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SMART HYBRID MICROGRID'S ENERGY MANAGEMENT AND CONTROL

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Abstract: Continuous growth and development of a country are measured by the increasing energy demand. In the countries like India major geographical part is covered by rural areas which either do not have access to electricity or connected to the weak/unstable distribution grid. In this study, the solar and the wind has been installed on the roof top of the Science and Technology Building and the sub control room for solarand wind is also set up adjacent to the installation on the same roof. The biogas powergenerating system including digester, gas engine, gas cleaning system and synchronizer, the VRF battery, maincontrol panel and the SCADA system based on Lab VIEW software are installed within the Micro-grid centre. The cable has been laid underground from sub control room to Micro-grid Centre which is about 500m away. The main control panel is connected with load as well as local grid. Holistically, this chapter describes the establishment of the micro-grid within IIEST campus.

Keywords: VRF battery, SCADA system, Lab VIEW software, Micro-grid Centre, IIEST campus.

1. INTRODUCTION

Continuous growth and development of a country are measured by the increasing energy demand. In the countries like India major geographical part is covered by rural areas which either do not have access to electricity or connected to the weak/unstable distribution grid. The Government of India has an aggressive target to extend the national grid to each and every part of the country by 2018 and 24×7 hours of electric power to all domestic consumers by March'2019 [1]. The major limitation to execute this project is the inadequate grid infrastructure for both the transmission and the distribution systems in rural areas. Inorder to match the load demand and energy generation as a demand response strategy, distributed renewable energy sources can be a potential solution. Due to the poor capacity utilization factor (CUF), only solar PV (CUF-17%) or only wind power generator (CUF-42%) may not show reliable performance to meet continuous load demand. Thus bio degradable wastes and animal manure may be used to produce biogas electricity and can be mixed with other renewable energy sources such as solar, wind, and battery energy storage system (BESS). Therefore, an intelligent and targeted combination of renewable energy sources and BESS operating through a distinct network for specified load patterns forming a hybrid microgrid may provide an effective solution towards rural electrification. Cai et al. [2] proposed an equivalent modeling method in their work which improves the utilization of renewable energy sources and their reliability in the power system.

2. LITERATURE REVIEW

The proposed characteristic model was used to simulate the dynamic response of the microgrid and also improved the model efficiency. Major challenges and the limitations in terms of reliability of a microgrid consisting of renewable energy sources were discussed by Cañizares and Behnke [3] in their work. Their work also discussed the different control strategies of microgrid and its operational aspects along with the associated grid.

Nikmehr and Ravadanegh [4] proposed the distribution networks for the future by explaining the Multi Microgrid System (MMGs). The economic optimization was done by minimum cost based economic analysis among the microgrids and the main distribution grid. In their work it was also proposed that sharing the power between the microgrids and the main grid can minimize the cost of the future power system networks. Microgrid management for distributed energy sources connected in the main distribution network was discussed in the work by Rocabert et al. [5]. It also showed that the efficiency of the system improves and stability increases in terms of voltage fluctuation by implementing this management strategy.

Hossain et al. [6] introdu ced a microgrid test bed and a survey of microgrids across the world. Chung et al. [7] discussed different microgrid models for grid connected as well as the islanded mode in their work. The simulation models of microgrid were developed through Particle Swarm Optimization (PSO) tool.

The challenges of integration of renewable energy sources in a microgrid were discussed and the model predictive control method was adopted by Ma et al. [8]. A decision was taken for sharing the power in an optimized way by their model simulation considering minimum capital cost and operational constraints.

Eghtedarpour and Farjah [9] discussed the challenges of power control and its management issues of different micro sources in AC and DC hybrid system. The work also proposed a decentralized power sharing method eliminating the requirement of communication constraints among the distributed energy sources. The performance of the proposed power sharing model was validated through PSCAD simulation. An energy management system for distributed generators such as solar PV, wind, diesel generator, and energy storage system was discussed by Shi et al. [10] for optimal operation of the microgrid. A power sharing methodology among distributed generators was proposed to schedule the load optimally by local controller as well as microgrid central controller.

A fuel minimization technique of different power sources in a microgrid was discussed by Aramburo et al. [11]. A cost optimization method had also been proposed in their work. Kumar et al. [12] proposed a design of sustainable microgrid based on solar PV, hydro, diesel generator (DG), pumped hydro storage (PHS) and battery storage.

