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Effect of Inductor for Designing an Inverter to Maximize Solar Panel Power Output

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Abstract— The current methods to maximize solar cell efficiency have proven too complex for low-power solar applications. In addition, traditional methods, such as changing the orientation of a solar panel, can be too difficult for large photovoltaic arrays. Therefore, in this work, various analyses will be done with the critical components of a solar PV circuit to estimate its maximum power point (MPP). The effect of inductance for designing a solar cell system for maximized power by controlling the DC/DC Boost controller.

Keywords: *Maximum Power Point Tracking, Internet of Things, PV*

1. INTRODUCTION

The sun is a core facet of all living beings as it influences the weather and seasons and makes plant life possible due to its photo-chemical energy being used in photosynthesis. Since fossil fuels are slowly being depleted, the world has transitioned to an all-sustainable future, where solar and wind energy are two of the rising contenders as they are the most abundant. An integral part of a solar cell is converting solar energy to electrical using photovoltaic modules. As solar photovoltaic (PV) panels are more available to consumers, this form of energy harnessing is becoming more widely known. Different techniques are employed to find the maximum power point to maximize the efficiency of these panels.

Using a Maximum Power Point Tracking (MPPT) algorithm is one approach to have a solar panel operate at its maximum power point. Most of the different types of MPPT algorithms probe the entire operating range of the panel to detect where the maximum power is being generated - some examples of integrated circuits which can do so are the LT8490 and the LTC4015[1-2]. The advantage of using this algorithm is that it can find and contrast between a local power peak from a global power maximum. It achieves this by continually sweeping the output range of the panel and detecting the operating conditions where maximum power was reached. After this is done, the system constraints the panel to return to this power point. While these periodic sweeps are being done, the MPPT algorithm will continuously dither the operating point to ensure it stays at/ near the peak [3]. Dithering adds noise to a signal to make quantization distortion less visible.

As global energy demand continues to grow, non-renewable energy sources such as oil are being depleted at an alarming rate. Solar energy is one of the most available forms of energy as it is readily present during the day. Still, the orientation of the solar panels might have to be changed for them to face the sunlight directly. For large PV arrays, this can prove to be an issue as these large panels can be quite cumbersome to move unless they use an automated system.

In this paper, the effect of inductance is observed for designing an inverter and its impact on power tracking.

2. MODELLING OF THE PROPOSED CIRCUIT

A closed loop system will be used with a fixed voltage to monitor the system. The algorithm specified before was the Perturb and Observe method, where the change of the duty cycle is directly proportional to the output voltage change. The system block diagram is shown in Figure 1, along with the main components.

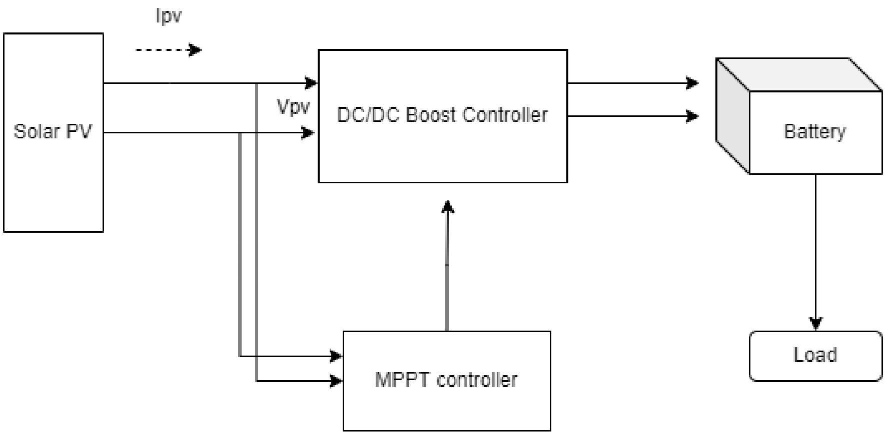

Fig. 1. Block diagram of the proposed system

The circuit is mainly comprised of a Booster circuit, an MPPT Controller and a battery. For the algorithm, the Perturb and Observe method (P&O) can be used to implement the MPPT for solar PV. Several papers have outlined that this algorithm is quite efficient and selects the future value of the output voltage while remembering the current and the past values as it fluctuates [4].

