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A PV system to operate a VHF transposer station

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Abstract

Thirteen yeas of cruel embargo imposed on Iraq, pushed people there to do a lot of things to keep survive. The main tradition distinguished that period is innovation and modification, depending upon the decreased available capabilities. In that spirit, a suitable PV system was designed to operate a VHF driver 50 w transposer. Modifications were made in some parts of the transposer unit to make it suitable for operation through the PV system. Different values of the inclination angle were examined, and the one with minimum peak power demand was chosen for the design. The designed PV system is composed of 144 solar modules, two regulators and 17 storage batteries. Each solar model has an area of 1×3 ft and a specification of 14.5 V, 759 ma and 11 W. Each storage battery has a specification of 12 V and 90A.h. The designed system provides sufficient energy to operate the transposer for 16 h daily and the storage system provides energy to the system for 3 consecutive days without insolation. The system was designed to be installed in a remote area near Baquba City. An evaluation of one year's operation is made for the whole system.

1. Introduction

For thirteen continuous years, Iraq complied with one of the cruelest embargos that has ever been known in history. Among severe effects of that situation, were the downgrading and depreciation of electricity generation plants. This caused a heavy shortage of electricity supplied to consumers.

One of the affected fields were television stations, where many VHF driver transposers became obsolete due to the lack of electricity. Moreover some of these VHF transposers still exist in remote areas far from the national grid, while others located within the grid are exposed to frequent interruption of electricity.

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The option of using diesel generators causes new problems such as undependable fuel transportation, continuous need of maintenance, and continuous need of consumable moving parts, in addition to pollution and noise problems.

To avoid the above-mentioned problems, the Energy Research Center has studied the ability of operating these transposers by using PV systems. Different designs were examined for different inclinations and periods of daily operation, according to the climate of the Ba'aquba city. An optimization based on cost and function was made to choose the most suitable design.

The design needed some modification in the transposer's power supply and ventilation units, hence some parts were omitted and others were changed.

2. Transposer system

2.1. System modification

The related type of tranposer has a power supply unit that receives 220 v-50 Hz and supplies +24 v and –12 v d.c. voltage. The unit has two fans on the 220 V side. Fig. 1 illustrates a simple circuit diagram of the power supply and ventilation units.

The transposer can be operated through a PV system in two ways: either by using an inverter to produce the same input a.c. voltage, or by generating the demanded d.c. voltage directly, with replacement of the a.c. fans by d.c. fans. These choices were discussed with the user, who selected the second option since it is simple and cost-effective.

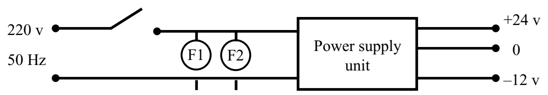

Fig. 1. The power supply and ventilation units of the transposer.

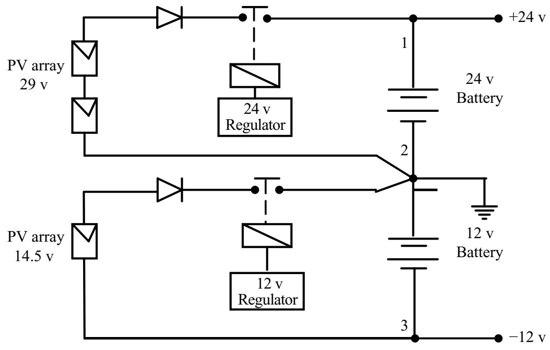

Fig. 2. Connection of PV modules and batteries.

As a first step, the power supply unit was cancelled and removed from the transposer case. To generate the demanded positive and negative voltages, without the dc converter, the PV array and batteries were connected as shown in Fig. 2.

As shown in the figure, point (2) is considered the ground of the system. Then consequently, points (1) and (3) give +24 v and –12 v respectively.

2.2. PV system design

After modification, the VHF transposer was tested by supplying it with the demanded d.c. voltages through a suitable d.c. power supply device. It was found that the +24 v part needed a current of 9A, while only 1A was demanded by the –12 v part.

The user requested that the PV system should provide sufficient energy to operate the transposer for 16 h daily. Therefore it must supply daily demands of at least 3456 w.h. and 192 w.h. for the +24 v and –12 v parts respectively.

To get the optimum power from the PV system, the tilt factor has been taken into consideration when placing the design. This being due to its effect on the received insolation.

