converter with the P&O algorithm. In the picture, it can be seen that the current and power voltages at the load have high ripple.

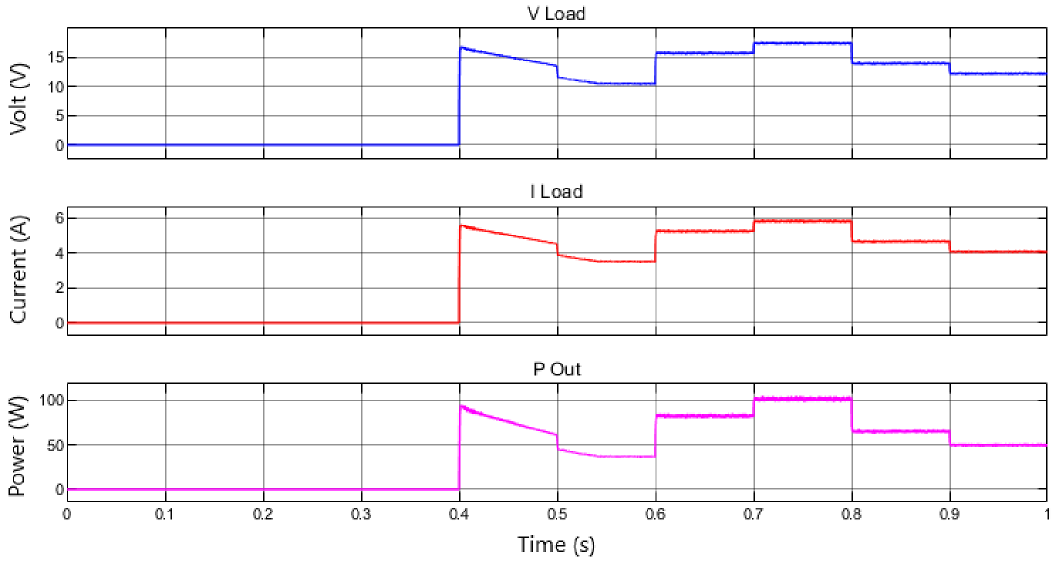

Figure 5. Voltage, current and load power in four-phase interleaved boost converter with P&O algorithm

In Figure 6 is a graph of the simulation results of voltage, current and PV array power in a four-phase interleaved boost converter with the PSO algorithm. At the beginning of the change in irradiation at t = 0.4 s the three graphs show stability even though the irradiation varies. So that the effect on voltage, current and power on the load still shows stability as shown in Figure 7.

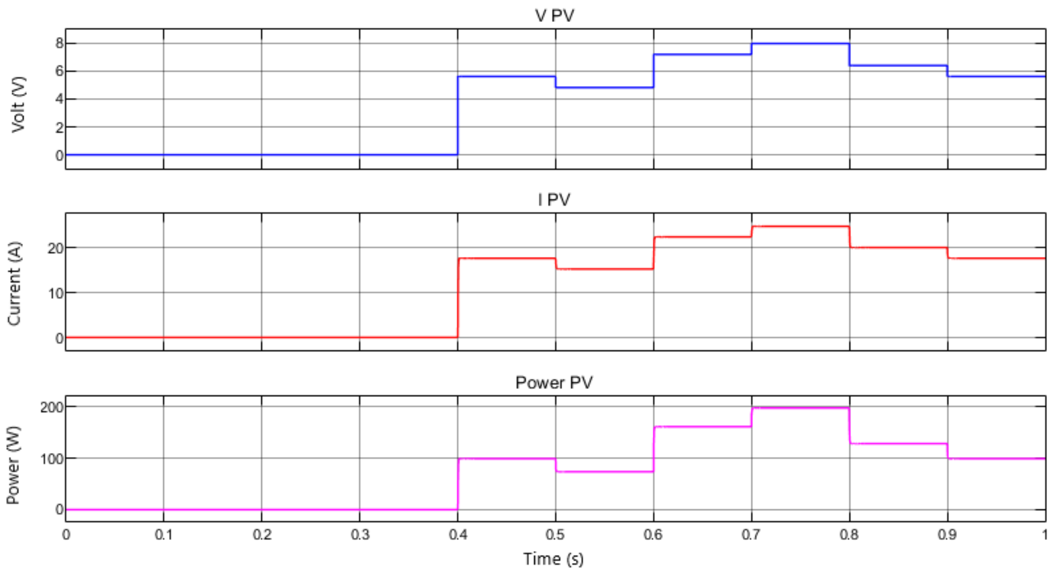

Figure 6. Voltage, current and PV array power in four-phase interleaved boost converter with PSO algorithm

