Optimal Sizing of Mini-grid System for Rural Electrification

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Abstract
Solar photovoltaic (PV) systems have shown their potential in rural electrification projects. A solar based mini-grid is a solar PV plant with a localized distribution network to a unit village. The proposed village Gwe Cho is very far from the national grid and the total household is 130. It is including in the dry zone and abundant of solar energy is obtained. This case study is to find out the optimal design of mini-grid for rural electrification. Battery and generator as a backup system is considered. The result is carried out by applying HOMER software. This paper is to provide as a guideline for balancing cost optimization process.

Keywords: Battery, Generator, HOMER, Mini-Grid, PV Plant

1. Introduction
The benefits of electrification is well known and demand of electricity is also increase day by day. Most the rural area are very far from the national grid and they faces many difficult and lack in their living standard. Therefore energy play the important role. Electrical energy can drive from various resources such as hydro, wind, geothermal and solar, etc. Energy can divided into two main categories. They are non-conventional and conventional energy. Non-conventional energy can reuse and can be covered one thing of life.

Among them, solar energy is widely used in all over the world. Solar photovoltaic is obtained directly from the sun and produced electricity. Energy produce electric from the sun when it is strike to the solar module. The more direct sunlight and the more energy can obtained. The utilization of solar energy can be broadly classified into two main type. They are off-grid and on-grid system.

A mini-grid (off-grid) is referred to the low voltage network within neighborhood supplied by solar PV. On-grid system is high voltage network as cluster network and supply to the industrial and commercial load[10]. In many countries the reliability of the grid is poor and high costs. But the load demand is increased and electricity supply is insufficient. Therefore, suitable technology is applied in nowadays. In Myanmar, 35% of household has access to electricity since 2016 and 70% of the population are lived in the rural area[1]. Government of Myanmar want to achieve 100% electrification by 2030. Therefore 60% of renewable source from Myanmar can cover all of the half of the new access. In the current study, the mini-grid system is focused which has distribution power source and supply electricity to the household. A mini-grid can be used as a backup power source for agriculture sector.

In section I introduction is described and literature review and theoretical framework are discussed. In section III methodology and system design are mentioned. Result outcome is present in section IV and conclusion discussed in detail from section V.

2. Literature Review and Theoretical Framework

2.1 Literature Review
In 2017, Chih-Ta, Yriga Belay Muna, Hsueh-Yunan Lin, Cheng-Chien Kuo and Rainy Hisung find the solution for the title of “Optimal design and performance analysis of solar power microsystem for mini-grid application”. The author considered the electrification strategies based on cost, efficiency performance, equipment utilization factor, excess electricity produced, etc[2].

In 2017, ADB point out the title of “Developing renewable energy mini-grids in Myanmar”. This guidebook documents the main experiences and lessons learned from the 12 pilot projects as well as training materials from the capacity building activities[3].
In 2013, Stephen Abaase determined the title of “Examining solar PV mini-grid system as a complement to grid extension for rural electrification with reference to YAMA community, Northern GHANA”. The author pointed out this system to compare the cost of electrification by using conventional grid systems[4].

In 2013, Solomon Teklemichael Bahta considered the title of “Design and analyzing of an off-grid Hybrid renewable energy system for rural electrification in Ethiopia”. The author simulated and optimized for rural community by using HOMER software[5].

In 2011, Raymond Kimera focused on the title of “Consideration for a sustainable Hybrid electric power mini-grid”. The author pointed out the renewable energy resources are identified, an estimation of the projected village short-term electricity demand is simulated by HOMER software[6].

2.2 Theoretical Framework

There are two main approaches to conduct rural electrification areas in a competitive and effective way; mini-grids and stand-alone system. Both types of systems operate independently of the national electricity grid and are thus known as off-grid systems.

Standalone system usually require battery banks to store energy and they must be carefully designed to meet expected loads during cloudy periods[6].

Since Myanmar is quite rich in solar radiation, the mini-grid system is provided sufficient electricity for both domestic and public lighting in rural area.

Solar mini-grid is divided into two partition for supplying load side. Centralized DC bus and distributed AC bus system configuration are shown in figure 2. The centralized DC-architecture is preferable in a situation of high solar fractions (e.g. PV/battery-systems) and evening loads. Centralized mini-grids can provide capacity for both domestic utilization and also support the growth of local businesses in rural communities.

