Hybrid Renewable based Dc Micro grid using Fuzzy Control Technique for Energy Management System

V.Ramudu
Assistant Professor
Department of Electrical & Electronics Engineering,
Global Institute of Engineering& Technology, Chilkur(V), Moinabad(M) R.R (Dt); Telangana, India.

T.V.V Pavan Kumar
Assistant Professor& HOD
Department of Electrical & Electronics Engineering,
Global Institute of Engineering& Technology, Chilkur(V), Moinabad(M) R.R (Dt); Telangana, India.

Abstract- This concept proposes an approach for the hybrid renewable base in Energy management for stand-alone applications. Energy charging process is non-linear, time-varying with a considerable time delay so it is difficult to achieve the best energy management performance by using traditional control approaches. A fuzzy control strategy for battery charging or discharging used in a renewable power generation system is analyzed in the paper. To improve the life cycle of the battery, fuzzy control manages the desired State Of Charge (SOC). A fuzzy logic-based controller to be used for the Battery SOC control of the designed hybrid system is proposed and compared with a classical PI controller for the performance validation. The entire designed system is modelled and simulated using MATLAB/Simulink Environment. The proposed concept can be implemented to fuzzy control technique using MATLAB/SIMULINK software.

Keywords—Renewable, DCmicro grid, energy management, DC link, energy storage system, power converters.

I. INTRODUCTION

The micro grid system is an electrical network which consists of the interconnected loads and distributed energy generation systems. The development of the hybrid renewable generation system has overcome all the disadvantages of the conventional generation systems. The architecture of the micro grid system consists of the interconnected loads and distributed energy generation systems, that consists of the standalone and grid connected loads applications. The micro grid system enhances the load reliability, reduce emissions and improve the power quality [1]. The implementation of the micro grid components composed of the modeling and integrating the energy sources parallel to the grid. The smart micro grid consists of some challenges are commonly called as the IT challenges for the energy distribution operators. The efficiency and viability of the energy management was improved by using the automated systems that depends on capturing the fine grained data composed of voltage and current consumed by the systems, accepted load demand commands. The process of micro grid system briefly discussed in [2]. The characteristics of the micro grid system are grouping of interconnected loads and distributed energy sources, can operate in islanded mode and grid connected mode if desired, acts as a single controllable entity as load systems. The brief classifications of the micro grids are discussed in [3]. In today's work the overall efficiency of hybrid AC or DC microgrid system is assessed in the grid tied mode. In this wind turbine generator, photovoltaic system in addition to electric battery are used for the growth of micro grid from the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and also lowering voltage dips and potentially reduced charges of energy offer [4-5]. Distributed energy sources can potentially reduce the requirement for distribution as well as transmission services. There are various advantages offered by micro grids to help end consumers, utilities and community, such as enhanced power performance, reduced overall power consumption, lowered greenhouse gases and pollutant emissions, increased service quality and local reliability [6]. The EMS consists of the communication systems such as RS 485 and Zig-Bee communication network protocol. The generation systems, storage system, and DC bus regulator system are provided with the above mentioned communication system that communicates to the EMS system [7-8]. This EMS commands the generation system when to operate as per the load demand and State of Charge (SoC)of the battery. This EMS incorporates the Induction Machine control algorithm, that gives first priority to the load satisfaction, battery management and selling the power to the EB system through the bidirectional AC-DC converter using the AC grid. The EMS incorporates the Induction Machinecontrols are so called as the intelligent control. Such control management system essential for the nonlinear DC microgrid system for the purpose of optimization and distributed energy generation [9-10].

II. DC MICROGRID

Fig. 1 represents a generalized block schematic of DC microgrid. Permanent magnet synchronous generator (PMSG) is suitable to be used as a generating source in microgrid as it has several advantages over other WTG topologies. PMSG is fully controllable variable speed topology which uses full power converters (VSC) [2]. It has high power-to weight ratio and does not have reactive power requirement for magnetization, which makes it easier to control.

