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A Case Study on Micro Grid with Flywheel Energy Storage System using Homer Software

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Abstract—*Renewable energy sources can provide an alternative solution along with added environmental benefits to minimize the ever growing difference between demand and supply of global energy. Consequently, the need of integration of small scale distributed energy resources is gaining importance. Micro grids are instrumental in utilizing such distributed energy resources in the form of small-scale, localized power station that can provide power to a particular area or locality. The efficiency as well as quality of power that can be delivered through micro grid can be substantially improved by incorporating in-line storage systems. It can also offer a range of both economic and environmental benefits. The objective of the present work is to study the economic benefits of a microgrid system in both grid-integrated and off-grid mode. A DG set and solar rooftop PV system has been used as a source of electricity and a flywheel as an energy storage device. HOMER software is used for simulation as well as analysis of the system for the location at GIMT Tezpur, Assam. The result of this study demonstrates that a micro grid along with flywheel energy storage system can be economically and environmentally beneficial compared to the one in off grid mode without energy storage facility.*

1. INTRODUCTION:

The development and use of renewable energy have given the option of rational use of traditional resources with increased share of renewable energy. Conventional utility grid is overloaded with ever increasing demand. Decentralized electricity production from renewable energy sources can provide a more assured supply to consumers with reduced environmental hazards [1]. However, due to the unpredictable nature of renewable energy sources, uncertainty of continuous energy supply exists irrespective of demand. With the developments in storage systems, micro power generation in distributed mode is gaining importance. Micro grids are small scale power distribution system which consumes less power from the conventional utility grid by managing power from alternative sources [2,3].

A. Concept of micro grid

A micro grid is a collection of distributed energy resources and loads that can be operated in a controlled and coordinated way. A micro grid can connect or disconnect from the grid enabling it to operate in either grid connected or island mode. Concept of micro grid is not a new one but has been continuously updated with the progress in technological development and falling prices of certain key components. A typical frame work of a micro grid is shown in theFig.1. They are formed by the interconnection of various energy sources, storage, AC and DC loads, AC/DC, DC/DC, or DC/AC converters. The energy sources may be renewable or nonrenewable.

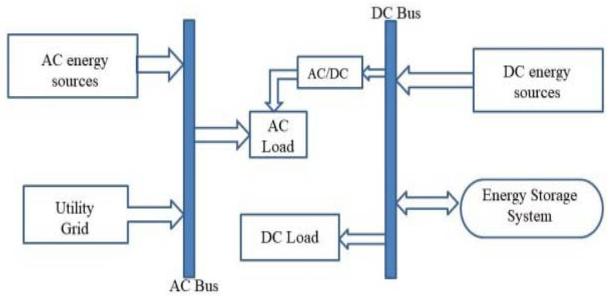

Fig. 1: Typical frame work of a micro grid

Banerji *et al.* discussed the effectiveness of the microgrid in a distribution system and presented a comprehensive review of various architecture and control schemes [4]. In a micro grid the power sharing between the distributed energy sources must be strictly monitored to enhance the quality of power, especially in standalone condition [5]. Renewable sources are highly dependent on climatic conditions and hence energy storage systems are very essential in maintaining quality of power in microgrid.

B. Energy storage systems:

The history of the stationary Energy Storage System (ESS) dates back to the 20th century when a Pumped Hydroelectric Storage (PHS) was put to use in 1929 as first central storage system [6,7]. Pumped hydro storage systems, compressed air storage systems, batteries, flow batteries, hydrogen based storage systems, superconducting magnetic energy storage systems, flywheels and super capacitors are commonly used storage technologies. Various energy storage technologies have been reviewed, and different features of them are presented by Doucette and McCulloch [8]. Altin explained different services that can be supported by the energy storage system and highlighted suitable energy storage technologies for these services [9]. Out of all the energy storage, flywheel storage system is considered to be an ideal one due to its high efficiency, long cycle life and wide range of operating temperature [10].