The distributed AC-based system on the other hand proved to be the more efficient solution in system with smaller solar fraction and high energy use during the day.

According to figure 2, four difference sources are applied for generating electricity. PV is connected to the DC converter and link to the DC busbar. After that power transfer to the inverter and to the load side. Nevertheless, the other source are also used for using as a backup system.

This paper is focused on the remote PV mini-grid and it is distinguished from the PV cluster (PV neighbourhood). Generator characteristics of remote PV mini-grid are following[8].

- Isolated grid only
- PV plus others (mainly diesel)
- Weak grid
- Many be required (normally battery storage)
- Grid stability and power quality
- Short-term power dispatch strategies
- Long-term energy management

3. Methodology and System Design

3.1 Methodology

Firstly selected location and collection the solar radiation data. Consider the resource from the desired
location. Average energy demand is collected and selected the system component. Finally simulated by HOMER software.

3.2 Desired Location and Monthly Radiation

Myanmar has an average solar irradiance of 4.5–5.1 kilowatt-hours per square meter per day (kWh/m²/day), making solar a suitable technology for mini-grids in many locations. Nevertheless, strong variations exist in the different areas of the country. Solar irradiance at a particular site can be obtained from on-site measurements, or derived from satellite data and nearby weather stations. The Dry Zone (consisting of Magway, Mandalay, and Sagaing regions) is highly suitable with an average radiation of more than 5 kWh/m²/day and limited variation in radiation during the rainy season [3].

Fig.3 Monthly solar radiation in Myanmar[3]

Fig.4 Gaw Cho Village, Pinlebu Township[9]

The selected location is situated around in the latitude 22° 57’ and longitude 95° 55’. Gaw Cho village which it is located in Pinlebu Township, Sagaing region.

3.3 Energy Demand for Proposed Village

The total household of the proposed side is 130 numbers. The consumers need electricity to apply their electrical equipment. Their economical are based on agriculture and livestock.

Fig.5 Monthly radiation data for Gaw Cho Village

Fig.6 Monthly Energy demand data for Gaw Cho Village

A total load profile is then generated to represent the estimated annual short-term load profile. This is simulated in HOMER software to take on the shape as shown in figure 6. This presents Gaw Cho village daily demand at 182kWh, with a peak load of 180kW.

3.4 System Design

According to the case study from system simulation, case study four is selected because it suitable not only for the load demand but also COE ($/kWh) is save. Diesel used for this system is 1999 Liter per year.
In this configuration, the system utilizes all available generator options, with a diesel generator added in the mix to provide backup supply, to PV and energy storage.

4. Simulation Result

4.1 PV Output Simulation

The following result show their rated capacity, mean output, capacity factor and total production. The total production per year is 1447.92 kWh.

Above the figure 10 is mentioned the PV penetration is 66.4% and the hours of operation is 4.368 hr/yr. The levelized cost is 0.00946 $/kWh.

Figure 11 show the PV output of the every month. The maximum rate of the output is around 85.6 kW. The mid of July is very in power generation because of the solar radiation is very less when compare to the March. According to this PV generation data, system must used back up diesel generator and battery storage.

4.2 Electric Production Simulation

Average electrical production for every month is shown in the following figure.

According to this result, the PV is not enough to produce the energy during January. Therefore, system is required to use generator back up system most to fulfill this requirement.

Above the figure 10 is mentioned the PV penetration is 66.4% and the hours of operation is 4.368 hr/yr. The levelized cost is 0.00946 $/kWh.

Figure 11 show the PV output of the every month. The maximum rate of the output is around 85.6 kW. The mid of July is very in power generation because of the solar radiation is very less when compare to the March. According to this PV generation data, system must used back up diesel generator and battery storage.
4.2 Battery State of Charge Simulation

Battery state of charge is described by the following figure.

Total NPC is $112,324 and operating cost is $5,387/year. The generator NPC is higher when compared to the PV operating cost.

4. Conclusions

The mini-grid system is proposed to the rural village developed for their lifestyle. According to this study, Gaw Cho village is applied total energy demand 597 kWh/day. The electrical production from generator and PV are around 150, 645 kWh/year. The battery energy output is 67723 kWh/year. Therefore this system design is sufficient to apply energy demand for 130 household. The HOMER simulations give the feasibility component structure of the mini-grid, which hence proved as an optimal design.

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References

[7] https://corresponsables.co
[9] https:// google.com map

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