3. THE PROPOSED MAXIMUM POWER POINT TRACKING SYSTEM

This section will focus on the critical circuits that are to be used, and their respective simulations are also shown here for clarity. Formulas for the components are shown where applicable, and detailed calculations are given in the appendix.

The schematic of the Boost circuit is shown below, and the calculations for the inductor and capacitor are elaborated here as well. For this initial analysis, the value of the inductor is increased from 2.5 uH to 22.5 uH with increments of 5 uH.

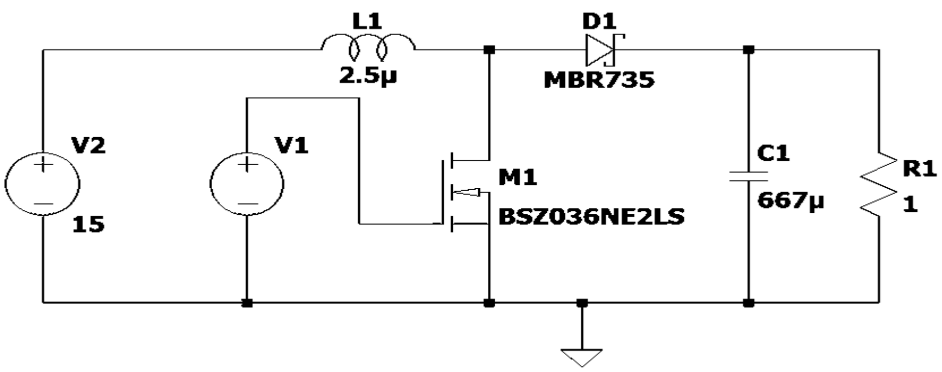

Fig. 2. Schematic diagram of the Booster circuit

The optimum value of the inductor and capacitor are calculated based on eqns. 1 and 2, respectively.

$$L = \frac{R.D(1-D)^2}{2.F_s} \tag{1}$$

Where, L – inductor value, H, D – duty cycle, F_s - switching frequency, Hz and R – equivalent load, Ω

Calculations for a capacitor:

$$C \geq \frac{V_O \,.\, D}{F_S.\ \Delta V_O \,.\, R} \tag{2}$$

Where, V_o – output voltage, V, D – duty cycle, F_s - switching frequency, Hz, ΔV_o - ripple voltage and R – equivalent load, Ω

The schematic of a dual 555 timer is shown in Fig. 3 for controlling the inverter clock.

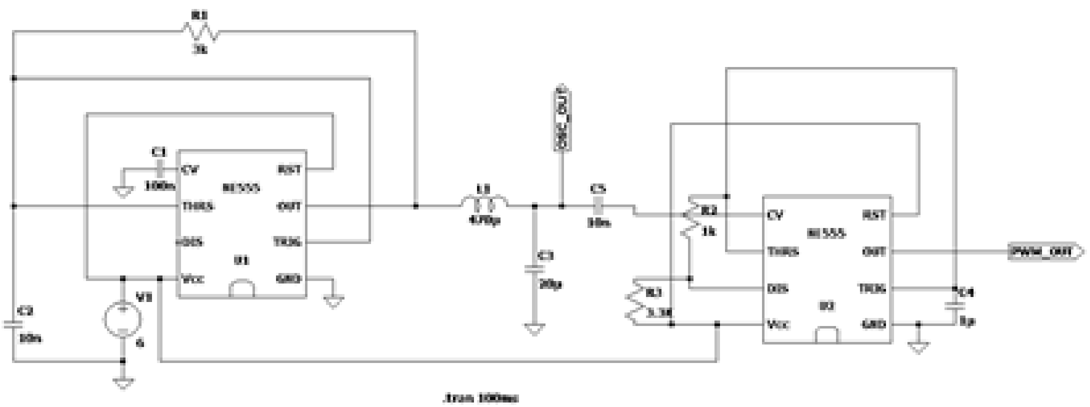

Fig. 3. Schematic of a dual 555 timer

To find the capabilities of an IC with Maximum Power Point Control, LTC3105 is being used.