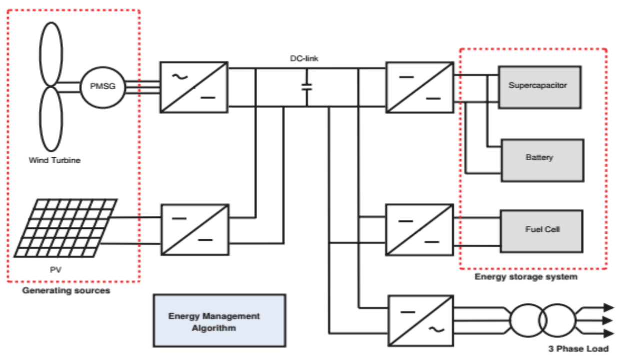


Fig.1.Block schematic of DC microgrid

Out of the different storages available, supercapacitor, fuel cell and battery have certain unique characteristics which complement each other, thus these could form a hybrid energy storage system. Supercapacitor has quick charge-discharge cycles and can be used to supply high amount of power for a short duration of time. Battery is generally used as standby and fuel cell can be used to provide huge amount of energy during high load demand. The following characteristics of DC microgrid have been proposed.

- The DC microgrid must be reliable. Power supply quality should be maintained to a suitable level.
- The DC microgrid must solely utilize renewable en energy resources.
- The DC microgrid must be stable. It should be able to sustain dynamic load conditions and variation in generating power due to intermittent nature of wind and solar energy.
- The system should have least maintenance requirement and minimum cost of installation.
- The DC microgrid should be able to adapt changes even after initial sizing and installation. These may be changes in storage or generation capacity, and changes in the load pattern.

III. NEED FOR ENERGY MANAGEMENT

Energy management algorithm and power converters together provide the necessary control to the system [3]. WTG and photovoltaic panel can be controlled to extract maximum power from the available natural sources. Energy storage system requires management for deciding which storage should be used in case of a hybrid energy storage system, and for deciding the charge-discharge cycles of chosen storage. The DC-link voltage must be maintained constant for balanced flow of energy among the multiple sources and loads, in a DC microgrid. Also, a variation of DC-link voltage would disrupt normal operation of the system and could cause the whole system to collapse [4]. Eq. 1 and Eq. 2 gives the generalized stability criteria for microgrid:

$$\frac{P_m - P_e}{\omega} = J\frac{d\omega}{dt} \quad (1)$$

$$P_{load}(t) \leq P_g(t) \pm P_s(t) \quad (2)$$

Where,
Pm = wind turbine mechanical power (W)
Pe = wind turbine electrical power (W)
J = inertia (kg.m2)
ω = WTG speed (rad/sec)
P_{load}(t) = instantaneous load power (W)
Pg(t) = total instantaneous power of generating sources (W)
Ps(t) = total instantaneous power delivered by ESS (W)
Energy management algorithm (EMA) provides intelligence to the system and controls the functioning of each block of the system. Energy management algorithm has several significant roles:

- Reliability: providing uninterrupted supply to the load.
- Quality: maintaining quality of supply.
- Stability: maintaining DC-link voltage constant.
- Maximum utilization of generating sources using MPPT algorithm.
- Efficient management of storages.

Sizing of generating sources and storages is a prime concern while designing any isolated system, since the load demand should be met completely by generating sources and the ESS, without grid intervention [5]. Inspite of this, sizing is not the fundamental requirement of the micro grid presented here. The micro grid would be able to adapt changes in storage or generation capacity. Battery would play a primary role of supplying voltage to the system. This is also essential for wind turbine generator and photovoltaic panel. Thus, battery should rarely be discharged and would be used as standby. Battery management in this manner leads to increased lifetime of the battery, reduced maintenance, cost and size of the battery.

