Analysis of Dual Power Supply System for Small Office by using Solar Power and Utility Grid

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Abstract: ***In this paper, analysis of dual power supply system with PV and utility grid is proposed for an office. The main aim of this research is to reduce the electricity costs financially and to reduce the carbon foot print of an office environment. The proposed system is designed for an office building which is located in Mandalay Region. Based on the average solar radiation and location, the photovoltaic system can produce power about 8.1 kW with battery backup which is supplied for this office. Based on the theoretical calculation, 27 numbers SANDISOLAR 300 W modules are required for this system. The nominal system voltage is 96 V and 8 numbers of batteries are required. The total battery capacity of the battery bank is 1370 Ah. There are three conditions included (1) while grid power is unavailable, necessary loads are supplied by PV system and (2) While PV power is unavailable, all of the loads are supplied by grid. (3) For both grid and PV available condition, loads are divided into two parts and supplied power from this two power sources. This system has two advantages for this office to reduce electricity costs financially and reduce carbon foot print.***

Keywords: dual power supply, solar energy, photovoltaic, utility grid, cost saving

1. Introduction

In order to cope with the rise in electrical energy demand at the same time to reduce carbon footprint, climate change and global warming issues caused by conventional petroleum based electrical generation system, the world has turned to renewable energy especially PV as one of the reputable auxiliary power supply. With the ever increasing prices related to conventional fuels such as crude oil, coal and natural gas, the optimizing all available alternative energy sources seemed to be vital.3R concept of reduce, reuse and recycle has been widely promoted in the apprehension to the earth critical sources and energy issues. When power interruption is happened, business or work will be delayed. Therefore, the use of Solar Energy Power Supply is considered for both utility supplies are available and un-available conditions.

The location is considered for an office building which is located in Mandalay Region, Myanmar. The area of the office is 40´ (12.19 m) × 19´ (5.79 m). The main purpose of dual power supply system is to supply electricity for an office for both grid available and un-available conditions.

2. Dual Power Supply System with PV and Utility Grid

In some developed countries, energy consumption in houses and offices is still increasing due to change of our daily life style, while it is getting better in industry area and transport area [1]. Energy saving in home and office is industry area and transport area [1]. Energy saving in home and office is important to prevent global warming.

There are two types of power source used in the proposed system. Normal power source (utility grid) supply all of the loads used in the office. When power interruption is occurred, priority power source (PV) supply the necessary loads used in the office. The one line diagram of proposed system is shown in figure 1.

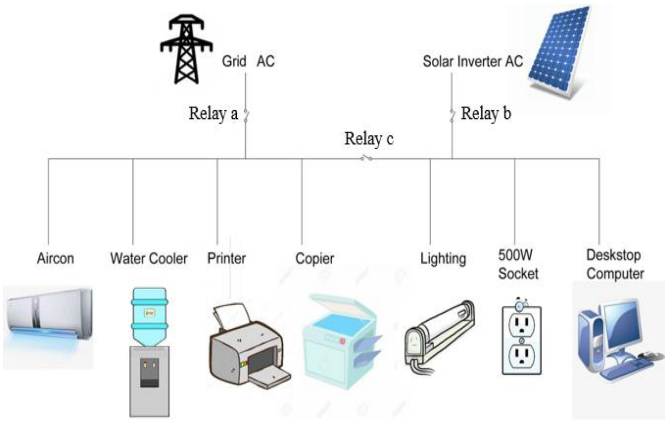

Figure 1: One Line Diagram of Proposed Dual Power Supply System for an Office

In proposed system, there are several Relay ON/OFF conditions are considered as shows in the table 1.

Table 1: Truth Table for the Dual Power Supply System

Grid Power	PV Power	Relay a	Relay c	Relay b
ON	OFF	ON	OFF	ON
OFF	ON	OFF	ON	OFF
ON	ON	ON	ON	OFF
OFF	OFF	OFF	OFF	OFF

3. Design Calculation of System Components

Estimating of daily load energy consumption, selection of system voltage, calculation of PV sizing, inverter sizing, battery sizing and charge controller sizing are included in this section.