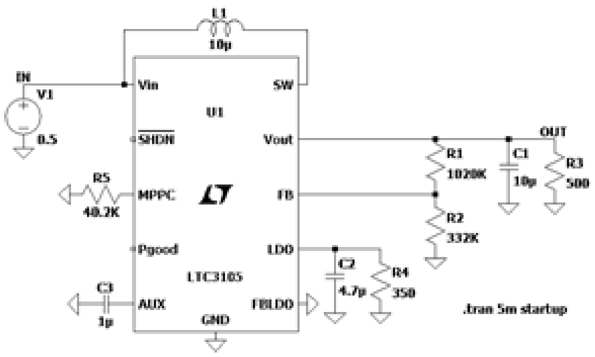

Fig. 4. Schematic of LTC 3105 (DC/DC step-up converter with Maximum Power Point Control)

4. RESULTS ANALYSIS

The simulations for the circuits shown in the previous section are given here. The analysis is done using LTSpice Simulation results for Boost converter:

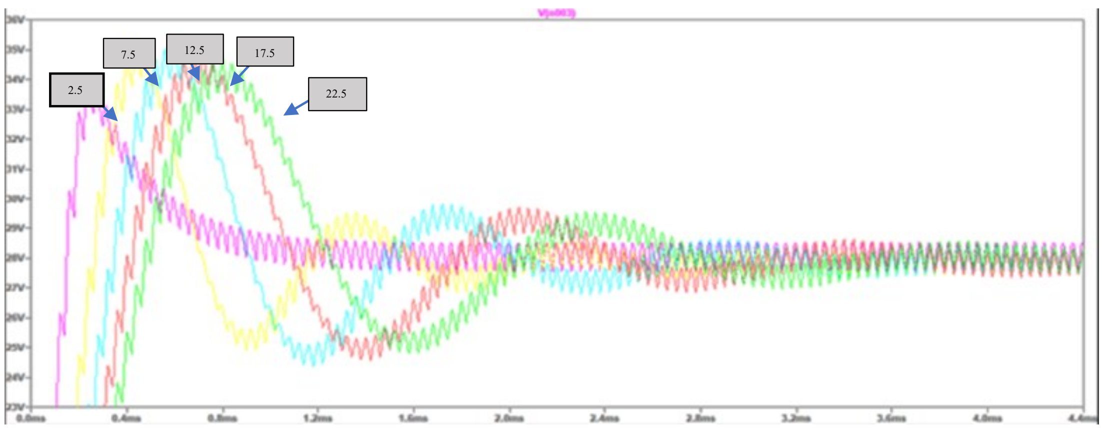

Fig. 5. Transient behavior with the variation of inductors as 2.5, 7.5, 12.5, 17.5 and 22.5 uH

Fig. 6 is a graph showing the inductor values, L, plotted against the peak output voltage, Vo_{max}. The peak voltage increases as the inductor value increases until a certain point, after which the peak voltage decreases with the increase in inductor value. This is due to a higher inductance reducing ripple current and thus increasing the maximum output current with the chosen integrated circuit.

