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STABILIZATION OF AGRICULTURAL EQUIPMENTS ELECTRICAL CIRCUITS VOLTAGE COUPLED WITH SOLAR CELLS ARRAY IN SPITE OF CHANGING THE INTENSITY OF SOLAR RADIATION

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ABSTRACT

In this paper, photovoltaic system (PVS) contains solar cells array, lead acid battery and a load is constructed. The lead acid battery is represented by the agricultural tractor battery. The PVS load is the agricultural tractor electrical circuits . These circuits are the lighting circuits , injunction pump and accessories such as laser system used for land leveling.

The main objective of the research is the evaluation of the electrical performance of each element of the PVS. The system is constructed and operated during five sun shin periods.

During these periods the evaluation of the performance for each PVS, elements is accomplished. The research shows that the solar calls array is a nonlinear element. Hence, its performance (I,V) is a nonlinear. This means that its output voltage is not constant on the load. Consequently, the flocculation of the tractor electrical circuit operation will be occurred. The research shows that, the tractor lead acid battery may solve the last problem. The electrical performance of the tractor lead acid battery during the sun shine periods is determined. Two levels of battery voltage (6V,12V) are selected for the evaluation . The selected level represent that the laser tractor batteries are such that, two 6 volt series batteries each 80 Ahr or 12 volt 155 Ahr one battery . The research shows that the tractor battery plays a good role for staplizing the voltage of the tractor electrical circuits . This leads to good improvements for the tractor system operation and for reserving the battery charging at predetermined levels. The last improvements prevent the voltage flocculation on the tractor circuits and the accessories connected to the battery. This leads to good performance of the laser system connected to the tractor electrical system.

INTRODUCTION

The Photovoltaic power systems are known to be nonlinear, and there exists one operating point corresponding to maximum power point (MPP). The MPP from PVPS depends on the environmental factors such as solar insolation, and operating cell temperature [Hunh *et al.*, 1995 and Mitchell, 1988]. The optimal operating point varies widely overtime. 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. The control objective for buck-boost and cuk converters are to move the operating point of PVPS to it's peak power point [Mashaly *et al.*, 1998].

Lead acid batteries provide the most common means of energy storage in PVPS today. A prominent feature of their operation is cycling. These, together with other operation parameters, affect the battery life and maintenance requirements which must be allowed for the design of a PVPS [Mahmoud *et al.* 2000, Margaret et.al. 1992 & Margaret *et al.* 1996]. The charge controller of the lead acid battery consists of three main circuits. The first one is the comparator designed according to limit the battery voltage between UTP and LTP. The second is the buffer circuits which are used for coupling the comparator circuit and the power transistor switches for safe operation of the whole circuits. The third circuit is the controller switch [Eskander, S. S. and H. M. Noor 2009]

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.

MATERIALS AND EXPERIMENTAL METHODS

1- Materials.

The PVPS under investigation consists of one modules of solar cells contains 36 grided single crystal solar cells with series connections, 75W, 19.5V. Lead acid battery suitable for tractor and any agriculture equipment and a resistive load. The load and battery are connected in parallel and supplied by solar cell module through blocking diode. The tractor electrical circuits and the accessories connected to the load (such as laser system) are represented by pure resistive load in the solar energy laboratory during the test. Digital voltmeters and ammeters are used for measuring the voltage and current at different points of the PVPS. A chart recorder is adjusted in the laboratory for recording the intensity of solar radiation during the sunshine five periods selected. Another chart recorder used for recording all performance parameters against time for the PVPS elements.

2- Evaluation method

First of all, the PVPS system is constructed. The battery and the resistive load are connected in parallel together with the module through blocking diode to prevent the revising of power flow from battery to the solar cells arrays . Initially. the battery must be fully discharged. The selected operating five periods are selected such that pure clear sky during summer season is selected. The PVPS system operates and the tractor battery is initially charged in the first period. The battery becomes full charge through the periods. During the operating periods measurements of the evaluation parameters are carried out. The evaluation parameters selected for measuring are;

* Intensity of solar radiation
* Load current and voltage against time
* Battery voltage and current against time
* I-V characteristics of the tested module at different levels of insolation
* Power voltage characteristics of the tested module at different insolation levels
* Maximum power output of the module against day time .
* Module output power against time at 6v module terminal voltage.

