Modeling of Solar Photovoltaic Assisted Rechargeable Battery for Running a Hospital in Remote Area

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Abstract— In the study, solar photovoltaic (PV) assisted rechargeable battery is used for running a hospital in remote area in Kolkata region. Solar PV is used for running the different appliances of hospital in which during peak sunshine hour's power is supplied to appliances and excess energy is used for charging rechargeable battery to be made available during period of non sunshine hours. The hospital contains 125 lights of 100 W each, 1 water pump of 500W , 75 fans of 65W each and a heater of 500kW for supplying hot water which is operated for 24 hours a day.2 modules in series and 15686 modules in parallel of Central Electronics Limited Make PM 150 can meet the electrical energy needs of designed hospital. The power back up is provided using a battery bank with a rated capacity of 156859 Ah. The heater of 500kW will supply 5714.28kg/hr or 5.714m3/hr of water throughout the day.

Key words: Solar Photovoltaic, Rechargeable Battery, Central Electronics Limited, PM150

I. Introduction

Powering appliances in remote area is a very important issue. Many people have done studies for powering in remote area or interior places. Also most important is the powering of hospital situated in remote area.

In [1] authors addressed the need for electricity of rural areas in southern Iraq and proposed a photovoltaic (PV) solar system to power a health clinic in that region. In[2] authors described the design of a solar organic Rankine cycle(ORC)being installed in Lesotho for rural electrification purpose. The system consisted of parabolic through collectors, a storages tank, and a small-scale ORC engine using scroll expanders. In [3] authors simulated off-grid generation for remote villages in Cameroon using a load of 110 kWh/day and 12 kWp. In [4] authors simulated pico-hydro (pH) and photovoltaic (PV) hybrid systems incorporating a biogas generator for remote villages in Cameroon using a load of 73 kWh/day and 8.3 kWp. In [5] authors designed a wind-photovoltaic(pv)-diesel hybrid power system for a village in Saudi Arabia which is presently powered by a diesel power plant consisting of eight diesel generating sets of 1,120 kW each. In [6] authors made an attempt in order to assess the features of rural electrification in India and the feasibility of Photovoltaic Solar Home Systems. In [7] authors first provided an overview of reforms and various electrification policy initiatives in India and secondly analyzed the specific problems as studied at the grass-roots level with respect to rural electricity access and the use of off-grid renewable. In [8]authors used solar home systems for providing basic electricity services to rural households that are not connected to electric grid. In [9] authors introduced the concept of an alternative Hybrid Power System configuration that combined photovoltaic modules and digesters fuelled by goat manure as the basis for rural sustainable development. Attention was drawn to the Northeast Region of Brazil, one of the largest semi-arid regions in a single country. In [10] authors developed a mixed integer linear mathematical programming model (time-series) to determine the optimal operation, optimal configuration including the assessment of the economic penetration levels of photovoltaic array area, and cost optimization for a hybrid energy generation system consisting of small/micro hydro based power generation, biogas based power generation, biomass (fuelwood) based power generation, photovoltaic array, a battery bank and a fossil fuel generator. In [11] authors utilized Integrated Renewable Energy System (IRES)for off grid electrification to satisfy the electrical and cooking needs of the seven-un electrified villages in the Almora district of Uttarakhand state, India. In [12] authors presented the results of an experimental study of a photovoltaic (PV)/diesel hybrid system without storage. It showed that for a reliability of a photovoltaic (PV)/diesel hybrid system, the rated power of the diesel generator should be equal to the peak load.

In the present study powering of appliances of hospital is done which is located in Kolkata's remote area.

II. Modeling

A. Modeling of Solar Photovoltaic System Assisted Rechargeable Battery System

The proposed integrated system consists of solar photovoltaic modules, charge controller, rechargeable battery and an inverter as can be seen in Fig.1 and Fig.2.