C. Flywheel Energy Storage System (FESS):

The total energy of a flywheel system is dependent on the size and speed of the rotor, and the output power is dependent on the motor-generator. A typical flywheel storage system consists of a rotating disc. The disc is required to spin at a very high velocity to achieve maximum storage of rotational kinetic energy within the given constraints. To minimise windage losses and to protect the rotor assembly from external disturbances, a bearing assembly providing a very low-loss support mechanism for the flywheel rotor is provided. It also consists of power conversion units and control system equipmentsfor operating the flywheel to store energy or generate the electricity on demand [11].

The kinetic energy stored in a flywheel is proportional to the product of mass and square of the rotational speed:

$$E = \frac{1}{2} I\omega^2$$

where,

E = kinetic energy

I = moment of Inertia

ω = angular velocity of the flywheel

FESS has three working modes, viz., charging mode, standby mode and discharging mode. FESS system has several benefits and is very useful for short duration application. It is also environment friendly and has the advantage of being a '100% clean' power source as the hybrid technology has neither direct fuel consumption nor subsequent emissions and does not involve water consumption. It is also independent of temperature provided it is kept in a vacuum chamber. Further, the life span is also more in comparison to others and has very low maintenance. [12]

2. SYSTEM DESIGN

The location of the present study is Girijananda Chowdhury Institute of Management and Technology (GIMT), Tezpur (26°40'N 92°45'E) in shown in Fig.2. The daily energy consumption of the institute is 242.42kWh/day. The peak load is 53 kW. At present, the electric power required for the institute is being supplied from utility grid along with a backup DG set as shown in Fig.3. The new microgrid designed in this work consists of PV panels along with backup from a DG set to reduce utility grid dependency. The amount of excess power generated from the PV system will be stored by flywheel energy storage system. DG will be used as a backup to supply the excess requirement.

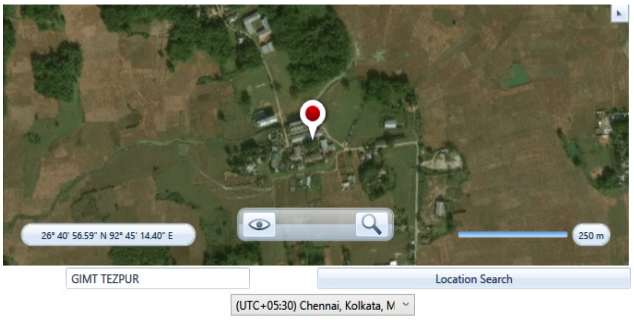

Fig. 2: Aerial view of GIMT, Tezpur

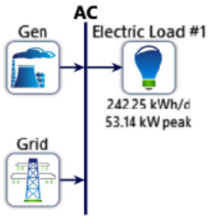

Fig. 3: Existing power distribution system of GIMT Tezpur

The micro grids can be connected or disconnected from the main grid. The four case scenarios considered are as given below.

1. Grid-integrated without storage. (Fig 4)
2. Grid-integrated with storage (Fig 5)
3. Off grid with storage (Fig 6)
4. Off grid without storage (Fig 7)

All the layout designs are done in HOMER software. Total net present cost and carbon emission has been compared and the optimum case is decided comparing with the existing one.

