Fuzzy Logic Controlled Hierarchical Power Management Scheme for A Solid-State Transformer (SST) Interfaced DC Micro Grid

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Abstract

The system integration of an advanced, integrated solid-state transformer (SST) micro-grid system is examined and, for the first time, used in this project. A power management strategy is required for this system in order to allow operating in islanding mode operation, SST-enabled operations, as well as the smooth switching between two modes. The recommended power management technique includes three levels of control: First control is for the local controller, second control for recovering the bus voltage of the dc micro grid, and third control for controlling battery state of charge.

This project delves into the proposed system design and control methodologies, as well as constructing a micro grid simulation to test the system's performance. All three regulating processes are controlled using the fuzzy logic technique in this project. For all three controlling operations in this project, the fuzzy logic control technique is applied. This project delves into the proposed system design and control methodologies, as well as constructing a micro grid simulation to test the system's performance. For all three controlling operations in this project, the fuzzy logic control technique is applied. This project delves into the proposed system design and control methodologies, as well as constructing a micro grid simulation to test the system's performance. All three of the above are controlled in this project using fuzzy logic control.

Keywords. Power management, fuzzy logic controller, solid state transformer (SST), Dc-microgrid.

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1. INTRODUCTION

Distributed generation (DG) is becoming more and more popular as a result of the decade-long rapid advancement of renewable energy technology [1]. Offering a continuous and stable supply of energy is difficult since the output power of distributed renewable resources (DRER) electricity depends on a number of uncontrollable natural elements, such as solar irradiance and wind speed.

Finding qualified DG electricity is a major problem for engineers, and micro grids seem to be a workable solution. The micro grid is composed of power electronic- based distributed renewable energy resources [DRER] and distributed energy storage devices [DESD], which can operate in island mode in rural regions and offer reliable and adaptable power to the conventional grid. Based on its architecture, micro grids fall into two kinds [2]. The a.c micro grid is the first, while the D.C micro grid is the second.

The dc micro grid does have the following benefits over the ac micro grid:

1. Hybrid systems that feed into a micro grid from a variety of power sources are simpler to build and may be expanded as needed.
2. They are more efficient since many power conversion steps are eliminated and filter requirements are reduced.
3. Renewable resources are easy to incorporate, particularly for Photovoltaic cell, fuel cell, battery, super capacitors, and so on.
4. They will be able to directly send power dc loads such as projectors, LEDs, and electric vehicles.

The present dc micro grid, on the other hand, can only connect to the distribution system via a big and bulky line frequency transformer and rectifier, which takes up too much space. Furthermore, grid support features such as harmonic filtering, VAR compensation and other grid support functions may not be available when passive transformer interfaces with the distribution system. A research focus is maintained on designing a much smaller and active grid interconnect to allow a more efficient dc micro grid system. The dc micro grid additionally encounters various issues in terms of power management, to name a few:

1. How to provide the loads or the utility with long-term and stable power.
2. How to regulate every element with in micro grid system intelligently; and
3. How to make the most of distributed renewable energy resources (DRER) and distributed energy storage system devices (DESD) in light of their character peculiarities.

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• In this study, SST [3] is combined with a fuzzy logic controller to maintain a steady voltage profile and increase system stability.

To regulate the micro grid, a combination of multiple techniques has been devised. Artificial intelligence (AI) has also been used by certain researchers as a major or secondary tool to operate and manage micro grids. Fuzzy logic-based control is the most common application of all AI systems, notably among power system engineers and the industrial electronics application industry. In many areas of science and engineering, fuzzy logic is a simple and useful tool rather than classical Boolean logic. The researchers favor a fuzzy logic-based control approach [4,5].

Because it has various advantages such as dependability, precision, simplicity, and ease of implementation. It is also utilized as a trustworthy tool for power system management, motor speed control, aeronautical control, power conversion control, and photovoltaic systems (PV) system, Maximum Power Point Tracking (MPPT) algorithm, among other things [6,7]. Particle swarm optimization (PSO) technique, multi-agent-based control, modified hill-climbing, fuzzy logic control, methods, and other current noteworthy research tactics in micro grid control include.

Using simulation and case studies, a fuzzy logic-based management and control system for a hybrid power system is devised and confirmed in this work [7,8].

The following are the major control objectives:

- To manage overall power generation in a micro grid while taking into account load variations.
- Managing the power needed for the storage system while taking into consideration both load changing and charge storing system.
- To avoid using diesel generators to power the storage system.
- To avoid the generators and storage system from supplying electricity when an external load is required.