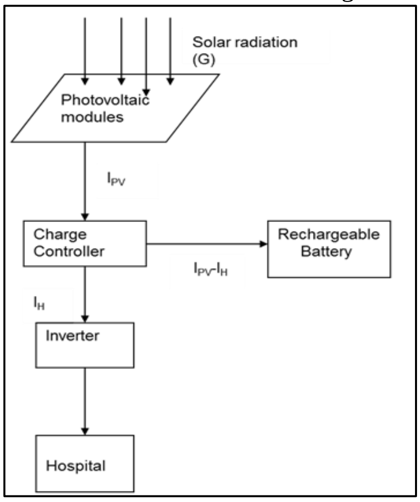

Fig. 1: Schematic view of proposed system when current generation is in excess of hospital requirement

In fig.1 it shows the schematic view of the integrated system during sunshine hours. During sunshine hours of a day solar radiation (represented by G) falls on solar photovoltaic modules. The modules generate current

I_{PV} and passes through charge controller of definite efficiency. The excess current after meeting the demand of hospital (I_H) goes to rechargeable battery by amount (I_{PV}-I_H). The current requirement of hospital (I_H) passes through inverter and goes to various appliances of hospital for smooth functioning of the hospital throughout the year.

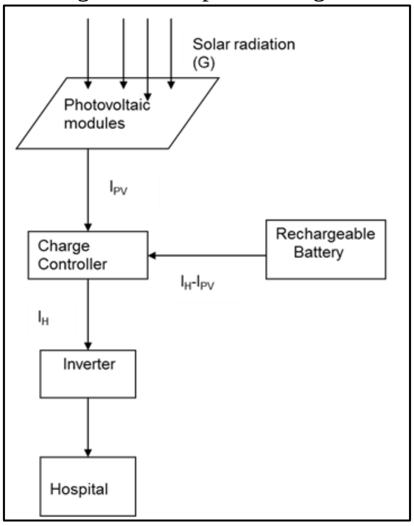

Fig. 2: Schematic view of proposed system when current generation is deficient of hospital requirement.

In fig.2 it shows the schematic view of the integrated system during deficient solar radiation of a day. The current requirement of the hospital(I_H) is obtained from rechargeable battery which stored excess current generated during sunshine hours. The current finally passes through inverter and goes to various appliances of hospital for smooth functioning.

Table 1 show the various appliances used in the hospital for 24 hours throughout the year.

	Numbers	Wattage(W)
Lights	125	100
Pump	1	500
Fans	75	65
Heater	1	500,000

Table 1: Appliances used in Hospital

B. *Modeling of Solar Photovoltaic System*

The module of solar photovoltaic system is taken from Central Electronics Limited Make PM 150[13].

The single cell terminal current is given by[14]:

$$i_{PV} = i_L - i_D \qquad (2.1)$$

Where i_L the light current generated by a solar cell as a function of solar radiation and i_D is the diode current.

The light current generated from a photovoltaic module at given intensity of solar radiation and temperature is given by[14]:

$$i_L = \left(\frac{G}{G_{ref}}\right)\left(i_{scref} + \mu_{isc}\left(T_{module} - T_{moduleref}\right)\right) \qquad (2.2)$$

Where, G, G_{ref}, is the solar radiation at actual[15] and reference condition(1000 W/m^2)[13] respectively, i_{scref} - short circuit current at reference condition(A)[13], μ_{isc} - manufacturer supplied temperature coefficient of short circuit current(A/K)[13], T_{module} and $T_{moduleref}$ module temperature at actual and at reference condition(K)[13].

The module temperature is a function of ambient temperature, wind speed,, total solar radiation. Ambient temperature, total solar radiation is taken from [15] and wind speed from[16].

$$T_{module}(K) = (0.943\times T_{ambient} + 0.028\times G - 1.528\times v_f + 4.3) + 273.15 \qquad (2.3)$$

Where, $T_{ambient}$ is in 0C, G in W/m2, $V_f$in m/s.

