Design of Grid Tied Microgrid for Pandit Deendayal Petroleum University

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Abstract

Microgrids are discrete energy systems that comprise of various distributed energy sources controlled to feed the localized loads and can operate in standalone or grid tied mode. They are responsible for energy demand management, storage and generation of power. Microgrids can be powered by various energy resources, such as wind, solar, biomass, diesel generators, fuel cells, etc. As solar energy is environmentally friendly, free and abundantly available, it is a preferred source for microgrids. Microgrids are an ideal solution for rural electrification and for reducing the grid dependency. This paper reports design, analysis, control and feasibility study of a grid tied microgrid comprising of photovoltaic (PV) array and battery packs to cater to the load demand for E-block building of Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India. The design procedure, control strategy, optimization, economic studies, and simulation results are discussed. The results indicate considerable annual energy and cost savings as well carbon footprint reduction.

Keywords: Battery Storage, Grid Integration, Microgrid, Renewable Energy, Solar Photovoltaic.

1. Introduction

Microgrids involve localized generation, distribution and consumption of electrical energy. There are two types of microgrids, (i) grid tied microgrid, and (ii) isolated microgrid. Grid tied microgrids are interconnected with the grid. In case of excess power generation, the microgrid can feed the power to the grid and if the microgrid is unable to cater to the load demand then the grid can supply the excess power. Various energy sources can be employed in microgrids. However, renewable energy sources are preferred due to the advantages of environmental friendly, free and abundant availability, government incentives, advancements in power and signal electronics. Moreover, with the exhaustion of fossil fuels, there is a necessity to switch to renewable energy sources for sustainability. In Indian scenario, solar photovoltaic (PV) systems are more commonly used due to its availability around the year, barring the days of monsoon. The microgrid with PV and battery back-up can feed power even during night times. The grid connection ensures the continuity of supply in case the PV generation is unable to meet the demand. On the other hand, if there is grid failure then the microgrid can operate in standalone mode to feed the localized without any interruptions. Moreover, if the PV generation is greater than the demand then the excess power can be fed to the grid.

Microgrids are an effective method of providing electricity to not only off-grid and remote areas but commercial and industrial buildings, residential locations and hospitals. References [1] and [2] have reported microgrids comprising of different energy sources. Dhass et al. have discussed economic aspects of a PV, biomass and wind microgrid for rural areas [3].

Pandit Deendayal Petroleum University (PDPU) is located in Gandhinagar, Gujarat, India and tends to have sun 10-11 months of sun over the year. The coordinates of PDPU are 23.1563 degrees North and 72.6655 degrees East. The E-block building has 3 floors and a terrace which has no shadows falling on it through-out the day. This building houses lecture halls, laboratories and administrative unit. The block has an energy demand of 150 kW. The annual power consumption is approximated as 685 MWh. With a microgrid comprising of PV rooftop arrays and battery packs, the energy consumed from the grid can be considerably reduced It is an ideal place for setting up a microgrid fed from PV arrays. This paper presents design, analysis, control and feasibility study of a grid tied microgrid for E-block building of Pandit Deendayal Petroleum University, Gandhinagar. PV arrays and battery packs are used as the energy source and storage elements. The design procedure, control strategy, optimization, economic studies, and simulation results are discussed in the following sections. The results indicate considerable annual energy and cost savings as well carbon footprint reduction.

2. Content
In this feasibility study, the objective is to calculate and form a feasible and cost-effective microgrid as well as calculate the approximate cost to set-up the microgrid. The following steps were taken to collect the data required from the building to calculate further. The calculation of the required specifications of the microgrid is required.

2.1. Power Consumption

In order to know the size of the system that will be studied, the power being consumed by the building must be known. For the entire university, the details are given below:

- Maximum power rating ($P_m$): 863 kVA
- Power factor ($\phi$): 0.9

$$ P = P_m \times \phi \quad (1) $$

By equation (1) the power consumed ($P$) by the whole university per month is 777 kW.

2.2. Rooftop Space

For the installation of solar PV, there must be sufficient space for the panels as well as shadow-free areas. This can mostly be found on the rooftop and hence that is the decided place for installation of solar PV panels. Figure 1 shows the layout of the E block building rooftop with the green shaded area indicating the installable area. With reference to Fig. 1, the following details are given below:

- Total area: 3386 m²
- Shadow – free area: 3386 m²
- Installable area: 3017 m²

3. Problem Formulation

As the problem is being formulated, the calculation of the required information for the design of microgrid needs to be carried out. The study involves determination of specifications and quantity of PV panels, battery packs and inverters.