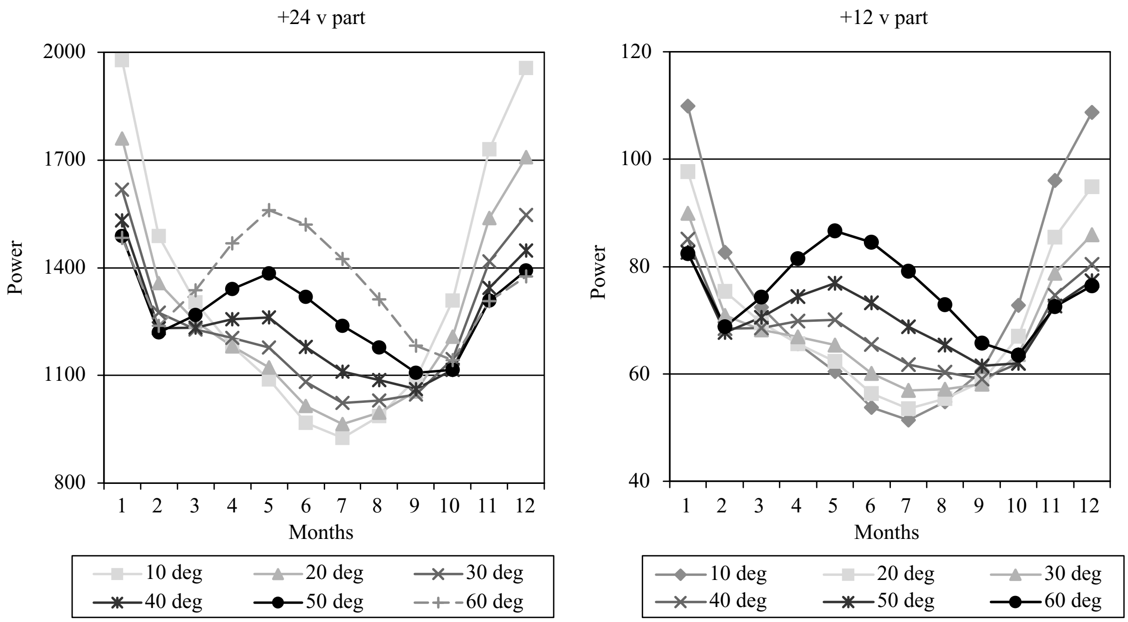

Fig. 3. PV peak power demands of the VHF transposer parts, for different inclinations during one year.

The tilt factor (Tf) can be expressed according to Liu and Jordan formula [1] as:

$$\mathrm{Tf} = \frac{R_b\ H_{Tb}}{H_T} + \left(\frac{1+\cos\beta}{2}\right)\cdot\frac{H_{Td}}{H_T} + \rho\left(\frac{1-\cos\beta}{2}\right) \quad (1)$$

where R_b, direct beam elevation factor; H_{Tb} and H_{Td}, monthly daily average total horizontal beam and diffuse radiation; β, inclination, in degree; ρ, ground reflectivity.

The demand area of PV modules (A) in m^2 is expressed as:

$$A = \frac{E}{\mathrm{Tf}.G.\eta_R.\eta_B.\eta_{PV}} \quad (2)$$

where E, monthly daily average demand of electric energy in w.h.; G, monthly daily average radiation in w.h/m^2; $\eta_R \cdot \eta_B \cdot \eta_{PV}$, efficiencies of regulator, batteries and PV modules.

Then the correspondent PV peak power demand (P), in watt is expressed as:

$$P = \mathrm{SC}.A.\eta_{PV}.\mathrm{SF} \quad (3)$$

SC is the solar constant = 1000 w/m^2.

SF is a safety factor that compensates the effects of temperature variations, dust, solar radiation variation and resistive wiring losses. For the site area, its value varied from 1.25 to 1.4 [2]. Substituting Eq. (2) into Eq. (3) yields:

$$P = \frac{\mathrm{SC}.E.\mathrm{SF}}{\mathrm{Tf}.G.\eta_R.\eta_B} \quad (4)$$

The peak power demand is calculated for different values of inclination angles.

Eq. (1) is applied for a range of inclinations from 0–60° using the climatic data of the Ba'aquba city [3]. The resultant tilt factors are consequently substituted into Eq. (4), with η_R and η_B equal to 0.95 and 0.7 respectively.

Table 1
PV peak power demands of the worst months at different inclinations

B	Mon	P_{+24}	P_{-12}
0	Dec	2355	130.8
10	Jan	1955	108.6
20	Jan	1747	97.0
30	Jan	1613	89.6
40	Jan	1532	85.1
50	Jan	1492	82.9
60	May	1622	90.1

The above-mentioned procedure is applied for both +24 v and –12 v parts. Substituting their related daily demands of energy for (E) into Eq. (4), the results of *P* are represented by Fig. 3.

The PV peak power demands (*P*) of the worst months during a complete year for both parts are shown in Table (1).

Where, P_{+24} and P_{-12} are the PV peak demands of +24 v and –12 v parts respectively.

By considering Table 1 it is clear that 50° is the optimum inclination angle for both parts, where it shows minimum values of peak power demands.

3. PV system configuration

3.1. PV array

Dismantled amorphous silicon modules of an old PV system, have been used to install the demanded PV array. The new array consists of 144 modules, of an area 1ft × 3 ft each, and with specifications of 14.5 V, 759 mA and 11 w. They have been arranged as follows:

136 modules of total peak power (*P*) equal to 1496w for the +24 v part, and 8 modules of 88 w peak power for the –12 v part.

