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USING A LEAD ACID BATTERY AS VOLTAGE REGULATOR OF PHOTOVOLTAIC POWER SYSTEM

استخدام بطارية الرصاص الحامضية كمنظم جهد لنظام القوى الفوتوفولتي

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خلاصة :

في هذا البحث يتم التعرف على امكانية استخدام بطارية الرصاص الحامضية المتوفرة في السوق المحلية كمنظم للجهد الخارج من خلايا شمسية حيث ان قيمة تغيير سعر قيمة الجهد. وقد تم عمل قياسات معملية لاداء نظام فوتوفولتي مكون من خلايا شمسية وبطارية والتي يتم عادة استخدامها كمخزن للطاقة. ولقد تمت ملاحظة اداء النظام الفوتوفولتي وذلك بقياس بعض المتغيرات مثل تيار الحمل وجهد الحمل وتيار شحن البطارية وجهد البطارية وكذلك تيار الخلايا وجهدها. وقد تم دراسة هذه المتغيرات مع الزمن لمدة حوالي ٤٠ ساعة. كذلك ايضا تم معرفة اداء المتغيرات السابقة مع شدة الاشعاع الشمسي الساقط. وقد تبين من النتائج انه يمكن استخدام بطارية الرصاص الحامضية كمصدر لتخزين الطاقة وكذلك ايضا كمنظم جيد للجهد الخارج

Abstract

In this paper the experimental measurements are carried out of Photovoltaic power system (PVPS) supplying static resistive load. The currents and voltages of solar cells array, lead acid battery and load are measured during 40 hours under actual conditions. The relationships between previous parameters against time as well as the intensity of radiation received by the Photovoltaic array are experimentally investigated. The experimental results show that the lead acid battery is a good voltage regulator for PVPS

1. Introduction

The Photovoltaic power systems are known to be nonlinear, and there exists one operating point corresponding to maximum power point (MP). The MP of PVPS depends on the environmental factors such as solar insolation, and operating cell temperature [1,2]. The optimal operating point varies widely over time. DC-DC converters are used to convert the unregulated DC input into a regulated DC output at desired voltage level. The control objective for boost converter is to move the operating point of the PVPS to the constant voltage level. The control objective for buck-boost and cuk converters are to move the operating point of PVPS to its peak power point [3]

Lead acid batteries provide the most common means of energy storage in PVPS today. A prominent feature of their operation is cycling. This, together with

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other operating parameters, affect the battery life and maintenance requirements which must be allowed for the design of a PVPS [4, 5, 6].

In this paper, the lead acid battery is used to regulate the terminal voltage of static resistive load connected directly with solar cells array as well as an energy storage element. Experimental measurements are carried out and analyzed for solar cells array, battery and load for 40 hours.

2. Experimental system under investigation and procedure

The PVPS under investigation consists of four modules of solar cells each of which contains 36 grided single crystal solar cells with series connections, 6V, 5.5 Ahr lead acid battery and a resistive load. The load and battery are connected in parallel and supplied by solar cell modules through blocking diode. The output current and voltage from solar cell arrays and the input currents of battery and load as well as their terminal voltages are measured throughout 40 hours. The experiment is carried out during the previous period through which the battery becomes full charge and the electrical performance of each element of the PVPS is investigated.

3. Results

The instantaneous values of solar radiation (W/m^2) are recorded through the experiment period as shown in fig.1. The figure contains five periods representing five days during which the experiment is carried cut.

3.1. Electrical Performance Of PVPS Elements

The electrical performance of PVPS elements is obtained during the previous periods and analyzed as follows;

3.1.1. Load electrical performance

Figure 2 illustrates the load voltage against time during the five periods under investigation. It illustrates that the load voltage is holding constant during the periods in spite of variable quantities of isolation levels. This figure shows that the terminal voltage of load may be held constant when the battery is connected at solar cells array terminal. The load current against time is represented by fig. 3. The figure illustrates that this current becomes constant in spite of the variability nature of insolation incident upon the solar cells array. So, the current through the load may be written as:

$$I_L = V_L / R_L \tag{1}$$

Where; V_L, I_L and R_L are the load voltage, load current and load resistance.

