Design and Analysis of Solar Power System for Sinywa Village in Mandalay Region

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***Abstract*—**In this work, a small village with a population of 500 and 100 households with a small clinic and a library are electrified by using solar PV system. Since it is a community it may have different usage of electricity according to their function. But load is limited to lighting and using household appliance such as TVs and a refrigerator for a clinic. Different usage time and frequency, day load and night load are carefully considered and calculated. Tip-to toe experience during designing stages and components selection are shared.

***Keywords*—**photovoltaic, solar module, stand-alone, battery, inverter.

I. Introduction

There are several ways in which we can extraction energy from our surroundings. This includes energy extraction from sunlight, wind, biomass, sea levels, etc. All these ways are renewable in nature, i.e. the energy source itself renews, which can provide us energy forever. All the above – mentioned energy sources originated due to presence of sun, which can collectively be referred as solar energy. It is a very large source of energy. The power from the sun intercepted by earth is about 1.8×10^{11}MW, which are many thousand times larger than our current power consumption from all sources. Thus, solar energy can satisfy our current and future energy requirements [1].

In many cases, it is difficult, in term of cost, to extent grid all the way to remote location, even if fossil fuels are available. On the other hand, solar energy sources are available almost at all parts of the country in one form or another. Solar radiation provides attractive alternative for providing energy to rural masses and accessibility to energy is an important ingredient of development. Human kind of modern day have to look for use of renewable energy sources such as solar, wind, biomass, micro-hydro, geo-thermal, ocean, etc to meet their daily electrical energy requirement. Renewable energy sources can offer a good way to bring power to rural areas. Solar energy is transmitted from the sun through space to the earth by electromagnetic radiation. Solar energy can be used in two ways, solar thermal and solar power to rural areas. Solar energy is transmitted from the sun through space to the earth by electromagnetic radiation. Solar energy can be used in two ways, solar thermal and solar electric. Photovoltaic (PV) systems are a good solution for basic needs in rural applications to improve living standards. By using solar power system, rural people can be used in lighting, watching TV, refrigerator, water pumping, etc. Therefore, renewable energy technologies should thoroughly pursued in the country. Solar energy is not available twenty-four hours so that storage system is required and then we are used batteries. We are used chare controller from excessive overcharging to batteries and over discharging from batteries. Solar power system is required AC load and so DC to AC (inverter) is needed to control the voltage and frequency [1].

II. Geometry of Mandalay

Mandalay is saturated between North Latitude 21˚ 91' and East Longitude 96˚ 06'. The elevation sea level is 74.67m and situated within tropical zone. The local standard time of meridian is 97˚30' E. The available average temperature is around 26˚C. Sinywa village is saturated Amarapura Township in Mandalay. The mean maximum and minimum temperature and sunshine hour and humidity of Mandalay Division of year 2010 are shown in Table 1.

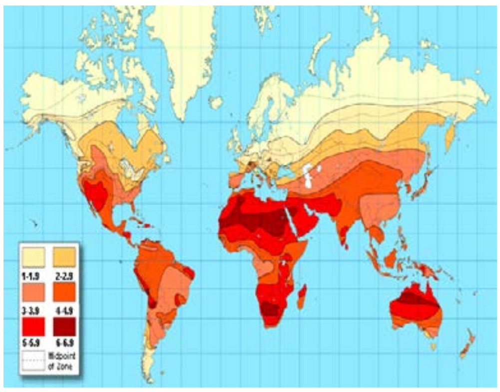

Fig. 1 Solar insolation values for the world

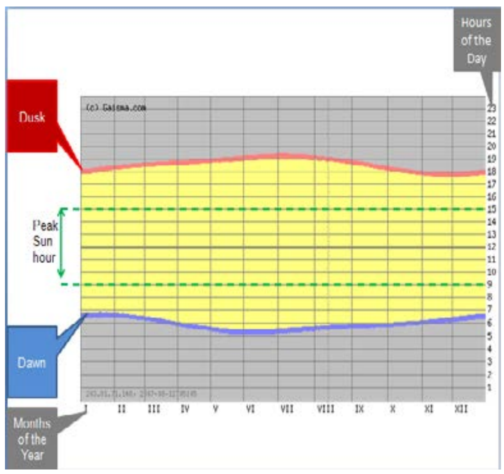

Fig. 2 Monthly average radiation records of the project site

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TABLE I
MONTHLY MEAN SUNSHINE HOURS, MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE AND RELATIVE HUMIDITY (%) FOR MANDALAY (2010)