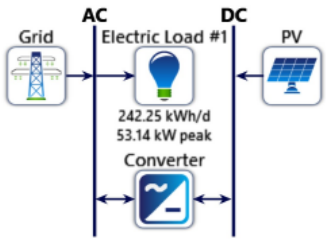

Fig. 4 Layout of grid-integrated system without storage

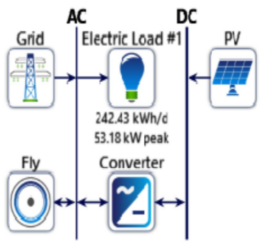

Fig. 5 Layout of grid-integrated system with storage

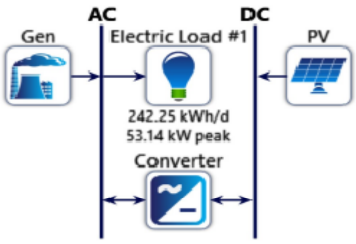

Fig.6 Layout of Off grid system without storage

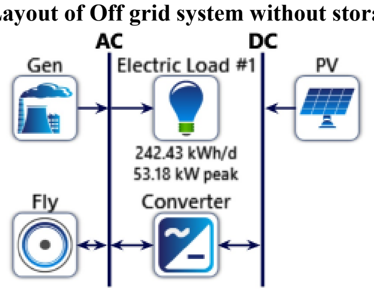

Fig. 7 Layout of Off grid system with storage

A. Solar PV system:

GIMT Tezpur consists of a 65 kWp Grid Connected Solar PV Rooftop Power Plant installed by M/s Renergy Solutions Pvt Ltd, under 14 MWp Rooftop Solar Programme of MNRE in CAPEX category. The plant has been installed in accordance with MNRE's Grid Connected Rooftop Solar programme guidelines/ standards as well as AEDA's Technical Bid document.

B. Data source:

The solar radiation data throughout the year has been collected from SynergyEnviro Engineers and NREL data base [13]. The annual average Direct Normal Irradiance is 4.27 kWh/m^2/day and annual Average Global Horizontal Irradiance is 4.76 kWh/m^2/day. The monthly average solar irradiance and clearness index data for each month of the year is shown in Fig. 8 and Fig. 9 respectively. It is found by substituting the collected data in HOMER Software.

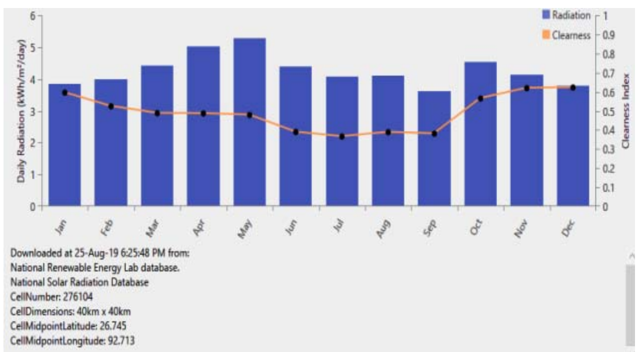

Fig. 8: Daily Average Solar Irradiancefrom January to December.

Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.595	3.839
Feb	0.524	3.986
Mar	0.487	4.427
Apr	0.486	5.034
May	0.478	5.294
Jun	0.389	4.397
Jul	0.365	4.073
Aug	0.388	4.103
Sep	0.380	3.607
Oct	0.564	4.530
Nov	0.618	4.140
Dec	0.622	3.779

Annual Average (kWh/m²/day): 4.27

Fig. 9: Monthly clearness index of Jan- Dec'2018

C. Electrical load of GIMT TEZPUR :

The monthly load profile of GIMT Tezpur is shown in Fig. 10.

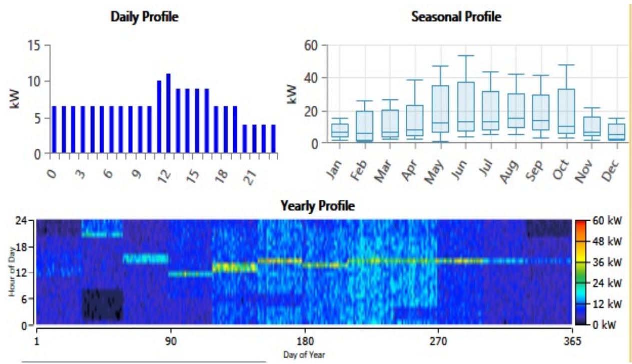

Fig. 10: Load profile of GIMT Tezpur.