A discursive result illustrating various renewable energy sources and storage of the microgrid based on daily, monthly and yearly basis accounting the load growth was also presented in their work. Changjie et al. [13] proposed a method for power balance & control of a DC hybrid microgrid system aiming to meet the load power demand with reliability and stabilizing the DC bus voltage. A novel remote monitoring unit platform for a renewable energy source with hydrogen based smart microgrid was proposed by González et al. [14]. In the work of Hossam et al. [15] the control of an AC-DC hybrid microgrid using static VAR compensator (SVC) under grid connected and islanded conditions were described. Different power management algorithm and control schemes of hybrid microgrid were proposed and demonstrated in the literature [17-19]. Zhang et al. [20] discussed economic and environmental scheduling in smart home applications with microgrid.

3. LITERATURE GAPS

Based on the above mentioned research and development works on the microgrid, it is evident that optimized capacity selection and integration of distributed renewable energy sources with proper BESS is necessary to ensure uninterrupted power supply at the consumer end even at weak or no grid conditions. Also there is hardly any report on the integration of Biomass generator with solar, wind and BESS to design and operate a hybrid microgrid. In this work, simulation and experimental study have been done to verify the power sharing capability of the distributed renewable energy sources including biomass in a microgrid in order to establish the reliability of the power system which ensures zero loss of power supply probability. The hybrid microgrid in this work consists of a solar PV, Wind, Biomass and Vanadium Redox Flow Battery (VRFB) storage as BESS. This type of microgrid may act as a reference model for rural electrification in any part of the world, depending upon its geographical and climatic coordinates. A simulation study has been done through HOMER software to select the renewable energy sources to form a microgrid along with their optimum capacity in order to meet the load demand and the economical viability considering various cost components throughout the life cycle. The modeling of each subsystem of the microgrid has been done using PSCAD software and the energy management algorithm has been simulated considering a case study of practical full day load profile. A pilot hybrid microgrid plant has been installed consisting of integrated 10kWp solar PV, 1kW wind power generator, 15kVA biogas engine-generator and 1kW 6h VRFB storage at Indian Institute of Engineering Science and Technology (IIEST), Shibpur campus, India. The variability of the renewable sources (Solar, Wind) in the microgrid system and their scheduling can be modeled by adaptive control and stochastic method [21-23].

4. General description of Hybrid Microgrid:

A hybrid system consisting of 10kWp grid connected solar PV, 1kW wind generator, 35 cubic meter bio digester with 15kVA gas generator and 1kW/6kWh vanadium redox flow battery has been set up at microgrid centre within IIEST, Shibpur campus for experimental study. Fig. 3a describes the line diagram of the overall microgrid system. The distributed energy sources along with load and the LT grid have been connected with the Main Control Panel (MCP) with proper protection system. The regular and random variability of the renewable sources (Solar, Wind) in the microgrid system can be modeled by adaptive control and stochastic method [21-23]. But in this work the variability of renewable energy sources (solar, wind) and the load profile is considered as regular variation in their magnitude with time, not in the randomness of their availability.

The real time variable energy generation profiles of the renewable sources have been collected from the SRRA (Solar Radiation Resource Assessment) centre installed at the roof top of the IIEST, Shibpur campus and used as input to the microgrid controller. The real time monitoring and control of the microgrid have been done through state of the art LabVIEW software with ether-netlink as well as wireless mode. The main server is installed in the microgrid center for monitoring and control purpose.

Thus the installed hybrid microgrid is upgraded into smart microgrid by establishing intelligent control communication among the three renewable energy sources, battery storage, load and the grid through smart meters as shown in Fig.1 The LabVIEW based smart communication and control scheme is shown in Fig 2

