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Performance Analysis of Loads Individually or Combindelly Powered by Seperate or Common Photovoltaic Sources.

Mohamed Mohamed El-Sayes
Associate Professor., Electrical Power and Machines Department ., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

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PERFORMANCE ANALYSIS OF LOADS INDIVIDUALLY OR COMBINDELLY POWERED BY SEPERATE OR COMMON PHOTOVOLTAIC SOURCES

تحليل أداء الأحمال عند تغذيتها منفردة من مصادر كهروضوئية مستقلة أو مجمعة من مصادر كهروضوئية مشتركة

BY

M.A.EL-SAYES

Associate professor in Electrical Power and Machines Department , Faculty of Engineering , Mansoura University , El-Mansoura , EGYPT .

خلاصة : يحلل البحث أداء الأحمال الأومية و بطاريات التخزين و مضخات المياه الحجمية و المركزية عند تغذيتها إما منفردة من مصادر القوى الكهروضوئية المستقلة أو مجمعة من مصادر القوى الكهروضوئية المشتركة والتي تعتمد على أساس كفاءة الاستغلال اللحظية للقدرة المولدة من المصادر الكهروضوئية عند مستويات الإشعاع المختلفة وكفاءة إستغلال الطاقة المستمدة.

و يشتمل البحث على ما يلي :

١- عرض طريقة جديدة لحساب الحمل الأومي الأمثل الذي يحقق أقصى كفاءة استغلال للطاقة.

٢- إستنتاج العلاقات الرياضية اللازمة لتمثيل أداء مضخات المياه الحجمية والمركزية المرتبطة بمحركات التيار المستمر على صورة [التيار - الجهد].

٣- تعيين أداء الأحمال المختلفة عند تغذيتها من مصادر كهروضوئية مستقلة و تحديد العوامل المؤثرة على أداء كل منها.

٤- تحديد خصائص تشغيل الأحمال التي تحتوي على حملين أو ثلاثة من نفس النوع أو أحمال مختلفة عند تغذيتها من مصادر القوى الكهروضوئية المشتركة.

٥- تحديد درجة تأثير كل حمل على أداء الآخر.

٦- تعيين الأحمال التي تتحسن أداؤها بربطها بأحمال أخرى و تغذيتها من المصادر المشتركة.

٧- عرض أهم النتائج المستخلصة في جداول خاصة و أشكال بيانية.

ABSTRACT

This paper analyzes the operation of the ohmic , battery storage , and water pump loads powered either individually from separate photovoltaic sources (SPVSs) or combindelly powered from common photovoltaic source (CPVS) . The performance of the loads is evaluated by determining the time utilization efficiency and the energy utilization efficiency , the later is considered one of the most important performance indices . The performance of the following situations are investigated :

1- The three loads are individually powered from SPVSs ,

2- Two or three loads of the same or different types are powered by a CPVS .

The improvement or the deterioration occured in the operation of the loads on combinding them and powering from a CPVS is determined and analysed .

Key-words : Ohmic load , volumetric and centrifugal pumps , time and energy utilization efficiencies , individual and combined loads , and separate and common photovoltaic sources .

1-INTRODUCTION

In many photovoltaic (PV) systems , the solar cells array is designed to power a specific single load . Several loads of the same or different types may be powered individually by separate PV sources or combindelly by a common PV source . Loads of either the same or different types may have different I-V characteristics , and since a PV source is a finite power one and has different I-V external characteristics from the conventional power source , it can be expected that the operation of the different loads will also be different when the loads are powered either by separate sources or by a common source . In a common source system it is possible that the operation of one load may be improved at the expense of another load , or the total performance of the loads powered by the common source can also be improved . In a common source system there exists an additional option where in certain cases , such as at low insolation it might be advantageous to disconnect a load from the system in order to improve the operation of another load . In general , the designer may wish to analyse the possibility of a common PV source / combined load system design to achieve high performance compared to separate source / individual load system . One criterion which indicate the degree of utilization of the PV sources is the " energy utilization efficiency " . Optimum matching between solar cells array , the storage batteries and the loads by switching of modules as a DC transformation has been presented in [1] . The power losses due to poor matching of the solar electrical system are determined in [2] . Optimum matching of an electric motor , with a varying mechanical load to a solar cell array is presented in [3] . Comparison of the performance of separate and common source systems for two different ohmic loads and two different electrolyzer loads is dealt with in [4] . Comparing the performance of a permanent magnet DC motor and a volumetric pump , and a permanent magnet DC motor and a centrifugal pump is studied in [5] . This paper analyses the operation of the ohmic , battery storage , and water pump loads on powering them individually from separate PV sources or combindelly from a common PV source . The improvement or the deterioration occured in the performance on combinding the loads to power them from a CPVS is determined .

2- LOADS POWERED INDIVIDUALLY BY SPVSs

a - OHMIC LOAD

Firstly , it is assumed that the operation of the load takes place on a clear day with the variation of the insolation given by [4] :

$$G = 100 \sin w \quad (1)$$

where G is the insolation in mw/sq.cm , and w is the solar angle in degrees . The solar angle is related to the solar time :

$$w = 15\,T - 90 \quad (2)$$

where at solar noon (T = 12.00) the solar angle is 90 .