D. Solar Photovoltaic panels:

The photovoltaic panels consist of polycrystalline silicon terrestrial modules. Moduleefficiency is up to 17% and they are Potential Induced Degradation (PID) resistant. It has a lifetime of 25 yrs. The installed capacity is 15kW.

E. Converter :

A bidirectional generic system converter with a life time of 10year has been used here. The efficiency of the converter is 95%.

F. Flywheel Energy Storage System:

100kW rated capacity flywheel of 3kW parasitic loadand a lifetime 20 years is considered. The product has a high AC-to-AC efficiency, and low standby losses.

G. Diesel Generator :

A generic auto sized generator is included in this system using HOMER library. It automatically sizes itself to meet the load demand.

3. RESULTS AND DISCUSSIONS:

Four designs of the system are generated and Total Net Present Cost (TNPC) is calculated. It has been found that micro grid which can be connected to the grid has the lowest TNPC as shown in Table 1. The simulation is performed using 8% annual real interest rate [14] and the diesel price is taken as Rs. 67/ltr. The simulation is done using HOMER Pro software version 3.13

Table 1: Analysis of micro grid system with existing system

Parameter	Existing system	Optimum micro grid
TNPC	₹9,294,537.00	₹8,711,377.00
CO_2 Emission	55882	44774

The results show CO_2 Emission reduces by 19% in comparison to the existing system. Around 6% saving in cost can be done yearly when the micro grid in connected to the utility.

Fig. 11 shows the cash flow summary for each component of the optimal system. It is clear that PV panels consume the over-all cost of the system. The purchase cost of energy from grid is shown in Fig.12.

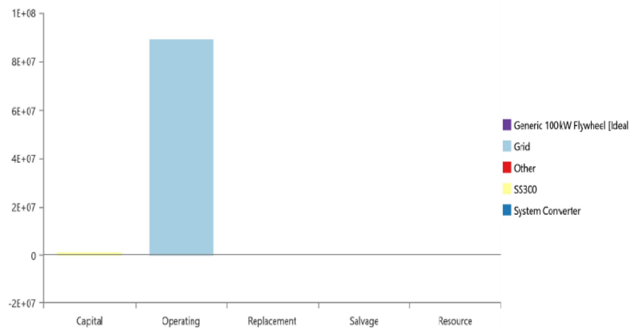

Fig. 11 Cash flow summary for total cost of each component.

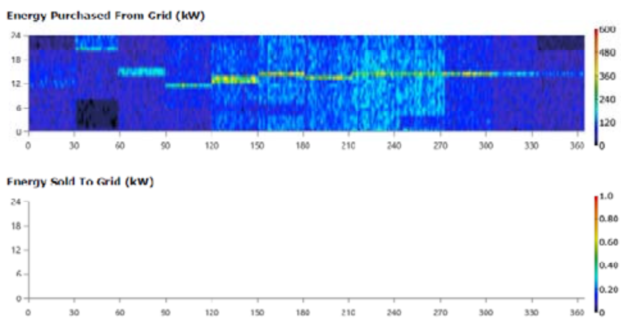

Fig. 12: Energy purchased from grid.

4. CONCLUSION :

Various microgrid configurations are analysed, considering both grid-integrated and off – grid conditions. It is clear from the optimization result that the micro grid connected with utility grid will not only reduce the total net present cost but also reduce the carbon dioxide emission in comparison to the existing distribution system. Micro grid disconnected from the utility will not be economical for this area as the TNPC is very high. The existing solar capacity is very less for a remote off-grid micro grid.

5. FUTURE PLAN :

Different micro grids will further be compared on the basis of economics and renewable penetration. A feasible off grid microgrid will be designed to meet the load requirement as well as to reduce the TNPC. The study of the microgrids will be extended and various other combinations will be analysed to study the impact of other renewable energy systems like biogas.

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