The whole PV array is mounted on three frames, fixed on suitable supports and inclined at 50°. The array is arranged in three sub arrays for the +24 v part and a small one for the –12 v part. Fig. 4 represents a simple circuit diagram of the array for the whole PV system.

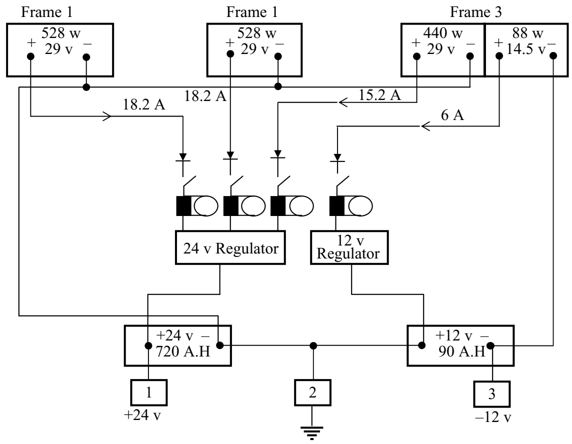

Fig. 4. Simple circuit diagram of the PV system storage and regulation.

A storage battery system with an appropriate capacity in amper-hour (a.h.), is designed to provide sufficient supply to the system for 3 consecutive days without insolation. This can be done by applying the following equation:

$$\text{A.h.} = 3 \times \text{E/DDL} \times \text{Voltage} \qquad (5)$$

where DDL is the deep discharge level of battery assumed to be 0.6.

Applying Eq. (5) to both the parts of the transposer gives a capacity of 720 a.h for the +24 v part and 80 a.h. for the –12 v part.

To meet the demand, 17 storage batteries of specifications 12 volt, 90 a.h. each were chosen. Sixteen batteries were connected as 2 series × 8 parallel to provide the demanded capacity of the +24 v part, while only one battery was sufficient for the –12 v part.

Two separate regulators of 24 v and 12 v systems were designed to protect the storage batteries against overcharge and deep discharge problems.

4. System evaluation

An evaluation of the whole system operation was made for a period of one year. The data is indicated in Table 2.

Table 2
Evaluation data of system operation for a one year period

Mon	Tf	*G*	EG_{+24}	E_{+24}	SE_{+24}	EG_{-12}	E_{-12}	SE_{-12}
Jan	1.57	4479	3888	3456	432	228	192	36
Feb	1.38	5307	4474	3456	1018	262	192	70
Mar	1.1	5152	4290	3456	834	251	192	59
April	0.9	4847	3965	3456	509	232	192	40
May	0.78	4720	3732	3456	276	218	192	26
June	0.71	4924	3815	3456	359	223	192	31
July	0.73	5256	3988	3456	532	233	192	41
Aug	0.85	5542	4218	3456	762	247	192	55
Sept	1.04	5848	4371	3456	915	256	192	64
Oct	1.34	5928	4484	3456	1028	262	192	70
Nov	1.54	4934	3968	3456	512	232	192	40
Dec	1.69	4661	3813	3456	357	223	192	31

Where EG_{+24} and EG_{-12}, monthly daily average of generated energy provides the +24 v and −12 v parts respectively, in w.h.

E_{+24} and E_{-12}, monthly daily average of energy demand of the +24 v and –12 v parts respectively, in w.h.

SE_{+24} and SE_{-12}, monthly daily average of surplus energy related to the +24 v and −12 v parts respectively.

Table 3
The allowable additional periods of daily operation

Mon	SE_{+24}	AP_{+24}	SE_{-12}	AP_{-12}	AP_t
Jan	432	2	36	3	2
Feb	1018	4.7	70	5.8	4.7
Mar	834	3.8	59	4.9	3.8
April	509	2.35	40	3.33	2.35
May	276	1.25	26	2.16	1.25
June	359	1.66	31	2.58	1.66
July	532	2.46	41	3.41	2.46
Aug	72	3.52	55	4.58	3.52
Sept	915	4.23	64	5.33	4.23
Oct	1028	4.75	70	5.8	4.75
Nov	512	2.37	40	3.33	2.37
Dec	357	1.65	31	2.58	1.65

It is clear from Table 2 that there is surplus energy available during each month. It allows the benefit of either reducing the PV array area based on the month of minimum surplus energy, or increasing the periods of daily operation corresponding to each month. The second benefit is chosen due to its convenience to the user.

Table 3 shows the allowable additional periods of daily operation corresponding to each month for both parts of the VHF transposer.

Where AP_{+24}, AP_{-12} and AP_t are the allowable additional periods of daily operation in hours corresponding to the +24 v, −12 v parts, and the total transposer as a unit, where both parts operate together as a single unit. For each month the lower allowable additional period is taken as the reference of operating hours for that month.

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