The solar cells array used in this study is represented by the following I-V equation [5] :

$$V = -0.9I + (1/0.0422) \ln \{(I - I_{ph} + 0.0081) / 0.0081\} \quad (3)$$

where for 100 mw/sq.cm insolation , I_{ph} = 13.615 A , V_{oc} = 176V , and P_M = 1400 W .

For the different solar radiation levels , the I-V characteristic curves of the solar cells array (SCA) are defined . The operation points of the ohmic load are the intersection of the operation line of the ohmic load and the I-V curves as shown in Fig.1 . The operation line of the ohmic load is represented by a straight line starts from the original point and its slope is ϕ , where :

$$\phi = \tan^{-1} 1 / R \qquad (4)$$

A " time utilization efficiency " η_T was defined in [4] by :

$$\eta_T = 100 P / P_M \qquad (5)$$

where P is the SCA output , and P_M is its maximum output power , both are functions of the insolation , G .

The " energy utilization efficiency " η_E of the PV source in the system was defined by [4] :

$$\eta_E = \int_{T1}^{12} P(T).dT \;/\; \int_{0}^{12} P_M(T).dT \qquad (6)$$

The time T_1 corresponds to some threshold operating value of the load . Because of the assumed symmetry of the insolation around noon , the calculation is performed for half a day . The η_E indicates the degree of utilization of the SCA in the system or the degree of matching the load and the SCA . η_T of different individual ohmic loads powered by SPVS represented by eq.3 and the resulted η_E are shown in Fig.2 . The optimum ohmic resistance , $R_{opt.}$ to be powered by the predescribed SCA that achieves the maximum η_E is directly determined from Fig.2.b . So , the total ohmic loads can be rearranged in a series / parallel configuration in which the total equivalent resistance equals $R_{opt.}$. Also , the operation line of each resistance makes an angle δ with the locus of the maximum operation power points of the SCA . The relation between η_E and the angle δ is shown in Fig.3 . By determining the optimum value of δ at which η_E is maximum , the optimum ohmic resistance can be easily determined .

2- BATTERY STORAGE LOAD

The graphical solution of the operation point of a battery storage load powered by a SCA is revealed in Fig.4 . The operation line of a battery is a straight line starting at the point E_b on the v-axis , whose inclination is arctan $1 / r_b$, where E_b and r_b are the back e.m.f. and internal resistance of the battery storage load . Fig.5 reveals the η_T of four storage batteries powered individually by the SPVS of eq.3 . η_E of these batteries is tabulated in Table 1 .

Table 1 : Energy Utilization Efficiency of the four batteries

B.S.	$B.S._1$	$B.S._2$	$B.S._3$	$B.S._4$
η_E	96.64	98.06	86.27	95.84 .

Since the locus of the optimum operation power points of the SCA is nearly considered a perpendicular straight line intersecting v-axis at the maximum power voltage . Therefore , the optimum battery storage to be fed from a SCA achieving a maximum η_E is that having back e.m.f. equals maximum power voltage of the SCA and its internal resistance is small as possible . The drop of the radiation level and the drop of the battery storage voltage together just happen to give a good degree of operation . From the above Table the second battery is the proper one because its operation line is adjacent to the locus of the maximum operation power points of the SCA .

3- WATER PUMP LOAD

Pumps can be divided into two categories : centrifugal ard volumetric and they have inherently different head vs. flow characteristics . The characteristics of the volumetric T_{Lv} and centrifugal T_{Lc} pumps on the mechanical planes are :

$$T_{Lv} = A_1 + B_1 . w \tag{7}$$

and

$$T_{Lc} = A_2 + B_2 . w + C_2 . w^{1.8} \tag{8}$$

respectively . The motor torque equation is :

$$T_m = C_\phi . I_L \tag{9}$$

and , the motor speed - torque characteristic is :

$$w = (V_L - (T_m / C_\phi) . R_a) / C_\phi \tag{10}$$

where :

- w is the motor angular speed ,
- V_L is the motor terminal voltage ,

I_L is the motor armature current ,

R_a is the armature resistance , and

C_e is a constant .

In the volumetric pump :

$$C_e \cdot I_L = A_1 + B_1 \cdot w \qquad (11)$$

hence ,

$$w = [\, C_e \cdot I_L - A_1] \,/\, B \qquad (12)$$

from eqs.10 and 12 :

$$(V_L - I_L \cdot R_a) \,/\, C_e = (C_e \cdot I_L - A_1) \,/\, B_1$$

Therefore , the operation characteristics of the DC permanent magnet motor - volumetric water pump load on the I-V plane is :

$$V_L = I_L \,(R_a + C_e^2 \,/\, B_1) - C_e \cdot (A_1 \,/\, B_1) \qquad (13)$$

Eq.13 solves the complixity of determining the operation line of the DC permanent magnet motor - volumetric water pump load on the I-V plane .
In case of centrifugal pump ,

$$C_e \cdot I_L = A_2 + B_2 \cdot w + C_2 \cdot w^{1.8} \qquad (14)$$

hence , the operation characteristics of the DC permanent magnet motor - centrifugal water pump on the I-V plane is :

$$I_L = 1 \,/\, C_e \,[\, A_2 + B_2 (V_L - I_L \cdot R_a / C_e) + C_2 (V_L - I_L \cdot R_a)/C_e] \qquad (15)$$