IV. INTRODUCTION TO FUZZY LOGIC CONTROLLER

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

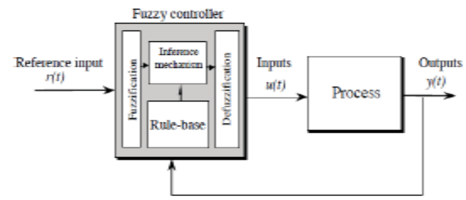


Fig.2. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

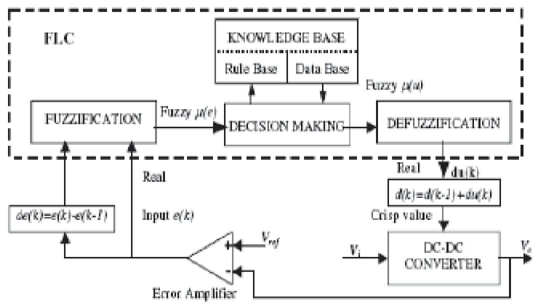
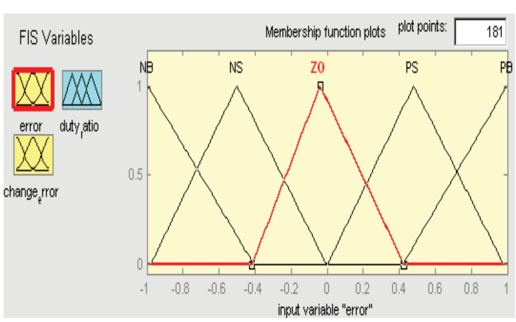


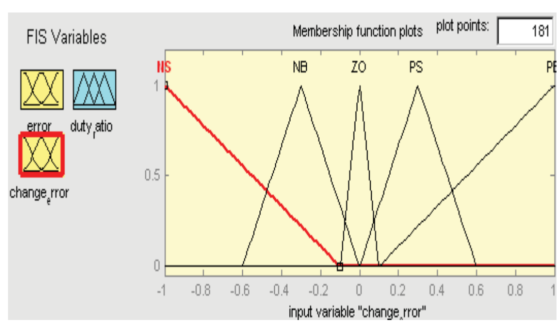
Fig.3. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

A. *Fuzzy Logic Membership Functions:*

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.



The Membership Function plots of error



The Membership Function plots of change error

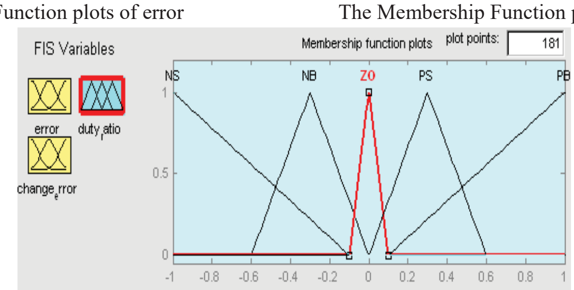


Fig.4. the Membership Function plots of duty ratio

B. Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table II
Table rules for error and change of error