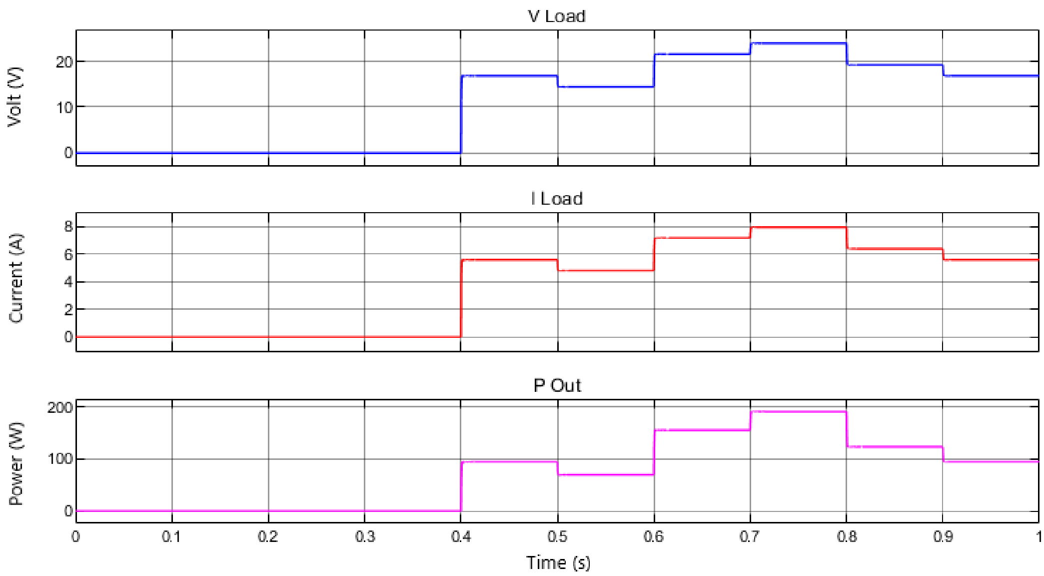

Figure 7. Voltage, current and load power in four-phase interleaved boost konverter with PSO algorithm

Figure 8 shows a graph of the results of the comparison of the P&O and PSO algorithms. Based on the figure, PSO has a higher output power value than P&O. PSO has better accuracy and fast tracking for MPP compared to P&O. So the PSO algorithm is suitable for four-phase boost converter circuits.

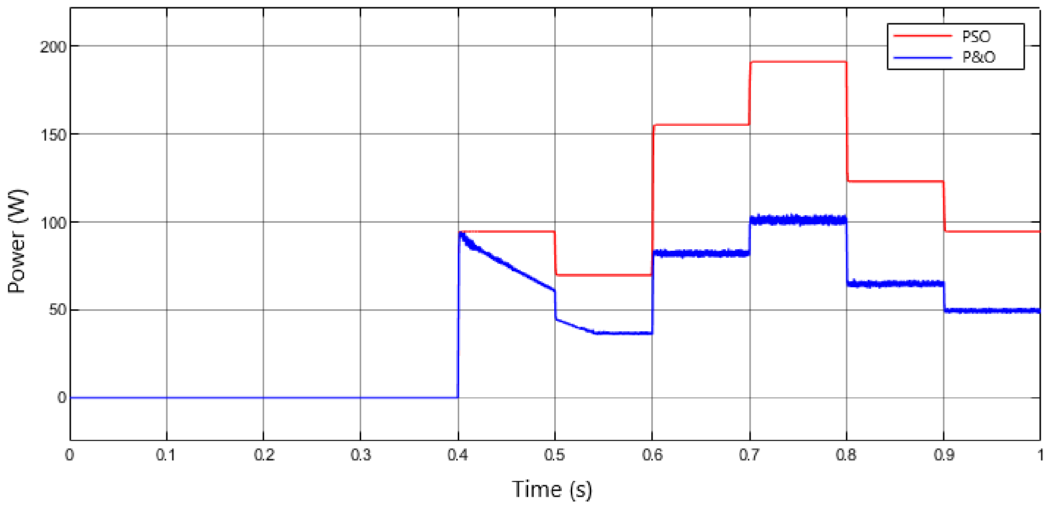

Figure 8. Power in four-phase interleaved boost converter with P&O and PSO algorithm