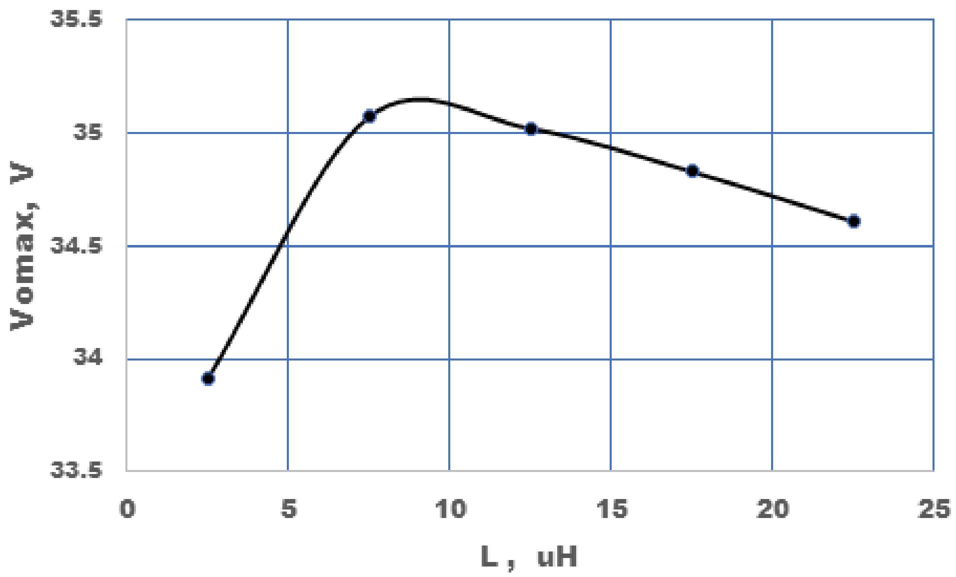

Fig. 6. The peak output voltage varies with the inductance variation during the transient state.

The transient peak also varies with the variation of the duty cycle, D. Figure 7 shows the variation of the peak voltage with the variation of the duty cycle and the output voltage. It is noted that the input voltage of the inverter also varies while changing the duty cycle to maintain the same output voltage. However, some variation in the output voltage was also observed.

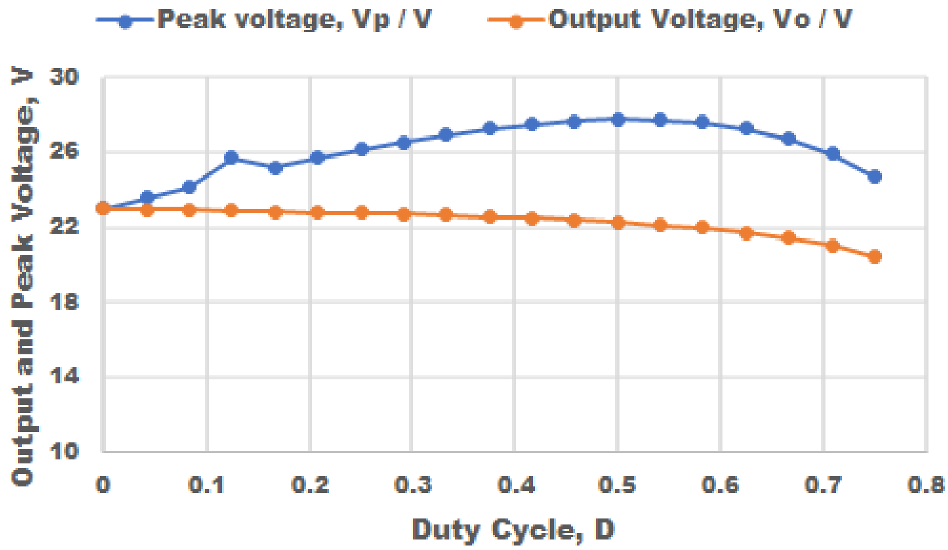

Fig. 7. Output and transient peak voltage phenomena with the duty cycle variation.

Table 1 shows the change in peak voltage, and output voltage, Vo, as the input voltage and duty cycle change. The formula used to calculate the duty cycle is:

$$D = 1 - \frac{V_i}{V_o}$$

Where, D – duty cycle, V_i – input voltage, V, and V_o – output voltage, V

To maintain the output voltage constant while the input voltage is decreased due to reducing solar output voltage, the duty cycle needs to be increased, as shown in Fig. 8. This figure shows a slight output voltage variation.

