wjert, 2020, Vol. 6, Issue 5, 277-285. *Original Article* **ISSN 2454-695X**

World Journal of Engineering Research and Technology

WJERT

www.wjert.org **SJIF Impact Factor: 5.924**

APPLICATION OF SOLAR PHOTOVOLTAIC SYSTEM FOR OPERATING A STEAM POWER PLANT

Dr. Kamaljyoti Talukdar*

Assistant Professor, Department of Mechanical Engineering, Bineswar Brahma Engineering College, Kokrajhar-783370, Assam, India.

Article Received on 27/07/2020 **Article Revised on 17/08/2020** **Article Accepted on 07/09/2020**

***Corresponding Author**
Dr. Kamaljyoti Talukdar
Assistant Professor, Department of Mechanical Engineering, Bineswar Brahma Engineering College, Kokrajhar-783370, Assam, India.

ABSTRACT

In this work the thermal energy required by a boiler is obtained by passing high amount of direct current (DC) generated by solar photovoltaic (SPV) modules after passing through a fixed resistance. Also current required by pump in steam power plant is obtained from solar photovoltaic modules after converting into alternating current(AC) by an inverter and the excess current is supplied to rechargeable battery for operating steam power plant during non sunshine hours. In this work boiler pressure is assumed to be 15 MPa, entry temperature of steam to steam turbine (ST) to be 600^{0}C, condenser pressure to be 0.01MPa with dryness fraction of steam 0.8041.The power produced by ST is 1 MW and a supply of 0.68 kg/s of steam is needed to produce 1MW power by boiler. For production of 0.68kg/s,178.256 A current is required considering 100 ohm resistance and for pumping power (10.294 kW), 62.35 A current is required and for that 963 SPV modules in parallel and 2 modules in series of Central Electronics Limited Make PM 150 for January and May in Kolkata city, India. The amount of charge stored and discharged by battery in January and May are 17823 Ah, 3113 Ah and 29084Ah, 3113 Ah respectively.

KEYWORDS: Alternating Current (AC), Direct Current (DC),Solar photovoltaic (SPV), Steam Turbine(ST).

1. INTRODUCTION

At present power in the form of electricity is obtained in large scale from steam power plant where it uses coal, natural gas for producing steam in boiler. Coal and natural gas causes a lot of environmental pollution, increase of fuel price and also they are non renewable sources of energy which will get exhausted one day. In order to continue to run the steam power plant without coal or natural gas, boiler should use alternate sources to produce steam. (Jamel et al., 2013) made a review of the previous studies and papers for integrating solar thermal energy with conventional and non-conventional power plants. The focus on hybrid solar conventional power plants consisted of the review of studies of hybrid solar–steam cycle power plants, integrated solar combined-cycle systems (ISCCS) and hybrid solar–gas turbine power plants, while for hybrid solar non-conventional power plants the focus of study was hybrid solar–geothermal power plants. (Koai et al.,1984)analyzed a novel hybrid steam Rankine cycle, which was designed to drive a conventional open-compressor chiller, but was equally applicable to power generation. Steam was generated by the use of solar energy collected at about 100°C, and is then superheated to about 600°C in a fossil-fuel fired superheater. The steam was used to drive a novel counter-rotating turbine, and most of its exhaust heat was regenerated. (Lior and Koai, 1984) made an analysis of a solar power/cooling system based on a novel hybrid steam Rankine cycle. Steam was generated by the use of solar energy collected at about 100°C, and it was then superheated to about 600°C in a fossil-fuel-fired superheater. The addition of about 20–26 percent of energy as fuel doubled the power cycle’s efficiency as compared to organic fluid Rankine cycles operating at similar collector temperatures. (Behar et al.,2013)reviewed the most important studies on the major components of central receiver solar thermal power plants including the heliostat field, the solar receiver and the power conversion system.

In this paper a steam is produced in boiler by passing high amount of current produced by photovoltaic modules through resistance and also for pumping power required to pump feedwater to boiler.

