Fuzzy Logic Based Direct Power Control Method for PV Inverter of Grid-Tied AC Microgrid

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ABSTRACT

In recent years, renewable energy sources, specifically solar power systems, have developed rapidly owing to their technological maturity and cost effectiveness. However, its grid integration deteriorates frequency stability because of insufficient rotating masses and inertial response. Hence, a synchro-inverter, which is an inverter that mimics the operation of a synchronous generator, is crucial to interface solar power in a micro-grid. The present work investigates a real time implementation of a photovoltaic grid connected chain, based on fuzzy logic MPPT controller (FLC). The DC-link voltage controller is based on normal stability theory ensuring best performance for both transient and steady state, whereas, the hysteresis current controllers of the inverter allow a quasi-total transit of the maximum extracted PV power to the grid under unity power factor operation. The obtained results via Matlab-Simulink simulation are confirmed through experiment proving the effectiveness of the used control method.

Keyword: *Photovoltaic, MPPT, Fuzzy logic controller (FLC), synchro-inverter, renewable energy system (RES), micro-grid stability.*

1. INTRODUCTION

The demand for global electricity has increased significantly in the past decade. To fulfil electricity demand, many grid operators from different countries have transitioned toward renewable energy sources (RESs) owing to their cost effectiveness and environmental friendliness. Among RESs, solar power systems are popular because of their cost effectiveness, sustainability, and technological maturity. As the power system evolves from centralized generation from oil and gas to distributed generation from RESs, the involvement of power-electronics-based converters is indispensable for ensuring power system stability. Unlike the conventional synchronous machine (SM), solar inverters in grid-connected solar power systems present disadvantages of zero inertial response, fast-changing behaviour, and insufficient rotating masses. The static structure of a converter deteriorates the frequency instability because of its inability to inject or absorb active power from the rotating inertia based on the power demand. If a sudden load change that causes power imbalance occurs, then the grid alternating current (AC) frequency will deviate from its nominal operating value. This will affect the power supply quality and result in power supply discontinuity. The current solution for controlling the solar power system is to inject the maximum power into the power grid; however, this method is only suitable when solar power contributes insignificantly to the grid power capacity. Maximum power point tracking (MPPT) can be performed to extract the maximum power from a solar array; however, it does not contribute to the system inertia. Such a problem can be mitigated using large-scale grid power. In addition to frequency regulation via active power, reactive power manipulation is performed to regulate the grid voltage for the grid integration of RESs with low voltage ride through capability.

To alleviate the aforementioned problems, an inverter that mimics the inertial response of an SM must be used to integrate a solar power system with a power grid. This type of inverter is known as a synchro-inverter or virtual synchronous generator, which is based on virtual inertia (VI) emulation. A synchro-inverter can stabilize the operating frequency when a sudden load change occurs by altering the electric torque (T) and active power (P). This emulated T is the synthetic inertia in the synchro-inverter. The main contributions of this study are as follows:

(1) A novel digitalized FLC framework is designed for a synchro-inverter controller to stabilize the operating frequency of a grid-connected solar power system under sudden load changes.

(2) The solar power system in a real-world environment with varying irradiance and temperature is considered for the design of the FLC framework.