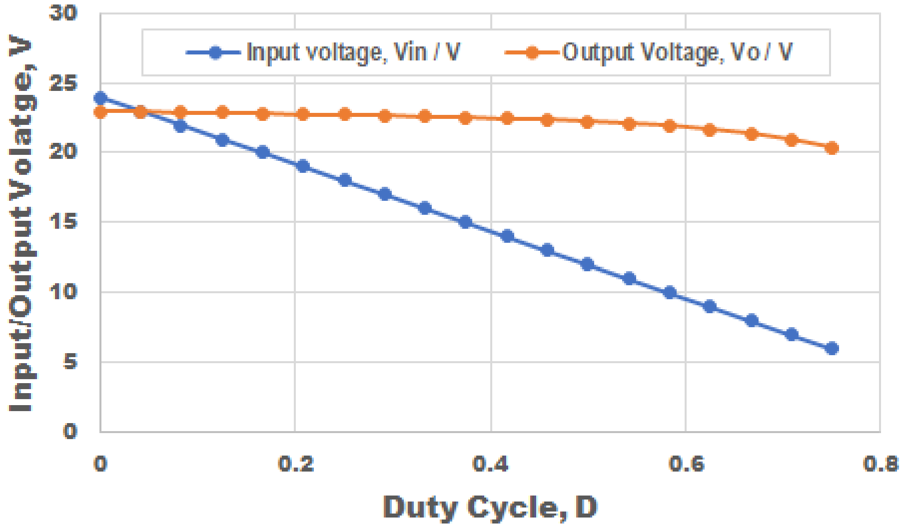

Fig. 7. Effect input voltage to maintain the constant output.

It can be seen that the duty cycle decreases as the input voltage is increased from 6V to 24V, while the output voltage, V_o, increases from 20.400 V to 22.977V

The simulation of the dual 555 timer is shown in Figure 8.

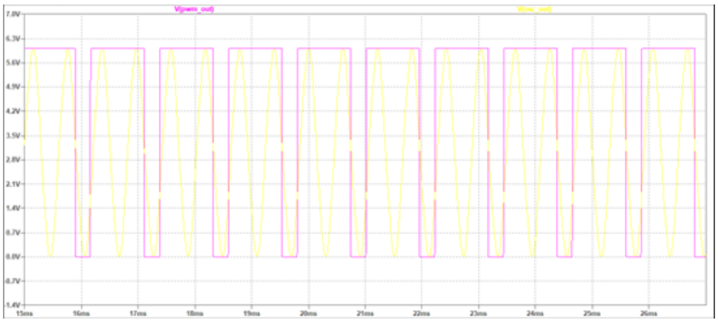

Fig. 8. Output voltage of the 555 timers

A 555 timer can generate a square-wave signal when set up like this. From the simulation, the voltage output for the oscillator (blue waveform) is changed to a square waveform at the PWM output.

To demonstrate the capabilities of an IC with Maximum Power Point Control, LTC3105 is being used. The simulation is shown in Figure 9.