2. System layouts

In Fig. 1, it shows the schematic configuration during sunshine hours. When sunlight is available, it falls on solar photovoltaic modules. Then current is generated and is made to pass through charge controller. The required current for boiler goes to boiler, where resistance present in boiler heats up the water to produce steam. Also required current for pumping feedwater to boiler goes to pump after passing through inverter. The excess current after meeting the requirements of boiler and pump goes to rechargeable battery for storing to be used during non-sunshine hours or deficient solar radiation periods.

In Fig.2, it shows the schematic configuration during non-sunshine hours. The current stored in rechargeable battery during sunshine hours is utilized for supplying current to boiler and pump during non sunshine hours or deficient solar radiation periods.

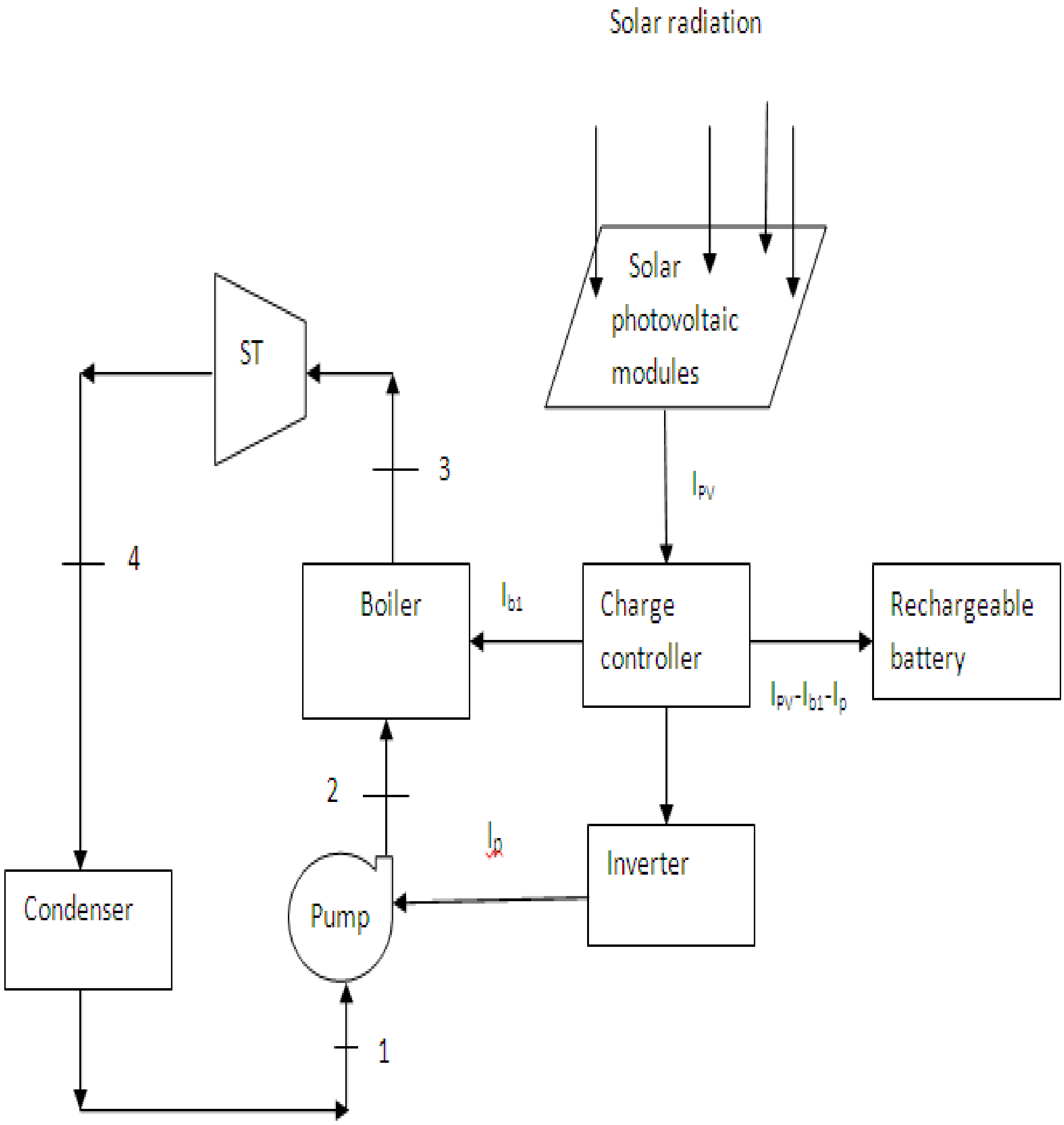

Fig. 1: Schematic view of combined solar photovoltaic system and steam power plant during sufficient solar radiation.

