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Standalone Solar Power Generation to Supply as Backup Power for Samara University in Ethiopia

[1]Ankamma Rao J
[1]Assistant Professor,
Electrical & Computer Engineering,
Samara University
Semera, Ethiopia

[2]Bizuayehu Bogale
[2]Lecturer, Head of Dept.,
Electrical & Computer Engineering,
Samara University
Semera, Ethiopia

[3]Asefa Sisay
[3]Lecturer,
Electrical & Computer Engineering,
Samara University
Semera, Ethiopia

Abstract- **The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have pushed mankind to explore new technologies for the production of electrical energy using clean, renewable sources, such as solar Energy, wind energy, etc. Among the renewable energy sources, solar energy affords great potential for conversion into electric power, able to ensure an important part of the electrical energy needs of the people. Ethiopia generates most of its electricity from Hydro power plants on the Blue Nile. In 2011, over 96% of Ethiopia's electricity was from hydropower. Although Ethiopia is endowed with abundant renewable energy resources and has a potential to generate over 60,000 MW of electric power from hydroelectric, wind, solar and geothermal sources, currently it only has approximately 2,300 MW of installed generation capacity to serve a population of over 95 million people. The Ministry of Water, Irrigation and Electricity (MoWIE) set to generate 300MW from solar energy in GTP II period (2015/16 to 2019/20). . The Samara University is the only university surrounded by rich and untapped natural resources. The temperature of weather of Samara University, located in Samara, Afar Regional state, Ethiopia, varies from 30^{0}C to 35^0 C from September to March and 40^{0}C to 50^{0}C from April to August. The average solar radiation is semera is nearly 7 kWh/m^2/day. The objective of this paper is to design a system to extract solar power using PV array, to supply power for Samara University as backup power to main power supply. The power generated from solar energy will be used to supply during shut down of main power supply from grid.**

Keywords: Solar Insolation, Solar Energy, PV Array, Charge Controller, Photovoltaic Effect, Inverter, Rectifier, Automatic Transfer Switch, Samara University.

1. INTRODUCTION

The Sun can be singular solution to our future energy needs [1] since all most all renewable energy sources originate directly or indirectly from the Sun. It delivers more energy per hour than the Earth uses in one year; it is free from pollutants, greenhouse gases and very secure geo-political constraints and conflicts. The amount of solar energy reaching the Earth's surface is about 100,000 TW [2]. From BP Statistical review of world energy [3], it is very glaring the global annual energy consumption can be supplied by solar energy in every 88 minutes or about 6000 times total annual energy consumption annually. It is the worlds most abundant and permanent energy source that shows different appearances depending on the earth's surface topography [4]. In essence the solar energy is expected to play a very significant role in the future global energy needs. Ethiopia receives a solar irradiation of 5000 – 7000 Wh/m² according to region and season and thus has great potential for the use of solar energy. The average solar radiation is more or less uniform, around 5.2 kWh/m^2/day. The values vary seasonally, from 4.55-5.55 kWh/m^2/day and with a location from 4.25 kWh/m^2/day in the extreme western low lands to 6.25 kWh/m^2/day in Adigrat area, Northern Ethiopia is still at its early stage. The solar radiation distribution in Ethiopia is shown in Fig.1.