* Module output power at terminal voltage 12v.
*Load current and voltage against intensity of solar radiation
* Battery current and voltage against solar intensity of radiation.
* Source current and voltage against solar radiation.

The previous system evaluation parameters are enough for the PVPS system evaluation. All evaluation parameters are recorded instantaneously by two channels chart recorders adjusted in the solar energy laboratory.

RESULTS AND DISCISSION

The instantaneous values of solar radiation (W/m^2) are recorded by chart recorder through the experiment period as shown in fig. (1) The figure contains five periods represent five days during which the experiment is carried out. Through these periods, the batter under investigation becomes full charge.

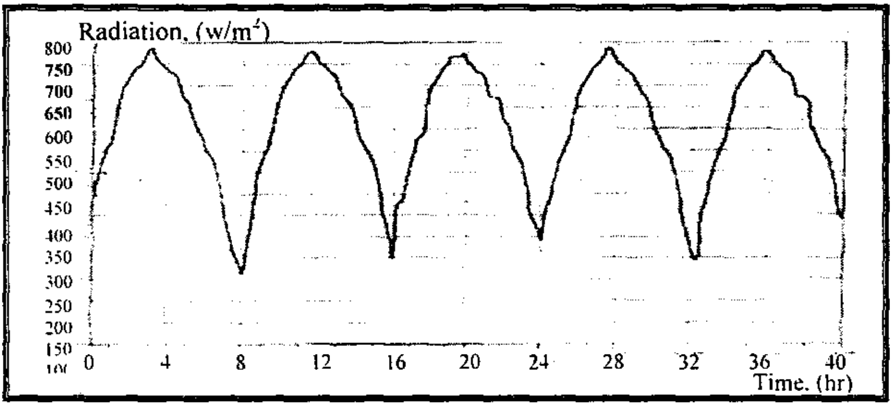

Fig. 1: Radiation Intensity against Time

1. Electrical Performance of PVPS Elements

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

1.1. Load electrical performance:

Fig.(2) illustrates the load voltage against time during the five periods under investigation. The figure 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 connects 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 insulation incident upon the solar cells array. So, the current through the load may be written as:

$$I_L = V_L / R_L \quad \text{.......(1)}$$

Where;

V_L = load voltage
I_L = load current
R_L = load resistance.

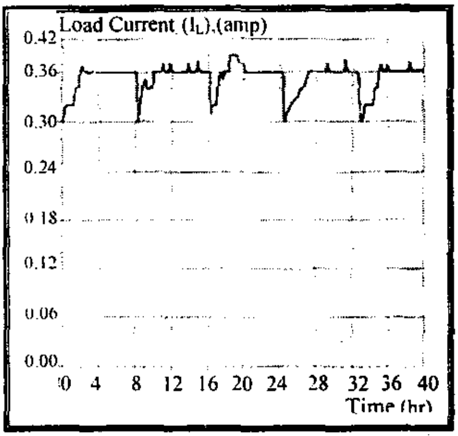

Fig. 2: Load Current against Time

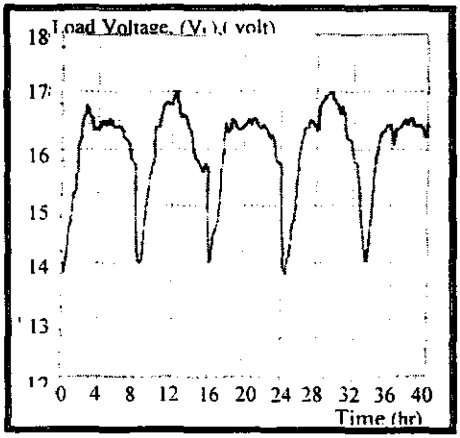

Fig. 3: Load voltage against Time

1.2. Lead Acid Battery Behavior:

The experimental behaviors of lead acid battery which operates as a lby figures. (4) and (5) . Fig.(4) illustrates the battery voltage against time which represents that it has a constant values during the periods under test. The battery under test is 12 V, 155 Ah. It's voltage reaches to 16V 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.

