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Analysis of Solar PV, Battery and Diesel Hybrid Generation System for Village Electrification

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Abstract: Myanmar, central dry zone has abundant solar resources. The government of Myanmar is trying to substitute using the new and renewable sources of energy. So, the proposed research paper is the one of the rural electrification project for Na Bu Taw (North) village, which is situated at Natogyi Township in Mandalay Region in Myanmar. The purpose of this paper is to propose the best hybrid technology combination for electricity generation from a hybrid of solar PV, Battery and Diesel Generator to satisfy the electrical needs in a reliable manner of an off grid area, in Myanmar. The system includes a 10 kW PV array, 2.76 kWh worth of battery storage, and a 4 kW diesel generator. The paper describes a detailed analysis of the energy flows through the system and excess electricity, LCOE and emission of the system.
Keywords: solar energy, renewable energy, rural electrification, off-grid area, mini-grid system, environmental friendly

1. INTRODUCTION

Myanmar has good solar resource potential, with 60% of the land area suitable for PV development, having Global Horizontal Irradiation (GHI) levels of between 1,600 and 2,000 kWh/m2/yr, and average Direct Normal Irradiation (DNI) levels of about 1400 kWh/m2/yr. Because of Myanmar's mountainous terrain and protected areas, more than a third of the land area is unsuitable for solar PV installations. Myanmar's maximum technical solar power potential is estimated at 40 TWh/yr.[1] With a population of 52.8 million, Myanmar is one of the largest countries in mainland Southeast Asia. However, Myanmar is one of the least developed countries in the region, with GDP per capita of US$1,275 in 2016. According to the 2017 World Bank Poverty Analysis, 37% of people still live near or below the poverty line. Poverty in Myanmar is concentrated in rural areas, where poor people rely on agricultural and casual employment for their livelihoods.[2] Therefore, some of Myingyan district area cannot access the electricity from the national grid, until now, Na Bu Taw village in Natogyi Township is essential and most of people from this village are willing to access the electricity for their economy and social development.

2. SITE LOCATION AND LOAD DEMAND FORECASTING

This case study is Na Bu Taw (North) village which is situated at Natogyi Township in Mandalay Region of central Myanmar. The geographical location of this village is between Latitude 22.039˚ and Longitudes 95.66˚. There are about 100 households, one monastery, one primary school, one clinic and the population is 606 in this village. The regional map of Na Bu Taw village, Natogyi Township is shown in Figure (1). The geographical location of the Na Bu Taw (North) Village from Homer Software is shown in Figure (2).

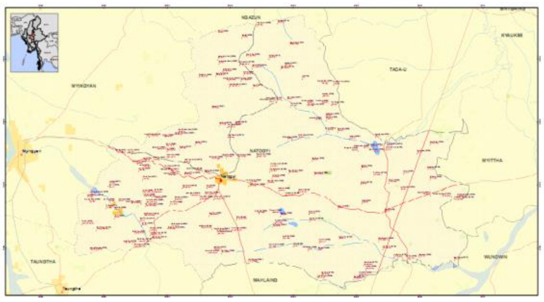


Figure 1. Rational map of Natogyi township

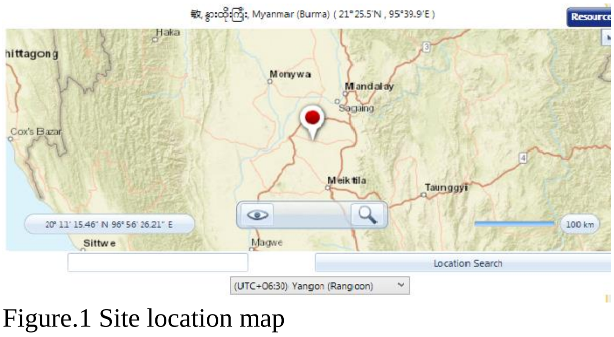


Figure.1 Site location map

2.1. Load Estimation for Na Bu Taw (North) Village

Load demand is essential consideration facts to construct modelling of this research village. In Na Bu Taw (North) Village, the load consumptions are three types of 100 households, one monastery, one primary school, one clinic. Different types of household consumption are 30 numbers of low power consumption, 60 numbers of the medium power consumption and 10 numbers of the high power consumption.

