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DC-DC Converter as a Maximum Power Point Voltage Tracker.

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DC-DC converter as a maximum power point voltage tracker.

مغير جهد التيار المستمر يعمل كمتتبع لجهد نقطة أقصى قدرة .

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KEYWORDS:
Solar energy; Photovoltaic; maximum power point tracing

***الملخص العربي:*-فى هذا البحث يتم تصميم وتشغيل متتبع نقطة جهد أقصى قدرة مع حمل مقاومات متغيرة ويتم استخدام الاسلوب الفني للمغير الجهد المستمر فى التصميم والمتتبع المصمم يعمل كمغير جهد DC خافض وهو من النوع الذكي وذلك لاستخدام الكمبيوتر المتناهى الصغر المبرمج للتحكم في دوائر المتتبع ويحتوى المتتبع المقترح على ثلاثة دوائر أساسيه وهى: دائرة الإحساس ودوائر القيادة ودوائر الطاقة. والمتتبع المصمم يتم إنشائه ليتناسب استخدامه مع الأنظمة الفوتوفولتية وقد تم الاختبارالمعملي للمتتبع عند مستويات احمال مختلفة عند نقطه أقصى قدرة للوح الخلايا الشمسية وقد تم الاختبار عند مستوى اشعاع ثابت.**

Abstract— **In this paper, the maximum power point voltage tracker is designed and operated with the DC variable resistive load. The DC-DC converter technique is used for the design. The designed tracker operates as a DC-DC converter down. The designed tracker is a smart type; this is due to the use of programmed microcomputer to control the tracker circuits. The tracker contains three main circuits, sensing, drive and the power circuit. The designed tracker is constructed suitable to use with the photovoltaic power system (PVPS). The tracker is tested in the laboratory under different load levels at fixed insolation level.**

I. INTRODUCTION

THE rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. Harnessing solar energy using PV modules comes with its own problems that arise from the change in insolation conditions. These changes in insolation conditions severely affect the efficiency and output power of the PV modules [1-3]. A great deal of research has been done to improve the efficiency of the PV modules. A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers [1-3]. As the market is now flooded with varieties of these MPPT that are meant to improve the efficiency of PV modules under various insolation conditions it is not known how many of these can really deliver on their promise under a variety of field conditions. This research looks at how a different type of converter affects the output power of the module and investigates if the MPPT that are said to be highly efficient and do track the true maximum power point under the various conditions [1].

A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load [4, 5]. A dc/dc converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the module figure 2 [5]. By changing the duty cycle the load impedance as seen by the source is varied and

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matched at the point of the peak power with the source to transfer the maximum power [5]. Therefore, MPPT techniques are needed to maintain the PV array's operating at its MPP [6].

Many MPPT techniques have been proposed in the literature; examples are the Perturb and Observe (P&O) methods [4, 6-9], and Incremental Conductance (IC) methods [7, 10].

The main aim of this paper is to design and construct the maximum point voltage tracker. In the thesis proposed design of the maximum power point voltage tracker (MPPVT) is ill lustrated. The proposed design is represented based upon the microcomputer. Hence, the designed tracker is a smart type. This chapter represents the design procedure at maximum power point voltage tracker. This taker can be used to stabilize the output voltage .at any solar cell module with any type. The proposed designed tracker architecture is designed based upon the micro compute so; the proposed tracker is smart type. The designed tracker operates as the load

II. PHOTOVOLTIC SYSTEM

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells are grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This photovoltaic system consists of main parts such as PV module, charger, battery, inverter and load.