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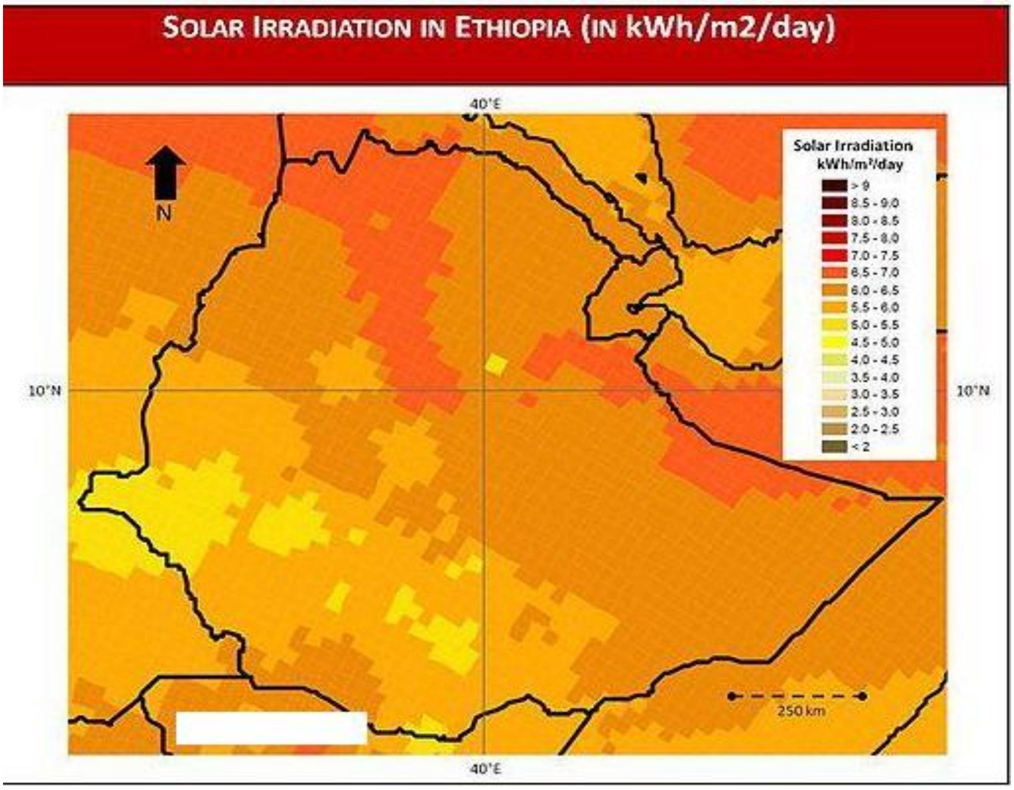

Fig .1. Solar Radiation map of Ethiopia

Samara University is a newly established pioneer academic institution located in Ethiopia specifically situated at "Semera" town which is the regional capital of the Afar Regional State. The region is endowed with considerable amount of natural resources which are totally unavailable or rarely available in other parts of the country and even in any part of the world. The climate varies from warm 30°C to 35°C during the rainy season (September to March) to extremely hot 40-50°C during the dry season (March-September). The daily average solar radiation of semera location is shown in Fig.2.

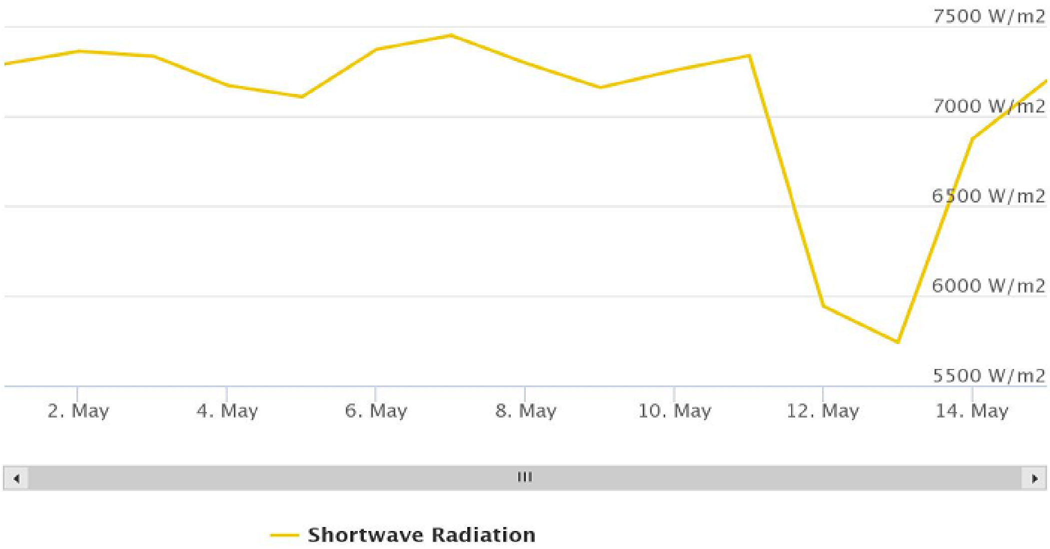

Fig.2. Daily Sun Radiation in Semera, Afar, Ethiopia.

As in Ethiopia, the Electrical power is generated mostly from water (Hydro Power Generation), due to lack of rains, during summer season, the power supply in semera is very poor. the main objective of Samara University is the Teaching & Learning Process in very good friendly Environment, but due to lack of proper power supply during second semester particularly from May to June, students as well as instructors suffered a lot for conducting classes as well as exams. In May 2016, there are nearly 7 days, no power supply in semera. So I decided to design system to supply electrical power from solar energy to all class room buildings REG-HA to REG-HE shown in Fig.3.as first step later it can be extended to all buildings of Samara University. This paper presents an approach of designing Standalone Solar PV System to supply as backup power when power is gone from main power supply. I tried my level best to design System at cheaper rate as well as fulfill all power requirements of all class rooms.