3.1.2. Lead Acid Battery Behavior

The experimental behaviors of lead acid battery which operates as storage and voltage regulated element in PVPS under test are shown by figures 4 and 5. Fig.4 illustrates that the battery voltage against time . It has a constant value during the periods under test. The battery under test is 6 V, 5.5 Ah. Its voltage reaches to 8 V at charging condition. On the other hand, the battery current takes another behavior as shown in fig. 5. This current depends upon the insolation levels incident upon the solar cells array.

3.1.3. Solar cells array behavior

The electrical characteristics of solar cells array (SCA) energizing the lead acid battery and load are measured and illustrated in figures 6 and 7. Fig. 6 shows that the SCA output voltage still constant during the five periods under investigation although the load on it has a variability in nature. The constancy of solar cells array voltage is the second goal obtained due to the using of lead acid battery with Photovoltaic system. Conversely, the SCA output current has a variable function with time, this is due to battery current variation as shown in fig. 5. Fig. 7 illustrates the variability nature of SCA output current. This current can be written in the following form,

$$I_s = I_{sc} - I_o\,(e^{kv} - 1) \qquad (2)$$

Where I_{sc} is the short circuit current of SCA, k is a constant and I_o is the dark saturation current.

Because the battery current takes the same behavior of SCA current so, this current can be obtained mathematically as;

$$I_B = I_s - I_L \qquad (3)$$

so,

$$I_B = I_{sc} - I_o\,(e^{kv} - 1) - I_L \qquad (4)$$

Where I_L has constant values during the testing periods and I_s, I_B have variable quantities during the same periods.

3.2. Effect Of Insolation Level Upon Electrical Performance Of PVPS Elements.

The effect of insolation level upon voltage and current of load, battery and SCA is experimentally investigated. The insolation levels selected for this investigation are splited into two groups The first one represents the levels obtained before noon instants of the five periods under investigation while, the second group represents the levels of insolation obtained after noon instants for all periods

3.2.1. Load

The load current is not approximately affected by the insolation level as shown in fig. 8. This is due to using of lead acid battery The last figure can be splited into two parts. In the first one a slight rise of the current is obtained. This is due to the instability nature of the battery directly after connecting it with SCA. The second part shows that the load current is constant with the insolation level. The load voltage-insolation level characteristic also has two parts. Through the first one, the insolation level has a pronounced effect upon load voltage as shown in fig. 9. This is also due to the instability nature of the battery directly after connecting it with SCA. In the second part of fig. 9, a slight variation of load voltage with the insolation level is obtained.

3.2.2. The Battery

Fig. 10 represents that the battery current-insolation level characteristic This is an expected behavior because the battery acts as a nonlinear load. Inversely, the battery voltage against insolation level, fig. 11, after and before noon instants during the periods under investigation takes approximately constant characteristic. In the first part of the characteristic (which represents the levels of insolation obtained before noon instants) a slightly increasing in battery voltage is obtained. This is due to the instability nature of the battery which occurs directly after the connection with SCA. After this the voltage becomes constant during the remained part of the periods.

3.2.3. Solar Cells Array

The output current of SCA against the level of insolation before and after the noon instants is represented in fig. 12. This characteristic takes linear behavior before and after the noon instants. The difference between the slopes before and after the noon instants is due to the battery behavior before and after these instants. Fig. 13 illustrates the relationship between solar cells array terminal voltage and insolation levels. It also can be splited into two parts. One of which before the noon instant, through which the voltage is varied between 7.25 V to 9 V with percentage variation of 19.4%. In the second part, the voltage variation lies between two limits which are 9 V and 8 V with percentage variation of 11 %. The large variation, which occurs in the first part, is due to the instability nature of the battery at this period.

4. Conclusions

This paper presents the importance of using lead acid battery as a voltage regulator in Photovoltaic power system. The experiment results show that a good regulation is obtained at load terminal. On the other hand, a regulation at solar cells array terminal in the range of 19.4 % to 11 % is obtained before and after noon instants. This is due to the instability nature of battery operation before noon instants. So, the battery may play a good role for fixing the voltage at the load terminal.