The proposed system load profile is 86 KWh/day and 15 kW peak.

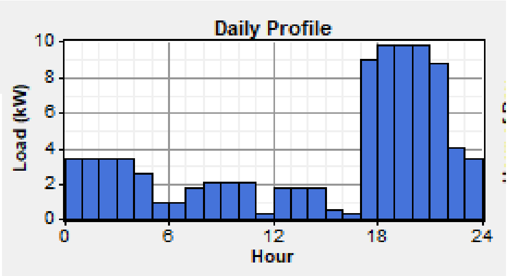


Figure 3. Daily load profile of proposed system

For simulation, Daily load profile input data as described in Figure 3.

3. Energy Resources in proposed site

Monthly average solar Global Horizontal Irradiance (GHI) resource is shown in Figure (4) and annual average solar radiation is 5.06 kWh per m2 per day.

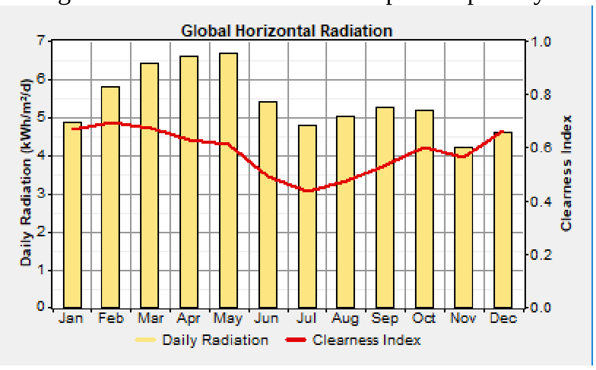


Figure 4. Monthly average solar Global Horizontal Irradiance (GHI) resource of proposed village

The proposed model for Na Bu Taw (north) village by Off-Grid, PV-Diesel Hybrid System is developed in HOMER as shown in Fig. 5. The schematic is created by adding the main components (PV, Generator, Storage, and Converter) and Load.

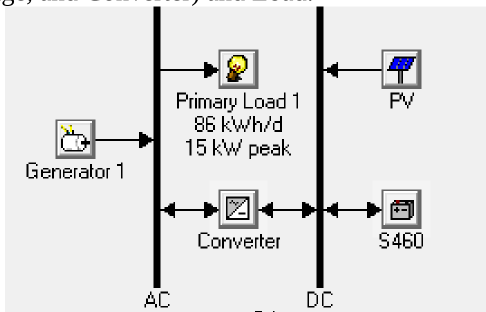


Figure 5. Schematic Diagram of Hybrid system

4. COMPONENT OF PV HYBRID SYSTEM

4.1. Solar PV

Beyond the local solar resource and the cost of fuel (and its potential escalation), many other parameters influence the actual payback period of a hybridization investment. Solar PV panels have a long lifespan (more than 20 years), but their yield gets slightly reduced over time. This parameter has to be computed in the economic analysis across the project timeframe. PV panel manufacturers generally guarantee 90% of initial performance after 10 years and 80% after 25 years. Further, the actual possibility of resorting to the guarantee, if needed after a few years, remains an open question in areas where distributors are not well-established companies.[3]

4.2. Battery Bank

The lifespan of the battery depends on many parameters related to the way they are operated and to external conditions, in particular the ambient temperature. For instance, typical lead-acid batteries designed for solar energy applications will lose between 15% to 20% of their lifespan for each 5°C above the standard temperature of 25°C. In addition, the deeper the battery is discharged at each cycle (depth of discharge), the shorter its lifespan. This implies that to reach an optimal battery lifespan, one has to install a large enough battery to achieve a suitable depth of discharge. Considering the battery cost (around 20% to 30% of total system cost) it is reasonable to design the battery bank and its operating conditions to last for six years minimum and ideally eight to ten years. [3]