Derivation of the operation line equation of the volumetric and centrifugal pumps on the I-V plane solves the comlixity of determining the operation points . The I-V characteristics of the SCA for different levels of insolation are computed by eq.3 . The operation points of the volumetric and centrifugal pumps are determined from the intersections of the operation lines represented by eq.13 and 15 and the I-V curves are shown in Fig 6.a. The time utilization efficiency of two different volumetric pumps is shown in Fig.6.b . Energy utilization efficiency of these pumps are : 60.91 , and 77.58 % , respectively . This because the first pump starts to operate at 26 mW/sq.cm insolation but the second one at 52 mW/sq.cm .

3- LOADS COMBINDELLY POWERED BY A COMMON PV SOURCE

I- Two Loads of the Same Type :

a- Two Ohmic Loads (R_1 // R_2)

In this case two ohmic loads of equal or different sizes are combindelly powered by a common PV source . This source is made from two equal separate sources of eq.3 connected in parallel . The I-V equation of this CPVS is :

$$V = -0.45 \cdot I + (1/0.0422) \ln (I_{ph} - I + 0.0162)/0.0162 \quad (16)$$

where for 100 mW/sq.cm insolation , $I_{ph} = 27.23A$, $V_{oc} = 176$ V and $P_M = 2800$ W .

The operation of the 13 ohms ohmic load combindelly powered with another ohmic load of 5 , 9 , 13 , and 17 is illustrated in Fig.7 at different solar radiation intensities . Energy utilization efficiency of different combinations of R_1 // R_2 are listed in Table 2 .

Table 2 : Energy Utilization Efficiency of Different R_1 // R_2

R_2 \ R_1	5	7	9	11	13	15	17
5	53.35	61.55	67.07	70.29	73.30	75.66	76.77
7	61.55	71.42	78.44	82.38	85.63	88.11	88.32
9	67.07	78.44	84.68	89.36	90.38	92.07	93.03
11	70.29	82.38	89.36	91.20	92.27	93.04	93.59
13	73.30	85.63	90.38	92.27	93.31	92.93	93.52
15	75.66	88.11	92.07	93.49	92.93	92.85	92.51
17	76.77	88.32	93.03	93.59	93.52	92.51	90.78

The improvement or the deterioration in the time utilization efficiency and the energy utilization due to combinding the ohmic loads for different combinations of R_1 // R_2 is shown in Fig.8 .

Table 4 and Fig.8 show that the equivalent resistance of the combination is the essential factor affecting upon the resulted time and energy utilization efficiencies . The optimum operation is achieved for both two resistances if the equivalent resistance equals half of the optimum resistance depicted in Fig .2.b.

b- Two Storage Batteries ($B.S._1$ // $B.S._2$)

In this situation two storage batteries are powered combindelly by a CPVS of eq.16 . The operation line of the two batteries is a straight line starting at the point :

$$E_{b2} + (E_{b1} - E_{b2}) / (r_{b1} + r_{b2}) \cdot r_{b2} \quad \text{at} \quad E_{b1} > E_{b2}$$

$$E_{b1} + (E_{b2} - E_{b1}) / (r_{b2} + r_{b1}) \cdot r_{b1} \quad \text{at} \quad E_{b2} < E_{b1}$$

on the v-axis whose inclination is :

$$\tan^{-1} (r_{b1} + r_{b2}) / r_{b1} \cdot r_{b2}$$

where E_{b1} , r_{b1} and E_{b2} , r_{b2} are the back e.m.f. and the internal resistance of the first and second battery , respectively . The time utilization efficiency of the first battery of 120 V , and 0.8 ohm , the second battery of 110 V and 0.8 ohm and the combination $B.S._1 // B.S._2$ is shown in Fig.9 .

The improvement and the deterioration in η_T of $B.S._1$ and $B.S._2$ due to powering the batteries from a CPVS is presented in Fig.10 . The energy utilization efficiency of the two batteries on powering them either from SPVSs or from a CPVS is listed in Table 3 .

