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Microgrid in Grid Connected and Standalone Modes using Fuzzy Logic Controlled Storage

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ABSTRACT: A microgrid is a small scale grid which is designed to provide power to local societies. The possibility to store energy and to exchange power according to demand among grids allows us to achieve an active distribution. Thus exchange of power can be achieved by Battery and Bidirectional Voltage Source Converter (BVSC). During no power in wind and the BVSC connected with Battery will supply the load to provide the satisfactory performance. This control of power flow from the system to the load will be done by Fuzzy logic unit as it is inherently robust. The approach used for fuzzy logic rules considering both grid connected and islanded modes. Microgrid tends to be driven by one of two principal ideas for improving electric power interactions for both generation and demand. We explore various management objectives, such as improvising the wind production, profiling demand and controlling emission.

KEYWORDS: Microgrid Network, Electricity Price, Wind Energy, Solar Panel, Demand, Load Modification, Fuzzy Logic Control.

I.INTRODUCTION

Recently the traditional energy networks has been facing enormous challenges. Many countries count on coal, oil and natural gas to supply their energy needs due to increase as way of life of the emergent countries, implying a considerable energetic demand rise. As the growing interest in intermittent renewables energies which increases the vulnerability and imposed technical limitations of power systems. With increased awareness of the depletion of traditional energy sources, the actual grid is waiting to achieve the demand and needs to meet the abundant, reliable and excellent environment [1]. The need to satisfy in sustainable energy, the demand requires active energy distribution networks where these networks as the possibility of bidirectional power flows.

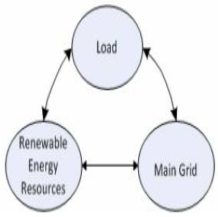

Fig.1. Structure of microgrid

The active energy distribution [2] supports intermittent low-carbon energy sources and provides content consumer participation on energy management. It provides affordable, efficient and reliable electric power as the structure connects every grid with the main grid. A microgrid comprises a storage units, controllable units, renewable energy resources as the structure is for low voltage distribution system. The power flow as to be control the microgrid design among the elements consisting a multi energy system (MES), an energy management system (EMS). The EMS offers a flexible and low cost energy [3]. The central controller of EMS, controls all elements and locally controlled battery [4].

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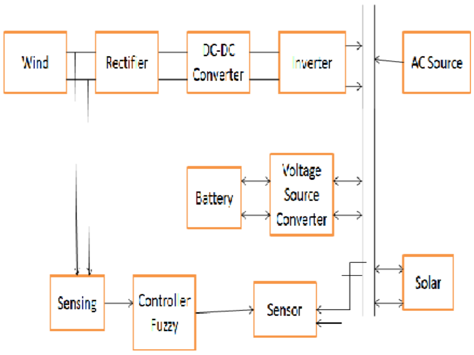

Fig.2. Block Diagram of the microgrid designed

The modified microgrid to a small islanded area interconnected with main grid and that as to interact with each other, independent and maintain the system reliability [6]-[8]. The interaction of loads to adapt consummation to safety of the grid, to ensure the best grid status, avoid blackouts and reduce the environment impact. The battery can charge and discharge in the local storage or sold to the connected grid where the production increases or decreases from the demand. In this paper, microgrid system of energy management and improved interactions are studied. Subsequently, the microgrid energy resources such as solar panel, battery, fuzzy logic controller unit and a wind turbine in section II are developed. The electricity demand is simulated via a residential load. The command approach used in this paper is fuzzy logic controlled storage considering the evolution of electricity prices. In section III, model and control of the microgrid are estimated and the evolution of the power flow are simulated and analyzed in section IV. Lastly, conclusion in section V are developed.

II.SYSTEM MODEL

A. Wind Turbine Model

Simulation for the PMSG generator does not require any gear box unit and are referred from [9] and are given as:

$$v(t) = v_a(t) + v_r(t) + v_g(t) + v_t(t)$$

Where, v_a is the average value, v_r, v_g, v_t are the parameters which are ramp, gust and turbulence components respectively.