The diode current in equation (2.1) is a function of reverse saturation current and given by[14]:

$$i_D = i_{sat}\left[\exp\left(\frac{q(V + i_{PV}R_s)}{\gamma k T_{module}}\right) - 1\right] \qquad (2.4)$$

Where i_{sat} - reverse saturation current(A), q - electron charge(1.6 x 10^{-19}C), V -terminal voltage(V), R_s - series resistance, γ -shape factor, k -Boltzamann constant(1.38 x 10^{-23} J/K).

$$i_{sat} = i_{satref}\left(\frac{T_{module}}{T_{moduleref}}\right)^3 \exp\left[\left(\frac{q\varepsilon_G}{kA}\right)\left(\frac{1}{T_{moduleref}} - \frac{1}{T_{module}}\right)\right] \qquad (2.5)$$

Where A – completion factor, ε_G -material bandgap (1.12eV for Si), and

$$i_{satref} = i_{scref}\times\exp\left(\frac{-qV_{ocref}}{k\gamma T_{moduleref}}\right) \qquad (2.6)$$

Shape factor (γ) which is a measure of cell imperfection is given by:

$$\gamma = A\times NCS \times N_S \qquad (2.7)$$

Where A, NCS, N_5 is completion factor, number of cells connected in series in a single module(specified by manufacturer of the module) and number of modules connected in series of the entire photovoltaic array respectively.

i_{sat}, i_{sarref}, γ is taken from[14].

$$N_S = \frac{V_{system}}{V_{module}} \qquad (2.8)$$

Where V_{system} is the system voltage of the photovoltaic array (considered 48 V in present study) and V_{module} is the voltage obtained from single module.

Total daily electrical load of any appliances is given by:

$$i = \frac{P\times 24}{V_{system}\times PF} \qquad (2.9)$$

Where Px24-total electrical load in a day,P-power of an appliance, PF-power factor(0.85)

The total daily electrical load(Ah) due to operation of equipments mentioned in table 1 is given by:

$$i_{total} = \frac{i_{light} + i_{pump} + i_{fan} + i_{heater}}{\eta_{inverter}} \qquad (2.10)$$

Where $\eta_{inverter}$ is efficiency of inverter (85%)

The design current requirement from photovoltaic array (i_{spv}) can be given by:

$$i_{spv} = \frac{i_{total}\times DF}{peakSunshineHours \times \eta_{chargecontroller}} \qquad (2.11)$$

Where DF-derating factor[17], $\eta_{chargecontroller}$ -charge controller efficiency[17], peak sunshine hours[18].

Number of photovoltaic modules in parallel (Np)

$$N_p = \frac{i_{spv}}{i_{mp}} \qquad (2.12)$$

Where i_{mp}- current available under peak power condition.

Hourly current from solar photovoltaic array is given by:

$$I_{PV} = i_{pv} \times N_p \qquad (2.13)$$

C. Modeling of Rechargeable Battery

Considering charge controller efficiency (85%), battery efficiency (90%) the required battery bank capacity is 156859Ah.

On the basis of availability battery capacity of 200x785 Ah can be selected.

III. RESULTS AND DISCUSSION

A numerical code in C was developed for simulation purpose of the integrated system. The code developed in C took intensity of solar radiation, ambient temperature, wind speed, electrical load requirement of various appliances for hospital as input parameters. The electrical load requirement for various appliances remains same throughout the year. But solar radiation, ambient temperature and wind speed varies from month to month.

It was found that 2 modules in series and 15686 modules in parallel of Central Electronics Limited Make PM 150 can meet the electrical energy needs of designed hospital throughout the year in Kolkata region. The battery bank required is 200x785 Ah(156859 Ah).The analysis of the integrated system is taken for four different months depending on different climatic seasons.

It is seen that for every month the electrical energy discharged(Ah) from battery remains same from 19 hours to 5 hours due to same demand at each hour being 3690.795Ah. The energy supply(Ah) to battery starts increasing from 6 hours and reaches peak at 12 hours and again decreases from 13 hours to 18 hours. This is due to the fact that intensity of solar radiation increases from 6 hours to 12 hours and again starts decreasing till 18 hours.