Fig.3. Class Room Buildings REG-HA to REG-HE of Samara University, Ethiopia

2. COMPONENTS OF SOLAR POWER SYSTEM

Standalone Solar PV system includes different components that should be select based on system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and appliances (loads)

i. Solar PV Module: It is made from semiconductor and converts the sunlight to electricity. The electrical power generated in this system is DC Power. The most common PV Modules includes single and polycrystalline silicon and amorphous silicon.

ii. Battery: Battery stores energy for supplying to electrical appliances when is there is demand. Battery Bank, which is involved in the system to make the energy available at night or at days of autonomy (sun days, dark days), when sun is not providing enough radiation as well as when there is no power supply continuously. These batteries, usually lead-acid, are designed to gradually discharge and recharge 80% the capacity of their hundreds of times. Automotive batteries are shallow cycle batteries and should not be used in PV system because they are designed to discharge only about 20% of their capacity [4].

iii. Solar charge controller: Solar charge controller regulates the voltage and current coming from the PV panels going to the battery and prevents the battery overcharging and prolongs the battery life.

iv. Inverter: Inverter converts the DC output of PV panels into clean AC current for AC appliances (AC loads). It is one of the solar energy system's main components, as the solar panels generate DC voltage. Inverters are different by the output wave format, out put power and installation type. It is also called power conditioner, because it changes the form of electrical power. The efficiency of all inverters reaches their nominal efficiencies (around 95%) when the load demand is 50% greater than the rated load.

v. Load: Load is electrical appliance that connected to solar PV system. fans of all class rooms of 5 buildings REH-HA to REG- HE are consider as load in this system as shown in Fig.3.

3. POWER SYSTEM SIZING

i. **Determine the power consumption demands:** the first step in designing solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system.

ii. **Size of PV Modules:** different size of PV Modules will produce different amount of power. To find out the size of PV Module, the total peak watt produced is needed. The peak watt (Wp) depends on size of PV Module and climate of the site location. We have to consider the "panel generation factor "which is different in site location. The panel generation factor of semera is calculated as 7kw-h/m^2/day from Fig.2.

iii. **Inverter Sizing:** An inverter is used in the system where AC Power is needed. The input rating of inverter should never be lower than the total watt of appliances. The inverter must have same nominal voltage as battery. For standalone system, the inverter must be large enough to handle the total amount of watts using at a time. The inverter size should be 25-30% bigger than total watts of appliances.

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iv. **Battery Size:** the battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged after day for years. The battery should be large enough to store sufficient energy to operate the appliances during power off time from main power supply.
∴Battery Capacity (Ah) =(Total watt-hours per day used by appliances× Days of autonomy)/(0.85×0.6×nominal baatery voltage).

v. **Solar charge controller size:** The solar charge controller typically rated in Amperes and voltages. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for application. Make sure that solar charge controller has enough capacity to handle the current from PV array. For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to controller and also depends on PV panel configuration (series or parallel configuration). According to standard practice, the sizing of solar charge controller is to take the short circuit current (I_{sc}) of the PV array, multiply it by 1.3
∴ Solar charge controller rating=total short circuit current of PV array ×1.3.

4. SOLAR POWER PLANT DESIGN FOR REG-HA to REG-HE BUILDINGS

The schematic block diagram of designing solar power system for all class rooms of REG-HA to REG-HE buildings is shown in fig.4.

