FUZZY LOGIC CONTROLLER BASED ENERGY MANAGEMENT (FLCBEM) FOR A RENEWABLE HYBRID SYSTEM

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Abstract *In recent days, the use of renewable energy like wind and solar energy is necessary to meet the load demand. It is useful for power generation due to their unlimited existence and environmental friendly nature. This paper deals with the energy management of wind and solar hybrid generation system. Photovoltaic (PV) array, wind turbine, and battery storage are connected via a common current source interface multiple-input DC-DC converter. The Fuzzy logic controller ensures the power management between intermittent renewable energy generation, energy storage, and grid.*

In order to obtain the maximum power, variable speed control is employed for the wind turbines, and maximum power point tracking (MPPT) algorithm is applied for the photovoltaic system. The grid interface inverter directs the energy drawn from the wind turbine and PV array into the grid by maintaining common dc voltage constant. Simulation analysis of the entire control scheme is carried out using MATLAB Simulink. The simulation results show the control performance and dynamic behavior of the fuzzy controlled photovoltaic/ wind hybrid system. Keywords—Renewable energy, solar energy, wind energy, hybrid system, energy management, fuzzy logic controller.

1. INTRODUCTION

Renewable energy is generally defined as energy that is collected from resources which are naturally available in nature such as sunlight, wind, tides, waves, etc. To meet the increasing demand of power, hybrid generation system is implemented. Different renewable energy sources are combined to form a hybrid system. In the proposed system, solar and wind are combined to form a hybrid system. Advanced wind turbine and photovoltaic generation technologies have given opportunities for utilizing wind and solar resources for electric power generation. They have unpredictable random behaviors. The Wind/solar integral power supply system is an equitable power supply which makes good use of wind and solar energy. For smooth and efficient power transfer in a hybrid energy system, multiple control strategies are used.

The micro-grid configuration depends on the type of converter used in the system, which is connected between the energy source and the loads. The control algorithm is used to manage the energy between different resources [1]. It is used in a real-time control environment. The Stand-alone hybrid system is used to supply isolated areas interconnected to a weak grid. Energy generation hybrid system is used to meet the power demand depends on the atmospheric condition. The battery is used to store energy, which comprises leadacid batteries connected in series/parallel array. The excessive power can lead to the over-voltage in the dc bus and affects the reliability of the system. To prevent reliability and prevent over-voltage issues during excessive generation, the adaptive control strategy is used [2]. It is archived by monitoring the dc bus voltage and the battery state of charge (SOC).

The energy management system based Multi-agent system (MAS) reduces the computational and communication requirement. It has two agents, middle level and upper-level agent [3]. It is easy to manage and control the system. A least mean mixed norm (LMMN) based adaptive control algorithm is used for the extraction of load current and switching of utility grid side converter (UGC) [7]. It is used to reduce the harmonics content in the grid currents, which improve the power quality of the system. There are different types of controllers used in the hybrid system.

The most commonly used controller is PID controller. Fractional-order proportional-integral-derivative (FOPID) controller is used for the control of frequency deviation in fractional-order power generation and energy storage systems [4]. PID controller is used to improve the transient response and oscillations are reduced at the output response. PID controller is used to reduce the settling time of the frequency deviation [11]. The permanent magnet synchronous generator (PMSG) can be driven by the wind turbine, avoiding a gearbox arrangement that requires regular maintenance. The hybrid wind-driven PMSG- PV system contains a hysteresis controller. It provides a high power factor and high efficiency. When PV and PSMG works it generates the current command to extract maximum power from both the sources [9].

An artificial neural network is used for a PV system and also used for the wind energy conversion system. It is used for gaining maximum performance from renewable energy. The architecture of an ANN includes the input layer, the hidden layer, and the output layer [12]. Radial Basis Function Network (RBFN) based MPPT controller is used to tracking maximum power from both the PV and wind energy systems [5]. The two MPPT algorithms are integrated together to form a modified single RFBN based single MPPT controller.

This reduced the complexity of the system. The adaptive neuro-fuzzy inference system (ANFIS) is faster when compared to other neuro-fuzzy models. To regulate the output power delivered to the grid, ANFIS-based control is applied to the three-phase inverter. It has two controllers, one for active power and another for the reactive power [6].