Fig.3,4,5,6 shows the discharge and charging of required battery capacity for the month of January, March, May and September respectively. It is seen that maximum charging of battery occurs at 12 hours being 42431.242 Ah, 53418.967Ah, 59090.045Ah and53418.637Ah for the month of Janaury, March, May and September respectively.

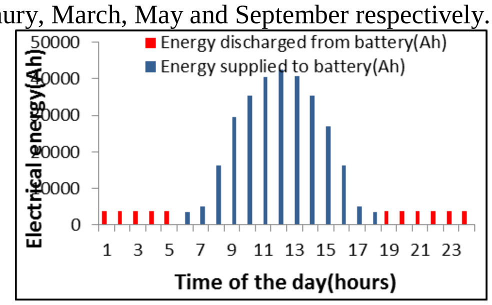

Fig. 3: Electrical load variation for the month of January

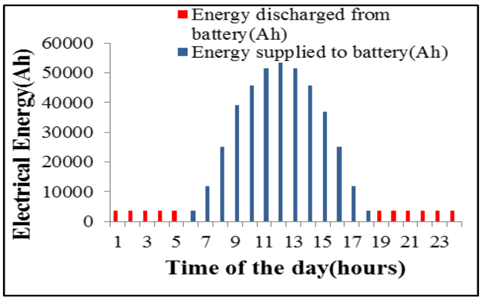

Fig. 4: Electrical load variation for the month of March

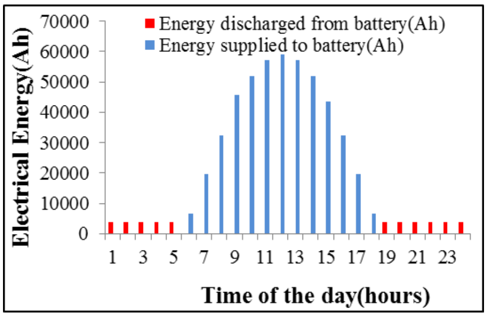

Fig. 5: Electrical load variation for the month of May

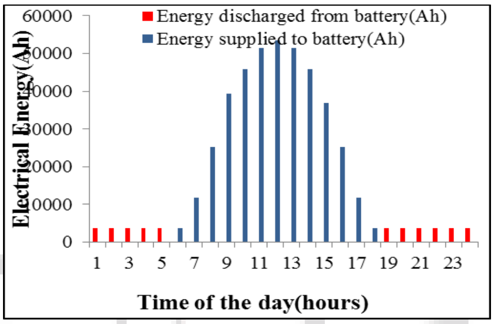

Fig. 6: Electrical load variation for the month of September

Table 2 shows the cumulative day long battery charging and discharge for different months.

	January	March	May	September
Energy to battery (Ah)	300594.052	405102.785	483999.383	405124.499
Energy from battery (Ah)	40598.745	40598.745	40598.745	40598.745

Table 2: Cumulative Day Long Battery Charging And Discharge For Different Months

From table 2 it is clear that for the designed system, the electrical energy supplied to the battery is much greater than the energy discharged or drawn from the battery for all the seasons of a full climatic cycle indicating that the designed system can be powered with the given number of solar photovoltaic modules with a battery backup satisfactorily.

IV. CONCLUSION

In the present work a model for running the hospital having various appliances mentioned in table 1 has been developed.

It is seen that 2 modules in series and 15686 modules in parallel of Central Electronics Limited Make PM 150 can meet the electrical energy needs of designed hospital. The power back up is provided using a battery bank with a rated capacity of 156859 Ah. It is revealed that for the designed system, there is a considerable surplus of electrical energy in the battery which can cater to the energy deficit hours of the day satisfactorily for all the seasons of a full climatic cycle The model was developed for fixed number of appliances. If appliances number and operation hours vary the results will vary accordingly.

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