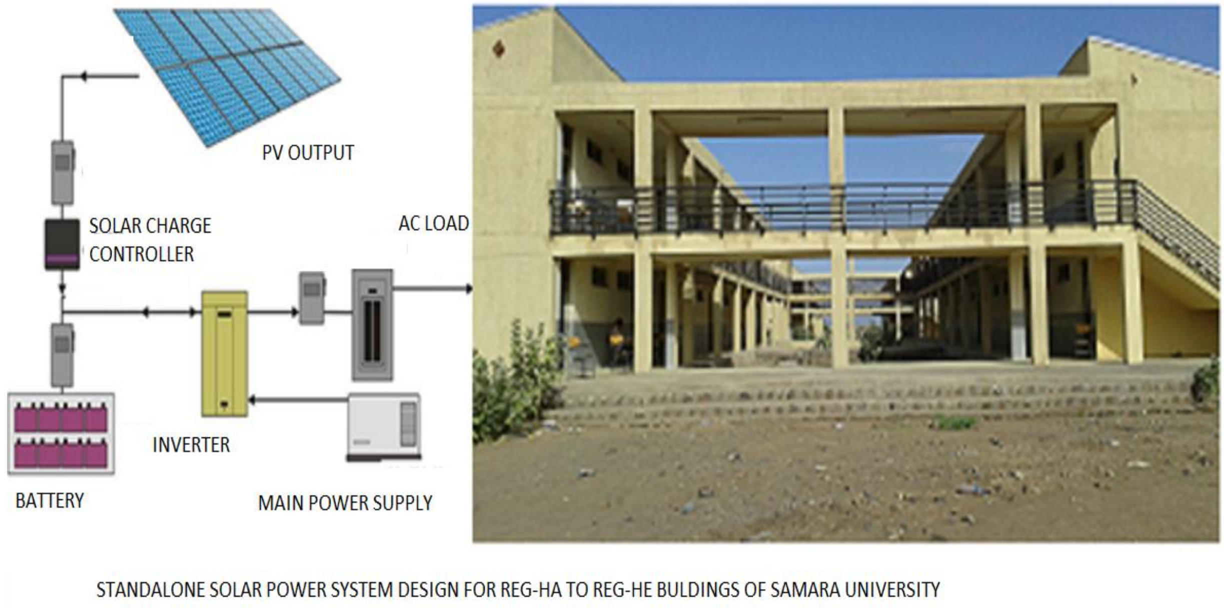

Fig.4. Solar power system design to all class rooms of REG-HA to REG-HE buildings of Samara University

TABLE 1. Solar Power System Designing: Calculation of various Ratings of Components & No of PV Panel

SOLAR POWER SYSTEM DESIGN		
Total no of fans	4×16×5=320	Nos
Average hours per day	5	Hrs
Average Sun hours per day whole year	5	Hrs
Total power per day	320×50W=16000	Wp
Total watt-hour per day	16000×5=80000	W-h/day
Maximum Solar Insolation in Semera	7	KW-h/m²/day
Total watt- hours per day/Insolation	80000/7=11428.57	
Total PV panel energy needed (1.3 times energy lost in the system)	1.3×11428.57=14857.14	W-h/day
SOLAR PV ARRANGEMENT		
Watt(Wp)	300	Wp
DC Voltage(Vmp (V))	36.72	V
DC current	8.17	A
Open circuit voltage	45.5	V
Short circuit current	8.65	A
NO OF PV PANEL		
The total no of PV panel to be use	14857.14/300=49.5238	Nos

Total PV panel	50	Nos
NO OF PANEL GROUP		
No of Group of PV panel	2	Nos
Total No of PV panel each Group	50/2=25	Nos
No of Strings	5	Nos
Each Strings contains No of panel	5	Nos
INVERTER SIZING		
The Inverter Size	1.3×16000=20800	W
BATTERY SIZE		
Day of Autonomy	1	Day
18 V Battery sizing for groups	2	Groups
Total watt-hours per day used by Battery loss	0.85	%
Depth discharge by battery	0.6	%
18 V Battery sizing for each group	80000×1×1.3/(0.85×0.6×18× 2)=5664.488	Ah
SOLAR CHARGE CONTROLLER SIZE		
Total Short Circuit current of PV Array	8.65	A
No of Strings	5	Nos
Solar charge controller rating	8.65×5×1.3=56.225	A
TOTAL COST OF POWER SYSTEM		
Approximate cost per watt	41.407	ETB
Total cost (When all class rooms of 5 Buildings are running)	16000×41.407=6,62,518.08	ETB

5. CONCLUSION

The geographical location of Samara University, semera, Ethiopia makes it relatively sun rich region with an average daily irradiance of more than 7000Wh/m^2/day. So this paper presents an approach for designing solar power plant to supply power to all class rooms of REG-HA to REG-HE buildings of Samara University. The summary of this power plant are given below:

a. The total load requirement is 16Kw/day
b. The total watt hours per day is 18KWh/day
c. The total no of PV panel require is 50
d. The Inverter size is 20.8KW
e. The battery capacity is 5664.488Ah
f. The solar charge rating is 56.225 A
g. The total cost of power plant is 6,62,518.08ETB

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