A. Equivalent solar cell model

A Photovoltaic cell is a device used to convert solar radiation directly into electricity. It consists of two or more thin layers of semiconducting material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated. A PV cell is usually represented by an electrical equivalent one-diode model shown in Fig.1

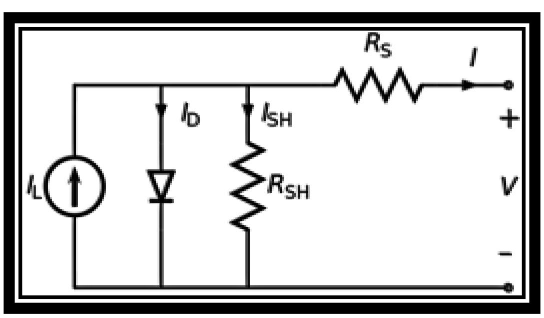

Fig.1. Solar cell model

The model contains a current source, one diode, internal shunt resistance and a series resistance which represents the resistance of each cell. The net current is the difference between the photo current and the normal diode current is given by equation [13].

$$ID = I_o\left[e^{\frac{q(V+IR_S)}{KT}} - 1\right] \quad (1)$$

$$I = I_L - I_o\left[e^{\frac{q(V+IR_S)}{KT}} - 1\right] - \frac{V+IR_S}{R_{sh}} \quad (2)$$

Where

I is the cell current (A)

q is the charge of electron (coulomb)

K is the Boltzmann's constant (j/k)

T is the cell temperature (k)

I_L is the photo current (A)

I_O is the diode saturation current. (A)

R_S, R_{sh} are cell series and shunt resistance (ohms)

V is the cell output voltage (v)

III. PV SYSTEM WITH THE PROPOSED MAXIMUM POWER POINT VOLTAGE, TRACKER

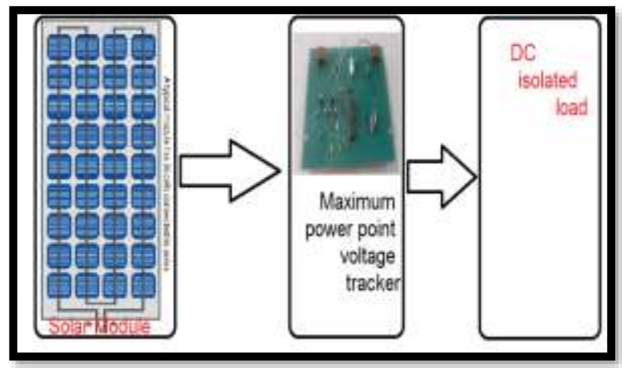

Fig. 2. Block diagram of PV system includes maximum power point voltage tracker

The PV solar cells array module used with the proposed maximum power point voltage tracker.

The system contains one of solar cells module has specifications of, maximum voltage 18.1v, maximum power point current 8.26A, maximum power is 150w open circuit voltage is 21.6v, and short circuit current is 9.1A. The PV solar cells module used is shown in figure 3, is constructed of 36 cells connected in series.

Fig. 3. Photo of solar cells module

IV. DESIGN STRATEGY

Initially, the selected module is tested in the laboratory for determining its electrical performance as well as to determine the maximum energy extracted from the module during the sunshine period. The module is oriented with tilt angle equal to the latitude angle, near 30°. The module is directed toward the equator during the test with fixed orientation angle.