2. LITERATURE REVIEW

1) "Fuzzy Logic based Battery Energy Storage System (Bess) for the Improvement in Stability of an Islanded Micro-Grid" by Priya Kumari, Ashutosh Pandey, D. Sivakumar, S. Balaji in International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8, Issue-1S4, June 2019. In this paper they discussed about, the dynamic power and the responsive control of power of a (BESS) Battery energy storage system using the fuzzy logic control to keep up recurrence & the constancy of voltage of the Islanded Micro-grid. In the primary extent of the introduced paper is to consider the adequacy of the Battery energy storage system controller in perspective on fluctuations of recurrence/voltage exposed to an aggravation happening in the islanded micro-grid. In the islanded micro-grid framework, the power is created from sustainable power source assets (RESs), i.e., sun & hydro based PV. The utilization of these spotless vitality sources has turned into the principle issue, visualizing the yield control vulnerabilities from renewable energy sources. Further, power vulnerability elevates control quality issues and prompts control disappointment. To beat such issues, the proposed fuzzy logic controller (FLC) approach is connected to BESS controller to advance the stability of the islanded Micro-grid. The simulation result represents that both the control approaches permit the dynamic dependability of the micro-grid and the maintenance of recurrence and the voltage inside satisfactory reaches. Therefore, the proposed BESS fuzzy logic control is not as much prone to vulnerability than the BESS robust control.

2) "Fuzzy Logic based Energy Management System Design for AC and DC Microgrid" by Prathyush M, Dr. Jasmin. E A in International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 8 Issue 10, October-2019. In this paper they said that, fuzzy logic control based energy management system for dc and ac micro grids. AC micro grid includes renewable energy sources connected to ac load and storage facility. Main intention of the design is to decrease the grid power profile deviations while preserving battery state of charge within the acceptable boundary. As a replacement for forecasting method we uses energy rate of change concept also a comparison with other method is introduced at simulation level. In addition to the above fuel cell is present in case of dc micro grid. Main target is to enhance the characteristics of battery, fuzzy logic control supervises the preferred state of charge. Modelling, analysis and control are done in matlab simulink platform.

3) "Fuzzy Logic-Based Energy Management System Design for Residential Grid-Connected Micro grids" by Diego Arcos-Aviles, Julio Pascual, Luis Marroyo, Pablo Sanchis & Francesc Guinjoan in © 2017 IEEE DOI 10.1109/TSG.2016.2555245, IEEE. In this paper they said that, the design of a low complexity Fuzzy Logic Controller of only 25-rules to be embedded in an Energy Management System for a residential grid-connected micro grid including Renewable Energy Sources and storage capability. The system assumes that neither the renewable generation nor the load demand is controllable. The main goal of the design is to minimize the grid power profile fluctuations while keeping the Battery State of Charge within secure limits. Instead of using forecasting-based methods, the proposed approach uses both the micro grid energy rate-of-change and the battery SOC to increase, decrease or maintain the power delivered/absorbed by the mains. The controller design parameters (membership functions and rule-base) are adjusted to optimize a pre-defined set of quality criteria of the micro grid behaviour. A comparison with other proposals seeking the

same goal is presented at simulation level, whereas the features of the proposed design are experimentally tested on a real residential micro grid implemented at the Public University of Navarre.

3. METHODOLOGY

A. Solar cell modeling

Solar based cells made of a p-n junction created in thin layer of semiconductors, whose electrical qualities vary practically very little from a diode represented by the condition of Shockley. Therefore the least complex comparable circuit of a solar based cell is a present source in parallel with a diode as appeared in Fig. 2. So the way toward equation.

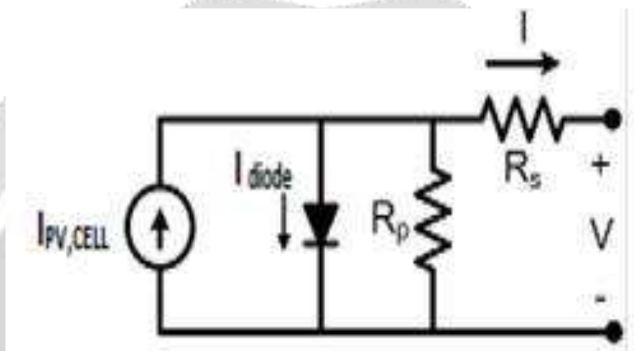

Fig.2: Equivalent Model of Solar Cell

$$I = I_{PV,CELL} - I_{DIODE} \quad (1)$$

$$I = I_{PV,CELL} - I_{O,CELL}[\exp\left(\frac{q+v}{\propto+k+T}\right) - 1] \quad (2)$$

Where:

$I_{PV,CELL}$ = Current generated by the incident light.