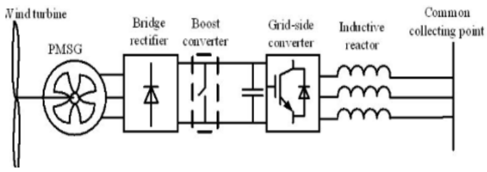

Fig.3. Wind Turbine Modelling

$$f\,(Hz) = RPM\frac{P}{120} \qquad (1)$$

The wind turbine is developed in the MATLAB/Simulink model platform. The model is then used for the investigation of the wind turbine operation and it is shown in fig.4

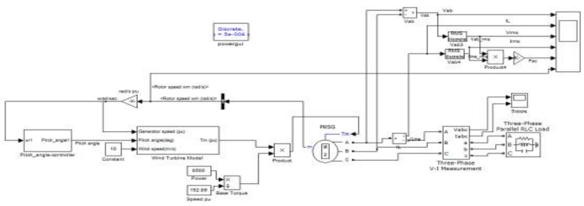

Fig.4. Simulation of the Wind Turbine Model

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$$Pm = \frac{\rho A}{2} \upsilon_{wind}^{3}$$

where,

Pm = mech O/p Power

ρ = Air Density equal to 1,225kg/m^3

A = Turbine Swept area(m^3)

υ = Wind Speed(m/s)

$$Tm = \frac{P}{\omega_m} \qquad (2)\text{-}(3)$$

Pitch Angle Calculation:

The wind turbine rotor speed should be in limited value. If it violates the limitation speed the system will be collapsed. Hence the pitch angle is developed in the MATLAB/Simulink which has the best platform to explore the wind turbine pitch angle and it is shown in fig.5

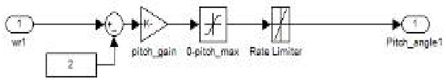

Fig.5. Pitch Angle Control Simulation

Where, β pitch angle and γ tip speed ratio

$$\gamma = \frac{R\omega_b}{v_w} \qquad (4)$$

R is blade radius (m) and ω_b is rotor angular speed (rad/ sec).

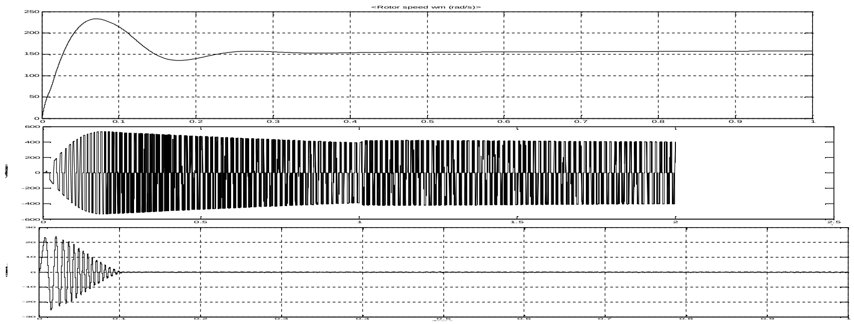
Fig.6. Output Simulation of rotor speed, voltage (Vab) and current (Iab)

Wind Model is then followed by the Bidirectional Voltage Source Converter. As it is used to convert the wind output ac-dc or ac-ac BVSC converter of the wind system.

A. Solar Model

Solar cell is constituted of PV modules which converts energy of the incident photons into electrical energy. When a solar cell is exposed to solar spectrum which are referred from the paper [8]. The PV cells are connected in series parallel configuration in the solar panel design. Photon energy in excess is converted into electrical energy while photon energy less than is either dissipated as heat. The current source I_{PH} results from the charge carriers excited by solar radiation. R_s Should be very large and R_{sh} should be very small. Resistance are neglected in expected cell as ideal.