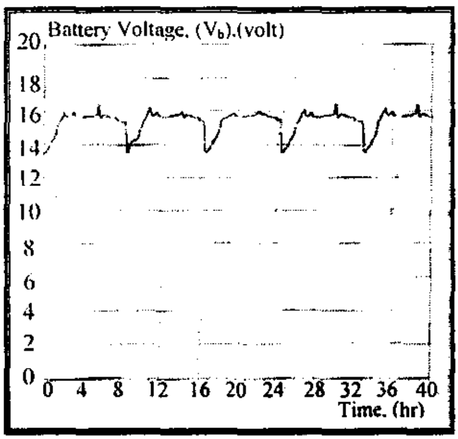

Fig.4: Battery Voltage against Time.

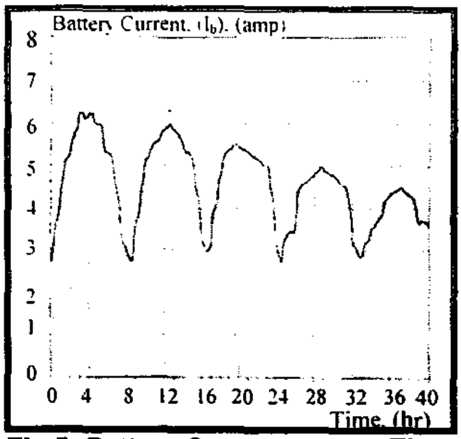

Fig.5: Battery Current against Time.

1.3. Solar Cells Array Behavior:

Initially, the solar cells module is connected with purely resistive load as well as ammeter and voltmeter. The recorded data become the current and voltage of the module at different values of the load. Along with at different isolation levels. The pervious testes are carried out during one day of sunshine period of that day. The current voltage characteristics of the tested module are recorded as illustrated in fig. (6). The fig represents that as the level of isolation increases the I–V Characteristic curve of the solar module goes up. Hence the short circuit current of the module increases linearly by the increasing of the isolation level. Conversely, the module open circuit voltage remains constant and does not affect with the isolation level. Investigation of each characteristic shows that it consists of two parts between them a knee connects with them. The maximum power point of each characteristic locates at the knee.

The maximum power output from the tested module is very important for the designer of photovoltaic power system (PVPS). As the PVPS designed such that it operates at maximum power point, this means that the optimum size of the array is achieved. Consequentially, the experimental determination of the maximum power point of the test module becomes very important. Experimentally for obtaining the maximum power point, the power – voltage characteristics of the tested module must be recorded.

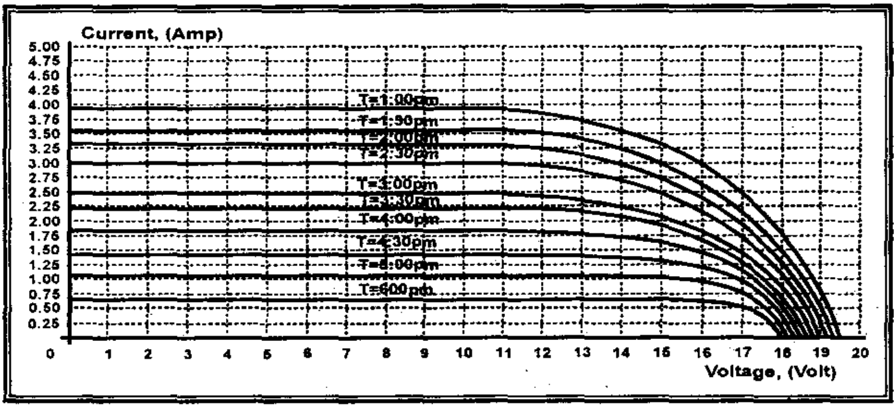

Fig. 6: Current- Voltage characteristic of the tested module at different insolation levels.

Fig.(7) illustrates the relationship between the output power of the tested module against its terminal voltage. The figure reveals that as the load increases the output power of the module also increases and reaches to the maximum value at voltage nearly equal to 13.5V. Breakdown occurs beyond the point of maximum power. Hence, as continuously increases of the load output power the module output power decreases. So, the best point of operation of the tested module becomes the voltage corresponding to the maximum power point (13.5 V). The figure also shows that the voltage at maximum power point for all characteristics is nearly constant. Consequently, the selection of the battery system must be related to the maximum power point of the tested module.

