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FUZZY LOGIC CONTROL BASED GRID INTEGRATION OF HYBRID ENERGY SYSTEM

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Abstract:

In this project, grid integration of a hybrid Photovoltaic (PV) and Doubly Fed Induction Generator (DFIG) based wind energy system is proposed. An intelligent controller was developed to generate maximum power from the above renewable energy sources and to solve the grid integration issue while improving the generated power quality. This paper has three major parts. The first pertains the design of a fuzzy logic controller to maximize power point tracking of photovoltaic power system and to generate maximum power under various weather conditions. The second part explains the design of a fuzzy logic controller for DFIG based wind energy conversion system to improve the system performance. The third part integrates the above two renewable energy sources and develop a hybrid fuzzy logic controller for solving grid integration issues and improving the power quality. standard for showing the effectiveness of the system. The fuzzy controller has been developed for maximum power point tracking for 10 KW photovoltaic power systems and analysed with various weather conditions.

Keywords: PV, DFIG, Grid, Fuzzy, Power Quality, Hybrid

1. INTRODUCTION

Due to the deficiency of inorganic resources and amplification of environmental pollution, nations all over the biosphere pays more care to the growth of renewable energy. As Solar Photovoltaic and Wind power play a significant role in renewable energy, there has been increasing interest in the analysis of PV and wind power in power system. The solar photovoltaic based power generation is playing a major role to meet consumer demand. Many Researchers have developed advanced configurations of PV. The main advantage of solar photovoltaic power is its ability of generating electricity from sunlight without environmental collateral damage, less maintenance, no noise and 15 - 25 % efficiency. A common arrangement for large wind turbines is based on the DFIG with back- to-back converters between the AC grid and the rotor windings. The main advantage of the DFIG is its ability to change operational speed with only 20 - 30 % of the generated power passing through the power converters. The conventional controllers do not perform well in a DFIG system. Therefore, in this paper, fuzzy logic controller has been designed for DFIG control systems and is based on rotor current vector control with d-q decoupling. In a characteristic hybrid energy system, the primary energy resource is at a lower availability level while the subordinate one is usually at a higher availability level. For the occasion, in the winter seasons, the wind speed is generally highly available while the solar radiation is at its lowest intensity. During the night hours, sunlight cannot be used for power generation, whereas the wind energy can be successfully used. Hence, simultaneous utilization of multiple energy resources significantly improves to meet consumer load demands. In this study, the objective function is to improve the power quality of the hybrid system as a function of PV and Wind parameters. To achieve this fuzzy logic controller has been developed for hybrid PV and DFIG wind energy system and synchronized with power grid for improving the power quality.

2.MPPT Controller for PV System

The Maximum power point tracking algorithm is playing a very essential role in renewable energy sources for generating maximum power at various weather conditions. The solar photovoltaic system generates electricity with respect to falling of sunlight on modules. The sunlight irradiance is nonlinear characteristics that intermittent availability cause solar PV modules unable to generate maximum power. In literate survey, different types of MPPT controllers based on Perturb and Observe (P&O) algorithm Incremental Conductance algorithm, Feedback voltage and current, feedback power algorithm etc are designed and verified. In this paper, the fuzzy logic controller based on MPPT algorithm has been developed and simulated in MATLAB environment and compared with conventional controller. The boost converter-based PV MPPT system has been developed in MATLAB as shown in fig 1.

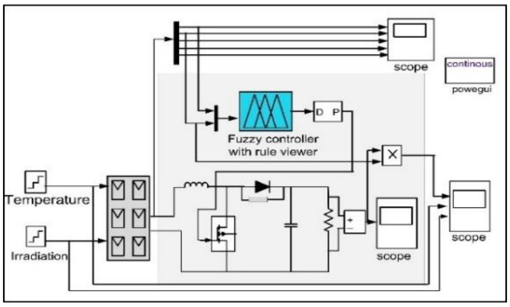

Fig. 1: Fuzzy based MPPT controller simulation model for 10KW PV system Design of Fuzzy Logic Controller

The proposed fuzzy control-based PV MPPT controller has been simulated at various climatic conditions such as various irradiance and various temperature ranges. To carry out the simulation the different irradiance values like 250 W/m^2, 500 W/m^2,750 W/m^2 and 1000 W/m^2 are considered. The irradiance of 250 W/m^2 is set during the period 0 to 0.05 sec. The PV boost converter voltage and current waveform are presented in fig 2. The PV output power waveform has been presented in fig 3.