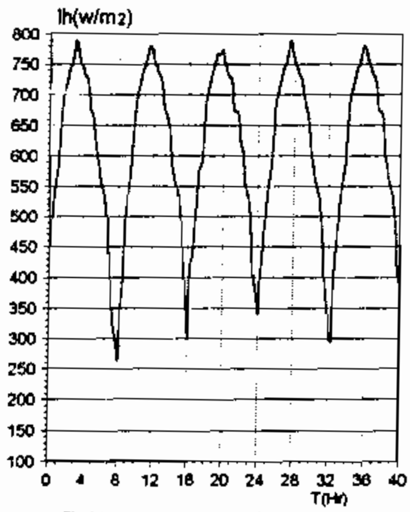

Fig.1 Radiation Intensity Against Time

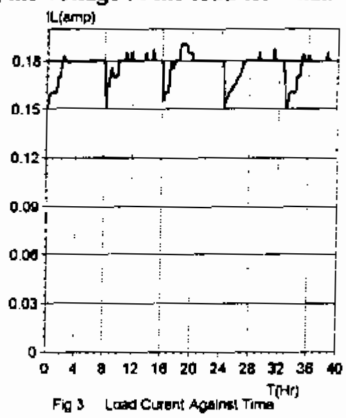

Fig 3 Load Curent Against Time

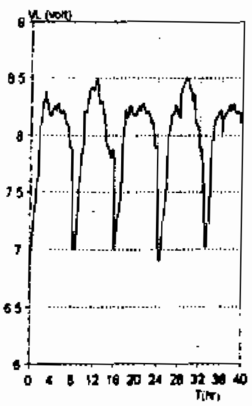

Fig 2 Load VoltagAagainst Time

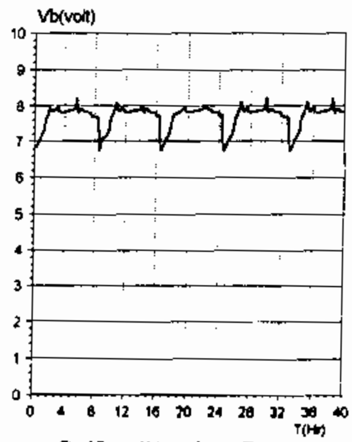

Fig 4 Battery Voltage Against Time

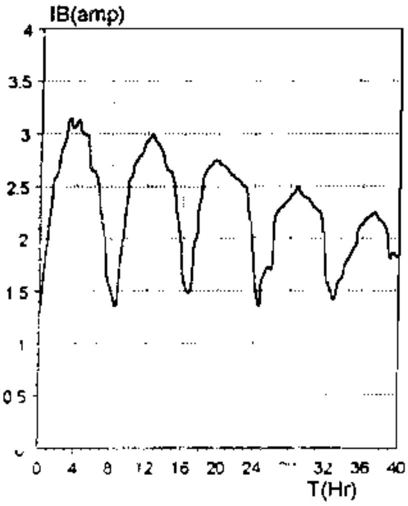

Fig.5 Battery Current Against Time

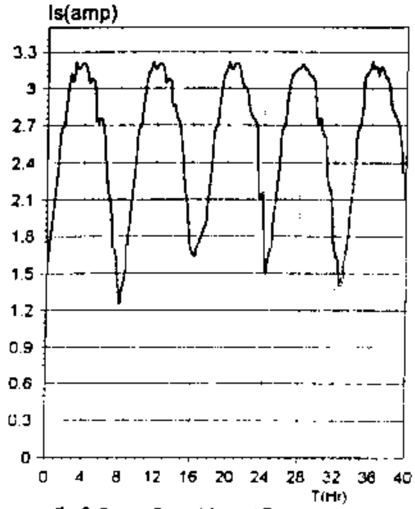

Fig.7 Source Current Against T

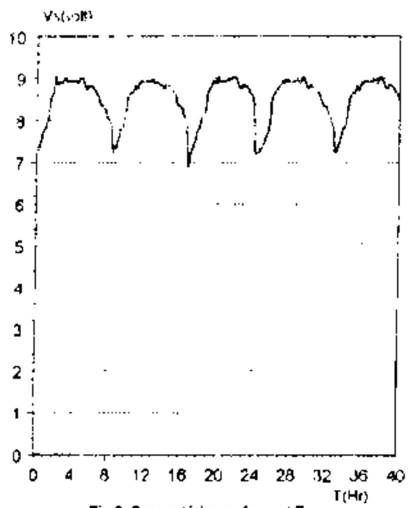

Fig.6 Source Voltage Against Time

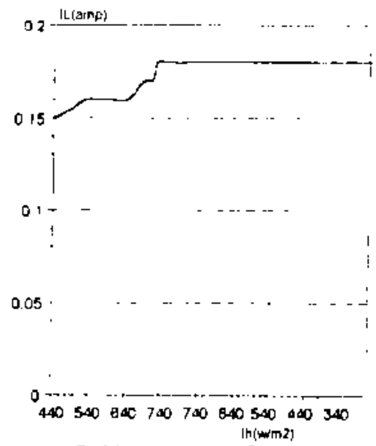

Fig 8 Load current Against Radiation