2. LITERATURE SURVEY

L. Xu and D. Chen, explains Control and operation of a dc microgrid, which can be operated at grid connected or island modes, are investigated in this paper. The dc microgrid consists of a wind turbine, a battery energy storage system, dc loads, and a grid-connected converter system. When the system is grid connected, active power is balanced through the grid supply during normal operation to ensure a constant dc voltage. Automatic power balancing during a grid ac fault is achieved by coordinating the battery energy storage system and the grid converter. To ensure that the system can operate under island conditions, a coordinated strategy for the battery system, wind turbine, and load management, including load shedding, are proposed. simulations are presented to demonstrate the robust operation performance and to validate the proposed control system during various operating conditions, such as variations of wind power generation and load, grid ac faults, and islanding.

Y. Hu, R. Zheng, W. Cao, J. Zhang, S. J. Finney, proposed DC microgrids are becoming popular in low-voltage distribution systems due to the better compatibility with photovoltaic panels, electric vehicles, and dc loads. This paper presents a practical dc microgrid developed in the Water and Energy Research Laboratory (WERL) in the Nanyang University of Technology, Singapore. The coordination control among multiple dc sources and energy storages is implemented using a novel hierarchical control technique. The bus voltage essentially acts as an indicator of supply–demand balance. A wireless control is implemented for the reliable operation of the grid. A reasonable compromise between the maximum power harvest and effective battery management is further enhanced using the coordination control based on a central energy management system. The feasibility and effectiveness of the proposed control strategies have been tested by a dc microgrid in WERL.

L. Xiaonan, J. M. Guerrero, S. Kai, and J. C. Vasquez," described a fault-tolerant structure and its controlling method for a cascaded H-bridge multilevel inverter is introduced. When a fault occurs in one of the modules, the proposed circuit is able to isolate and eliminate the defective module from the whole system. The isolation and elimination is done by four relays in each module and a controlling circuit. This solution makes the system continue the normal operation by means of the remained healthy modules with decreased output voltage level.

Therefore, the whole system failure will be prevented and higher reliability of the inverter will be guaranteed. Principles of operation and the controlling method are presented in this study. Reliability evaluation and comparison of the proposed fault-tolerant structure and the conventional one are considered.

Problem statement

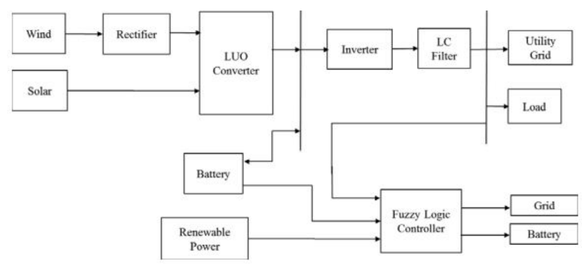
In recent days, the use of renewable energy like wind and solar energy is necessary to meet the load demand. It is useful for power generation due to their unlimited existence and environmental friendly nature. This paper deals with the energy management of wind and solar hybrid generation system. Photovoltaic (PV) array, wind turbine, and battery storage are connected via a common current source interface multiple-input DC-DC converter.

The Fuzzy logic controller ensures the power management between intermittent renewable energy generation, energy storage, and grid. In order to obtain the maximum power, variable speed control is employed for the wind turbines, and maximum power point tracking (MPPT) algorithm is applied for the photovoltaic system. The grid interface inverter directs the energy drawn from the wind turbine and PV array into the grid by maintaining common dc voltage constant. Simulation analysis of the entire control scheme is carried out using MATLAB Simulink. The simulation results show the control performance and dynamic behavior of the fuzzy controlled photovoltaic/ wind hybrid system.

3. FUZZY LOGIC CONTROLLER BASED ENERGY MANAGEMENT

The proposed Fuzzy logic controller based energy management for the renewable hybrid system consists of photovoltaic (PV) array, wind turbine, multiple input DC/DC converter, and PWM inverter. The block diagram of the proposed FLC controlled PV/ Wind hybrid generation system is shown in figure .

The photovoltaic cell transforms the energy in sunlight to electricity. Photovoltaic cells are connected in series or parallel to produce higher voltages, current and power levels. The current obtained from the PV system is direct current (DC). No atmosphere emission causes a greenhouse effect when solar panels are used to produce electricity. Electricity from solar power is very essential to move to clean energy production. MPPT technique is used to track maximum power from the PV system. The wind turbine generator (WTG) is used to generate current from the wind. A wind turbine is used to convert the kinetic energy into mechanical energy. Using generator mechanical energy is converted into electrical energy. The current obtained from wind turbine is alternating current (AC). The output of wind turbine is directed to rectifier, which converts AC to DC.