The next simulation is to compare the standard circuit and the four-phase interleaved boost converter with the P&O and PSO algorithms. Figure 9 shows the power tracking speed for standard and modified circuits. From the graph it can be seen that the value of the speed to reach the maximum power is the same, which is equal to 2 ms, but for the standard and modified circuits, they still contain ripples of up to 6.1 ms and 4.5 ms, respectively.

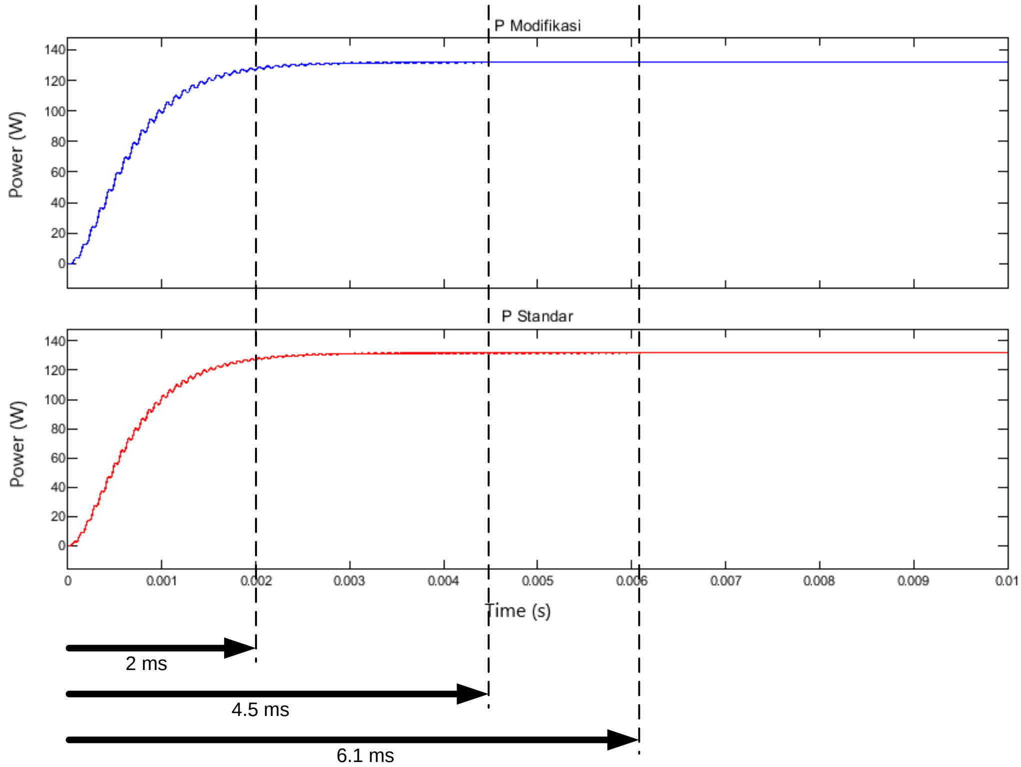

Figure 9. Maximum power tracking speed for standard circuits and four-phase interleaved boost converters

In Figure 10 is the result of power simulation in the standard circuit and four-phase interleaved boost converter with the PSO algorithm. From the two graphs there is no significant difference, both have a good tracking response. Similar to Figure 11, which is the result of a power simulation on a standard circuit and a four-phase interleaved boost converter with the P&O algorithm, it also has the same tracking response. But when compared between the PSO and P&O algorithms from the two images, the P&O algorithm has a larger ripple of 3.33% while the PSO algorithm has a 0.001% ripple and the tracking response on P&O is less stable at t = 0.4 s and irradiation 600 W/m2 to t = 0.53 s and irradiation 900 W/m2.