- Estimating daily load energy consumption
- List of necessary loads which are supplied by solar system
- Selection of system voltage
- PV array sizing
- Inverter sizing
- Battery sizing
- Solar charge controller sizing

3.1 Daily Load Energy Consumption

Table 1. shows Daily Load Energy Consumption estimate for an office. The total power demand per day of the whole office is about 14723W and energy consumption per day is nearly 78040 Wh.

Table 1: Shows Daily Load Energy Consumption Estimate for an Office

Appliances	Consumption	Qty	Power/ Day (W)	Use hr/ day	Energy/ day (Wh)
1HP Air con	800 W	4	3200	8	27428.57
2 HP Air con	1150 W	1	1500	8	10285.71
Copier	750 W	1	750	2	1285.71
Water cooler	600 W	1	600	2	4114.28
Desktop Computer	160 W	10	1600	10	9600.00
Printer	726 W	2	1452	4	4978.26
Projector	245 W	1	245	7	1470.00
3 pin(13A) socket	500 W	8	4000	4	14928.57
2 × 36W lamp(LED)	72 W	8	576	8	3949.71
Total Consumption			14723 W		78040 Whr

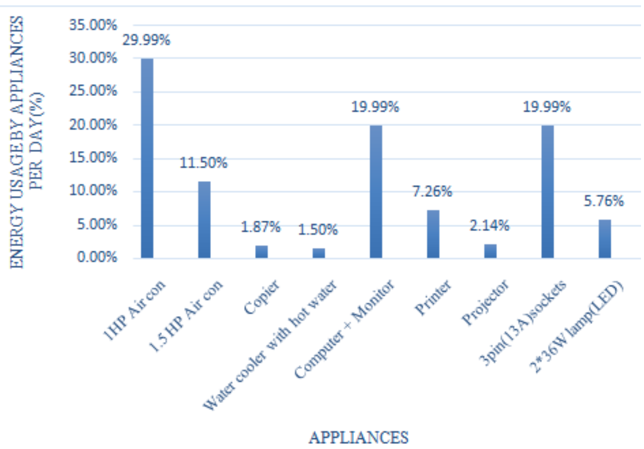

Figure 3: Energy Usage By Appliances per Day in an Office

3.2 List of Necessary Loads which are Supplied by Solar System

By dividing all of the loads into two groups, necessary loads which are supplied by solar system are listed in Table 2.

Table 2: Necessary Loads which are Supplied by Solar System

Appliances	Consumption	Qty	Power/ Day (W)	Use hr/ day	Energy/ day (Wh)
2×36lamp (LED)	72 W	8	576	8	3949.71
3pin(13A) sockets	500 W	6	3000	4	10285.71
Computer + Monitor	160 W	8	1280	7	7680
Total Consumption			4856 W		21920 Whr

3.3 Selection of System Voltage

The inverter's DC input voltage, which is the same as the voltage of the battery bank and PV array, is called the system voltage. The system voltage is usually 12 V, 24 V, 48 V, 96 V, 120 V or 240 V, etc. Higher voltages need less current, making easier to minimize wire losses [3]. On the other hand, higher voltage means more batteries wired in series, which impacts the number of batteries that may be needed to supply the load [3].

The system is designed for standalone PV system with battery storage. In this system, the daily loads are only single-phase loads. The system voltage is selected based on the requirements of the system. To meet the requirement of the system, the system voltage is selected based on the input voltage of the inverter.

4. Photovoltaic Array Sizing

In designing PV array, the maximum daily energy consumption must be selected. The daily energy consumption in summer is higher than other two seasons. So, the energy consumption in summer is selected and designed for the system. PV array sizing is based on the energy demand (Wh) of the system.

4.1 Solar Insolation and Irradiance Data of Mandalay

Mandalay is situated at (21º 97'N, 96º 08' E) .The data collected for insolation, irradiance and ambient temperature are shown in Table 3. In this table, monthly radiations for horizontal radiation are mentioned. Here, the highest PSH is in April and the lowest PSH is in November.

MEPE (Myanmar Electric Power Enterprise) experimental measurements indicate that irradiation intensity of more than 5 kWh/m2/day was observed during the dry season. In practical applications, solar cells do not operate under standard conditions. The two most important effects that must be allowed for are due to the variable temperature and irradiance. Temperature has an important effect on the power output from the cell. Irradiance is directly proportional to the short-circuit current of a solar cell [2].