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2. SYSTEM DESCRIPTION

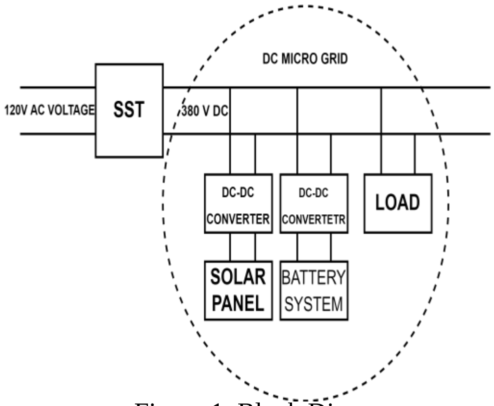

Figure 1. Block Diagram

A 380V dc bus bar is enabled by the solid-state transformer (SST) in the Upcoming Renewable Electric Energy Delivery and Management System, essentially producing an SST enabled dc micro grid, as shown in Figure 1. The SST transports power between both the distribution network and the low-voltage dc system, allowing real power monitoring of the dc micro grid, which includes DRER, DESD, and loads (380 V). Dc/dc converters link these devices to a common 380 V bus. The SST-enabled dc micro grid, in comparison to the traditional transformers plus rectifier architecture, not only acts as an active grid interface, needing less size and space but it may also effectively supply reactive power, balance harmonic currents, and so on. It also serves as an interface to the distribution network for both ac and dc home grids. Whenever the dc micro grid goes offline from the SST in a system, the islanded mode is defined. The SST-enabled mode is defined because when the dc micro grid is interconnected to the SST. This study makes a significant contribution by demonstrating the simulation integration of SST with dc micro grid for the first time to illustrate the practicality of this innovative concept. A power control strategy is also required to ensure the efficient and optimum operation of the micro grid under various operating situations.

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3. SST INTRODUCTION

It is also clear from the SST's design that it may be possible to obtain some additional potential features not available with regular transformers. First, solid-state semiconductor device and circuits, similar to Facts controllers, allows for both current and voltage regulation. This offers prospective benefits including power flow management. Fault current limiting, voltage sag compensation, and other features that standard transformers cannot provide. The SST can thus improve the electricity distribution grid's stability and controllability. Second, voltage source converters linked to the SST's secondary terminal could easily support a regulated dc bus that could be attached to the dc micro grid, allowing the new micro -grid design to be implemented-. The SST architecture used in this research is seen in Figure 2, with the font-end being a cascaded seven-level rectifier. The floating dc links of the rectifier are connected to three dual active bridge (DAB) converters, with the secondary connected in parallel. As a result, a lower voltage bus is created. A lower voltage a.c terminal can be generated using a single-phase inverter. provide detailed details on this simulation and control mechanism.

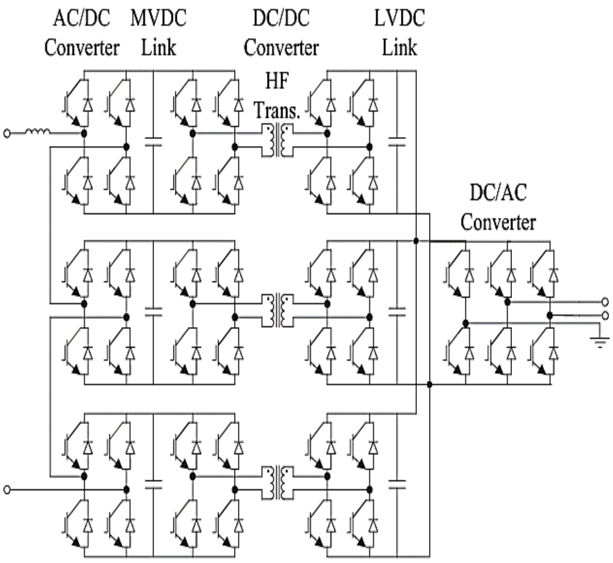

Figure 2. Topology of Presented SST

4. SOLAR CELL

Sun-based cells, as their name implies, are designed to convert (at least a part of) available light into electrical energy. This is performed without using synthetic processes or moving parts. The sun-based cell, that is mostly constructed of PV wafers, produces power without using an electrolytic effect by directly converting the energy from the sun from sun-oriented illumination into the voltages and flows for load. The solar-powered cell is sometimes referred to as a PV cell because the electrical energy is obtained directly from the semiconductor's PN junction [9]. The similar circuit of a solar-powered cell is shown in Figure 3.