The designer of PVPS attends with the energy output from the solar cells module during each day of the year. The maximum energy output from the module is related with the maximum power output of the module. Hence for determining the maximum energy output during the day, the maximum power points of the module must be determined and recorded

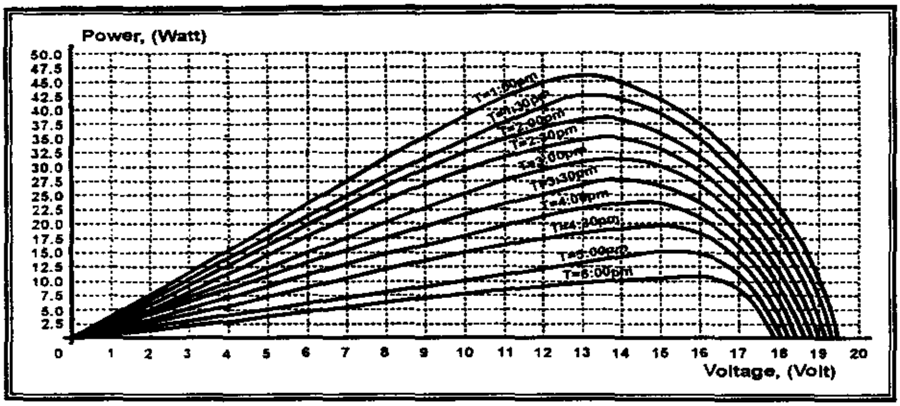

Fig. 7: Power- voltage characteristics of the solar cells module under test.

Fig.(8) represents the module maximum power output during the sunshine period against day time. The figure illustrates that, the maximum power output from the module is directly proportional with the solar radiation. Hence it reaches to maximum value at noon instant.

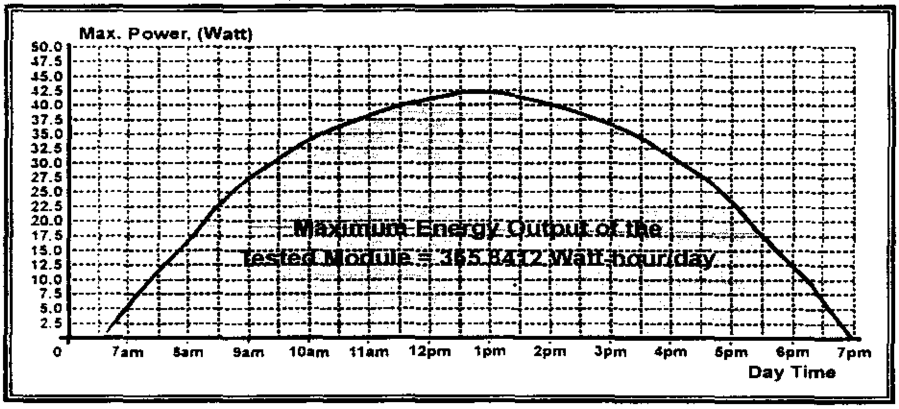

Fig. 8: Module maximum Power output against day time.

The maximum energy extracted from the module represented by the area under the curve of fig. (8) The calculations by the aid of computer represent the energy is 365.8412 watt-hr/day. The previous energy is very important for designing of PVPS array area.

The batteries are suitable elements for storage systems of photovoltaic power system. The selections between batteries are based up many factors. The important factor is that to make the solar cells array operates at maximum power point. Selection of battery voltage connected with the solar cells array is the main factor of selections. Hence the experimental work is carried out at tow levels of battery voltages (6 , 12 v). These two levels are selected because the batteries market has the two levels of voltage.

Fig.(9) illustrates the relationship between the output power of tested module against time at terminal voltage 6v of the module. The calculated energy during the day at this level of voltage calculated by the aid of the computer is 173.802 watt-hr/day.