3.1. E-Block Building Consumption

As previously mentioned, the university’s power consumption is estimated to about 777 kW. The university has 8 major buildings but the E-block has the maximum labs as well as machinery, hence it can be assumed the building consumes about 20% of the power. This gives a power consumption of about 150kW. Considering 140 kW consumption for 9 hours, 50 kW consumption for 12 hours and 80 kW consumption for 3 hours per day, 685 MWh is consumed per year. It is safe to assume that for a microgrid, about 150% of the load demand of the building i.e. 225 kW is installed.

3.2. Tilt Angle of PV Panels

To optimize the sun rays falling incident on the panels, it must be ensured that the rays fall perpendicular to the surface of panels, hence the panels must be tilted at an angle equal to the latitude of the location. The latitude of Pandit Deendayal Petroleum University is 23.1563 degrees North. Hence the panels must face South at a tilt angle of 23 degrees. In the winters, the ideal tilt angle should be 15 degrees more than 23 degrees and during the summer, the tilt angle should be 15 degrees less. Hence to fix the angle, the average is taken.

![Fig. 1. 2D-model of the E-block building rooftop with dimensions in mm](image-url)
3.3. Apparent Panel Area

Since the panels are tilted, the area occupied by the panel decreases. To calculate this area, equation (2) given below must be used:

Original area of panel \( (A) \): 1956mm x 992mm
Tilt angle (\( \Theta \)): 23 degrees

\[ A_\theta = A \times \cos(\phi) \]  

The apparent panel area is 1786103.43 mm\(^2\).

3.4. Number of PV Panels

For the power generation, PV panels are required to be installed where the sun’s rays are incident. To figure out the number of PV panels that can fit on the rooftop the following must be known:

- Power of system to be installed (\( P \)) = 225 kW
- Panel capacity (\( kW \)) = 0.3 kW
- Apparent panel area (\( A_\theta \)) = 1.786 m\(^2\)
- Area between adjacent panels (\( A_i \)) = 1.3 m\(^2\)

\[ n = \frac{A_i}{(A_\theta + A_i)} \]  

Equation (3) determines the number of PV panels (\( n \)) that can be installed on the rooftop which is 977. But the number of panels that need to be installed (\( N \)) on the rooftop is given below:

\[ N = \frac{P}{kW} \]  

Equation (4) states how many panels need to be installed on the roof, 750 panels, which is considerable lesser than the number of panels that can fit. Hence, a 225 kW system can fit on the rooftop.

3.5. Inverters

Depending on the temperature and irradiance levels, PV panels provides variable dc supply. Most of the loads are designed for regulated ac supply. Hence, voltage source inverters are incorporated in the design of microgrids. As the power produced will be of 225 kW, an inverter capacity of 200 kW will be required, as the inverter can be overloaded up to 20%. So 2 inverters of 100 kW capacity will be required.

3.6. Battery Storage

In order to calculate the kWh rating of battery pack, the number of hours for which the battery pack is to be operated is to be determined. Since the building is in full use from 9am to 6pm, electricity will be needed for nine hours. Out of these nine hours, the sun’s rays will be incident on the panels for five hours, hence the battery will be required for only four hours in the day. The battery capacity (\( kWh \)) can be found out by equation (5) and (6).

\[ \text{Power consumed (P)} = 225 \text{ kW} \]
\[ \text{Time (h)} = 4 \text{ hours} \]
\[ \text{Battery efficiency (} \eta) = 75\% \]

\[ (\text{kWh}) = P \times h \]  

\[ (\text{kWh}) = \frac{(\text{kWh})}{\eta} \]  

Hence the battery capacity required for the microgrid is 1200 kWh. A battery pack of the capacity will suffice.

4. Conclusion

In this paper, design, analysis, control and feasibility study of a grid tied microgrid for E-Block building of PDPU. Photovoltaic (PV) arrays and battery packs are the energy sources and storage elements in the microgrid. The design procedure, control strategy, optimization, economic studies, and simulation results are presented. The practical implementation of the design microgrid would result in considerable annual energy (540 MWh per annum) and cost savings to the tune of 32.4 lakh rupees per annum while otherwise electricity would have cost 41.1 lakh rupees per annum. Being grid connected, the reliability of the power supply is ensured even during the monsoon season. For an extension of this paper, the cost of the project, a layout of the microgrid as well as optimization methods will be discussed. The simulation studies will also be presented.

References