4.3. Inverter

An inverter's lifespan can extend to more than ten years, but this component is a high-technology product and the replacement of a failing component has to be undertaken by a technician from the supplying company. The specific complexity of the inverter often requires that a proper after-sales service plan be implemented to ensure long-term sustainability of the system. Risks associated with the failure of an inverter should be considered, especially in remote locations or countries with very limited presence of specialized suppliers. [3]

4.4. Diesel Generator

Regarding the diesel generator, major maintenance operations should be considered with respect to the cost and unavailability of the equipment. Gensets in the range of 30 kVA to 200 kVA would typically need a major maintenance operation after 15,000 to 25,000 running hours.[3]

Table 1. Energy data and cost and lifespan of Components

Energy Data	
Solar Resource	5.06 kWh/m2/day
Energy Demand	86 kWh/day

Peak Load	15 kW(based line)
Fuel Cost (constant)	0.7 US $/L
Cost of Components	
Genset kVA	400USD/kW
Solar PV	1000USD/kW
Battery	200USD /kWh
Converter	250USD/kW
Life Span of Components	
Solar PV panel	20 years
Genset	25000hrs
Battery	8 years
Converter	10 years

5. THEORY OF PV HYBRID SYSTEM

HOMER defines the levelized cost of energy (COE) as the average cost per kWh of useful electrical energy produced by the system. To calculate the COE, HOMER divides the annualized cost of producing electricity (the total annualized cost minus the cost of serving the thermal load) by the total electric load served, using equation 1:

$$COE = \frac{C_{ann,tot} - C_{boiler}H_{served}}{E_{served}} \quad \text{Eq: 1}$$

where:
$C_{ann,tot}$ = total annualized cost of the system [$/yr]
E_{served} = total electrical load served [kWh/yr]
The discount factor is a ratio used to calculate the present value of a cash flow that occurs in any year of the project lifetime. HOMER calculates the discount factor using equation 2:

$$f_d = \frac{1}{(1+i)^N} \quad \text{Eq: 2}$$

where:
i = real discount rate [%]
N = number of years

HOMER uses the following equation to calculate the output of the PV array:

$$P_{PV} = Y_{PV} f_{PV} \left[\frac{\bar{G}_T}{\bar{G}_{T,STC}}\right] \left[1 + \alpha_p \left(T_c - T_{c,STC}\right)\right] \quad \text{Eq: 3}$$

where:
Y_{PV} = the rated capacity of the PV array, meaning its power output under standard test conditions [kW]
f_{PV} = the PV derating factor [%]
G_T= the solar radiation incident on the PV array in the current time step [kW/m2]
$G_{T,STC}$= the incident radiation at standard test conditions [1 kW/m2]
α_P = the temperature coefficient of power [%/°C]
Tc = the PV cell temperature in the current time step [°C]
$T_{c,STC}$ = the PV cell temperature under standard test conditions [25°C]
In every time step, HOMER calculates the renewable penetration using the following equation:

$$P_{ren} = \frac{P_{ren}}{L_{served}} \quad \text{Eq: 4}$$

where:
P_{ren} = total renewable electrical power output in this time step [kW]
L_{served} = total electrical load served in this time step [kW]

The battery capacity is the total Ampere-hour required to support the load requirement and is given by:

$$BC = \frac{Ebat}{\eta_{disch}(N_{cell}.V_{disch}).DOD.N_{par}} (Ah) \quad \text{Eq: 5}$$

where, BC- battery capacity (Ah)
E_{bat}- energy required from the battery per discharge
η_{disch} - efficiency of discharge path (including inverters, wires, diodes, etc)
N_{cell} - Number of series cells in one battery
V_{disch}- average cell voltage during discharge
DOD- maximum allowed Depth of Discharge for required life cycle
N_{par}- number of parallel batteries
Batteries are generally not allowed to be discharged fully. The minimum value to which a battery can be discharged before it is recharged is called maximum depth of discharge, DOD. Deep discharge batteries can discharge up to 30-40 percent of their state of charge, SOC.[4]