Table 3: Monthly Average Insolation, Irradiance and Ambient Temperature

Month	Insolation (kWh/m2) or PSH	Irradiance (kW/m2)	Ambient Temperature (˚C)
January	5.07	0.73	18.3
February	5.59	0.78	21.4
March	6.11	0.84	25.3
April	6.37	0.83	27.2
May	5.89	0.73	26.2
June	5.14	0.62	26.2
July	4.71	0.56	24.2
August	4.51	0.55	24.1
September	4.55	0.59	23.9
October	4.57	0.61	22.7
November	4.38	0.61	20.0
December	4.54	0.66	17.7

From Table 2, total power demand per day for summer is 4856 W and total energy demand per day for summer (E) is 21920Wh. Factor energy losses from PV array is 1.2 and Overall efficiency of PV array is assumed as 0.8. Then, the energy required per day is calculated as 33kWh by using equation (1).

$$\text{Energy required per day} = \frac{1.2 \times E}{\eta} \quad (1)$$

The module has a rated power of 300W and nominal voltage of 36V. SANDISOLAR module is made up of 72 cells connected in series.

4.3. PV Array Sizing with Minimum Peak Sun Hour

The average value of minimum peak sun hour is obtained from winter that is referred to October, November, December and January. These months have the lowest solar insolation over the year. Based on the data from Table 3,the required parameter are calculated as shown in table 4.

Table 4: Average values of four months with minimum PSH

Parameter	Symbol	Values	Unit
Irradiance	G	652.5	W/m^2
Peak sun hour	PSH	4 .64	Hr
Ambient temperature	TA (˚C)	19.675	ºC
Cell temperature	Tc(˚C)	40.07	ºC

From Table 4, we can calculate heat losses efficiency factor as 99.4% and assuming tolerance/ dust/ mismatches efficiency factor as 90 %. Then PV's efficiency is calculated as 89.94%. Taking overall values of battery, wire and inverter efficiency is 65.96%, the output power of 300W PV panel is 177.97W. Total Peak Sun Hour (PSH) is taken as 4.64 and Energy output per day is calculated as 825.8 Wh/day.

For the required energy demand per day 21920 Wh, the total number of modules is calculated as 26.54≈27 Nos. PV module's peak output voltage is selected 36V and nominal system voltage is selected as 96V. From these data, we can calculate modules arrangement as 3 numbers of series connected and 7 numbers of parallel modules. The detailed design data of PV arrays is shown in Table 5.

Table 5: Design data of PV Array

Model	SANDISOLAR 300W Solar Panel
Number of Parallel Modules	9 Nos
Number of Series Modules	3 Nos
Total Number of Modules	27 Nos
Rated Array Current	74.97A
Rated Array Voltage	108 V
Array Short Circuit Current	82.44A
Array Open Circuit Voltage	129 V

5. Inverter Sizing

The input rating of inverter should never be lower than the total watt of appliances. The inverter must have same nominal voltage as of the battery. Generally for safety, the inverter should be 30% bigger size than the total Watts of appliances 4.856kW which is shown in Table 4.2. So the inverter with the rating of 6 kW is chosen for solar PV system.

6. Charge Controller Sizing

The rating of charge controller should be 25 percent greater than short circuit current of PV array.

Charge controller sizing = 1.25 × Total short circuit current of PV array (2)

$$= 1.25 \times 82.44$$
$$= 103.05 \text{ A}$$

The solar charge controller should be rated at 103.4 A and 96 V or greater. Therefore, the charge controller with maximum charging current of 200 A is selected.

7. Battery Sizing

Batteries used in all solar systems are sized in Ampere hours under standard test condition (Temperature 25˚C). Battery manufactures usually specify the maximum allowable depth of discharge for their batteries. The depth of discharge is for measuring how much of the total battery capacity has been consumed. For the batteries used in this design, the maximum allowable depth of discharge 0.5 or 50 percent is considered.