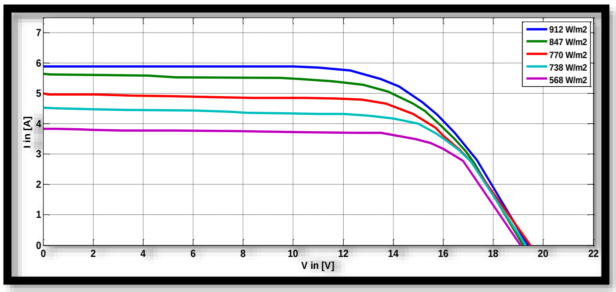

Fig.4. Electrical characteristics of PV module at different levels of insolation

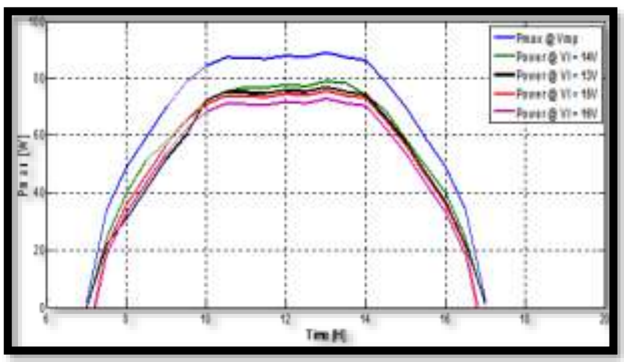

Fig.5. Maximum power extracted from the PV module at one day for different operating load voltages

The areas under the curves represent the energy output during one day at different operating voltage points of the loads locus in zone 2. The energy output of the module at maximum power point voltage, Vm =14V is 750Whr.

On the other hand, it has values of 584, 557, 557.8and 531Whr at voltage levels of 14V, 13, 15, and 16V. The load voltage level of 13V locates in the first zone of the I-V characteristic of the tested module and the other levels 14V, 15 and 16V locate at the second zone of the characteristic.

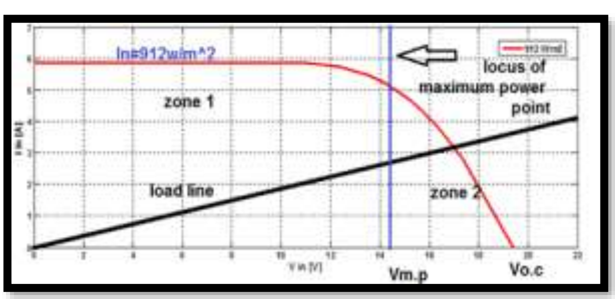

Fig.6. I-V Characteristic of tested module at in=912w/m^2

4.1 Operation zone of designed maximum power point tracker

Figure 6 illustrates the I-V characteristic of the module under test in solar energy laboratory at insolation level of 912 w/m2.

The characteristic can be separated into two distinct zones. Zone 1 presents the part of the characteristic during which the voltage of the solar cells array is gradually reduced. On the other hand, the current of the module through this zone is nearly constant. Zone 2 illustrates the second part of the array voltage. During it the array voltage is nearly constant but the current is rapidly reduced.

The designed maximum power point voltage tracker is designed to operate in the second zone. consequently, all loads operate below the maximum power point voltage must be forced to return to the point of maximum power. The designed maximum power point voltage tracker operates to force the load to operate at maximum power point voltage.

The proposed tracker is operated in zone 2 because nearly all of loads operate during the later zone

4.2 Control Method for The DC/DC Converter to get the PPT

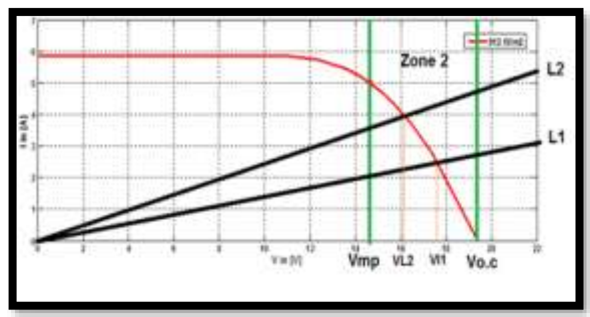

Fig. 7 Locus of two loads on I-V of solar cell module

Fig. 7 illustrates two distinct loads with different values supplied from the tested solar cells module. Load L_1 supplies from the solar cell module at voltage VL_1.

On the other hand, load (L_2) is provided its power from the module at voltage V_{L2}. The main function of the designed maximum power voltage tracker is to maintain the provided voltage to the loads constant at a value of Vmp.