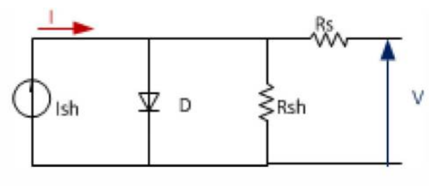

Fig.7. Equivalent Circuit of the Solar panel

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The mathematical model is:

$$I = I_{ph} - I_s \left[\exp\left(\frac{q(V + IR_s)}{kT_c A} \right) - 1 \right] - (V + IR_s)/R_{sh} \quad (5)$$

The photocurrent I_{ph} is the function of solar insolation λ and working temperature of cell T_c. Saturation current I_s is also defined with the function of solar insolation λ and working temperature of cell T_c.

Here, the photocurrent is modelled as:

$$I_{PH} = \left[I_{SC} + K(T_c - T_{ref}) \right] \lambda \quad (6)$$

Where, I_{SC} is short circuit of cell at 1kW/m², K is temperature coefficient, T_c and T_{ref} is cell temperature and reference temperature respectively.

Saturation current is modelled as:

$$I_s = I_{RS} \left(\frac{T_c}{T_{ref}} \right)^3 \exp \left[\frac{qE \left(\frac{T_c - T_{ref}}{T_c T_{ref}} \right)}{kA} \right] \quad (7)$$

k is Boltzmann's constant, $1.38 \times 10^{-23} J/K$, A is ideal factor and E is the energy gap of semiconductor cell, q is the electron charge $1.6 \times 10^{-19} C$, I_{RS} is reverse saturation current of cell.

The solar panel is developed in the MATLAB/Simulink platform to investigate the PV module. It is shown in fig .7

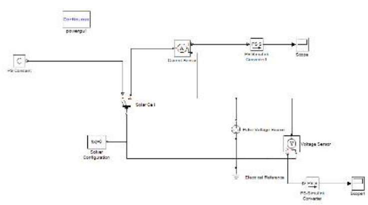

Fig.8. Simulation of the Solar System

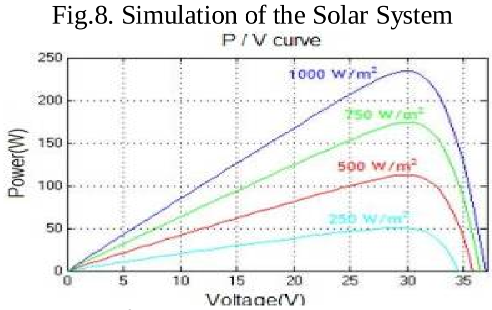

Fig.9. Output simulation of the solar cell with the various irradiance intensity

A. Battery Model

Li-ion batteries are suitable and best option among different batteries for hybrid energy locally stored system. As the battery is concerned of better life cycle and efficient energy density. The State of Charge (SOC) is represented as:

$$SOC = 100 \left(1 - \frac{\int i_b \, dt}{Q} \right) \quad (8)$$

Where Q is the battery capacity and i_b is the battery current. The discharge and charge equation of the lithium-ion battery is written as:

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$$f_1(i,t) = E_o - R\frac{Q}{Q-i}i^* - R\frac{Q}{Q-i}it + A\exp(-B, it)$$
$$f_2(i,t) = E_o - R\frac{Q}{it+0.1Q}i^* - R\frac{Q}{Q-i}it + A\exp(-B, it) \quad (9)\text{-}(10)$$

Where, R is the polarization resistance in ohms, it is the battery extraction capacity (Ah), A is the exponential voltage in volts, B is the exponential capacity (1/Ah)

The simulation represents the nonlinearity between the SOC and the exponential voltage A of the Lithium-ion battery. There are two batteries used and are connected as the alternate usage for the local storage of power. The life cycle and the State of charge are directly proportional and are designed such a way that the battery should satisfy the excess demand. The input variables of the fuzzy logic are ΔSOC and excess demand ΔD.

$$\Delta SOC = SOC - SOC_{new} \quad (11)$$

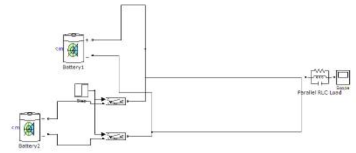

Fig.10. Simulation of the Battery modelling

B. Fuzzy Controller System

Fuzzy controller are based on the rules proposed by the Mamdani for the MATLAB/Simulink. The fuzzy controller are explored by the formation of the function of membership and rule base. The fuzzy rules are shown in table below.