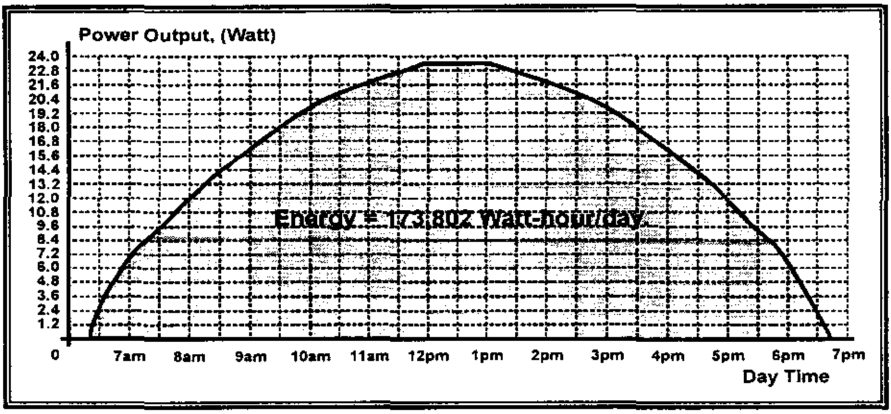

Fig. 9: The Output Power of Tested Module against Day Time at Terminal Voltage 6v.

The module power output against time at voltage level 12 is illustrated in fig.(10). The energy output from the module extracted is calculated as 336.2234 watt-hr/day. The calculations reveal that the energy output from the module reaches to maximum value at the voltage level corresponds that the voltage at maximum power point (13.5 v) approximately.

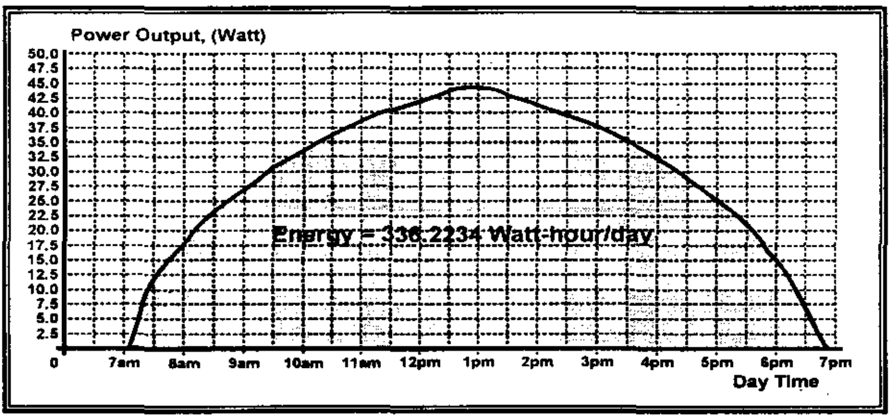

Fig. 10: The module power output against day time at voltage level 12V.

The electrical characteristics of solar cells array (SCA) energized the lead acid battery and load are measured and illustrated in figures (6) and (7). Fig. (6) represents 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.(6). Fig. (7) illustrates the variability nature of SCA output current.

This current can be written in the following form;

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

Where

I_{sc} = the short circuit current of SCA.
k = constant.
I_o = dark saturation current.

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

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

so,

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

Where:

I_L =has constant values during the testing periods.

2. Effect of Insolation Level upon Electrical Performance Parameters of PVPS Elements.

The effect of insolation level upon voltage and current of load, battery and SCA are 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 where, the second group represents the levels of insolation obtained after noon instants for all periods.

2.1. Load:

The load current is not approximately affected by the insolation level as shown in fig. (11). This is due to using of lead acid battery. The last figure can be splited into two parts. In the first one a slight variation of the current is obtained. This is due to the instability nature of the battery directly after connecting it with SCA. The second part represents the constancy of load current with the insolation level. Besidelly, The load voltage-insolation level characteristic also have two parts. Through the first one, the insolation level has a pronounced effect upon load voltage as shown in fig. (12). This is also due to the instability nature of the battery directly after connecting it with SCA. In the second part of fig. (12) a slight variation of load voltage with the insolation level is obtained.