6. ANALYSIS AND EVALUATION OF SOLAR HYBRID SYSTEM

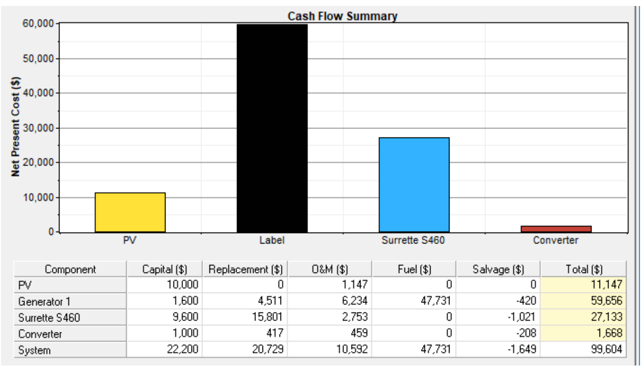
The proposed system consists of three main generation components such as Solar PV, Diesel Generator and Battery Storage system to cover the whole load demand.

In accord with the simulation results, Total net present cost (NPC) is 99604 US$ and the optimized cost of energy for the project is 0.321US$ per kilo watt hour and it is more cost effective than other compared systems.

In this system, 10 kW PV Solar system and 4 kW diesel generator are the electric power producing sources and the battery is the storage unit. According to the cost summary, net present cost for each component of system and cash flow are shown in Figure 6 and 7. In figure 8, the monthly average energy production is described in figure 8, in this system, 15747 kWh of energy production from solar PV and 17983 kWh of energy production from diesel generator annually and the excess electricity is about 10%. The values of key elements of the system are as described in Table 2.

Table 2. Electrical System, Cost Summary and Emission of the whole System

Electrical System		
Quantity	**Value**	**unit**
Auto geset	4	kW
Solar PV	10	kW
Battery	24	
Production (solar PV)	15747	kWh/yr
Production (DEG)	17983	kWh/yr
Consumption	27067	kWh/yr
Excess Electricity	3443(10.2%)	kWh/yr
Fuel Consumption	5945	L/yr
Cost Summary		
Total net present cost (NPC)	99604	US$
LCOE	0.321	US$/kWh
Emission		
Carbon Dioxide	15655	Kg/yr
Carbon monoxide	38.6	Kg/yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	10,000	0	1,147	0	0	11,147
Generator 1	1,600	4,511	6,234	47,731	-420	59,656
Surrette S460	9,600	15,801	2,753	0	-1,021	27,133
Converter	1,000	417	459	0	-208	1,668
System	22,200	20,729	10,592	47,731	-1,649	99,604