Fig.8 represents thatV_{L2} is taken less than V_{L1}, while Vmp takes values less than V_{L1} and V_{L2}

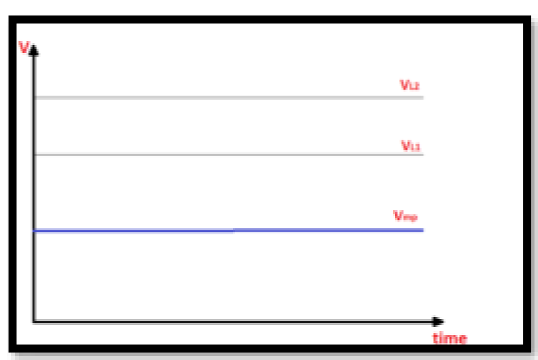

Fig. 8 Time levels of load voltage at different loads and at maximum power Vmp

The operation of the designed tracker generates voltage pulses on the load terminals. Fig.9 illustrates the voltage pulses referred to the two levels selected of load voltage.

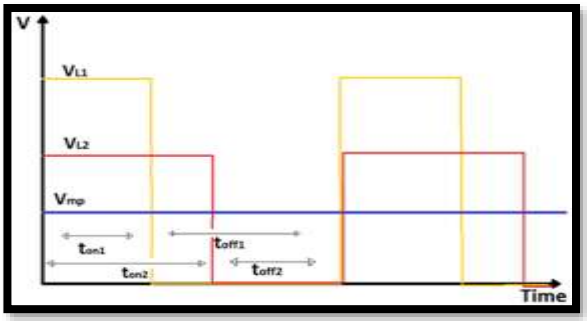

Fig.9. Pulses of tow load voltage generate by the designed tracker

Suppose that, load I upon the solar module has a level value of voltageV_{L1}such thatV_{L1}>Vmp.

To toggle the voltage level V_{L1} to the selected value VMP, the voltage level V_{L1} must be cut to the train of pulses. The chopping frequency is selected as 500 Hz hence:

$$V_{L1av} = V_{mp} = \frac{V_{L1} X\, t_{on1}}{T} \quad (3)$$

Where $\frac{1}{T} = f_{chopping}$ (4)

Put $\frac{t_{on1}}{T}$ =D (5)

Where D is the duty cycle

$$V_{mp} = V_{L1} \times D_1 \quad (6)$$

$$V_{L1} = \frac{V_{mp}}{D_1} \quad (7)$$

$$V_{L2} = \frac{V_{mp}}{D_2} \quad (8)$$

Hence,,

$$D = \frac{V_{mp}}{V_L} \quad (9)$$

Hence, the duty cycle is decreased as V_L increased and so, the ON time of the power switch of the tracker is show in Figure 9.

V. VALIDATION OF THE PROPOSED TRACKER

The load voltage is recorded at the instant of fixed insolation. Different load levels are selected in the range of the second zone of the I-V characteristic (Fig. 6) for the tested module. The last zone represents the operation zone of the designed maximum power point voltage tracker. The output load voltage is a train of pulses with frequency about 500Hz.

The output voltage pulse contains steady part superimposed on it exist a pulse likes as a spike. The spike amplitude depends on the value of load resistance. The spike has duration depends upon the switch ON time of the power switch used. Figures 10 to 15 represent the output load voltage at the load terminals at different load levels, they show that, the spike depends on the load levels. As the value increases, the spike amplitude decreases. This is due to decreasing of the spike time constant as a result of increasing the load level