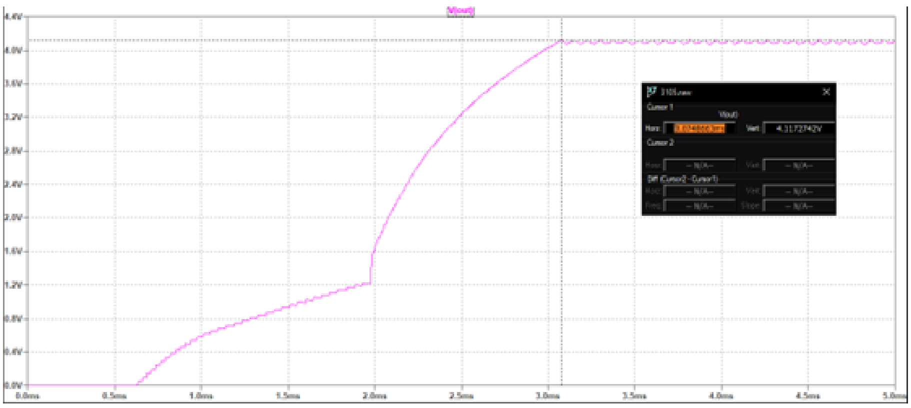

Fig. 9. Output voltage for the circuit of LTC3105

From the simulation, it can be deduced that the maximum power point for this circuit is reached at 3.07ms and when the voltage is 4.12V. This IC's maximum power point control (MPP) will constantly adjust the current or voltage depending on which of the two changes first so that the voltage output remains relatively constant.

Now, to compare the maximum power points, an equivalent solar cell circuit will be used, as shown in Fig.10.

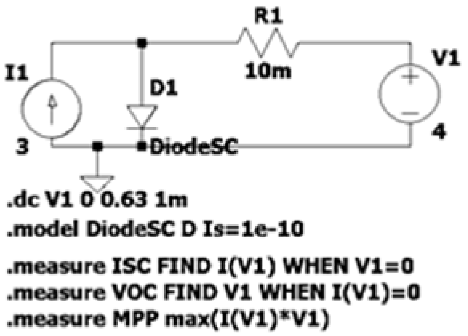

Fig. 10. Solar cell equivalent circuit

For this simulation, this circuit will be used to find it's maximum power point (MPP). The MPP is the point on it's current-voltage (I-V) curve where the product of current and voltage is at its maximum. Comparing this with the I-V simulation for the circuit shown in Figures 11 and 12 will prove that it aligns with the established theory.

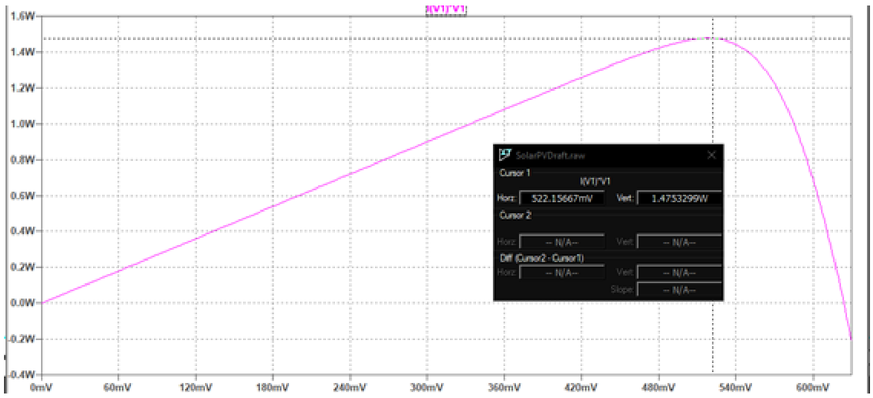

Fig. 7. I-V simulation graph showing the Maximum Power Point (MPP)

For a more detailed view of the short-circuit current, Isc, and the open circuit voltage, Voc, the data log for the simulation is shown in Figure 11.