For battery sizing, Days of autonomy is 3, allowable depth of discharge (DOD) is 0.5, nominal system voltage is 96 V, and rated array current is 74.97 A. The battery parameters are calculated as shown in Table 6.

Table 6: Sizing of battery parameters

Parameters	Equation	Value
Total Battery Capacity	$\frac{\text{Energy input} \times \text{Autonomy day}}{\text{DoD} \times \text{Norminal voltage}}$	1370 Ah
Number of Batteries	$\frac{\text{Total Battery Capacity (Ah)}}{\text{Capacity of a Battery (Ah)}}$	6.85 ≈ 8 Nos
Usable Battery Capacity	Total Battery Capacity (Ah) × DoD	685 Ah
Charging Time	$\frac{\text{Usable battery capacity}}{\text{Rated array current}}$	9.13 hr

8. Cost Saving of Electricity

Before July 2019, residential electricity prices in Myanmar are Kyats (Ks) 35 per kilowatt-hour for the first 100 units, Ks 40/kWh for the next 100 units, and Ks 50/kWh for all units after that.

Prices for commercial and industrial customers are much higher, ranging from Ks75 - Ks150kWh. During fiscal year 2016-2017, the average cost of supplying 1kWh was Ks96 [18HEA].

But electricity rates will increase substantially from July 2019 for both residents and commercial in the first changes in tariffs for five years, the government has announced.

Under the new rates, residential households and religious buildings will continue to pay at the previous rate at Ks 35 per unit, but only for up to 30 units. Consumers will be charged Ks 50 for 31-50 units, Ks 70 for 51-75, Ks 90 for 76-100, Ks 110 for 101-150, Ks 120 for 151-200, and Ks 125 for over 201. For commercial use, Consumers will be charged Ks 125 for 0-500 units, Ks 135 for 501-5000, Ks 145 for 5001-10000, Ks 155 for 10001-20000, Ks 165 for

20001-50000, Ks 175 for 50001-100000and Ks 185 for over 100000.

With new rates of electricity, we can calculate cost of electricity bill as following.

Total energy consumption per month	=78.04 kWh per day × 30 days
	=2341.2 kWh per month
Cost of electricity by kWh per month	=500kWh × 125 Ks + 1841 kWh × 135 Ks
	= 311035 Ks

From table 2, we noticed that necessary load by supplying PV system is 21.92 kWh per day. For 30 days, 657.6 kWh can be successfully supplied by solar PV system. So, the total energy consumption per month with PV system and cost of electricity with PV system is calculated as follow;

Total Energy Consumption per month (with PV)	= 2341.2kWh – 657.6 kWh
	= 1683.6 kWh
Cost of electricity by kWh per month	=500kWh × 125 Ks + 1184 kWh × 135 Ks
	= 222340 Ks

Total saving amount per month = 311035 – 222340
= 88695 Ks

Therefore, by using this proposed dual power supply system, the electricity bill of 88695 Ks can be reduced per month.

9. Conclusion

Nowadays, to provide a suitable power production and safe the world for the future generation, there is an increasing demand for energy from natural resources such as solar, wind, ocean tidal wave and geothermal heat. Among the renewable energy resources, solar energy is the best and prerequisite resource of sustainable energy because it is abundant in nature. Solar energy is indeed going to be predominant because it is available free at any place on the earth and it also reduces environmental pollution.

For only grid power supply available condition, all of the loads used are supplied by grid. For only solar power supply available condition, only necessary loads in office can be used. For both grid and solar available condition, loads are divided into two parts and are supplied separately. This proposed system is not only expected to be implemented on a ready available stand-alone PV system which later-on got connected to grid but as well as the grid connected electrical community with expansion of future power rating which needed distributed generation on site.

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Author Profile

Wunna Swe received the B.E degrees in Electrical Power Engineering from Mandalay Technological University (Myanmar) in 2002 and also received M.E and Ph.D in Electromechanics and Electrical Apparatuses in 2005 and 2008, respectively. During 2008-2011, he worked as a lecturer at Mandalay Technological University. During 2011-2015, he worked as a principal at Technological University (Monywa). During 2015-2017, he worked as an associate professor and head at Yangon Technological University (YTU). He now worked as a professor and head at Mandalay Technological University (MTU).