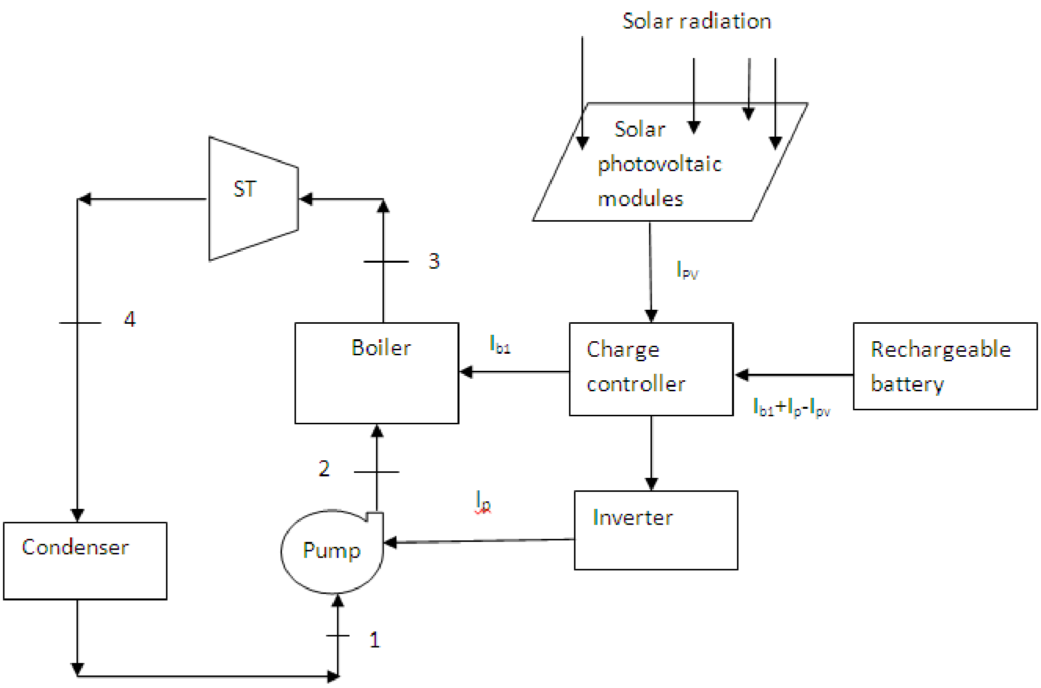

Fig. 2: Schematic view of combined solar photovoltaic system and steam power plant during deficient solar radiation.

3. Modeling

3.1 Modeling of solar photovoltaic system

The current required for operating steam power plant is obtained from solar photovoltaic modules. In the present work Central Electronics Limited Make PM-150 solar photovoltaic module has been used (Solar photovoltaic modules pm 150). The single cell terminal current (i_{pv}) is given by (Chenni et al., 2007)

$$i_{pv} = i_l - i_d \qquad (1)$$

Where i_l is the light current and i_d is the diode current. The solar radiation data, ambient temperature data are obtained from (Tiwari, 2004) and wind speed data required for calculating light current is obtained from (Wind speed in Kolkata, West Bengal 700001, India).The other values required are obtained from (Solar photovoltaic modules pm 150)and (Chenni et al.,2007)

For calculating diode current values are obtained from (Solar photovoltaic modules pm 150) and (Chenni et al.,2007).

The number of modules required in series (N_s) is given by:

$$N_s = \frac{V_{system}}{V_{module}} \qquad (2)$$

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 (Solar photovoltaic modules pm 150).