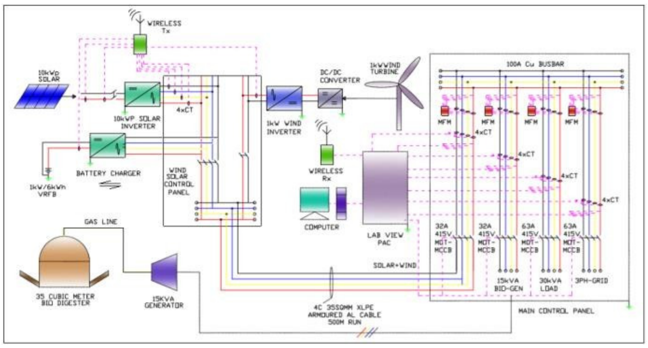

Fig .1 Line diagram of the Microgrid at IIEST, Shibpur campus

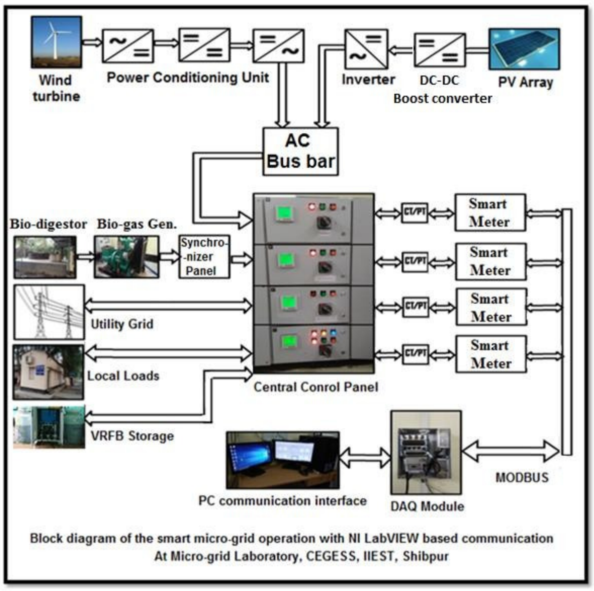

fig .2 the control scheme for the smart hybrid microgrid system

4.2 Power conditioning units (PCU): DC/DC, DC/AC and AC/DC power converters are required when there are AC and DC components in the system. In this study the hybrid microgrid consists of SolarPV source and VRF battery which are DC systems while the Biogas generator, considered load and the grid are AC. The power converter size is chosen based on the peak load demand ($P_L^{max}(t)$). The inverter rating (P_{inv}) is calculated by equation (22),

$$P_{inv}(t) = \frac{P_L^{max}(t)}{\eta_{inv}} \quad (22)$$

4.3 Generation Potential of Renewable Energy Sources

4.3.1 Solar energy potential:

Daily average Global Horizontal Irradiance (GHI) and yearly average energy production of Kolkata are depicted in Fig. 4.3 The data has been collected from Solar Radiation Resource Assessment (SRRA) Centre at Indian Institute of Engineering Science and Technology (IIEST), Shibpur campus. The maximum energy generation is found in the month of April.

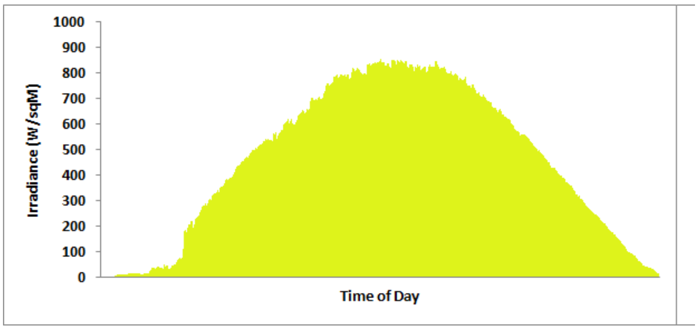

Fig 4. 3 Daily average GHI and yearly average solar irradiance profile [33]

4.3.2 Wind energy potential:

Similarly, Daily and yearly average wind velocity pattern of Kolkata is depicted in Fig. 4.4. The data has been collected from Solar Radiation Resource Assessment (SRRA) Centre at the Indian Institute of Engineering Science and Technology (IIEST) campus. The maximum wind speed is found nearly 5.3m/s and 3.8m/s for summer and winter respectively. The wind potential is not significant for power production in West Bengal. It has been incorporated to study the characteristics of a hybrid system.