Month	Sunshine Hours	T_{max}	T_{min}	RH(%)
Jan	280.9	31.6	14.5	78
Feb	216.9	34.4	16.4	66
Mar	214.7	38.1	22.7	57
Apr	241.8	41.7	27.2	50
May	225.3	39.9	28.0	56
June	218.0	36.6	27.1	69
July	173.5	36.4	27.1	73
Aug	182.2	34.0	26.1	78
Sep	185.5	34.4	25.7	81
Oct	155.8	33.1	24.7	85
Nov	280.5	32.8	20.4	77
Dec	280.7	28.3	15.7	83

III. OPERATION PROCESS OF SOLAR POWER SYSTEM

Day by day increase in demand of electrical energy place depletion of fossil fuel sources in alarming rating. Therefore different kind of modern day have to look for use of renewable energy sources such as solar, wind, biomass, micro-hydro, geothermal, ocean, etc to meet their daily electrical energy requirements. For generating electricity, PV modules are now widely used in developed countries to produce electrical power in locations where it might be inconvenient or expensive to use conventional supplies. Solar power system can be used for generating power to provide electricity in these areas. The photovoltaic is the location independent, environmentally, friendly and silent power sources for all leisure activities. A stand-alone system is a photovoltaic system that is not connected to a utility grid and often has a battery for storage. These systems are very useful and economic in remote location. Stand-alone systems are not ideal due to inefficiencies, including battery losses not operating at their most efficient operating point. The typical PV stand-alone system consists of a solar array and a battery connection as shown in figure 3.

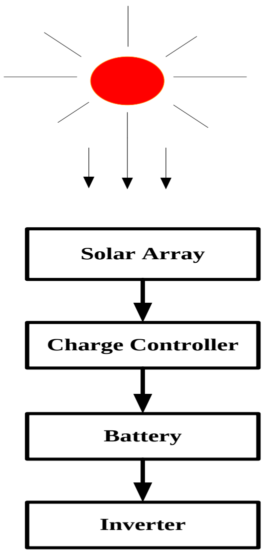

Fig. 3 Illustration of operation Process of Solar Power System

The solar array powers to the load and charges the battery during daytime for using load at night. The battery powers the load after dark. The stand-alone PV system is required charge controller and inverter. As a stand-alone PV system, the system sizing to gain maximum energy to match with the load is essential because of without any connection from the grid or generators. For sizing the stand-alone PV system, firstly we need to calculate the load, battery size, PV array size etc.

IV. MAIN COMPONENTS of SOLAR POWER SYSTEM

The requirements of solar power system are;

(1) PV array
(2) PV array circuit combiner
(3) PV Array switch
(4) Charge controller
(5) Ground-Fault protector
(6) Battery
(7) Inverter
(8) AC Fused Switch
(9) Utility Switch
(10) Wire

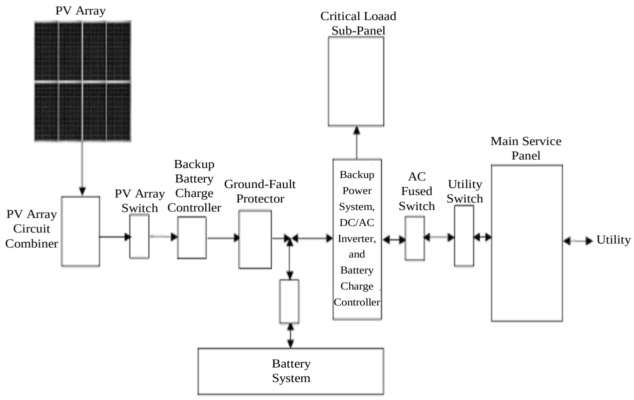

Fig. 4 The components of Solar Power System

V. SIZING THE PV SYSTEM

For sizing the stand-alone PV system, firstly the designer need to calculate the load, battery size, PV array size etc.