Table 3 : The energy utilization efficiency of the two batteries powered from SPVSs or from a CPVS

B.S. Source	$B.S._1$	$B.S._2$	$B.S._1 // B.S._2$
SPVSs	48.32	49.03	97.35
CPVS	14.42	83.62	98.04

The battery of a higher e.m.f. charges of the lower e.m.f. in the low solar radiation intensities . Therefore ,

$\eta_E(B.S._1)$ deteriorates by 48.32 - 14.42 = 33.90 %

$\eta_E(B.S._2)$ improves by 83.62 - 49.03 = 34.59 %

$\eta_E(B.S._1 // B.S._2)$ improves by 98.04 - 97.35 = 0.69 %

c- Two Water Pumps ($W.P._1 // W.P._2$)

In this situation two different volumetric pumps are fed by the CPVS of eq.16 . Equation 3 shows that the volumetric pump is a straight line starting at the point of :

$$- C_e \cdot A_1 / B_1 \quad \text{on the v-axis}$$

whose inclination is :

$$\tan^{-1} R_a + C_e^2 / B_1$$

Therefore , the operation of the pump depends upon A_1 , B_1 , R_a , and C_e , the latter is the most effective factor . Two pumps have the following data are combindelly powered by a CPVS of eq.16 :

W.P.$_1$: C_e = 0.6 , R_a = 0.1 , A_1 = 4.2 , B_1 = 0.002387

W.p.$_2$: C_e = 1.0 , R_a = 0.2 , A_1 = 4.2 , B_1 = 0.002387

The time utilization of the two pumps W.P.$_1$, W.P.$_2$ and the combination (W.P.$_1$ // W.P.$_2$) is shown in Fig.11 , and the change in it in Fig.12 due to powering from a CPVS . The energy utilization efficiency of these pumps is tabulated in Table 4 when powered either by SPVSs or by a CPVS .

Table 4 : Energy utilization efficiency of the two pumps when powered either by SPVSs or by a CPVS

W.P. / Source	W.P.$_1$	W.P.$_2$	W.P.$_1$//W.P.$_2$
SPVSs	38.79	30.45	69.25
CPVS	46.26	26.55	72.81

The operation of the first W.P. improves by :
46.26 - 38.79 = 7.47 % at the expense of the operation of the second pump in which the operation deteriorates by :
30.45 - 26.55 = 3.90 % but the operation of the combination improves by :
72.81 - 69.25 %
The degree of operation of the pumps is essentially dependent on their parameters as explained above .

II- Two Loads of Different Types

a- Ohmic Load // Battery Storage Load

Now the ohmic load and the battery storage are connecting in parallel across the CPVS of eq.16 as shown in Fig 13 . The operation line is a straight line starting at the point of :

$[E_b / (R + r_b)] . R$ on the v-axis whose inclination is :

$(r_b + R) / r_b . R$

Fig. 14 shows the time utilization efficiency of the ohmic load of 11 ohm and the battery storage of 120 V and its internal resistance is 0.8 ohm and the combination R // B.S. . The change in the time utilization efficiency due to powering by a CPVS is shown in Fig.15 . The energy utilization efficiency resulted from using SPVSs and CPVS is listed in Table 5 .

Table 5 : Energy utilization efficiency of the ohmic and battery storage loads when powered either by SPVSs or by CPVS

Load / Source	R	B.S.	R // B.S.
CPYS	65.64	31.91	97.55
SPYSs	45.64	48.32	93.96

In the low solar radiation intensities , the battery storage associates the CPVS in powering the ohmic load . Therefore ,
a- the operation of the ohmic load improves by :
65.64 - 91.28 = 20 %
b- the operation of the battery storage deteriorates by :
31.91 - 96.64 = - 16.4%
c- the operation of the combination R // B.S. improves by :
97.55 - 93.96 = 3.59%

b- Ohmic Load // Water Pump Load

In this situation , the ohmic load is connected in parallel with the volumetric water pump across the CPVS . An ohmic load of 11 ohms and the volumetric water pump has the following data :
120 V , 9.2 amps , 157.1 rad. / sec. , R_a = 1.5 ohms , C_e = .621

The operation line is represented by a straight line starting at the point of :

$$-[C_e . (A_1 / B_1) / (R + R_a + C_e^2 / B_1)].R$$

on the v-axis , whose inclination is :

$$(R + R_a + C_e^2 / B_1) / R (R_a + C_e^2 / B_1)$$

The time utilization efficiency of the ohmic , pump and combined loads is shown in Fig.16 and the change in it due to powering from the CPVS is revealed in Fig.17 . The energy utilization efficiency of the ohmic , pump and combined loads is listed in Table 6 on powering them either from SPVSs or from a CPVS .

Table 4 : Energy utilization efficiency of R , W.P. , and R // W.P powered either by SPVSs or by a CPVS

Load / Source	R	W.P.	R // W.P.
CPVS	50.88	37.48	88.36
SPVSs	45.64	38.79	84.43

Table 4 demonstrate the following :
1- the operation of the ohmic load improves by :
55.88 - 45.64 = 5.24 %
2- the operation of the W.P. deteriorates by :
37.48 - 38.79 = -1.31 %
3- the operation of the combination R // W.P.improves by :
88.36 - 84.43 = 3.93 %

c- Battery storage // Water Pump

The battery storage taken in the case II.2 and the water pump taken in the case II.3 are connected in parallel across the combined PV source of eq.16 . Time utilization efficiency of the B.S. , W.P. , and B.S.//W.P. is revealed in Fig.18 , the change in it in Fig.19 . The energy utilization efficiency of B.S , W.P. , and B.S.//W.P. on powering them either by SPVSs or by a CPVS is listed in Table 7 .