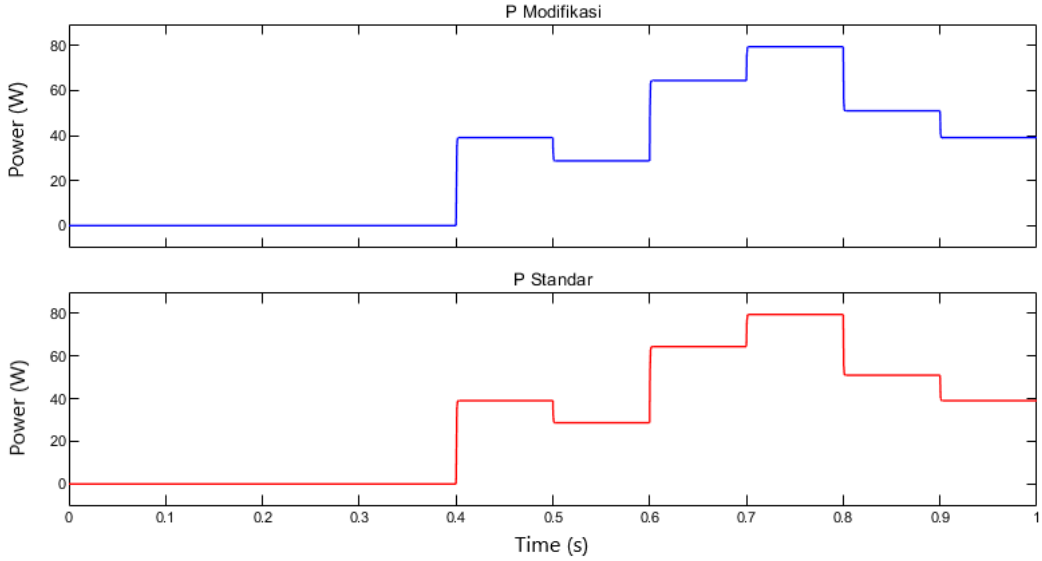

Figure 10. Power on standard circuits and four-phase interleaved boost converters with the PSO algorithm

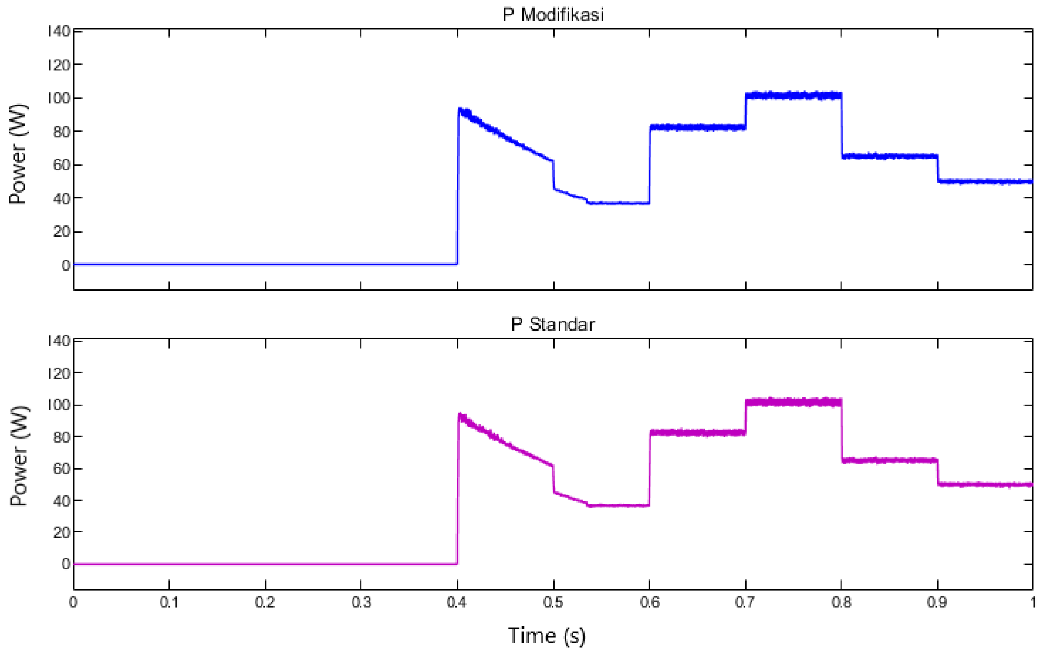

Figure 11. Power on standard circuits and four-phase interleaved boost converters with P&O algorithms

CONCLUSION

A four-phase interleaved boost converter with PSO and P&O MPPT algorithms for the PV array has been presented. The simulation results for the two MPPT algorithms are at PSO almost zero steady-state oscillation, capability to track MPP under unsettled irradiation conditions. Whereas the P&O has a large steady-state oscillation, poor to track MPP under unsettled irradiation conditions. The simulation results for the tracking speed between the conventional circuit and the four-phase boost converter are the same, namely 2 ms, they still contain ripples of up to 6.1 ms and 4.5 ms, respectively.