I_{DIODE} = Shockley diode.

$I_{O,CELL}$ = Reverse Saturation current.

q = Electron charge (1.6021×10^{-19}).

k = Boltzmann constant (1.3805×10^{-23}).

T = PN junction diode Temperature.

$\propto$ = Ideally constant (between 1 to 2).

B. MPPT

This area covers the operation of "Maximum Power Point Tracking" using P & O as utilized as a part of solar electric charge controllers. A MPPT or maximum power point tracker is an electronic DC to DC converter that improves the match between the solar based group (PV panels), and the battery bank or utility grid. Fundamentally, they change over a higher voltage DC output from solar panels down to the lower voltage anticipated that would charge batteries. There are numerous calculation for MPPT. I utilized the power under quick differing climatic conditions however it still exceptionally mainstream and basic than some other strategy. With the goal that the state of the output is Square PWM wave. In this paper utilized this on the grounds that on the off chance that we pass this sort of flag in a low pass channel than we get sine wave which matches to the network.

C. FUZZY LOGIC

The system variables and a rule table which depend on the variables are described for the control algorithm. The buck converter output voltage is controlled by changing the switching duty cycle. The system error is defined as a difference between the reference voltage and measured output voltage value [2]. For the system; *r(k)* is the reference voltage and *y(k)* is the measured output voltage values then the error voltage is calculated using Equation.

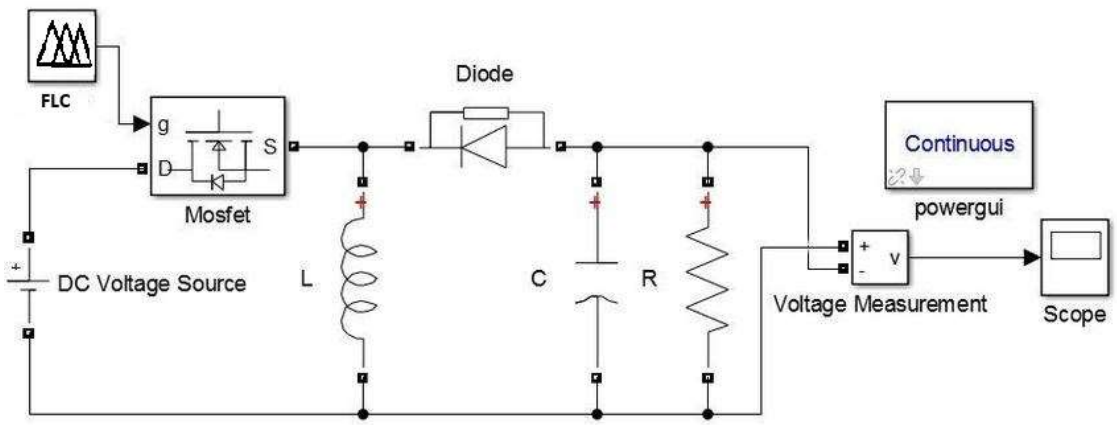

Fig.4: Fuzzy logic control with boost converter

4. CONCLUSIONS

Herein, a novel FLC-based framework was proposed to control a synchro-inverter in a grid connected solar power system under dynamic weather conditions. The performance of the FLC-based synchro-inverter was optimal even under sudden load changes or varying irradiances and temperatures.

In this work, a real time implementation of a small scale grid connected photovoltaic system was presented. The various control techniques have been tested through simulation and validated with experiment, providing similar performances. The fuzzy logic based MPPT controller provides a notable efficiency, since it permits to track the optimum power quickly despite the atmosphere condition changing. Besides, the regulation of the DC link voltage based on normal theory, and the current control of the VS inverter has permitted an operation of the system under a unit power factor.

5. REFERENCES

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