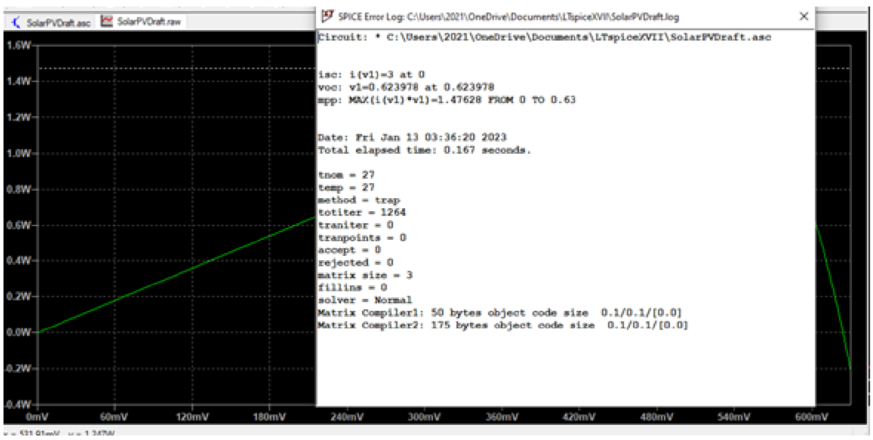

Fig. 8. Data log of the simulation

From Fig. 10, it can be deduced that the MPP is approximately 1.475W, and it reaches this value at 522.16mV. This is very close to a laboratory solar-cell voltage reading of 650mV. From the data log, the short circuit current, Isc, is 3A, and the open-circuit voltage, Voc, is 0.624V.

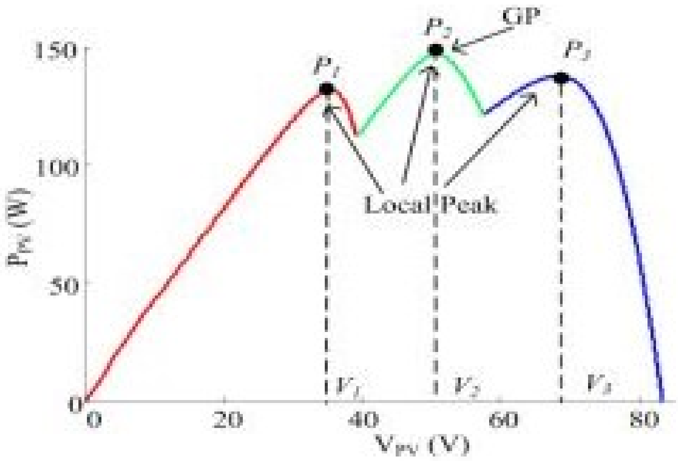

Fig. 9. PV curve for an entire array [5]

Comparing Fig. 12, taken from a research paper by Logeswaran & Senthil Kumar [5], which shows three power output peaks for the PV curve of an entire solar array, to Fig. 10, the maximum power output of Fig. 12 is about 150W (for peak, P2). The LTSpice simulation for a single solar cell is approximately 1.48W. Therefore, it can be concluded that at least 102 solar cells can be used to achieve the maximum power output of 150W.

5. CONCLUSION

This paper proposes a photovoltaic (PV) system utilising a Maximum Power Point Tracking (MPPT) algorithm by controlling the duty cycle of the inverter as one of the techniques to maximise the solar panel power output and the effect of the inductor for designing an inverter.

REFERENCES

[1] https://www.analog.com/en/products/lt8490.html (accessed July 2022)
[2] https://www.analog.com/en/products/ltc4015.html (accessed July 2022)
[3] Elbarbary, Z.M.S. and Alranini, M.A. (2021), "Review of maximum power point tracking algorithms of PV system", Frontiers in Engineering and Built Environment, Vol. 1 No. 1, pp. 68-80. https://doi.org/10.1108/FEBE-03-2021-0019
[4] U. U. Khan, M. Raheem, S. Ata, and Z. H. Khan, "Design and implementation of a low-cost MPPT controller for solar PV system," in *2016 International Conference on Open-Source Systems & Technologies (ICOSST)*, Lahore, Pakistan: IEEE, Dec. 2016, pp. 156–163. doi: 10.1109/ICOSST.2016.7838594.
[5] T. Logeswaran and A. Senthil Kumar, "A Review of Maximum Power Point Tracking Algorithms for Photovoltaic Systems under Uniform and Non-uniform Irradiances," *Energy Procedia*, vol. 54, pp. 228–235, 2014, doi: 10.1016/j.egypro.2014.07.266.