REFERENCES

Bayoumi, E. H. E. (2015). Power electronics in renewable energy smart grid: a review. *International Journal of Industrial Electronics and Drives*, *2*(1), 43–61.

Faizal, A., & Setyaji, B. (2016). Desain Maximum Power Point Tracking (MPPT) pada Panel Surya Menggunakan Metode Sliding Mode Control. *J. Sains, Teknol. Dan Ind*, *14*(1), 22–31.

Geetha, S., Satheesh Kumar, K. K., Rao, C. R. K., Vijayan, M., & Trivedi, D. C. (2009). EMI shielding: Methods and materials—A review. *Journal of Applied Polymer Science*, *112*(4), 2073–2086.

Ikawanty, B. A., Ashari, M., Suryoatmojo, H., & Taufik. (2022). Design of a novel multiphase interleaved boost converter with split inductance and bypass capacitance. *International Review of Electrical Engineering (IREE)*, *17*(4), 391–400.

Ikawanty, B. A., Ashari, M., & Taufik, T. (2019). Low Input Current Ripple MPPT System with TwoPhase Boost Converter for Photovoltaics. *2019 5th International Conference on Science and Technology (ICST)*, *1*, 1–5.

Ikawanty, B. A., Ashari, M., Suryoatmojo, H., & Taufik. (2022). A Novel Multiphase Interleaved DC-DC Boost Converter with Reduced Input Current Ripple for Renewable Energy Application. *International Journal on Engineering Applications (IREA)*, *10*(1), 77–86.

Ji, Y.-H., Jung, D.-Y., Kim, J.-G., Kim, J.-H., Lee, T.-W., & Won, C.-Y. (2010). A real maximum power point tracking method for mismatching compensation in PV array under partially shaded conditions. *IEEE Transactions on Power Electronics*, *26*(4), 1001–1009.

Lentz, N. H. (2017). *A Modified Boost Converter with Reduced Input Current Ripple*.

Lopa, S. A., Hossain, S., Hasan, M. K., & Chakraborty, T. K. (2016). Design and simulation of DC-DC converters. *International Research Journal of Engineering and Technology (IRJET)*, *3*(01), 63–70.

Midya, P., Greuel, M., & Krein, P. T. (1997). Sensorless current mode control-an observer-based technique for DC-DC converters. *PESC97. Record 28th Annual IEEE Power Electronics Specialists Conference. Formerly Power Conditioning Specialists Conference 1970-71. Power Processing and Electronic Specialists Conference 1972*, *1*, 197–202.

Ngan, M. S., & Tan, C. W. (2011). Multiple peaks tracking algorithm using particle swarm optimization incorporated with artificial neural network. *International Journal of Electronics and Communication Engineering*, *5*(10), 1325–1331.

Rosas-Caro, J. C., Ramirez, J. M., Peng, F. Z., & Valderrabano, A. (2010). A DC–DC multilevel boost converter. *IET Power Electronics*, *3*(1), 129–137.

Salah, C. Ben, & Ouali, M. (2011). Comparison of fuzzy logic and neural network in maximum power point tracker for PV systems. *Electric Power Systems Research*, *81*(1), 43–50.

Schofield, D. M. K., Foster, M. P., & Stone, D. A. (2012). *Impact of ripple current on the average output power of solar cells*.

Valdez-Resendiz, J. E., Claudio-Sanchez, A., Guerrero-Ramirez, G. V, Aguilar-Castillo, C., Tapia-Hernandez, A., & Gordillo-Estrada, J. (2013). Interleaved high-gain boost converter with low input-current ripple for fuel cell electric vehicle applications. *2013 International Conference on Connected Vehicles and Expo (ICCVE)*, 812–817.