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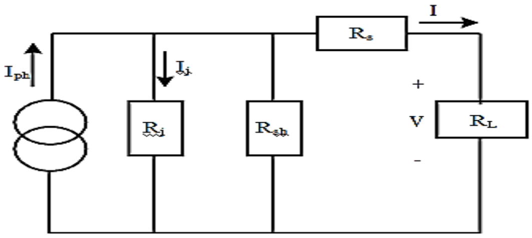

Figure 3. Equivalent Circuit of PV Array

The newest source the photo - voltaic current with in cell is controlled by I_{ph}, the nonlinear obstacle at the p-n junction is controlled by R_j, and the conventional series and shunt safeties are controlled by Rs and R_{sh}, respectively. Normally, R_{sh} has a very high value while Rs has a very low value. Therefore, in order to improve the research, both of them might be disregarded. Photovoltaic cells arranged in larger clusters are what make up PV modules. By joining devices in a series-equal mix, PV clusters can likewise be created. The numerical approach used to create the PV display handles the condition. Where ns is just the number of series cells, np is the number of equal cells, q is the charge of an electrons, and K is the Boltzmann steady, I is the PV cluster producing current, V is the PV exhibit yield voltage, and n_s, n_p, and q are all numerical values. An, T, and I_{rs} all address the p-n intersection ideality factor, cell temperature, and invert immersion current, respectively.

5. Fuzzy Logic Controller

Fuzzy logic is used successfully in a variety of control applications. Almost every item purchased has some form of fuzzy control. Controlling the temperature of the room with a forced-air system, anti-lock brakes in automobiles, clothes washers, traffic signal control, massive financial frameworks, and so on are just a few examples. A control device is a collection of real-world components that are used to alter the behavior of another real-world structure so that it exhibits the desired characteristics [10].

The following are among some of the reasons why fuzzy logic is used in charge frameworks.

- It's vital to fully know the concept and the objective rationale while using regular control. This makes it difficult to apply in some circumstances.
- By using fluffy logic for control, we can use human knowledge and experience to construct a regulator.
- The fantastic designing a control framework is the fuzzy control principles or IF-THEN standards. The significant segments of the FLC, as seen in the above image, are as follows:

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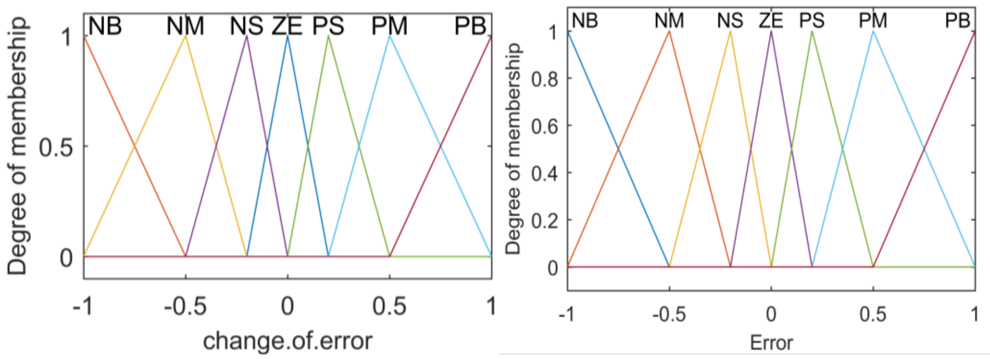

Figure 4: Membership Functions of Fuzzy Inputs

6. Simulation Results

At initial stage the 120 v AC input voltage (as shown in Figure 5) is given to SST, SST converts the 120 v AC to 380 v DC at the final stage of the SST output, and the output is fed to the DC micro grid. The operation of the proposed system flows by taking input at SST from an AC source and processes the voltage through AC/DC converter and MVDC link, which undergoes different stages of operations and system tries to maintain a constant output voltage.