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

V. MATLAB/SIMULATION RESULTS

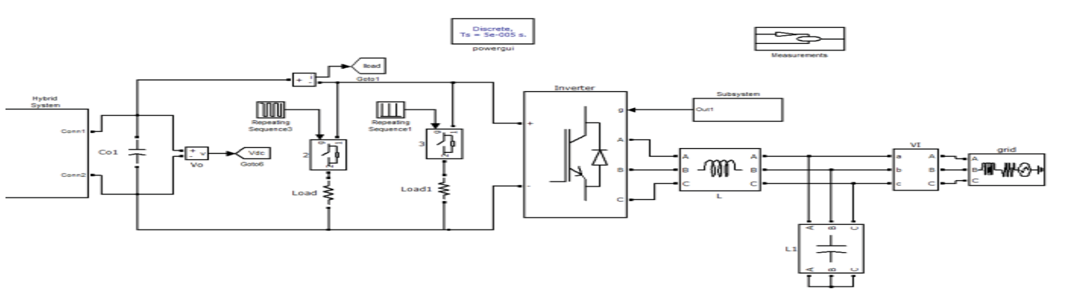


Fig 2 Simulation model for hybrid system connected to microgrid

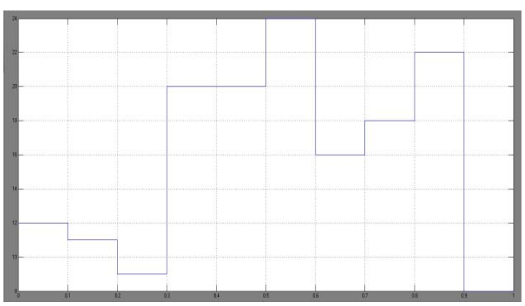


Fig 3Simulation wave form ofWind velocity

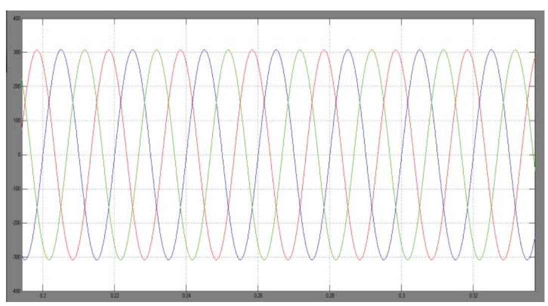


Fig 4 Simulation wave form of wind voltage

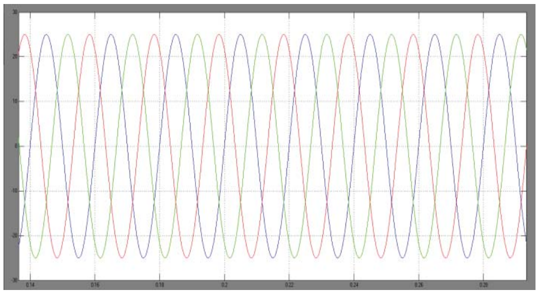


Fig 5 Simulation wave form of wind current

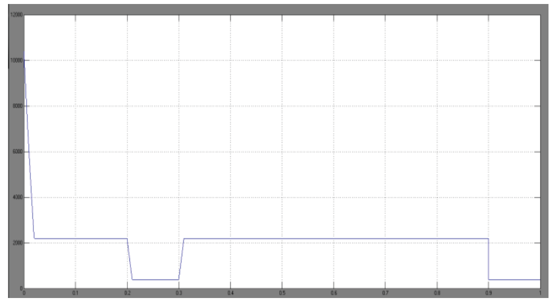


Fig 6 Simulation wave form ofWind speed

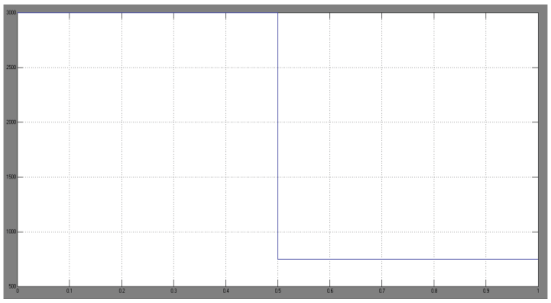


Fig 7 Simulation wave form of Power extracted from PV

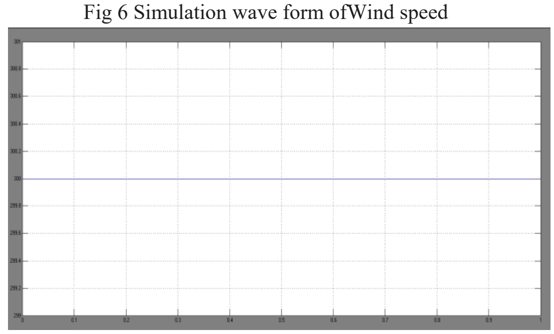


Fig 8 Simulation wave form of DC link voltage

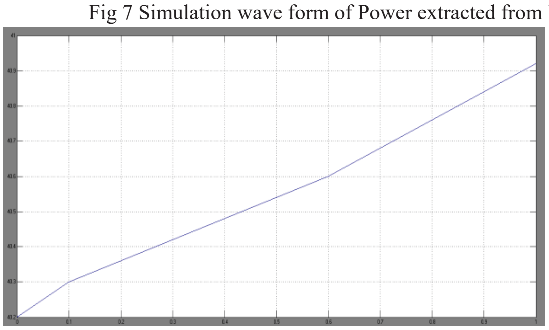


Fig 9 Simulation wave form of State of charge of Super capacitor

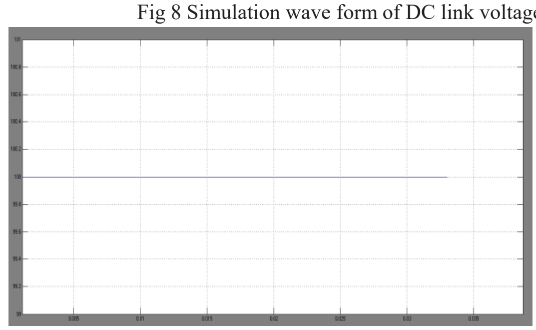


Fig 10 Simulation wave form of Battery voltage

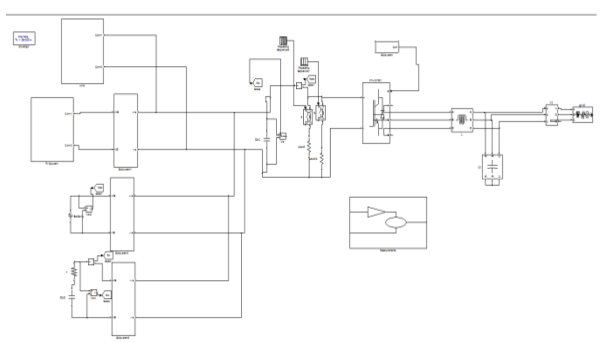


Fig 11 Simulation module for hybrid system connected with fuzzy logic controller