A. Calculation the Load

The total amount of power required can be estimated by the two desktop computers, one refrigerator, thirteen television, LED lighting for streets, houses, library, school and monastery. The above equipment will consume 2.5 kW. The consumption of each load item is considered in order to get the resultant load as follow. Computer and LED lighting will consume about (average) eight hours per day and five day in a week. Refrigerator will consume twenty-four hours per day and seven days in a week. Television and LED street lighting will consume about (average) six hours per day and seven days in a week. Since each load has different in consumption of hours and days so that we can calculate and divided in to three parts. Our load demand is assumed constant every week for each month, but sometime have a little variation. System size is dictated by the worst month condition; the month with the largest load and the lowest insulations.

Group-A: Refrigerator
Group-B: Two desktop computers and LED lighting
Group-C: Thirteen television and LED street lighting

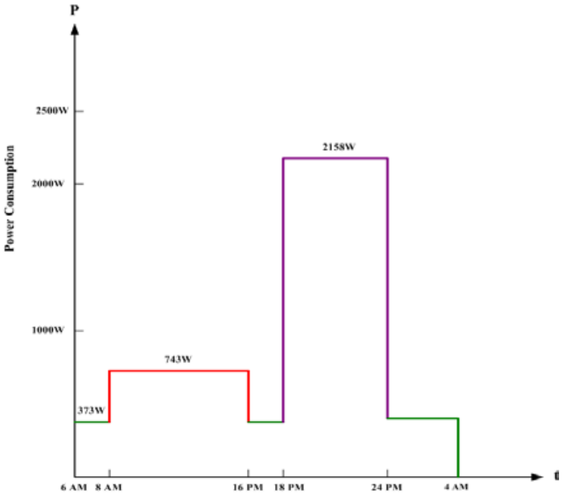

Fig. 5 Power Consumption of Daily Load

We can calculate AC average load (Wh).
For load in Group-A:
AC average load (Wh)

$$= \frac{\text{Total load (W)} \times \text{Hours per Day} \times \text{Days per Week}}{\text{Days per Week}}$$

$$= \frac{373\,(\text{W}) \times 24\text{Hours per Day} \times 7\text{Days per Week}}{7 \text{ Days per Week}}$$

$$= 8952 \text{ Wh}$$

For load in Group-B:
AC average load (Wh)

$$= \frac{\text{Total load (W)} \times \text{Hours per Day} \times \text{Days per Week}}{\text{Days per Week}}$$

$$= \frac{370\,(\text{W}) \times 8\text{Hours per Day} \times 5\text{Days per Week}}{7 \text{ Days per Week}}$$

$$= 2114 \text{ Wh}$$

For load in Group- C:
AC average load (Wh)

$$= \frac{\text{Total load (W)} \times \text{Hours per Day} \times \text{Days per Week}}{\text{Days per Week}}$$

$$= \frac{1785\,(\text{W}) \times 6\text{Hours per Day} \times 7\text{Days per Week}}{7 \text{ Days per Week}}$$

$$= 10710 \text{ Wh}$$

System total Watt-hour is 21776 and than we can calculated total AC average load (Ah). System voltage is decided to be 24V and power conversion system efficiency is assum0.85.

AC average load (Ah)

$$= \frac{\text{AC average load (Wh)}}{\text{System Voltage} \times \text{Power Conversion Efficiency}}$$

$$= \frac{21776\,(\text{Wh})}{24\text{ V} \times 0.85} = 1067 \text{ Ah}$$

Total AC average load Ampere-hour is 1068 Ah. We can calculate correct Ah load with wire efficiency factor default value is choosing to be 0.98 and battery efficiency factor default value is 0.90 for the assumption of constant voltage operation.

Corrected Ah load

$$= \frac{\text{Total amp - hr load}}{(\text{Wire Efficiency}) \times (\text{Battery Efficiency})}$$

$$= \frac{1067\text{Ah}}{0.98 \text{ Wire Efficiency} \times 0.9 \text{ Battery Efficiency}} = 1210\text{Ah}$$

Total correct Ah load is 1210 Ah.