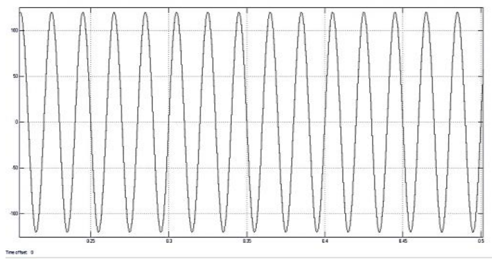

Figure 5. A.C Input Voltage

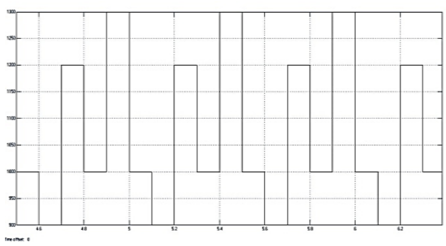

Figure 6. PV Panel Irradiance

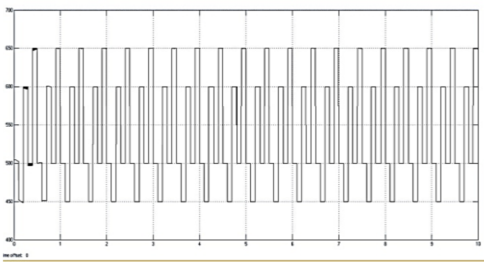

Figure 7. PV Panel Voltage

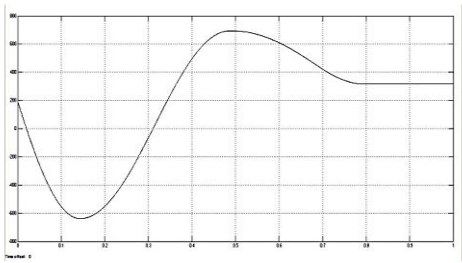

Figure 8. PV System Final Stage Output Voltage

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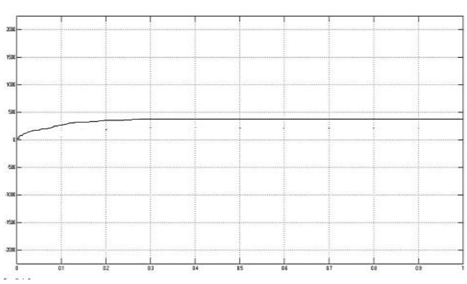

Figure 9. Battery System Output Voltage

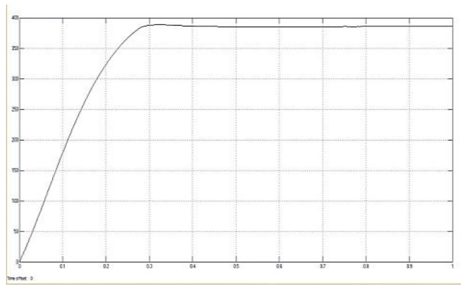

Figure 10. D.C Micro Grid Voltage

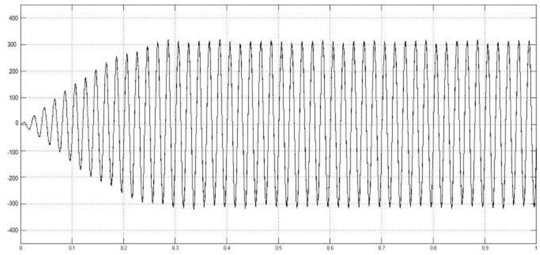

Figure 11. A.C Load Voltage Response

The fuzzy logic controller based on the errors in the system inputs , it generates the switching pulses for maintaining the constant output voltage at 380 v , the fuzzy controller also provides inputs to the battery and the PV system which do not have a constant output due to change in irradiance conditions(as shown in Figure 6) ,the switching inputs are given such that the both systems will maintain the output which will match the SST output(as shown in Figure 8,Figure 9), by maintaining all the voltages at a proper level, the micro grid will have a balanced voltage (as shown in Figure 10)to supply the loads, from Figure 11 we can observe that AC load connected to it have a consistent load voltage of 300 v.

7. CONCLUSION

In this study, a hybrid micro grid power regulation system based on fuzzy logic is developed. An active grid interface which is more compact and lightweight than previous micro grid architectures is used by the presented micro grid system to communicate with the distribution network. The proposed micro grid is really a significantly smaller system as a result. The dc micro grid can operate more reliably in islanding mode by employing primary control, and it can quickly switch between islanding operation mode and SST-enabled operating mode by using secondary control. The paper's main contribution is the incorporation of battery state - of - charge (SOC) inside tertiary control for battery storage

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management via regulated charging and discharge. To further verify that the system stays reliable, more PV panels will also be connected to the dc bus.

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