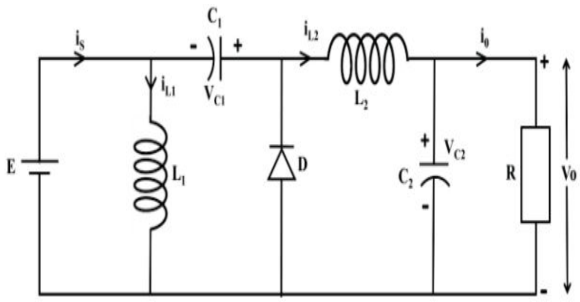


Fuzzy Logic Controller based Energy Management

The power from PV and wind are fed as input to the multi-input DC-DC converter. Here Luo converter is used as DC-DC Converter. It is used to step-up the voltage at the output side. Luo converter is used to obtain high voltage gain and to improve the efficiency of the system. Figure 2 shows the circuit diagram of Luo converter. The output of the Luo converter is DC and it is converted to AC by means of Pulse Width Modulation (PWM) Inverter. PWM technique used in the inverter gives steady output voltage irrespective of the load. It controls the amount of power delivered to the load without any dissipation. LC filter is used to reduce harmonics and ripples, which leads to get pure output signal. The output signal is directed to utility grid, from where can be used for residential and industrial applications.

The Fuzzy logic controller ensures the power management between renewable energy, battery and grid. The fuzzy logic controller is designed for the charging and discharging of a lead-acid battery. FLC controllers involves fuzzification, inference mechanism and defuzzification. The reference load is compared with the renewable generation to produce the error signal which is used as input to the FLC.

The input of the FLC is converted to the membership function. The rule base is combined with the membership function. It identifies the error and rectifies it, giving the required output. The Mamdani Fuzzy model is used in the proposed hybrid system.

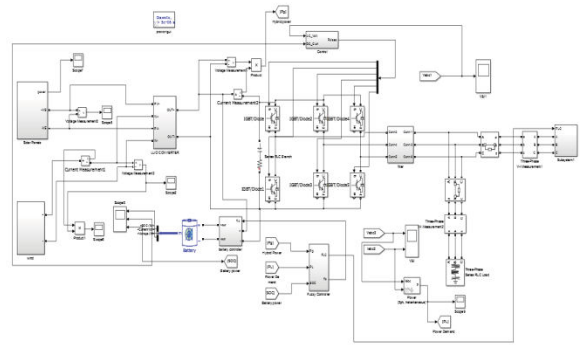


Circuit Diagram of Luo Converter

4. SIMULATION AND RESULTS

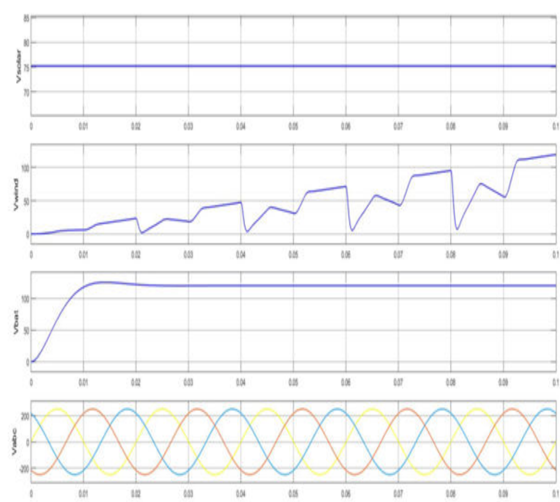
The circuit behavior of the proposed fuzzy controlled solar wind hybrid system is analyzed using MATLAB/Simulink software. Figure 3 shows the simulation model of the fuzzy controlled hybrid system. The simulation model of the proposed system consists of a PV module, wind module, battery, Luo converter, and fuzzy logic controller. The photovoltaic system generates a current in DC form. Maximum power can be obtained from PV by using MPPT technique. The output of wind turbine is in AC form. A rectifier is used to convert AC to DC. The power from wind and PV is fed as input to the DC-DC Luo converter.

Now the output of the Luo converter is DC, which is converted to AC by means of PWM inverter. The ripples and harmonics in the output signal is reduced by LC filter. The output is fed to utility grid or AC loads. The power management between renewable energy generation, energy storage, and grid are integrated by fuzzy logic controller. The steps involved in FLC controller are fuzzification, inferencing and defuzzification. The proposed FLC is designed using Mamdani model. The power generation (Pg), load power (PL) and state of charge (SOC) of battery are given as input to FLC as shown in figures below