After that this is required calculated the maximum current or peak current draw.

$$\text{Peak current draw} = \frac{\text{Total load}}{\text{Nominal system voltage}}$$

$$= \frac{2500}{24\text{V system}}$$

$$= 104 \text{ A}$$

It is necessary to calculate the current required or the design current.

$$\text{Design current} = \frac{\text{corrected Ah load}}{\text{Peak Sun Hours per Day}}$$

$$= \frac{1211 \text{ Ah}}{5 \text{ Hours per Day}} = 242\text{A}$$

B. Battery

The size of battery need for a particular design depends on whether the load requires. We select the lead acid deep cycle battery and which nominal capacity and voltage is 200Ah and 12V respectively. The nominal voltage of our PV system is 24 V; therefore, batteries are connected in series and parallel to gain required voltage and current [6].

Fig. 6 200Ah batteries for storing the charges for later use.

TABLE II
BATTERY

Storage days	Total battery required
1 day	18 numbers
3 days	52 numbers
6 days	104 numbers

Depend on the storage days total required battery is variable. Total battery required is showed in Table. 2

As loadings are consumed every days so the battery storage day is defined 1 day.

Required battery capacity

$$= \frac{\text{Corrected amp - hr load} \times \text{storage days}}{DOD_{max} \times \text{Derate for Temperature}}$$

$$= \frac{1210\ \text{Ah} \times 1}{0.7 \times 1.0} = 1728\text{Ah}$$

Assume battery capacity (available in the market)to be 200Ah

$$\text{Battery in parallel} = \frac{\text{Required battery capacity}}{\text{Nominal battery capacity}}$$

$$= \frac{1728\ \text{Ah}}{200\ \text{Ah}} = 9\ \text{no.}$$

Total number of battery to be connected *in parallel* is 9.

$$\text{Battery in series} = \frac{\text{System voltage}}{\text{Nominal battery voltage}}$$

$$= \frac{24\text{V}}{12\text{V}} = 2\ \text{no}$$

Total number of battery to be connected in series is 2.

Required total battery = Battery in series × Battery in parallel = 2 × 9 = 18 no.
Total number of battery required is 18.

Usable battery capacity = System battery capacity × DOD_{max}
= 9× 200Ah × 0.7 = 1260 Ah

Derated design current

$$= \frac{\text{Design current}}{\text{Module derate factor}} = \frac{242\text{A}}{(0.9\text{A})} = 269\text{A}$$

Total dated current is 269A.

C. Solar panel

To calculate the size of the photovoltaic array, and then module derate factor is required to adjust module current from standard operating conditions (SOC) of 1000W/m^2 and 45˚C temperature to fiend conditions. This factor differs among single or polycrystalline silicon and amorphous silicon solar module which is 0.90 and 0.70 respectively. We can calculate the total require module.

Consider solar module capacity to be V_{pm}= 3404 V and I_{mp}=4.5A.

$$\text{Module in parallel, } M_p = \frac{\text{Derate design current}}{\text{Rated module current}}$$

$$= \frac{269\text{A}}{4.5\text{A}} = 60\ \text{no.}$$

= 60/0.9 = 65 modules

Module in series, M_s

$$= \frac{\text{Nominal battery voltage} \times \text{Battery in Series} \times 1.2\ \text{compensation}}{\text{PV output voltage}}$$

$$= \frac{12\text{V} \times 2 \times 1.2}{34.4\text{V}}$$

Module required is 65 modules.

D. Controller

System controller must be specified to match the photovoltaic system voltage. Secondly, a controller must be chosen that is capable of handling the maximum load current (amperage) that will pass through the controller under worst case conditions. System designers should note that some loads may operate directly from the batteries or through an inverter and not pass through the controller. Third, a controller must be specified that can handle the maximum photovoltaic array current. Use the maximum array amps at short circuit current which is greater than the operating amps, plus a 25% margin as a safety factor [6].