Table 7 : Energy utilization efficiency of B.S. , W.P. , and B.S. // W.P. powering by SPVSs or CPVS

Load / Source	B.S.	W.P.	B.S.//W.P.
CPVS	48.79	48.28	97.07
SPVSs	48.32	38.79	87.11

The operation of the B.S. , W.P. , and B.S.//W.P. improves by :
48.79 - 48.32 = 0.47 % ,
48.28 - 38.79 = 9.49 % ,and
97.07 - 87.11 = 9.96 % , respectively .
The results out of the above three cases are summerized in the following :

1- the operation of the ohmic load improves by :
43.76 - 30.43 = 13.33 % (R // B.S.)
33.92 - 30.43 = 3.49 % (R // W.P.)
43.52 - 30.43 = 13.09 % (R // B.S. // W.P.)

2-the operation of the B.S. deteriorates by :
32.21 - 21.27 = 10.94 % (R // B.S.)
32.21 - 25.29 = 6.92 % (R // B.S. // W.P.)
but improves by :
32.53 - 32.21 = 0.32 % (R // W.P.)

The operation of the W.P. improves by :

32.19 - 25.86 = 6.33 % (B.S. // W.P.)

29.88 - 25.86 = 4.02 % (R // B.S. // W.P.)

but deteriorates by :

25.86 - 24.98 = 0.88 % (R // W.P.)

Therefore , the operation of the W.P. and the ohmic load is improved when powered combindelly with B.S. at the expense of its operation .

III- Three Loads of Different Types

In this situation the ohmic load , the battery storage , and the water pump are combindelly powered by a CPVS . This system is made of three equal separate sources of eq.3 connected in parallel . The I-V equation of this source is :

$$V = -0.3\ I + (1/0.0422).\ln((I_{ph} - I + 0.0243)/0.0243) \qquad (17)$$

where for 100 mW / sq.cm insolation , I_{ph} = 40.845 A , V_{oc} = 176V , and P_M = 4200 W .

Time utilization efficiency of the ohmic load of 11 ohms , the battery storage of 120 V back e.m.f. and internal resistance of 0.8 ohms and the predescribed W.P. in the previous item combindelly powered by the CPVS of eq.17 is shown in Fig. 20 . The change in it due to powering from the CPVS is depicted in Fig.21 . THe energy utilization efficiencies of the ohmic , the battery storage , and the water pump loads are listed in Table 9 .

Table 9 : Energy utilization efficiency of R , B.S. , W.P. and R // B.S. // W.P.

Load / Source	R	B.S.	W.P.	R // B.S. // W.P.
CPVS	43.52	25.29	29.88	98.69
SPVSs	30.43	32.21	25.86	88.50

Table 9 shows that the operation of the ohmic load , the water pump , and the entire combination are improved by 13.09 , 4.02 , and 10.19 % , respectively but the operation of the battery storage deteriorates by 6.92 % .

CONCLUSIONS

In this paper the performance of the ohmic load , battery storage , and water pump is determined when powered individually by SPVSs or combindelly by a CPVS . The indices for the performance were : the " Time Utilization Efficiency " and the " Energy Utilization Efficiency " . The conclusions were drawn for the following particular cases :

(a) Individual ohmic , battery storage , and water pump loads ,

(b) A cobined load consisting of two loads of the same type .
(c) A combined load consisting of two loads of different types ,
(d) A combined load consisting of three different loads .
Firstly , the optimum ohmic load , $R_{opt.}$ at which the energy utilization efficiency is maximum is determined . Also , the operation of the volumetric and centrifugal pumps on the I-V plane is derived and solved the complixity of determining the operation characteristics . The conclusions are :

1- The ohmic loads supplied either by SPVS or by CPVS can be rearranged in a series/parallel combination in which the equivalent resistance equals the optimum one .

2- The operation of the battery storage can easily be optimized and the battery storage itself is considered as a maximum power tracker .

3- Operating the ohmic loads and the water pumps combindelly with the battery storage improves their operation at the expense of it .

4- The ohmic load deteriorates the operation of the loads powered combindelly with it .

5- In a CPVS there exists an additional option where in certain cases it might be advantageous to disconnect a load from it in order to improve the operation of another load .

6- The designer of PV system may wish to analyze the possibility of a common/multiple system design to achieve higher performance compared to separate source/individual systems .

7- The parameters of the PV sources and the supplied loads can be determined in order to achieve a high degree of operation .