The current required from photovoltaic array(i_{spv}) is given by summation of total boiler current required in a day and total pump current required in a day:

$$i_{spv} = I_{b1(total)} + I_{p(total)} \qquad (3)$$

The number of photovoltaic modules required in parallel(N_P) is given by:

$$N_p = \frac{i_{spv}}{i_{mp}} \qquad (4)$$

Where i_{mp} is the current available from single module under peak power condition (Solar photovoltaic modules pm 150)

Net current obtained from solar photovoltaic array(I_{pv}) is given by:

$$I_{pv} = i_{pv} \times N_p \qquad (5)$$

3.2 Modeling of steam power plant

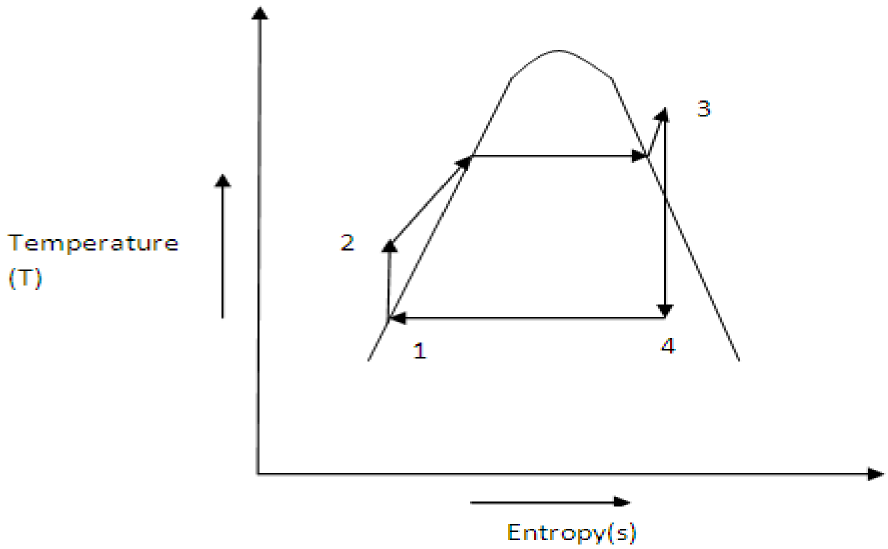

Fig. 3: Temperature (T)-Entropy(s) diagram of steam power plant.

Fig.3 shows T-s diagram for steam power plant. Process 1-2-3-4-1 is the cycle that takes place for steam power plant. Process 2-3 is the conversion of water to superheated steam in boiler at particular pressure. Process 3-4 is the work done by steam turbine (ST). Process 4-1 is the heat rejected by condenser, and process 1-2 is pumping work done by pump to boiler pressure on feedwater.

Boiler heat rate required: $$Q_{boiler} = m_s(h_3 - h_2) \quad (6)$$

Where m_s-mass flow rate of steam (kg/s), h_3 and h_2 specific enthalpy at points 3 and 2.

Current required in boiler : $$i_{boiler} = \sqrt{\frac{Q_{boiler}}{resistance}} \quad (7)$$

Net current required in boiler from photovoltaic modules after passing through charge controller:

$$I_{b1} = \frac{i_{boiler}}{\eta_{chargecontroller}} \quad (8)$$

Where $\eta_{chargecontroller}$ -efficiency of charge controller (0.85)(Telecommunication Engineering Centre (TEC), New Delhi, Planning and maintenance guidelines for SPV power)

Pumping work done by pump:

$W_{pump}=m_s$ x(specific volume of water) x (boiler pressure- condenser pressure) (9)

Net current required by pump from photovoltaic modules after passing through charge controller and inverter is given by: $$I_p = \frac{W_{pump} \times 1.25}{V_{system} \times powerfactor \times \eta_{inverter} \times 7 \times \eta_{chargecontroller}} \quad (10)$$

Where 1.25-derating factor for photovoltaic modules (Telecommunication Engineering Centre (TEC), New Delhi, Planning and maintenance guidelines for SPV power), power factor-0.85, $\eta_{inverter}$ -inverter efficiency (0.85), 7-sunshine hours in Kolkata city (Patra and Datta, 2009).

