Microgrid Resource Management System using Fuzzy Logic Controller(FLC)

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***Abstract*—In this paper, an intelligent and efficient Fuzzy logic controller (FLC) based algorithm is developed for the islanded Micro grid comprising of solar, wind, fuel cell and battery. The intermittent nature of the renewable sources in the microgrid makes the system as dependent with the conventional grid. The algorithm is developed for the optimum usage of the sources that can satisfy the load demand in an efficient manner and reducing the usage of grid operation. The fuzzy logic controller (FLC) is used to maintain the DC bus link voltage at the required level.**

Keywords—Microgrid, Power Management, Fuzzy logic controller (FLC), optimum utilization.

I. Introduction

In countries like India, the dependency of the power from the conventional sources is not effective one, since the availability of the sources is no longer existed. The increase in population leads to the shortage of the power and increase the usage of renewable sources. The combined sources of diesel generator, solar, wind along with the energy storage devices such as the battery, super capacitor and the loads is defined as the microgrid. These micro grids are having the small transmission and distribution lines where the power generated is distributed within the local loads. The micro grid may be self-sustainable if the proper control algorithm is being developed for the system to distribute the reliable power to the loads [1]. The coordination between the fossil fuel sources and the renewable sources are done by driving the principles of system perspective and business case model. The ministry of new and renewable energy (MNRE) along with private sector and energy development agencies has initiated many projects for micro grid in India.

In [1], the status of micro grids in India, main and emerging economic issues in Indian view was discussed. The standards to be followed for the grid connected distributed energy resources; the energy storage technologies and the integration of these storage devices with the system were explained. The authors [2] has presented a two stage optimization technique for scheduling the power generation in order to reduce the long run average operating cost satisfying the conditions. In the first stage, the hourly unit commitment of the conventional generators and in the second stage, economic dispatch of the sources and storage devices has been done. The modelling of the conventional, renewable sources, battery and load has been developed and the optimization problem has been formulated for the energy management solution in [2]. In the simulation results, the optimum solution for the micro grid setup subject to the constraints has proved the efficacy of the proposed algorithm. For the isolated microgrid setup consisting of wind, solar, biogas and battery, an efficient energy management system with a central controller has been implemented that has the ability to take the decision based on the source and load status [3]. Each load and source has been treated as an agent in the system forming Multi agent concept and data acquisition system for collecting the online data's. The main constraint assumed in the work was the SOC (Sate of Charge) of the battery with the minimum and maximum as 20% and 80%.

The two operating modes of the micro grid have been efficiently managed in order to reliable power supply to the consumers by the double layer coordinated control approach proposed in [4]. The schedule layer finds the economic operation from the forecasted data and the dispatch layer affords the power to the units from the real time data. The case studies proved that the control algorithm accurately optimize the power flow and reduces the error. A Particle swarm optimization (PSO) based energy management [5] using two time scale via day ahead scheduling and real time scheduling was proposed to carry out the optimal and economic scheduling there by maintaining the stability of the system. From the results, it is clear that the time scale was useful for the minimization of the cost, maximization of PV and wind efficiency.

For hybrid micro grids, a supervisory control system has been proposed in order to split the power between its different sources using robust optimal power management systems [6].The optimization problem for maximum utilization of renewable sources, minimum utilization of fuel based sources herby increasing the lifetime of the battery has been formulated after taking the uncertainty conditions into account. Based on the simulation results, the cost analysis is effectively done for different cases and it is proved that the management system has been successfully implemented as two level control schemes.

A day ahead and an hour ahead scheduling [2] has been employed for handling the uncertainties occurred in the load side and gives an efficient solution for the limited resources in order to meet out the long term and short term service meet outs. The simulation carried with the real data showed the significance of the energy management systems in micro grid.