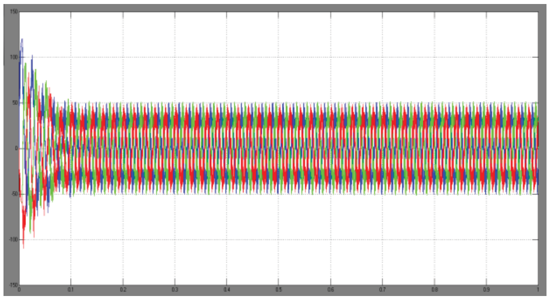


Fig 12Simulation wave form of line currents

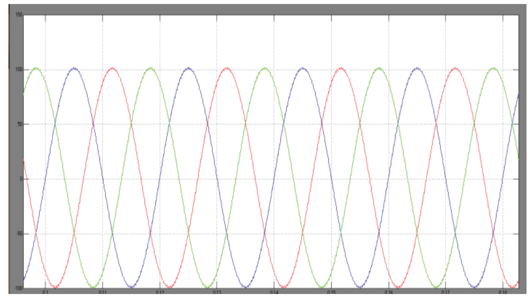


Fig 13Simulation wave form of gird current with fuzzy logic

VI. CONCLUSION

This paper implements the fuzzy logic control to achieve the optimization of an energy management system for the smart grid applications. The sources had been successfully integrates and the respective waveforms are obtained. The optimization control of the smart grid system was done through the implementation of Induction Machine, which comprises of the number of rules. Such type of intelligent management system increases the accuracy of this nonlinear system and it also achieves the optimization and distributed energy generation by its control algorithm. In future the Energy Management System will be implemented by using the artificial neural network and also integrated with some other energy sources.

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