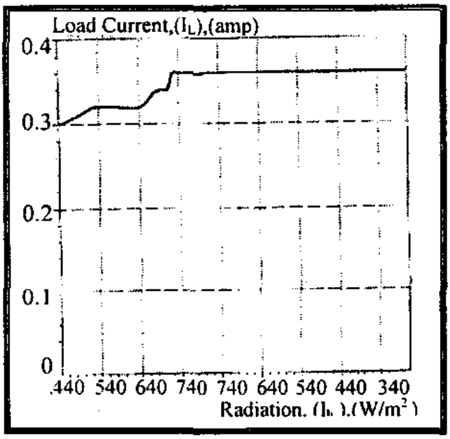

Fig. 11: Load Current against Radiation Before And After Noon Instant.

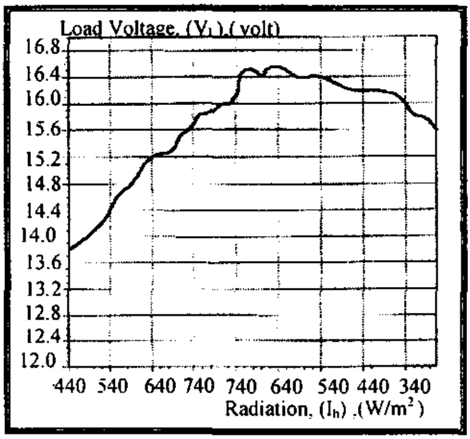

Fig. 12: Load Voltage against Radiation Before And After Noon Instant.

2.2. The Battery:

Fig. (13) represents the battery current-insolation level characteristic. This is an expected behavior because the battery represents as a nonlinear load. Inversely, the battery voltage against insolation level, fig. (14) after and before noon instants during the periods under investigation takes approximately constant function. 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 obtained directly after the connection with SCA. After this the voltage becomes constant during the remained part of the periods.

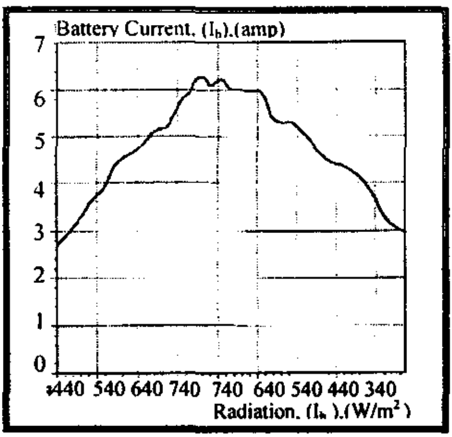

Fig. 13: Battery Current Against Radiation Before And After Noon Instant.

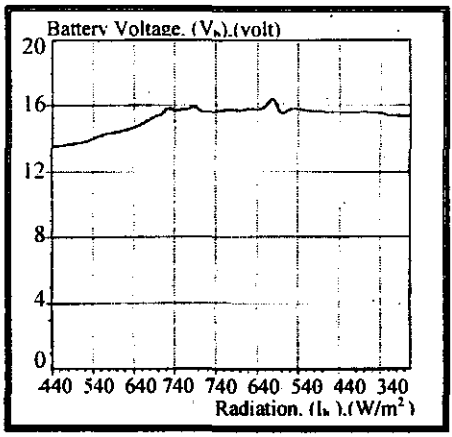

Fig. 14: Battery Voltage Against Radiation Before And After Noon Instant.

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. (15).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. (16) illustrates the relationship between solar cells array terminal voltage and insolation levels. It is also can be splited into two parts. One of them before the noon instant, through which the voltage is varied between 14.5 V to 18 V with percentage variation of 19.4%. In the second part. the voltage variation lies between two limits which are 18V and 16V with percentage variation of 11.11 %. The large variation, which occurs in the first part, is due to the instability nature of the battery at this period.

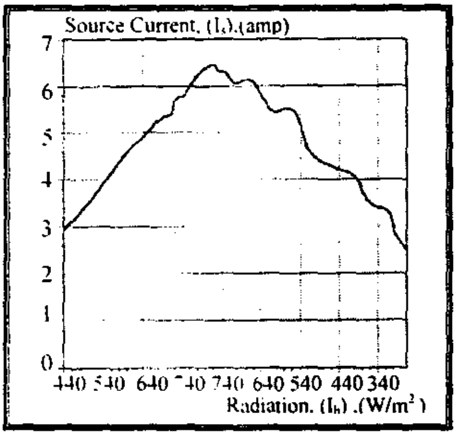

Fig. 15: Source Current Against Radiation Before And After Noon Instant.