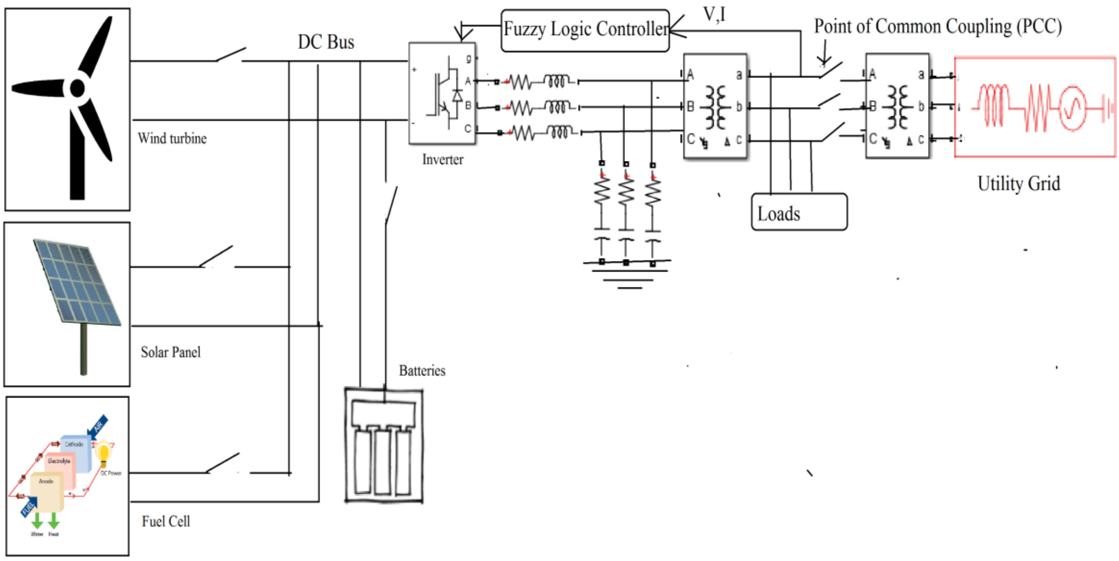

Figure 1. Block diagram of the Micro grid with Fuzzy Logic controller

In this paper, the Fuzzy Logic Controller (FLC) based Energy management system is proposed for the Micro grid comprising of solar, wind, fuel cell and battery with the loads. Section II presents the modelling of the components, Section III discusses the different modes of operation of the micro grid, and Section IV gives the simulation results. Conclusion is presented in Section V.

II. Modelling of the Components

The micro grid is having various distributed energy sources such as solar, wind turbine, fuel cell and battery with the priority and non-priority loads. Each component is modelled from its equivalent circuit and it is developed in MATLAB/SIMULINK. This chapter describes the modelling of all the components. The figure 1 shows the block diagram of the micro grid.

a) Modeling of Solar/PV cell

The process of producing electricity directly from the sun is called as photovoltaic process. The equivalent circuit of a solar cell is shown in figure 2.

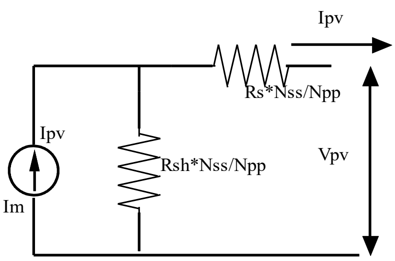

Figure 2. Equivalent circuit of solar cell

$$\text{Im} = Ipv - Id(Nss * Npp \text{ modules}) \text{ ----------------- (1)}$$

Where Ipv is the current generated by the incident sun light, Id is the Shockley diode current. Nss is the number of solar modules in series and Npp is the number of solar modules in parallel.

$$Io = \frac{Isc,n + KI\Delta T}{\exp\frac{Voc,n + Kv\Delta T}{VT * \alpha} - 1} \text{ ------------------------- (2)}$$

Isc,n =Short circuit current, Voc,n = open circuit voltage, VT = Thermal voltage, KI =Temperature coefficient of Isc, Kv = Temperature coefficient of Voc, ΔT =T-Tn (T and Tn being the actual and nominal temperatures in K), α = Diode ideality factor, usually the value lies between 1 and 2 for mono crystalline silicon.

$$Ipv = (Ipv,n + KI\Delta T)\frac{G}{Gn} \text{ -------------------------- (3)}$$

Ipv,n =light generates current at the nominal condition (for 25°C and 1000W/m^2), G=the irradiation in W/m^2 and Gn= the irradiation at standard operating conditions.