The fuzzy is designed as to charge the battery whenever the battery SOC is low and discharge whenever the battery SOC is high. It is also used to protect from the deep discharge of the battery and referred from the paper [5].

If SOC DC = 1, then fuzzy rules are activated. If the SOC battery <1, then maximum charge.

$$\Delta D = ModifiedLoad - (wind + solar)$$

I	Excess Demand (D)						
	EH	***VH***	***H***	***M***	***L***	***VL***	***EL***
SOC	**VH**	EH	EL	VL	L	M	H
	H	VH	EH	EL	VL	L	M
	M	H	VH	EH	EL	VL	L
	L	M	H	VH	EH	EL	VL
	VL	L	M	H	VH	EH	EL
	EL	VL	L	M	H	VH	EH

Table: Fuzzy rules

III.MATHEMATICAL MODELLING

The microgrid is connected as the wind turbine, solar with the battery and utility grid or main grid. This makes the whole system reliable. Whenever the utility grid or the microgrid is not sufficient with the available load, the solar and wind turbine satisfies the demand and the other way of satisfying the demand by connecting battery.

A. Modelling of Utility Grid

The utility grid and the load must meet the demand. It is designed in both the standalone and grid connected conditions. There are two circuit breakers connected as CB1 and CB2 and is opened at time (t) = 0.1 seconds. It is modelled as the circuit breaker CB2 disconnects the main grid from the rest of the network during 100ms. It is calculated with the transmission line and the three phase circuit breakers where the existing system does not support for long transmission line.

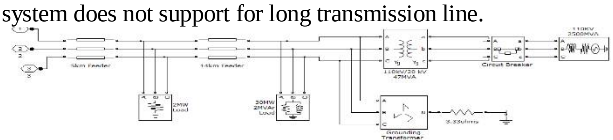

Fig.11. Utility Grid for the simulation for 20MW Load

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B. Modelling of renewable energy

The compensation to meet the demand by connecting the wind and solar energy with the locally connected battery. The fuzzy system is used to measure the maximum demand at the particular period and satisfy the load with the renewable energy or the main grid. Microgrid which has the locally connected battery will serve more comfortable interchanging of the power to the maximum demand. Where, the bidirectional converter are used to convert AC/DC and DC/AC for both solar and wind energy as the main grid is AC grid.

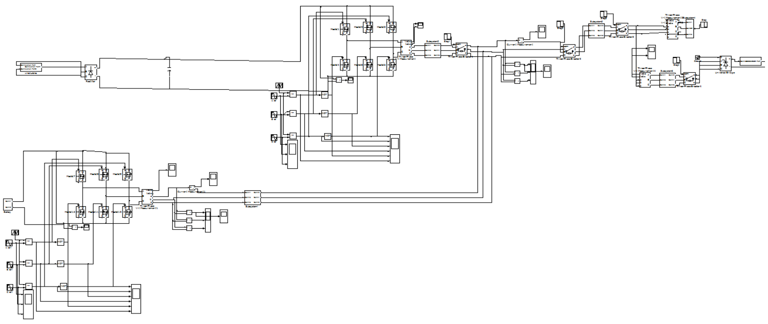


Fig.12. Final Simulation

C. The System Management

The Fuzzy Logic concept is managed in the microgrid model with the results in multiple shades of grey. The fuzzy load management is implemented containing all the management commands as it is logical but a vague sense and uses various fuzzy rules. It is used to adapt with the human being departure a space between some of the true and false values. The amount of power exchange to the utility grid is determined in function of input level in 10 minutes period.Power interaction and load are managed with the utility grid in function of actual state of the model as the price of the electricity, day time value, load, extra demand and production cost on weather forecast. The aim is to determine the grid interconnecting and has the power interaction inputs as time (T) in hour, wind energy (Wind) in kW, solar energy (Solar) in kW, excess demand (D) in kW and load (L) in kW per hour.