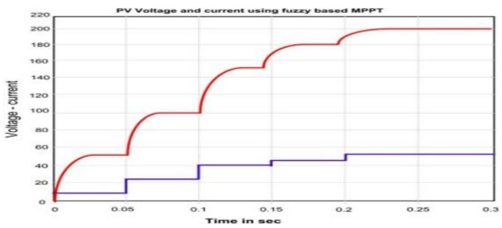

Fig. 2: Fuzzy based MPPT controller boost converter voltage and current waveform under various irradiance and temperature

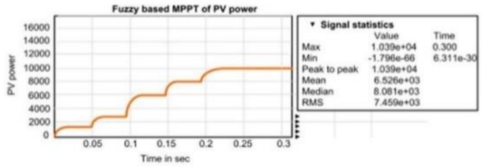

Fig. 3: Fuzzy based MPPT controller PV output power waveform under various weather conditions

3.Fuzzy Based Rotor Current Control For DFIG

The doubly-fed induction generator (DFIG) system is a widespread system in which the power electronic interface controls the rotor currents to achieve the variable speed necessary for maximum energy capture in variable winds Because the power electronic only processes the rotor power, typically less than 25% of the overall output power, the DFIG offers the advantages of speed control with reduced cost and power losses. The fuzzy logic controller has been developed for DFIG rotor current controller for improving the system power quality as shown in fig 4 and fig 5.

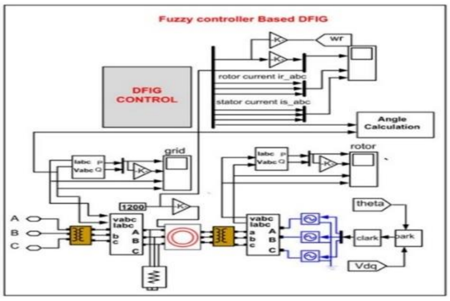

Fig 4: A simulation model of fuzzy controller based DFIG based wind energy conversion system

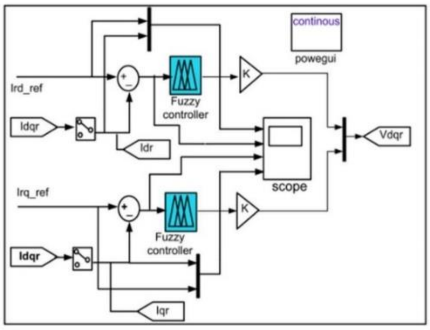

Fig. 5: Fuzzy based Rotor Current controller

The DFIG rotor currents are classified into two types such as direct axis current (Id) and quadrature axis current (Iq). Therefore, fuzzy logic controller has been developed separately for controlling currents Id and Iq.

Therefore, fuzzy logic controller has been developed separately for controlling currents Id and Iq as shown in fig 6. The fuzzy input and output membership function are developed by using trapezoidal function, then the centroid is used for defuzzification method.

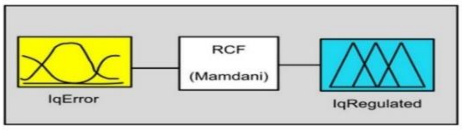

Fig.6: Fuzzy based Rotor Current controller

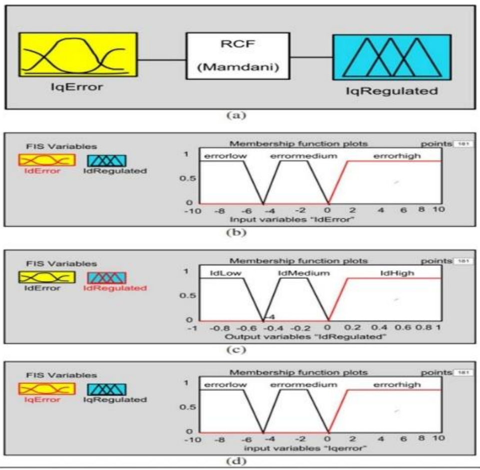

Fig. 7: (a) Design of Fuzzy Controller for Iq regulator (b) Input Membership function for Id regulator (c) Output Membership function for Id regulator (d) Input Membership function for Iq regulator

The fuzzy controller has been developed for direct axis current regulation and has direct axis current as an input membership function as shown in fig (7 b), regulated direct axis current as an output membership function as shown in fig (7 c). Also, the fuzzy controller has been developed for quadrature axis current regulation and has one input and one output membership functions such as quadrature axis current as an input membership function as shown in fig (7 d).