b) Modeling of wind turbine

The wind turbine is designed such that the electrical output power is 1.67kW.The base wind speed is taken as 12m/s. The wind drive train is modelled based on two mass analogy and the pitch angle controller is used for controlling the speed of the wind turbine. As per the Betz's limit, the maximum power that can be extracted from the wind turbine is around 59% only [7]. The power from the wind turbine can be calculated as follows [7]:

$$P_m = \frac{1}{2}\rho C_p A V_\infty^{3}\text{-----------------------------------(4)}$$

Where

$$A = \frac{\pi d^2}{4} \text{ is the area of the rotor----------------(5)}$$

$$\lambda = \frac{2\pi RN}{v_\infty} \text{ is the Tip speed ratio---------------(6)}$$

$$C_T = \frac{C_p}{\lambda} \text{ is the torque coefficient--------------(7)}$$

d= diameter of the rotor, R=radius of the swept area in m, N = rotational speed in revolutions per second, v_∞ = wind speed without rotor interruption in m/sec, C_p is taken as 0.35, ρ = air density $\approx 1.225\,kg/m^3$ at $15\,^{\circ}C$ and at normal pressure.

c) Modeling of Fuel cell

Proton Exchange Membrane (PEM) fuel cells are widely used in transportation and cogeneration applications. Based on the number of stacks selected, the stack voltage is given as follows: [8]

Vstack = Vcell x N---------------------------- (8)

Vcell=E – Vact – Vohm – Vconc---------------------- (9)

Where Vcell is the cell potential, E is the no load voltage which is found from the Nerst equation, Vact is the activation voltage, Vohm is the ohmic voltage and Vconc is the concentration over voltages.

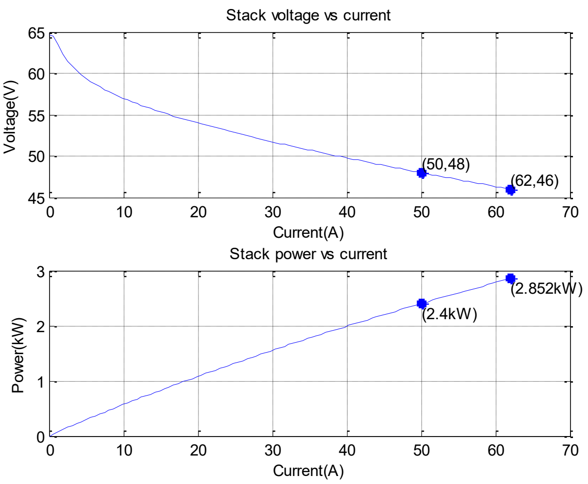

Figure 3. Characteristics of Fuel cell

d) Modeling of battery

Each battery is modelled as the nominal output from battery is 48V.Initial State of Charge (SoC) is assumed to be 70%. Totally five batteries are connected in series. The backup time is calculated as:

Back up time = (Ah * V * no. of battery * efficiency of battery) / load

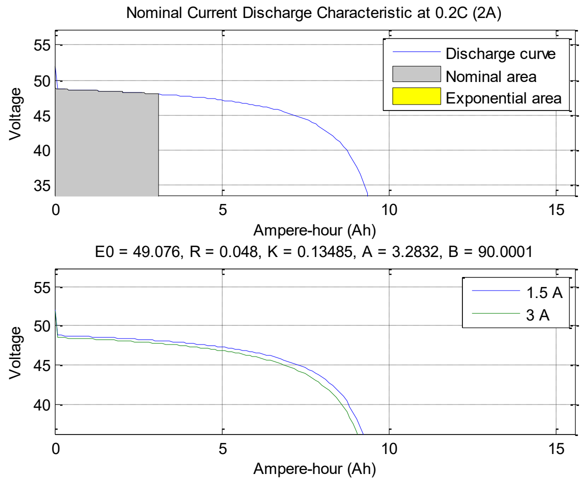

Figure 4. Characteristics of Battery

III. Modes of Operation

In micro grid, there are three types of mode of operation is considered. I) Islanded mode of operation II) Grid connected mode of operation III) Transition mode of operation. In the micro grid, when more power is generated from the sources, the excess power may be properly utilized by implementing suitable algorithm using controller. The algorithm may be considered as

Step 1: Check the mode of operation. If it is connected to conventional grid, the load demand will be satisfied and the battery is getting charged.