Excess Demand = Load – Renewable energy. The principle is based on the conditions are

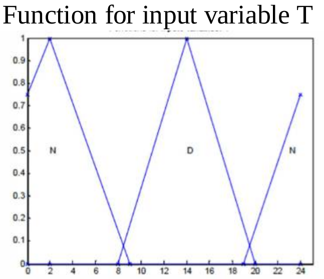
1) **If Excess Demand >0, then the D is positive and price is low, which means the renewable generation rate requires power and utility grid should provide extra power and meet the demand.**

2) **If Excess Demand <0, then the D is negative and price is high, which means the renewable energy rate is available with the extra power.**

Furthermore, the outputs are modified as, Load Drop is obtained by the product of Load and Modified Load percent.
Exchanged Power = (Modified Load – Solar – Wind)

- Time: Day (7am to 2pm to 9pm) Night (8pm to 2am to 8am)
- Excess Demand (D): Negative Large (NL), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Large (PL)
- Modified Load: Extremely Low (EL), Very low (VL), Low (L), Medium (M), High (H), Very High (VH), and Extremely High (EH). Result Analysis

Function for input variable T



(a) Time Input (t)

Funtions of input variable D

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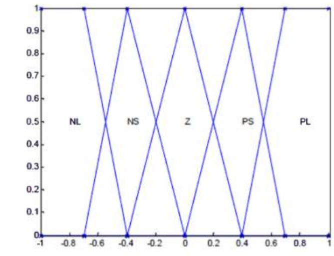
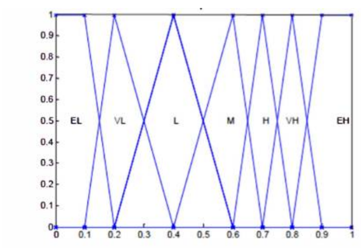


(b) Excess Demand(D)
Function of input varaible Modified Load



(c) Modified Load
Fig.13. Membership of input and output variables in fuzzy logic controller

IV.SIMULATION RESULTS

The system under certain concerns is the same as presented. The power flow evolution between the microgrid and the main network is developed considering a photovoltaic generator and a wind turbine associated with a load. Capacity to regulate a load via control strategy using fuzzy rules is examined.

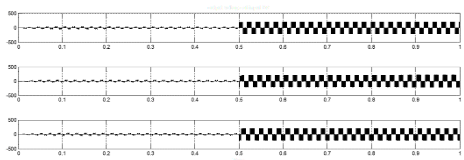


Fig.14. Simulation result for Battery

Battery can provide whenever required for appropriate usage time chance for utmost storage of energy as the excess demand is high. Control system is applied in the battery for stored energy within the maximum and minimum limits which is in limited capacity and are assumed.

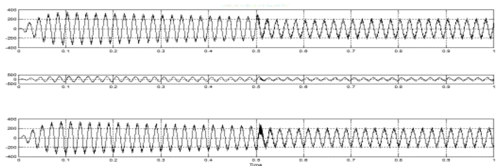


Fig.15. Simulation result for the solar and wind energy

The power consumption is supplied by the solar panel and wind turbine, which are connected to the main grid to compensate if the production is lower than the demand. Improvements in the battery and protection for both standalone and grid connected conditions can be solved to good extents.

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V. CONCLUSION

In this paper, the system under certain concerns is the same as presented. The power flow evolution between the microgrid and the main network is developed considering a photovoltaic generator and a wind turbine associated with a load. Capacity to regulate a load via control strategy using fuzzy rules is examined. The power consumption is supplied by the solar panel and wind turbine, which are connected to the main grid to compensate if the production is lower than the demand. As the output depends on rules is a conclusive solution to regulate the load, supply and demand to reduce costs.

Therefore, a fuzzy logic controlled local energy storage system could be executed through a battery to study the microgird in an islanded mode and in connected mode. The smart load management will be developed as the subject of future work.

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