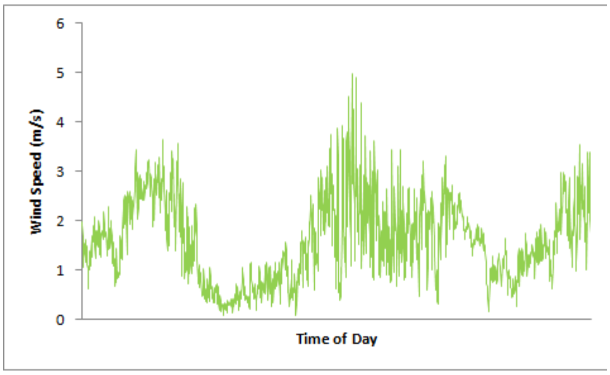

Fig 4. 4 Daily average wind speed of summer time and yearly average wind speed [33]

4.3.3 Bio energy potential:

From the survey done within the university campus, it is found that nearly 900kg of bio degradable waste such as kitchen and table waste are generated per day basis from different student canteens, guest house, and staff residences. According to the calculation, 25kg of waste can produce 1 cubic meter of bio gas which contains nearly 60% methane, 30% carbon di-oxide, 10% water vapor and the negligible amount of hydrogen sulfide. The heat value of the gas is between 21 to 25MJ/cubic meter which again generates 0.278kWh/MJ. Therefore, from 700kg of waste will generate 220.17kWh of thermal energy [30]. The yearly average waste generation is shown inFig. 6.5.

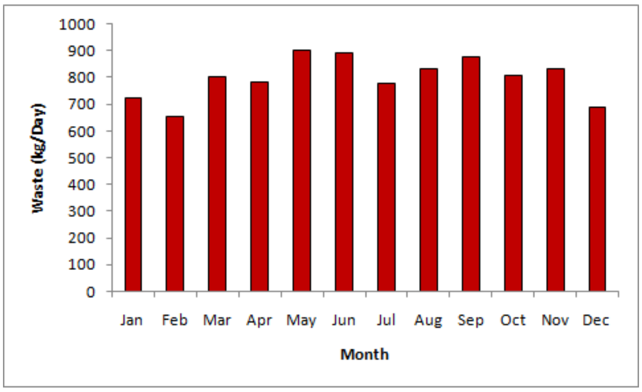

Fig 4. 5Yearly average of biogas raw material [33]

Fig. 4.6 also presents the fuel curve of the biogas generator. Based on power output per unit fuel consumption, HOMER models the biogas generator and gives the output power. This data has been taken from the biogas generator data sheet.

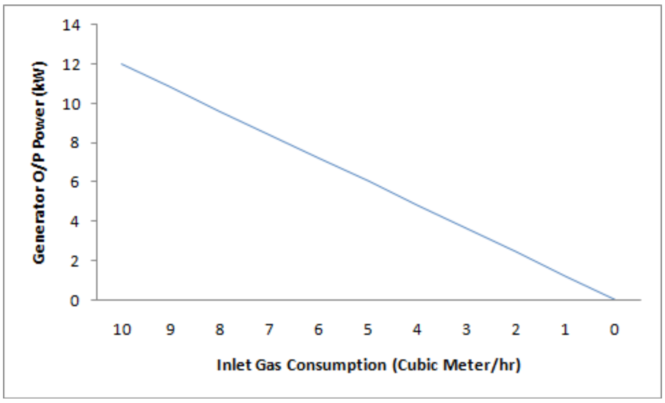

Fig 4. 6 Biogas generator fuel curve

5 CONCLUSION

The solar and the wind has been installed on the roof top of the Science and Technology Building and the sub control room for solar and wind is also set up adjacent to the installation on the same roof. The biogas power generating system including digester, gas engine, gas cleaning system and synchronizer, the VRF battery, main control panel and the SCADA system based on Lab VIEW software are installed within the Micro-grid centre. The cable has been laid underground from sub control room to Micro-grid Centre which is about 500m away. The main control panel is connected withload as well as local grid. Holistically, thischapter describes the establishment of the micro-grid within IIEST campus. In this work, a smart hybrid micro-grid consisting of different renewable energy sources such as 10kWp solar PV, 1kW wind power generator, 15kVA biogas engine-generator, 1kW/6kWh VRFB storage, loads and the existing local grid has been set up at IIEST, Shibpur campus. The real time monitoring and control of the micro-grid system are implemented through Lab VIEW communication platform. An optimized energy management algorithm has been implemented to satisfy the demand side management, peak power shaving and to ensure zero loss of power supply probability at the distribution end considering the intermittency of renewable sources.

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