4. CALCULATIONS AND RESULTS

The turbine work is considered to be 1MW. For that mass flow rate of steam should be 0.68kg/s. For boiler pressure of 15 MPa and superheated temperature of steam (600^0C), enthalpy (h) and entropy(s) at point 3 is obtained from (Cengel and Boles, 2007). The condenser pressure is considered .01MPa. For calculating enthalpy at point 4, dryness fraction of steam at point 4,(x)is to be known, which can be calculated by:

$s_3 = s_1 + x(s_{fg,\ 0.01MPa})$ (11)

Where $s_{fg,0.01MPa}$ is the specific entropy difference of saturation vapour point and saturation liquid point at condenser pressure (Cengel and Boles,2007),s_1-specefic entropy at point1 (Cengel and Boles,2007). The dryness fraction (x) is found to be 0.8041.

Specific enthalpy at point 4 is given by: $h_4 = h_1 + x(h_{fg,0.01MPa})$ (12)

Where $h_{fg,0.01MPa}$ is the specific enthalpy difference of saturation vapour point and saturation liquid point at condenser pressure (Cengel and Boles, 2007). and h_1 is the enthalpy at point 1 (Cengel and Boles,2007).

Pumping work done by pump is obtained by using equation no.9, where specific volume of water is-0.00101m^3/kg, boiler pressure-15MPa, condenser pressure-0.01MPa and is found to be 10.294 k W.

Specific enthalpy at point 2 is given by: $h_2 = h_1 + \text{pump work}$ (13)

Boiler heat rate is obtained from equation no.6 and is found to be 2295.782 k W. The boiler current(I_{b1}) required from photovoltaic modules is given by equation no. 7 and 8, where resistance is 100 ohm and is found to be 178.256 A. The current required by pump(I_p) from photovoltaic modules is given by equation no. 10 and is found to be 62.35 A. The total current required (i_{spv}) given in equation no. 3 is given by:

$$i_{spv} = I_{b1(total)} + I_{p(total)} = (I_{b1} \times 24) + (I_P \times 24) \qquad (14)$$

The number of photovoltaic modules in parallel is obtained from equation no.4 and is found to be 963 and number of modules in series is given by equation no.2 which is 2.

For storing extra current generated by solar photovoltaic modules rechargeable battery is used which has an efficiency of 0.9.Fig. 4 and 5 shows the amount of charge discharged and stored in battery for January and May.

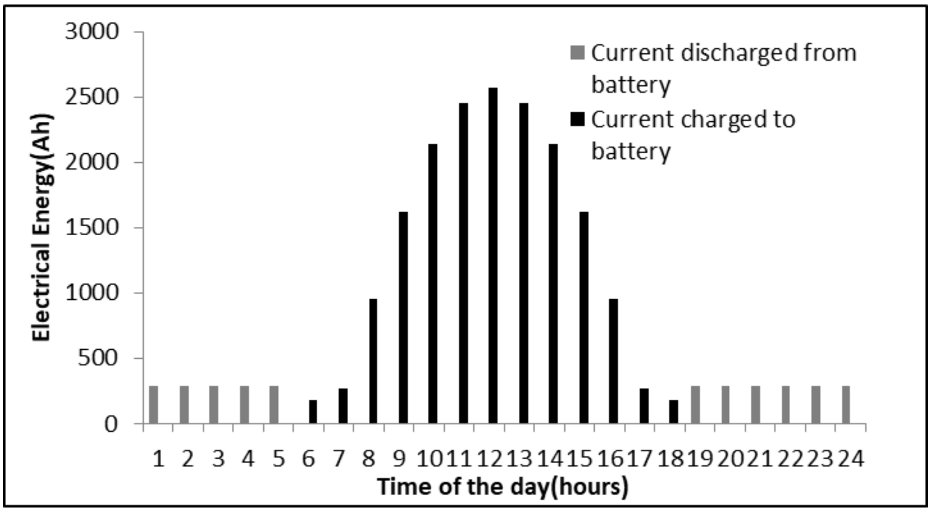

Fig. 4: Battery discharge and charging of battery bank for January.