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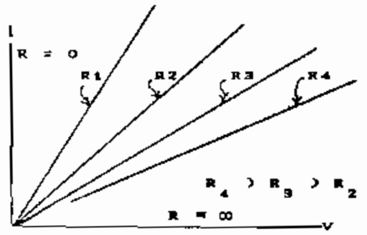


Fig.1 : The performance of different ohmic loads powered by SPVS

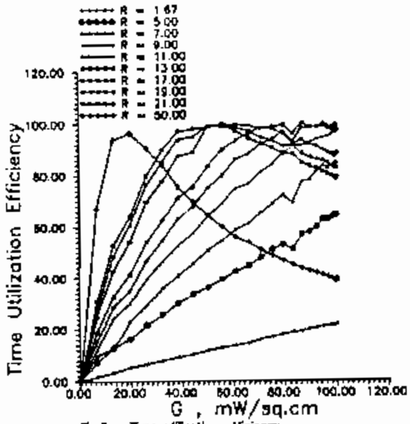


Fig.2.a: Time utilization efficiency of different ohmic loads

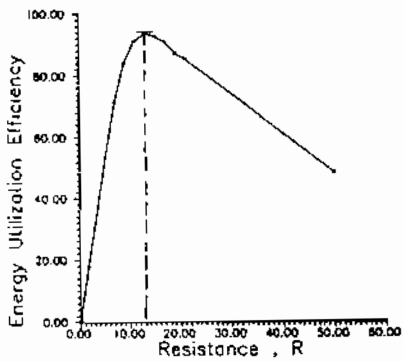


Fig.2.b : Determinating the optimum ohmic load

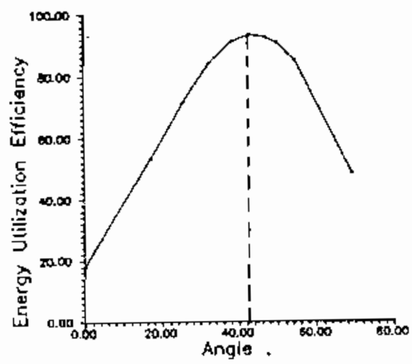


Fig.3 : Energy utilization efficiency versus angle ,

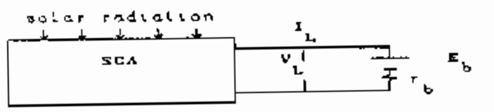


Fig.4.a : A battery storage charged by a SCA

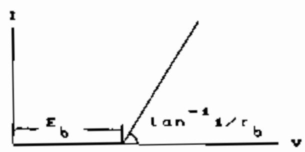


Fig.4.b : Graphical solution of the operation of the battery storage supplied by SPVS

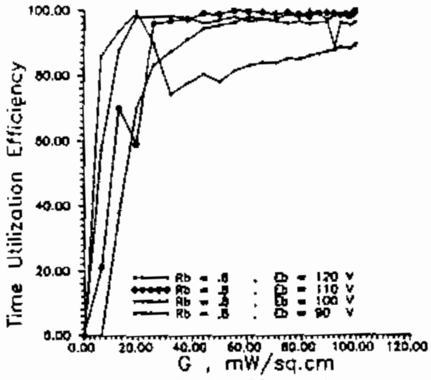


Fig.5 : Time utilization efficiency of three different batteries powered by SPVS

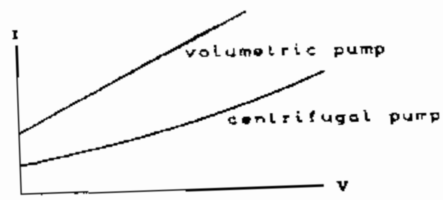


Fig.6.a : I-V characteristics of the SCA , volumetric and centrifugal pumps

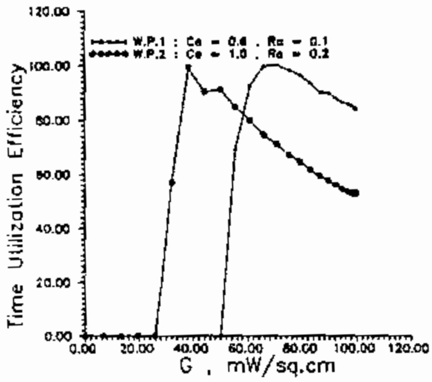


Fig.6.b : Time utilization efficiency of two different volumetric water pumps

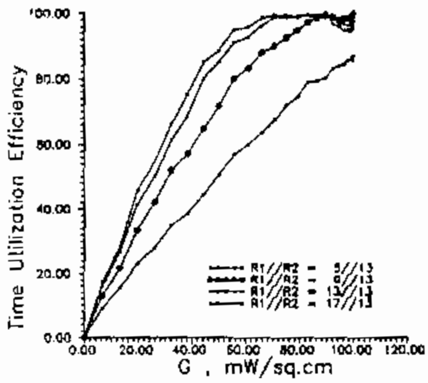


Fig.7 : Time utilization efficiency of 13 ohm resistance powered combindetly with others

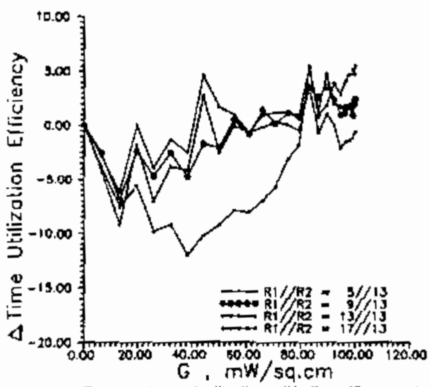


Fig.8.a : Change in the time utilization efficiency of different combinations due to powering from a CPVS