Fig. 7 Microcontroller-based 30A Solar Charge Controller

Array Short Circuit Amps = Module Short Circuit Current ×Modules in Parallel × 1.25
= 4.5 × 4× 1.25 = 22 .5A

Controller Array Amps = 30 A

$$\text{Maximum DC Load Amps} = \frac{\text{DC Total Connected Watts}}{\text{DC System Voltage}}$$

E. Inverter

The total energy needed for the AC equipment is calculated including all the lose that introduce the DC/AC converter or inverter. When choosing an inverter, remember that the performance of the inverters is not constant with the power. In order to avoid this waste of energy it is important to consider not the peak power of all the equipments but the peak power of equipments that are expected to work simultaneously.

Specification

- true sine wave inverter
- 2000W
- 24VDC, 220VAC, 50-60 Hz, 85A charger

F. Wire Sizing

Choosing the proper wire size requires satisfaction of two criteria are Ampacity and Voltage Drop. Each wire size is carefully select according to the international practices. DC fuses are also included in each combiner box with the correct current rating. Wire size is given in terms of AWG or American Wire Gauge. The minimum wire size allowed for direct current is # 8 AWG, #10 AWG and # 12AWGare specified for all direct current circuits in the system even though a smaller wire would satisfy the requirements of ampacity and voltage drop.

G. Grounding

Most PV modules have aluminum frames and circuit conductors. All PV systems will require equipment grounding with the equipment grounding conductors. If we look closely at PV systems we see two areas where they present some unique grounding issues. The first is the grounding of the frames of PV modules (see the sidebar). The second area relates to grounding the circuit conductors. Hence, both AC and DC grounding are properly done to avoid danger and damage [4].

TABLE III
TEST OF THE PERFORMANCE OF SOLAR POWER SYSTEM

Description	Total
AC average load(Wh)	21176Wh
Battery (200Ah)	18nos
Charge Controller (30A)	8nos
Module (150W)	65nos
Inverter (2kW)	2nos

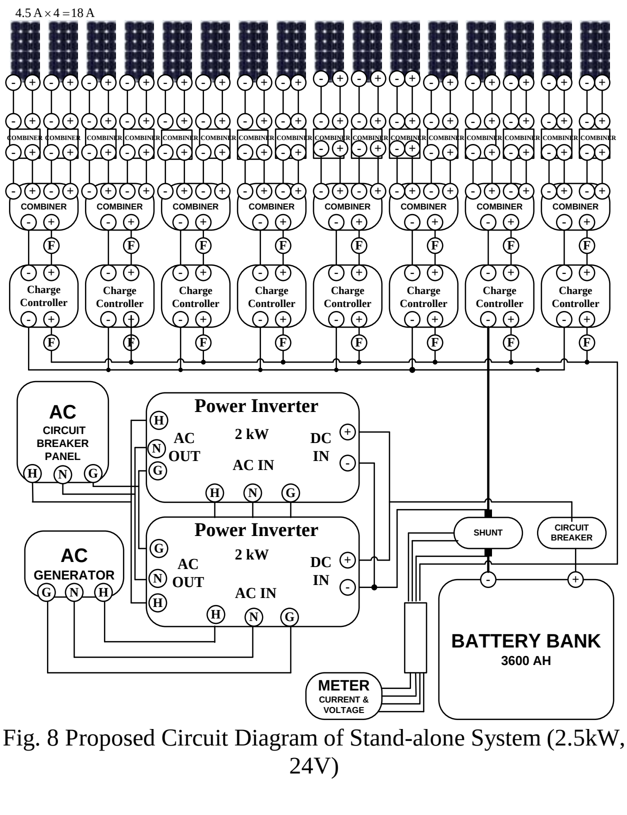

Fig. 8 Proposed Circuit Diagram of Stand-alone System (2.5kW, 24V)

VI. CONCLUSION

A small village with a population of 500 and 100 households with a small clinic and a library are electrified by using solar PV system. Since it is a community it may have different usage of electricity according to their function. But load is limited to lighting and using household appliance such as TVs and a refrigerator for a clinic. Different usage time and frequency, day load and night load are carefully considered and calculated. This work can be applied to any village which has similar load value and function. Energy saver dc home appliance are appeared on the market, the cost might be down day by day and daily life of they rural people will be more comfortable ever since.

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