Step 2: If the micro grid is in islanded mode of operation, the controller gives the command to utilize the distributed energy sources to its maximum, thereby reducing the usage of grid. At the point of common coupling (PCC), the breaker is opened.

Step 3: In islanded mode of operation, if the power from the solar, wind and fuel cell is more than the demand, the excess power is used for charging the battery. If the battery charging is going beyond its SoC, the power will be given to the grid.

Step 4: If any one of the source is not giving power, the controller checks the power available and the load demand. If the power is less than the demand, the battery discharges its stored energy to the load.

By the given algorithm, the controller is giving command to the inverter to maintain the required power at DC bus where all the voltages are connected.

IV. Simulation and Results

The simulation has been done for the islanded mode of operation. When all the renewable energy sources are connected and working with MMPT algorithm to extract maximum output, the battery is getting charged. If any of the sources is not working or the power from the sources is not satisfying the load demand, the battery comes into operation. The battery will discharge the power along with the fuel cell to the load. The priority and non-priority loads are considered as 2kW and 4kW loads in the system.

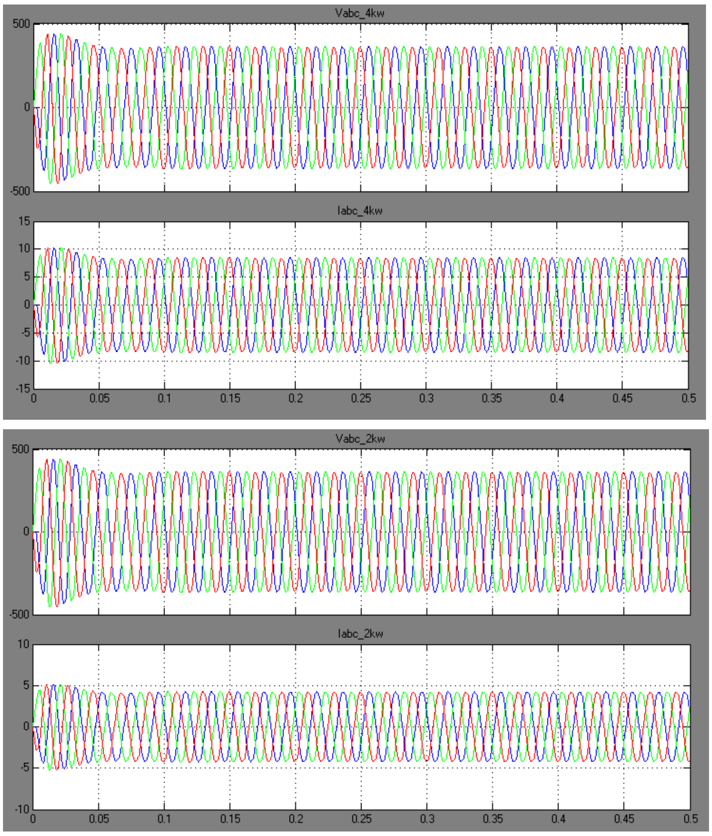

Figure 5.Voltage and current waveforms at the loads when the battery gets discharging. (No sources and grid are connected to loads)