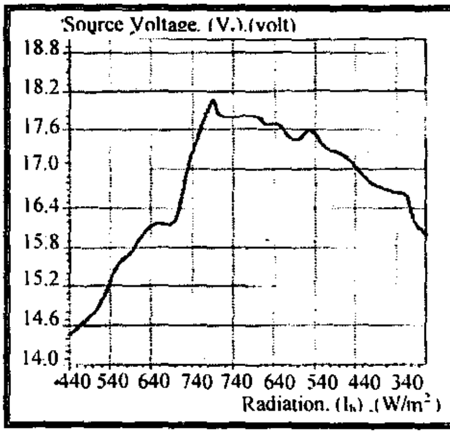

Fig. 16: Source Voltage Against Radiation Before And After Noon Instant.

Conclusions

In this paper, the tractor electrical circuits are used a load in photovoltaic power system. The electrical performance of each elements of PVPS is illustrated .The solar cells array performance is represented as its output become 6 and 12 volt .these two levels of voltage are very suitable for the agricultural tractor .

This paper also 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 19.14 % to 11.11 % 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.

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استقرار جهد الدوائر الكهربية فى المعدات الزراعية الموصلة بمنظومة خلايا شمسية بالرغم من تغير شدة الاشعاع الشمسى

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هذا البحث يتناول دراسة الاداء الكهربى لمنظومة قوى فوتوفولتية مكونة من لوح من الخلايا الفوتوفولتية وبطارية وحمل . وقد تم دراسة الاداء الكهربى لكل عنصر من عناصر المنظومة على حدة اثناء وجودة فى المنظومة الفوتوفولتية وقد تم دراسة الاداء السابق الذكر خلال خمسة فترات متتالية وتمثلكل فترة يوم شمسى كامل يبدا من لحظة الشروق وحتى لحظة الغروب .

ويهدف البحث الى كيفية تثبيت جهد المنظومة الفوتوفولتية واختيار الجهد الامثل الذى عنده يجب ان يثبت جهد المنظومة حيث ان تثبيت جهد المنظومة يعنى تثبيت جهد الحمل المحمل على النظام الفوتوفولتى لان اى حمل كهربى مثل الاحمال الكهربية الموجودة فى المعدات الزراعية مثل وحدات التحكم الخاصة باجهزة لليزر والمثبتة على الجرار الزراعى والتى يفضل تغذيتها من منظومة فوتوفولتية ثابتة الجهد حيث ان جهد البطارية الموصلة بالجرار ليس ثابتا مما يؤدى الى حدوث اخطاء فادحة اثناء عملية التسوية بالليزروبالتالى فان من الامثل ان يثبت نظام كهربى فوتوفولتى على الجرار اثناء عملية التسوية يكون احد الاغراض منة تغذية جهد التحكم الخاص

بشعاع الليزر حيث انة يمكن تثبيت جهد اجهزة التحكم وبالتالى تقل نسبة حدوث الاخطاء اثناء عمليات التسوية ، ويمكن ان يكون الحمل الكهربى الموجود بالمنظومة الفوتوفولتية عبارة عن مراوح التهوية الموصلة بالبيوت المحمية حيث يتم تثبيت الجهد عليها بالطريقة المعروضة في البحث وهذا يؤدى الى ثبات التيار المسحوب بواسطة المرلوح مما يؤدى الى زيادة عمرها الافتراضى بالاضافة الى تثبيت سرعات المراوح داخل البيت المحمى .

ان النظام الفوتوفولتى ثابت الجهد يمكن تطبيقة بنجاح مع معدات استصلاح الاراضى وخاصة تلك التى تستخدم فى الاراضى الصحراوية تحت الاستصلاح .