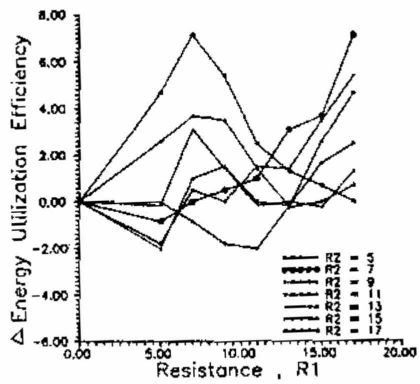


Fig.8.b : Change in the energy utilization efficiency of different combinations of R1//R2 due to powering by a CPVS

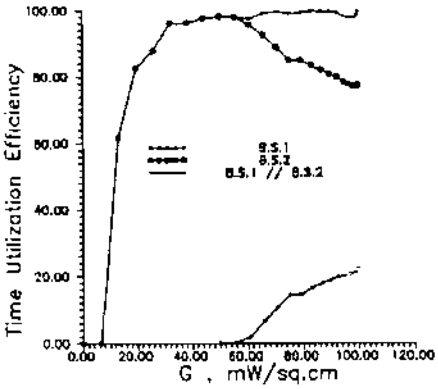


Fig.9 : Time utilization efficiency of B.S.1 , B.S.2 and B.S.1 // B.S.2

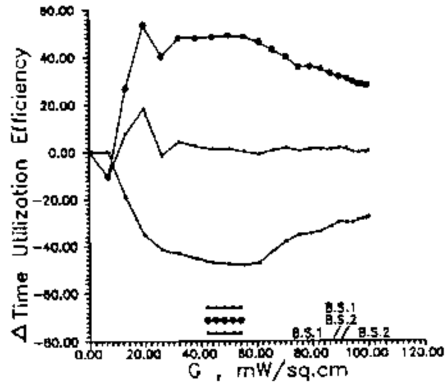


Fig.10 Change in the time utilization efficiency of B.S.1 , B.S.2 and B.S.1 // B.S.2 due to powering by a CPVS

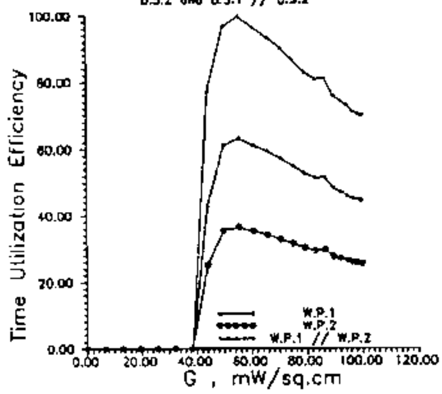


Fig.11 : Time utilization efficiency of W.P.1 , W.P.2 and W.P.1 // W.P.2 powered by a CPVS

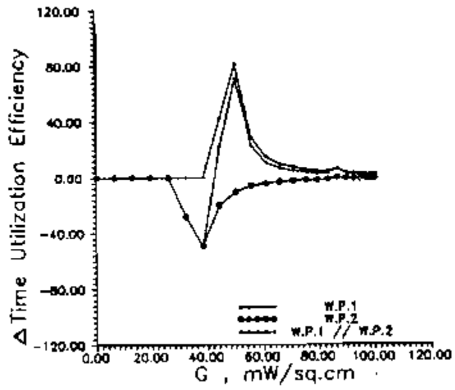
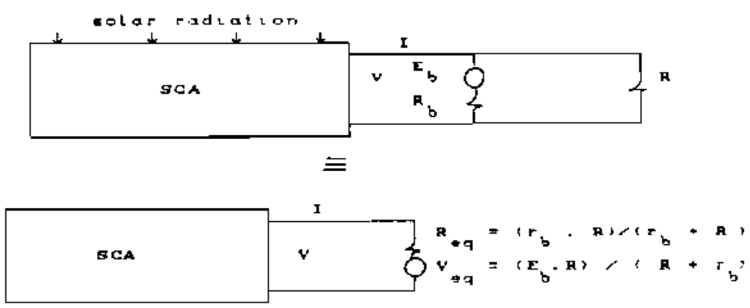


Fig.12 : Change in the time utilization efficiency of W.P.1, W.P.2 and W.P.1 // W.P.2 due to powering by a CPVS



F1g.13 : A connection of a load , R and storage battery to a PVCS

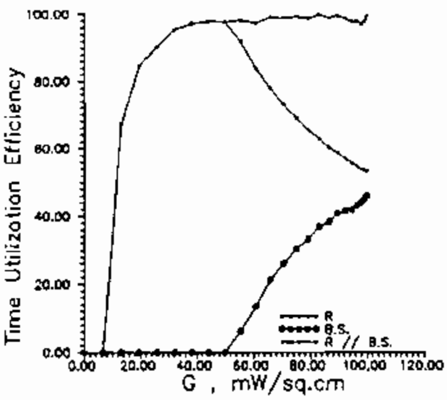


Fig.14 : Time utilization efficiency of R , B.S., and R // B.S. powered by a CPVS