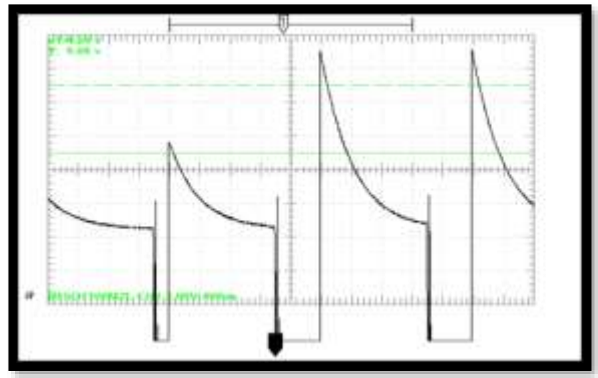

Fig. 10 Output plus at load terminal at load level L1

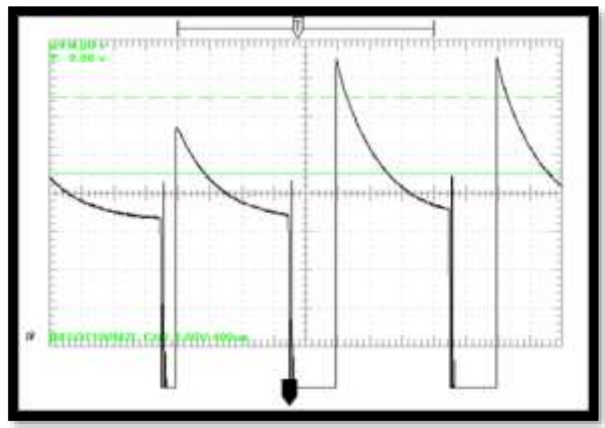

Fig. 11 Output plus at load terminal at load level L2

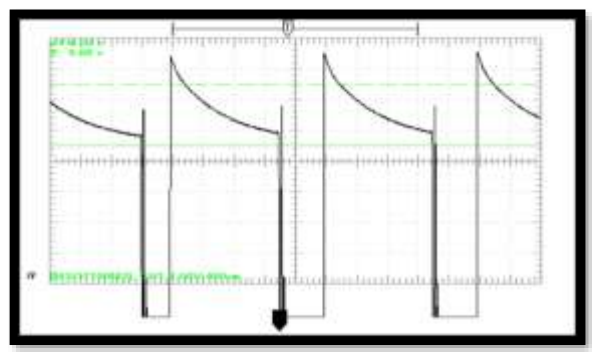

Fig. 12 Output plus at load terminal at load level L3

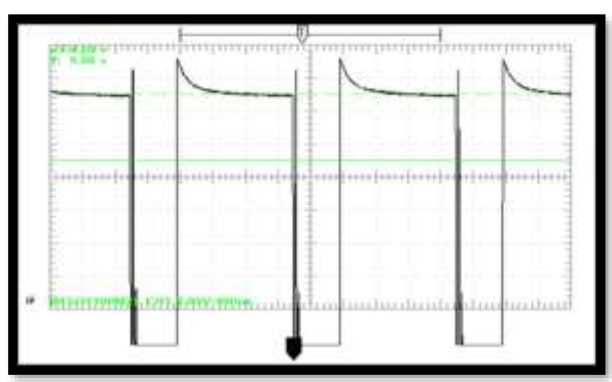

Fig. 13 Output plus at load terminal at load level L4

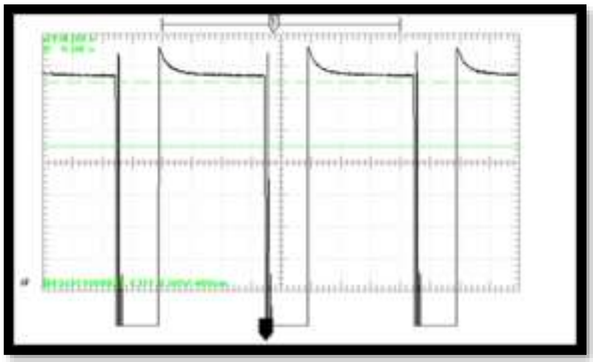

Fig. 14 Output plus at load terminal at load level L5

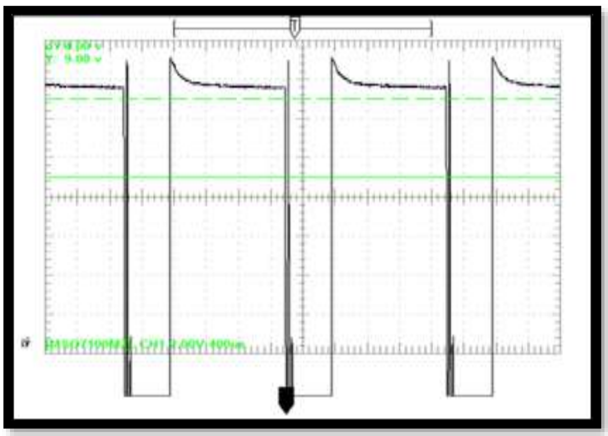

Fig. 15. Output plus at load terminal at load level L6

VI. ANALYSIS OF THE LOAD PULSES

The load pulse depends upon the load level value as shown in the previous figures. Each pulse of the load contains two parts, a steady voltage level and a transient term in the form of a spike. The amplitude of the steady part is varied as the load level changes. The last amplitude is decreasing as the load increases in its level value

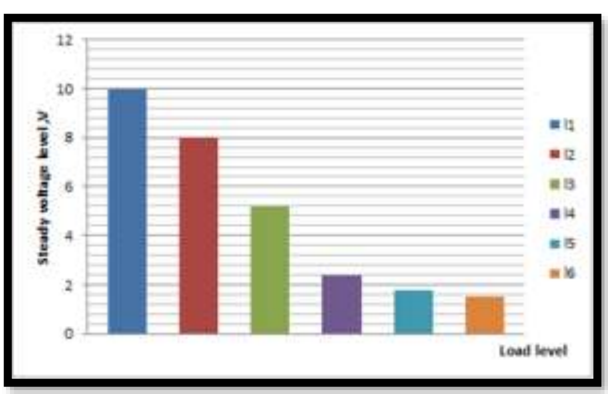

Fig. 16 Steady amplitude of the load voltage against load level

On the other hand, the spike amplitude superimposed on the steady voltage is directly proportional to the load level. Its amplitude decreases against the load value. This is due to the decrease of its time constant.

Figure 17 illustrates the relationships of the spike amplitude withe the load levels.

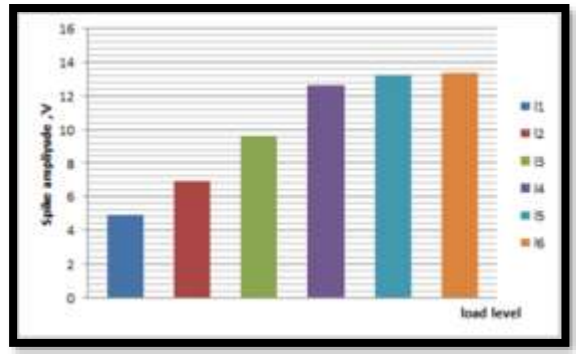

Fig. 17 Relationship between the spike amplitude and the load level.

VII. CONCLUSIONS

This paper presents the use of DC-DC converter as a maximum power point voltage tracker. The operation strategy of the tracker is proposed survey of the designed tracker is illustrated the proposed designed maximum power point voltage tracker is experimentally tested. The test purpose is to show the validity of the designed tracker. The tracker relates to the solar cell module along with variable resistive load.

The tracker is designed to operate in the second zone of the I-V characteristic of the provided module. So, the variable range of the connected load is selected to force the tracker to operate in the selected operation region. The tracker operates at different load levels and at a fixed insolation level. Hence, no interval is selected as the best operation interval.

The load voltage is investigated at different load levels. The inspection of the load terminal voltage shows that it has a spike at the instant of closing the switch (switch on). This spike is attenuated by increasing the load level, this due to the decreases of the spike time constant. As the switch turns off, the spike voltage reaches the ground level. The experimental test of the tracker shows that, the maximum amplitude of the module terminal voltage equals to the maximum amplitude of the load voltage. The last two quantities are equal to the voltage at maximum power point of the module under test, thence the designed tracker is employed in the proper purpose.

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