4.Fuzzy Based Voltage Source Converter Controller

The complete simulation model of hybrid PV and DFIG based wind energy system for the grid integration using fuzzy controller is presented in the figure 8. The synchronizing of renewable energy source into the power grid has many challenges such as to match two AC source voltage profile, frequency profile and phase angle.

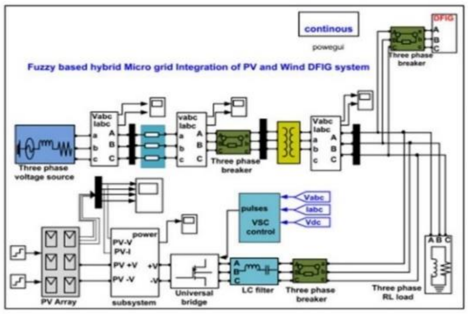

Fig. 8: A simulation model of hybrid PV / DFIG based grid integration system using fuzzy controller

The voltage source converter controller performs a major role in solving the above said problems and is presented as shown in fig 8. The voltage source converter controller has three major parts such as a Phase lock loop, Voltage regulator and current regulator. A phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal as shown in fig 10. Voltage regulation is to provide real-time control of voltage fluctuation, sag, surge and also to control other power quality issues such as spikes and EMI/RFI electrical noises. It uses a MOSFET regulator generating pulse width modulated (PWM) AC voltage at high switching frequency as shown fig 11. The current regulator will control the inverter operation of power flow.

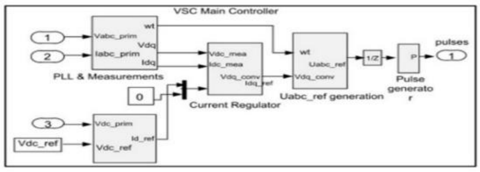

Fig. 9: Design of voltage source converters controller

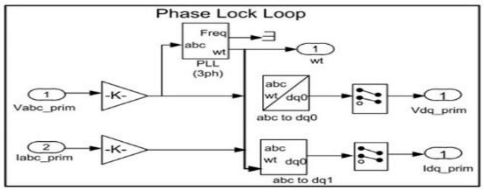

Fig. 10: Design of Phase lock loop

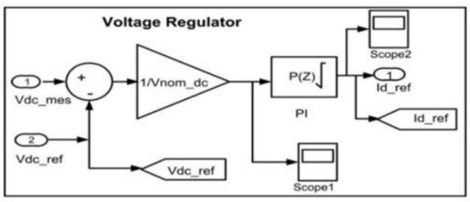

Fig. 11: Design of voltage regulator for grid integration of PV system

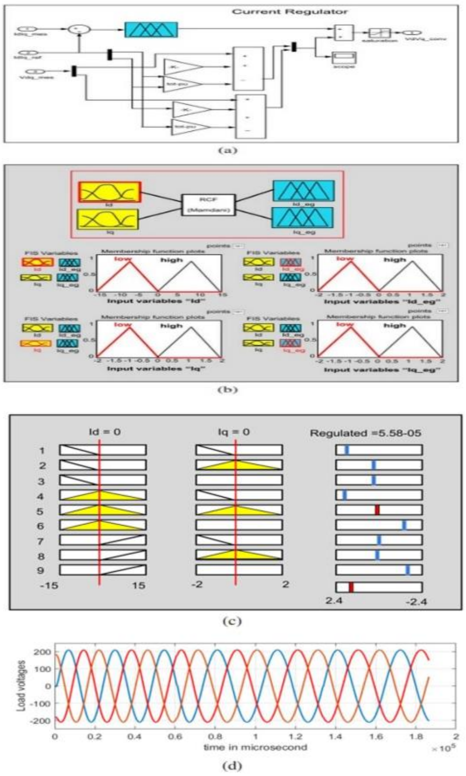

Fig. 12: (a) Design of current regulator for grid integration of PV system.; (b) Fuzzy controller membership function and its rules for current regulator of VSC.; (c) Fuzzy rules for current regulator.; (d) Voltage waveform of grid integrated hybrid PV / DFIG power system.