Simulation Model of the Fuzzy Controlled Hybrid System

An Energy storage system, battery is also connected to the main DC bus for continuous power supply. The solar module generates a DC voltage of 75V. The output voltage generated by wind turbine is 110V. The battery is charged to 120 V during the power generation. The solar and wind voltages are integrated by Luo converter. The Luo converted boost the DC voltage and fed it to inverter for converting DC to AC. The final AC voltage generated by the proposed fuzzy controlled hybrid system is 250V. The simulation results of the proposed fuzzy controlled solar/ wind hybrid system are shown in figures



a) solar voltage b) wind voltage c) battery voltage d) out put voltage

5. CONCLUSIONS

In this paper, a fuzzy logic controller based solar/ wind hybrid system is proposed for energy management. The effectiveness of the MPPT algorithm is obtained from the proposed hybrid system. DC link voltage is maintained and regulated using the Luo converter. The Luo converter has the potentiality to remove the high-frequency current harmonics in the wind generator. It improves the voltage gain and power density. Using the Fuzzy logic controller (FLC) in the hybrid system reduces the harmonics and the dissipation of power is low. Thus, the performance of the hybrid system increases system reliability, power availability, quality, and operational efficiency. Simulation results obtained from Matlab/Simulink shows that this proposed hybrid system becomes a viable way to produce uninterrupted electrical energy, especially in rural areas.

REFERENCES

[1] Adel Merabet, Khandker Tawfique Ahmed, Hussein Ibrahim, Rachid Beguenane, and Amer Ghias, "Energy Management and Control System for Laboratory Scale Microgrid based Wind-PV-Battery", IEEE Transactions on Sustainable Energy, vol. 8, no. 1, pp. 145-154, Jan 2017.

[2] Janviere Umuhoza, Yuzhi Zhang, Shuang Zhao and H.Alan Mantooth, "An Adaptive Control Strategy for Power Balance and the Intermittency Mitigation in Battery-PV Energy System at Residential DC Microgrid Level", IEEE Applied Power Electronics Conference and Exposition, pp. 1341-1345, Mar 2017.

[3] Junzhi Yu, Chunxia Dou and Xinbin Li, "MAS-Based Energy Management Strategies for a Hybrid Energy Generation System", IEEE Transactions on Industrial Electronics, vol. 63, no. 6, pp. 3756- 3764, Jun 2016.

[4] Komeil Nosrati, Hamid Reza Mansouri and Hossein Saboori, "Fractional-order PID controller design of frequency deviation in a hybrid renewable energy generation and storage system", IET Journals, CIRED, vol. 17, no. 1, pp. 1148-1152, Oct 2017.

[5] K. Kumar, N. Ramesh Babu, and K. R Prabhu, "Design and Analysis of RBFN-Based Single MPPT Controller for Hybrid Solar and Wind Energy system", IEEE Access, vol. 5, pp. 15308-15317, Aug 2017.

[6] Pablo Garcia, Carlos Andres Garcia, Luis M. Fernandez, Francisco Llorens and Francisco Jurado, "ANFIS-Based Control of a Grid- Connected Hybrid System Integrating Renewable Energies, Hydrogen and Batteries", IEEE Transactions on Industrial Informatics, vol. 10, no. 2, pp. 1107-1117, May 2014.

[7] Farheen Chishti, Shadab Murshid and Bhim Singh, "LMMN Based Adaptive Control for Power Quality Improvement of Grid Intertie Wind-PV System", IEEE Transactions on Industrial Informatics, vol.15, no.9, pp. 4900-4912, Sep 2019.

[8] E. Jayashree and G. Uma, "Analysis, design and control of zerovoltage switching quasi-resonant-positive output super lift Luo converter", IET Power Electronics, vol. 4, no. 1, pp. 21–28, Jan 2011.

[9] M. M. Rajan Singaravel and S. Arul Daniel, "MPPT with Single DCDC Converter and Inverter for Grid Connected Hybrid Wind-Driven PMSG-PV System", IEEE Transactions on Industrial Electronics, vol. 62, no. 8, pp. 4849-4857, Aug 2015.

[10] S. Merlin Joys Mary, S. Rajesh Babu, and D. Prince Winston, "Fuzzy Logic Based Control of a Grid Connected Hybrid Renewable Energy Sources", International Journal of Scientific & Engineering Research, vol. 5, no. 4, pp. 1043-1048, Apr 2014.

[11] Anurekha Nayak and Manoj Kumar Maharana, "Tuning of PID Controller to Maintain Load Frequency for Hybrid Power System", International Conference on Innovative Mechanisms for Industry Applications, pp. 24-28, July 2017.

[12] Aditi, Dr. Ashok Kumar Pandey, "A Review Paper on Hybrid Power System with different Controllers and Tracking Method", International Journal of Engineering Research & Technology, vol. 5, no. 1, pp. 6-9, Jan 2016.