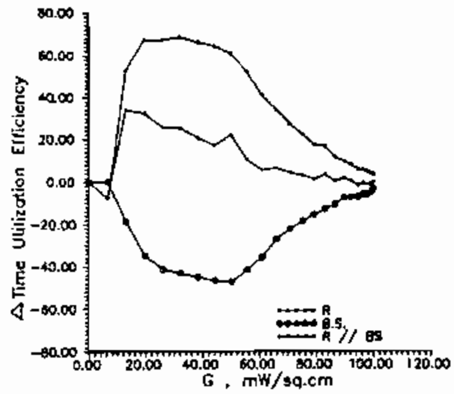


Fig.15 : Change in the time utilization of R , B.S. and R // B.S. due to powering by a CPVS

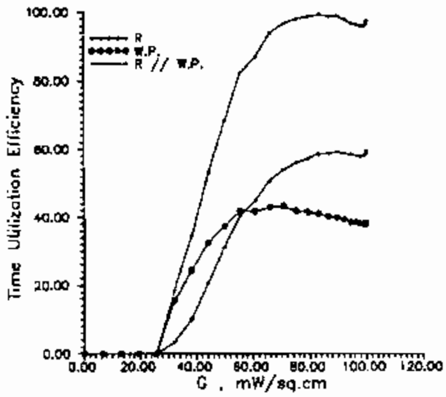


Fig.16 : Time utilization efficiency of R , W.P. and R // W.P. due to powering by a CPVS

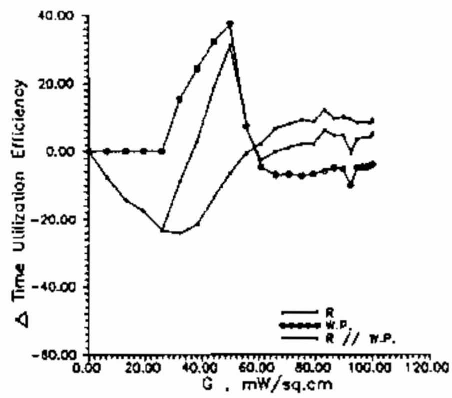


Fig.17 : Change in time utilization efficiency of R , W.P. and R // W.P. due to powering by a CPVS

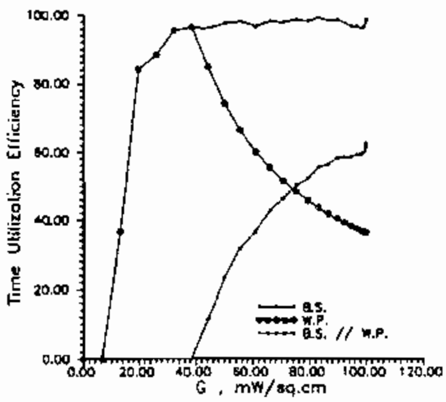


Fig.18 : Time utilization efficiency of B.S.,W.P. and B.S. // W.P. powered by a CPVS

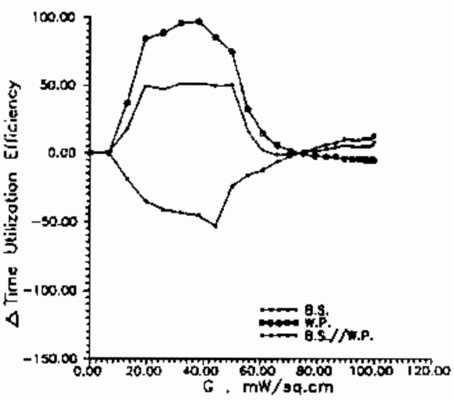


Fig.19 : Change in time utilization efficiency of B.S. , W.P. and B.S. // W.P. due to powering by a CPVS

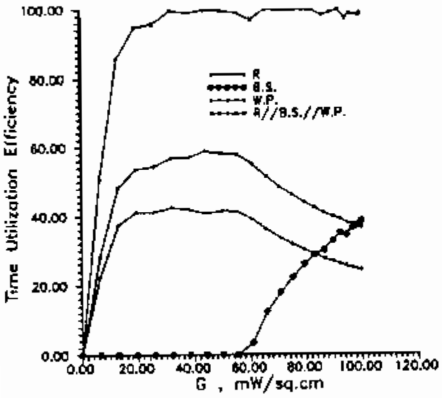


Fig.20 : Time utilization efficiency of R . B.S.. W.P and R//B.S.//W.P. powered by a CPVS

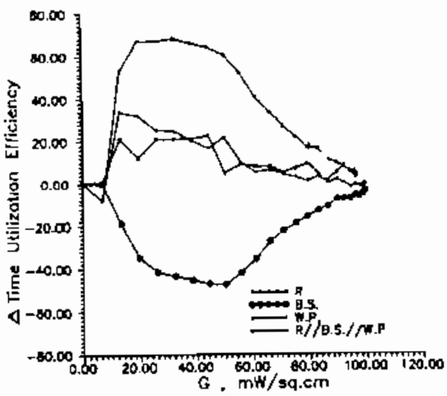


Fig.21 : Change in the time utilization efficiency of R . B.S., W.P. and R//B.S.//W.P. due to powering by a CPVS