When the Ids current is positive the inverter generates the active power and when Iq positive the inverter absorbs the reactive power. In this paper the fuzzy controller has been developed for current regulator as shown in fig (12 a). The fuzzy logic controller has been designed for a current regulator for VSC. The fuzzy controller has two input signals and two output signals such as input (direct axis and quadrature axis current) output (regulated direct axis and quadrature axis current) shown in fig (12 b). The fuzzy membership function is designed based on the triangle method for fuzzification process and used centroid method for defuzzification process the fuzzy rules are represented in fig (12 c). The direct axis current value is positive converter deliver the active power to Microgrid and quadrature axis current value is positive converter that absorb the reactive power from Microgrid.

The proposed fuzzy control has been applied hybrid PV /Wind with Microgrid and its voltage source converter. The fuzzy output signal is fed into the feed forward current regulator of converter based on the input signal of PWM controller generates triggering pulses of inverter for synchronize into microgrid. Figure (12 d) and figure (13 a) presents Voltage and Current Waveform of fuzzy controller-based grid integration of Hybrid PV- DFIG Power system respectively.

The resultant load current is in phase with load voltage as presented in figure (13 b). Finally, the total harmonic distortion values are measured and presented in figures (13 c) and (13 d) respectively. The THD values for the proposed system for load voltage is 0.04% and the load current is 3.89%. Also, the performance of the hybrid system is also analyzed using conventional PI controller.

The total harmonic distortion values in this case are measured and presented as shown in figures and respectively. The THD values for the proposed system for load voltage is 0.04% and the load current is 3.89%. The above observed THD values are compared with IEEE 1547 standard. Based on the standard value of grid integration of renewable energy source THD values less than 5% is acceptable. The proposed system THD values are very less than IEEE 1547 standard.

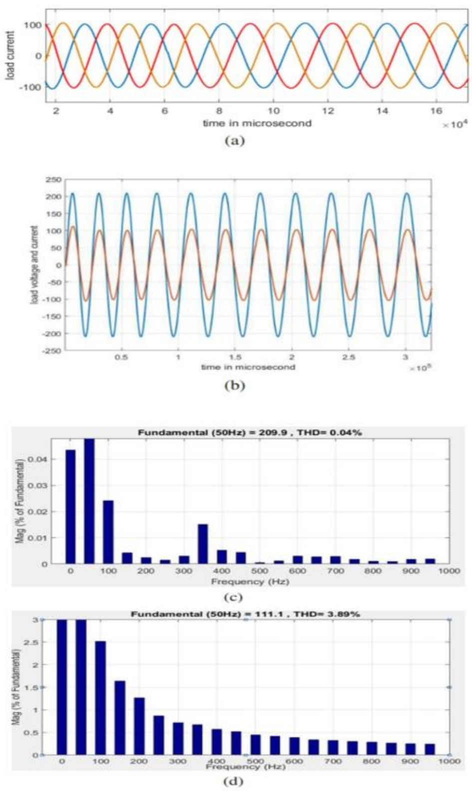

Fig. 13: (a) Current waveform of grid integrated hybrid PV / DFIG power system (b) Current in phase with voltage waveform (c) Voltage THD of hybrid system with fuzzy controller (d) Current THD of hybrid system with fuzzy controller

CONCLUSION

This paper, discussed the modelling of hybrid solar PV system and DFIG based wind energy system. The fuzzy controller has been developed for maximum power point tracking for 10 KW photovoltaic power systems and analysed its performance under various weather conditions. The DFIG wind energy system has been developed in MATLAB environment and the designed fuzzy logic controller for rotor current controller. The proposed grid integration of hybrid PV and DFIG system has been simulated in MATLAB environment and hence developed a fuzzy controller for grid synchronizing of hybrid system into the power grid. The obtained results are compared with conventional controller and tabulated as shown in table 2. Also, the proposed model simulation results are analysed with different operating conditions and evaluated with IEEE 1547 standard for proving the effectiveness on the system.

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