Figure 6. Cash Flow Summary for the System

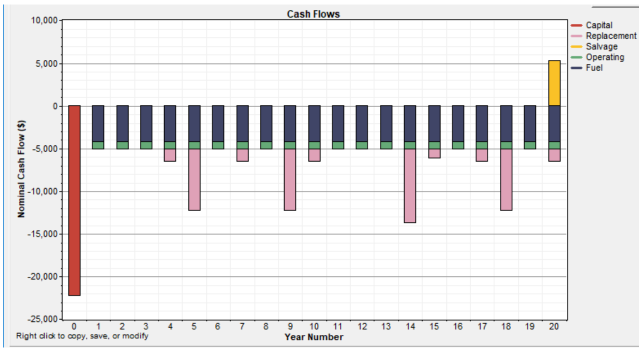


Figure 7. Cash Flow for the project life

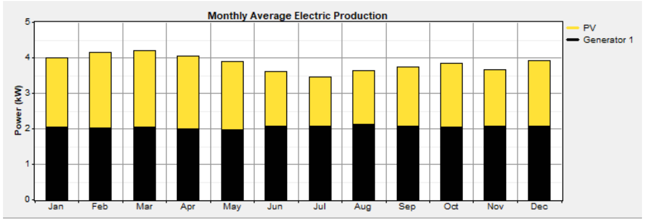


Figure 8. Monthy Average Electric Production

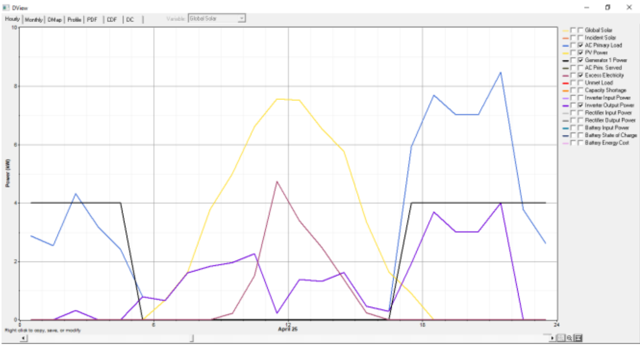


Figure 9. Energy mix in Clear Sky day

In accord with result of figure 9, this condition show a results of energy mix when the weather is clear sky and the solar resource is good condition for this day. Therefore, the most of electricity generation are from the solar PV system in day time and the load for the evening and night time are compansated by diesel generator and battery storage system.

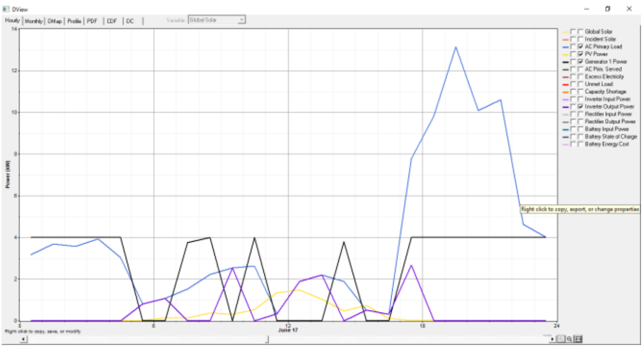


Figure 10. Energy mix in Cloudy day

According to the results of figure (10) a cloudy day, the availability of energy production from solar is very weak therefore, in order to meet the load demand more diesel generating likely to be used in energy mix of hybrid system elsewhere.

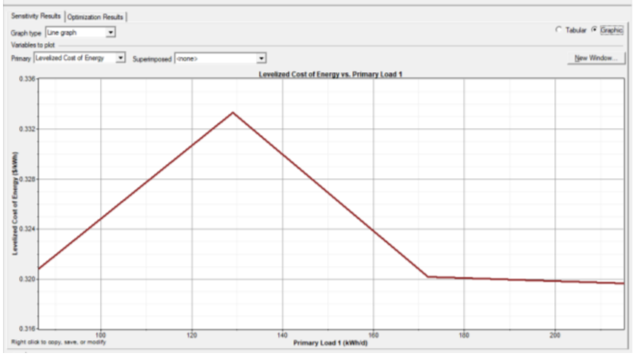


Figure 11. The sensitivity analysis for evaluating the increase of load

The sensitivity analysis for evaluating the increase of load demand, according to the figure (11), firstly the levelized cost of energy is increased to 0.334US$ per kWh for a marginal increase in load and then the cost of energy is gradually declined in original value (0.32US$) even though the load increased in maximum demand of this village.

7. CONCLUSION

In fact, according to discussion the condition of solar energy resource is good potential in proposed site area and nearly 50 % of energy can get from solar energy resource but requires additional backup diesel generator for covering the load demand in proposed area.

8. ACKNOWLEDGMENTS

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9. REFERENCES

[1] Renewable energy developments and potential in the Greater Mekong Subregion, ISBN 978-92-9254-831-5, Asian Development Bank, Published in 2015.

[2] Project Information Document/Identification/ Concept Stage (PID), World Bank Group, 18-Jun-2018, Report No: PIDC142398

[3] IEA PVPS Task 9, Subtask 4, Report IEA-PVPS T9-13:2013, CLUB-ER, Thematic Paper, July 2013, ISBN: 978-3-906042-11-4 Author: Grégoire Léna (IED)].

[4] www.homerenergy.com