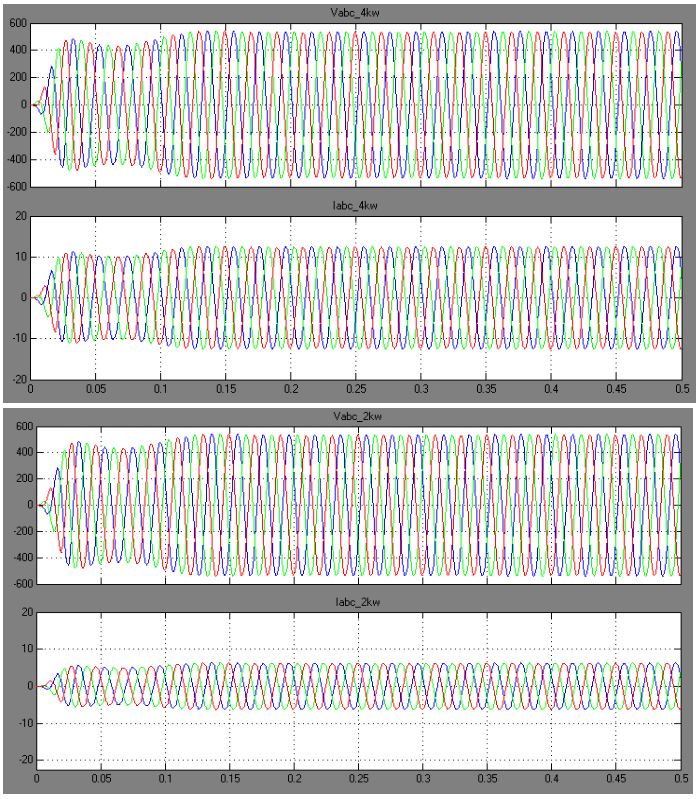

Figure 6.Voltage and current waveforms at the loads when the battery gets charging. (All sources are connected to load and grid is not connected to load)

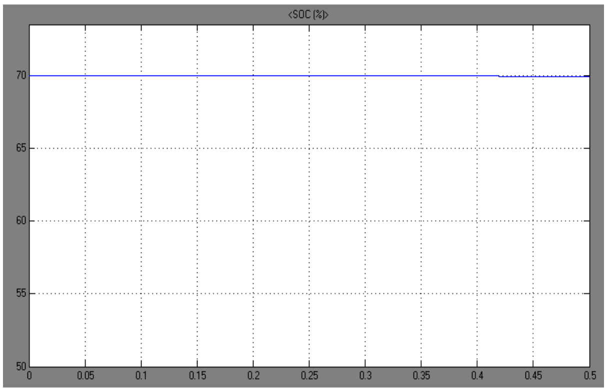

Figure 7.Battery SoC level

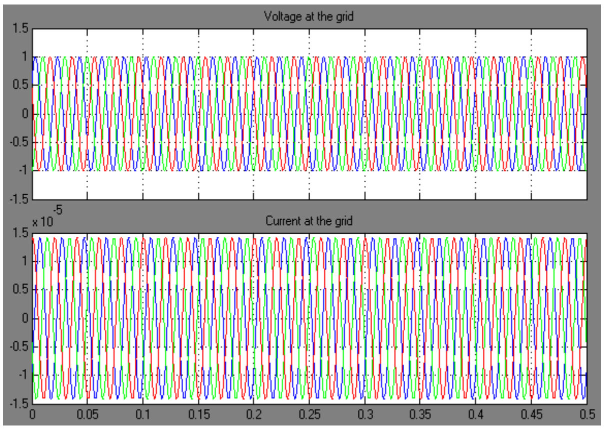

Figure 8. Voltage and Current at Grid

From the results, it is understood that the proposed Fuzzy Logic Controller for the islanded micro grid comprising of solar, wind, fuel cell, battery and loads gives the optimum results for two cases: sources are connected or producing the power output and the if it is not connected to the system. In both the cases, the voltage and current at load is maintained at the required level. The battery is also charged to its maximum SoC. Hence the lifetime of the battery is increased. The dependency of the micro grid with the conventional grid is completely reduced.

V. CONCLUSION

In this paper, the micro grid is assumed to be operated in islanded mode. In this mode of operation, the micro grid should be self-sustainable and it has to give continuous and reliable power supply to the load. The stable operation of the micro grid can be obtained by properly designed the controller. The Fuzzy logic controller proposed in this paper tries to maintain the constant DC level voltage at the DC bus link before it is connected to the Grid. The voltage is sensed by the controller and it is compared with the reference level. If any deviations are there, the controller gives commands to the inverter so as to maintain the voltage at constant. The future scope of this work is the grid connected operation of the micro grid. A new algorithm may be implemented in the same system to improve the performance and efficiency.

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