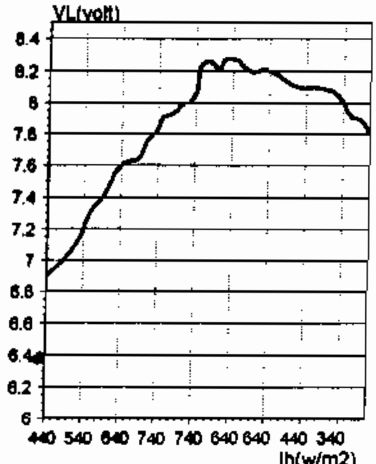

Fig.9 Load Voltage Aganist Radiation Before and After Noon Instant.

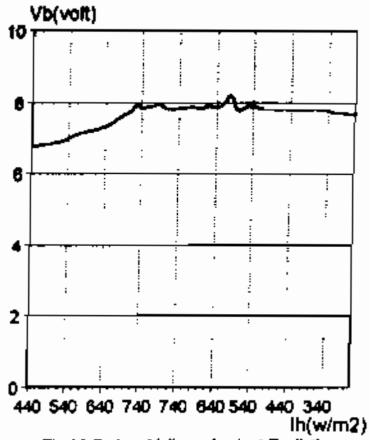

Fig.11 Battery Voltage Against Radiation Before and After Noon Instant.

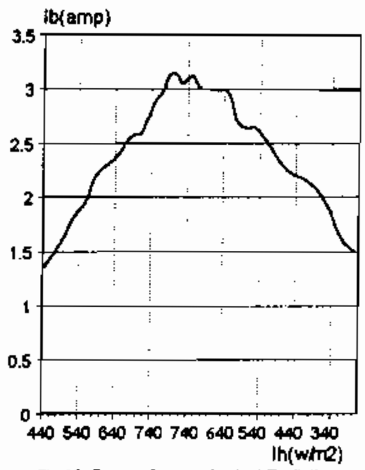

Fig.10 Battery Current Against Radiation Before and After Noon Instant.

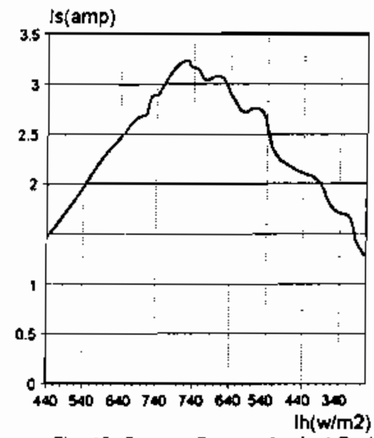

Fig .12 Source Current Against Rediatio Before end After Noon Inrtant.

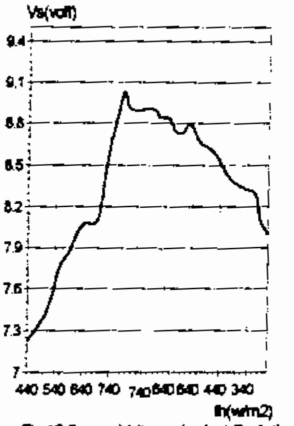

Fig.13 Source Voltage Against Radiation Before and After Noon Instant

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