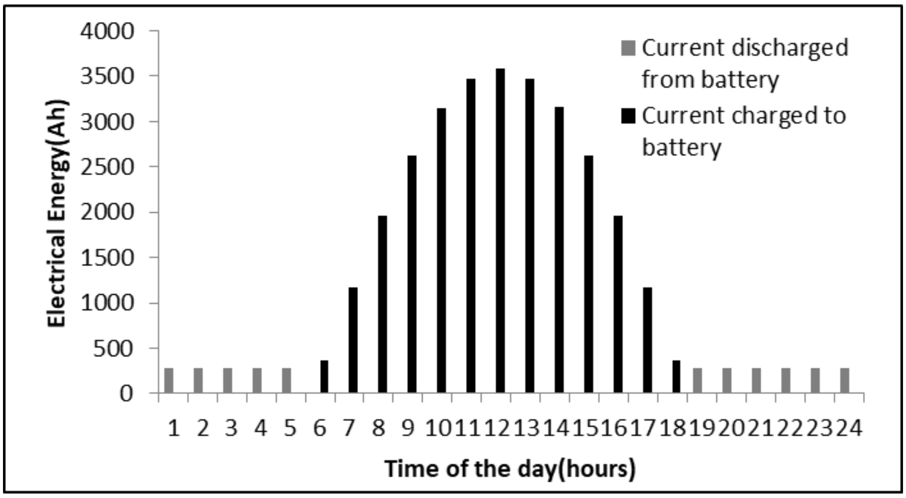

Fig. 5: Battery discharge and charging of battery bank for May.

Based on fig. number 4 and 5 it is found that amount of charge stored and discharged by battery in the months of January and May are 17823 Ah, 3113 Ah and 29084Ah, 3113 Ah respectively. The battery bank of rated capacity needed is 16657 Ah.

5. CONCLUSIONS

Based on the above discussions it is found that 963 SPV modules in parallel and 2 modules in series of Central Electronics Limited Make PM 150 is necessary for running 1 MW steam power plant throughout year. For month selection January and May months of Kolkata city are taken because January and May month have least and maximum solar radiation respectively. So if the combined system works well in these two months it can work well throughout the year. The amount of charge stored and discharged by battery in the months of

January and May are 17823 Ah, 3113 Ah and 29084Ah, 3113 Ah respectively with battery bank capacity of 16657 Ah.

6. REFERENCES

1. Behar O, Khellaf A and Mohammedi K “A review of studies on central receiver solar thermal power plants”, Renewable and Sustainable Energy Reviews, 2013; 23: 12-39.
2. Cengel Y A and Boles M A Thermodynamics An Engineering approach in SI units, Tata McGraw- Hill Publishing Company Limited, 2007.
3. Chenni R, Makhlouf M, Kerbache T and Bouzid A “A detailed modeling method for photovoltaic cells”, Energy, 2007; 32: 1724-1730.
4. Jamel M S, Rahman A Abd and Shamsuddin A H “Advances in the integration of solar thermal energy with conventional and non-conventional power plants”, Renewable and Sustainable Energy Reviews, 2013; 20: 71-81.
5. Koai K, Lior N, and Yeh H “Performance analysis of a solar-powered/fuel-assisted Rankine cycle with a novel 30 hp turbine”, Solar Energy, 1984; 32: 6; 753-764.
6. Lior N and Koai K “Solar-Powered/Fuel-Assisted Rankine Cycle Power and Cooling System: Sensitivity Analysis”, J. Sol. Energy Eng, 1984; 106(4): 447-456.
7. Patra S K and Datta P P Some insights into solar photovoltaics-solar home lighting system, NABARD Technical Digest 7, http://www.nabard.org, 2009.
8. Solar photovoltaic modules pm 150, http:-celindia-co-in.preview1.cp247.net/cal /PM150.pdf. Accessed on 1st November, 2011.
9. Telecommunication Engineering Centre (TEC), New Delhi, Planning and maintenance guidelines for SPV power, http://www.tec.gov.in/guidelines.html. Accessed on 23rd March, 2011.
10. Tiwari G N (2004), Solar energy-Fundamentals,Design, Modeling and Applications, Narosa Publishing House, New Delhi.
11. Wind speed in Kolkata, West Bengal 700001, India, http://www.synergyenviron.com /tools/wind_data.asp?loc=Kolkata%2CWest+Bengal%2CIndia. Accessed on 23.4.2012.