وقد تم فى هذا البحث تحديد الجهد الامثل الذى يجب ان يثبت عندة جهد المنظومة الفوتوفولتية حيث ان قيمة هذا الجهد يختلف باختلاف نوع الخلايا المستخدمة .

ولتحديد قيمة الجهد الذى يجب ان يثبت عندة جهد المنظومة الفوتوفولتية, فقد تم عمليا بمعمل الطاقة الشمسية تحديد الاداء المعملى الكهربي اولا لمنظومة الخلايا الشمسية وهى العلاقة بين مقدار القدرة الكهربية الناتجة والتيار الناتج منها وكذلك العلاقة بين القدرة والجهد الناتج ، وقد تم تحديد قيمة اقصى قدرة يمكن ان تؤخذ من هذه الخلايا داخل المنظومة الفوتوفولتية ، وتم تحديد قيمة الجهد المناظر لنقطة اقصى قدرة للخلايا ولاختيار القيمة المثلى للجهد الذى يجب ان يثبت عنده جهد المنظومة الفوتوفولتية (الخلايا، الحمل ، البطارية) فقد تم حساب مقدار الطاقة التى تعطيها الخلايا الشمسية عن قيمتين مختلفتين للجهد حول قيمة الجهد المناظر لنقطة اقصى قدرة ١٢،٦ فولت ، وقد تم اختيار هاتين القيمتين لانهما يمثلان جهود البطارية الكهربية المتاحة فى السوق حيث يمكن توصليهم على التوالى اوعلى التوازى على حسب احتياجات الحمل.

وقد اوضح البحث ان مقدار الطاقة التى تعطيها الخلايا الشمسية الموصلة بالمنظومة الفوتوفولتية عندما يكون جهدها ١٢ فولت اكبر بكثير عنة عندما يكون جهدها ٦ فولت ، وبناء على ذلك فقد تم اختيار جهد التثبيت ليكون ١٢ فولت . وعلية فقد تم وضع بطارية جهدها ١٢ فولت ، ١٥٥ امبير ساعة بالمنظومة الفوتوفولتية وتم تحديد الاداء الكهربى لكل عنصر من عناصر المنظومة خلال خمس فترات متتالية حيث تمثل هذة الفترات فترات شحن البطارية حتى الشحن الكامل .

وقد اظهرت النتائج :

ثبات تيار الحمل مما يؤدى الى الحفاظ على الحمل واطالة عمرة ، ثبات جهد الحمل ، ثبات جهد البطارية الموصلة بالمنظومة . اما تيار البطارية فقد لوحظ انه يقل باستمرار اثناء الخمس فترات وهذا امر طبيعي لان البطارية اثناء الخمس فترات كانت فى حالة شحن وهذا يعنى انه بزيادة الشحن فان التيار يقل نظرا لان سعة الشحن بالبطارية تقل باستمرار . وقد تعرض البحث ايضا السلوك الكهربى للوح الخلايا الشمسية الموجودة بالمنظومة الفوتوفولتية وقد لوحظ ثبات التيار والجهد الناتج من الخلايا وبناء عليه فان هذا يعنى ان جهد الخلايا يظل باستمرار ثابتا رغم تغير شدة الاشعاع الشمسى وقد لوحظ تغير طفيف جدا لتيار الحمل مع شدة الاشعاع الشمسى وهذا يعنى ان تيار الحمل شبه مستقر رغم تغير شدة الاشعاع الشمسى .

وجد ايضا ان مقدار التنظيم فى جهد الخلايا كان داخل نطاق ١٩,١٤ و ١١,١١% وذلك قبل فترة الظهر وبعدة على التوالى وهذا يرجع الى عدم الاستقرارالذى يحدث فى البطارية فى بداية تشغيلها اى قبل الظهر (١٢ ظهرا) وبالتالى فان البطارية قد لعبت دورا هاما فى تثبيت جهد الحمل الكهربى للجرارالزراعى ، واى احمال كهربية اخرى تحمل على الجرار مثل جهاز الليزر.

وعليه وبعد استعراض الاداء الكهربى لهذه المنظومة فانه يمكن القول انه يمكن تغذية اى حمل زراعى باستخدام هذه المنظومة الغير معقدة ويمكن الثقة فى ادائها .