An Modified Renewable Energy Integration System with Motor Generator Pair Using Fuzzy Logic Controller

M. Karthik and Dr.A. Rathinam

Abstract--- The Motor-generator Pair load tests and power characteristics shown in the tests. The major purpose of the operations Motor-generator Pair was to check power characteristics such as voltage and frequency and to stabilize the system. The Motor-generator Pair for Renewable Energy Integration synchronous generator, converters do not have inherent inertia which is important for frequency response. More complex interaction induced by renewable energies cause's problems of power system dynamics, for example, damping oscillation. In addition, converters cannot support high fault current, leading to limitation of some existing control schemes during transient events. However, compared with converters, the synchronous generator has some advantages to solve the aforementioned problem. However, compared with converters, the synchronous generator has some advantages to solve aforementioned problems. Therefore, this study proposes a synchronous motor-generator pair (MGP) system as a possible grid-connection way for high penetration of renewable energies to improve stability. The rotor angle relation, active power regulation, small signal stability and frequency response are important for inertia and stability of the grid. However, compared with converters, the synchronous generator has some advantages to solve aforementioned problems. Therefore, this study proposes a synchronous motor-generator pair (MGP) system with a stochastic fuzzy controller as a possible grid-connection way for high penetration of renewable energies with a Fuzzy controller to improve stability. Finally, the simulation result has been derived in MATLAB /Simulink with the required formulation.

Keywords--- Renewable Energy Integration, Synchronous Motor-generator Pair, Fuzzy Controller.

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I. INTRODUCTION

Renewable Energy Integration focuses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies, and demand response into the electric distribution and transmission system. A systems approach is being used to conduct integration development and demonstrations to address technical, economic, regulatory, and institutional barriers to using renewable and distributed systems. In addition to fully addressing operational issues, the integration also establishes viable business models for incorporating these technologies into capacity planning, grid operations, and demand-side management.

The wind and solar photovoltaic (PV) had record additions for the second consecutive year, accounting for about of new installations. The Penetration rate of more than even higher has appeared in some countries and districts. However, the high penetration rate of renewable energies also brings challenging reliability and security issues to a power grid. One major challenge is frequency instability induced by replacement of synchronous generator. The Rotor speed of the synchronous generator is tightly coupled with grid frequency hence its moment of inertia can be extracted to support frequency deviation. However, renewable energy sources generally cannot provide enough inertia. For example, doubly fed induction generator (DFIG) only has limited inertia response, the rotor speed of the permanent magnet synchronous generator is completely decoupled with grid frequency and its inertia response does not even exist, as well as solar PV. In most cases, they operate with maximum power point tracking mode hence the active power interaction with grid depends on fluctuation, leading to lack of enough inertia energy.

A second major challenge is the complexity of power system dynamics. With more and more renewable energy sources being connected to the grid, the complexity is also increasing because of non-linearity and many other factors including fluctuation, different wind turbines, control strategies and parameters, penetration rate and operating region. This will cause uncertainty of dynamic interaction between renewable energy and power flow. One of the most concerns is damping control. In recent years, some power oscillation events have been observed in wind farms consisting.

Hence it is necessary to improve damping capability for power grid with high penetration of renewable energy Lots of inertia and damping control methods achieved by converter have been proposed to solve abovementioned problem. A control method called virtual inertia or virtual synchronous generator is proposed to make renewable energies have similar ways like the synchronous generator to enhance stability. For wind power, the kinetic energy of rotor can be released to support grid frequency and damp oscillation. For PV, an auxiliary energy storage system is used to achieve enough power interaction with the grid. Some auxiliary damping controllers are also designed for wind turbines to enhance damping. However, it is always not able to support high short circuit current when large disturbance events happen, hence its overload and transient voltage supporting abilities are not as good as the synchronous generator. Fluctuation and some specific operation modes, as well as cost concerns also make it difficult for renewable energy sources to provide enough power for a dynamic process.

It can be seen obviously from above discussion that synchronous generator being gradually replaced by renewable energy sources makes the future grid a configuration dominated by converters, which may lose some good characteristics of the traditional power source. A highly-reliable power network with large-scale penetration of distributed renewable resources. Moreover, some research has also tried to reuse retired generator as the synchronous condenser to improve grid stability not only for frequency response but short-circuit performance. Therefore, based on the fact that synchronous machine and Synchronization are significant for grid stability, this paper proposes a possible solution, synchronous motor-generator pair (MGP) system, to solve stability issues. Power generated by renewable energy is used to drive synchronous motor, which operates as a primary mover of the synchronous generator. The generator is then connected to the grid. For the purpose of grid stability, it is necessary to study this special dual synchronous machine system from power system point of view.

Therefore, this paper investigates its characteristics related to small signal performance. To increase asset use through integration of distributed systems and customer loads to reduce peak load and thus lower the costs of electricity. To support achievement of renewable standards for renewable energy and energy efficiency.

II. LITERATURE REVIEW

The High penetration rates of renewable energy will bring stability problems for the future power grid. One of the critical issues is lack of inertia. The system is a possible solution for renewable energy integration to enhance inertia and improve grid stability. First, feasibility studies of on inertia, damping, efficiency, and cost are presented. Second, an analytical model is established based on its rotor angle relation. An active power control scheme based on voltage phase difference between renewable energy source and grid is then, and state equations are derived for small signal stability[1-5]. Next, two experiments are designed and implemented to verify stable operation and active power regulation of the system. A single-machine infinite bus system is tested to investigate small signal stability and frequency response. The results show that the MGP system has a solid base in physics and is a feasible solution for providing enough inertia and improving small signal performance in the power grid with high penetration of renewable energy[6-11]. The concludes with a discussion on future research directions to gain a better understanding. The penetration rate of renewable energy is generally defined as the ratio of active power actually generated by renewable energy to total load demand. Increasing the penetration rate fundamentally changes the configuration of the power grid. This will impact the power system in the future and will present a significant challenge in terms of its stability[12-17]. The synchronous generator plays a critical role in the stability of the traditional power grid because inherent inertia is provided by its rotor to support frequency response, and damping control is achieved by its excitation system to restrain oscillation in dynamic processes of the power system. These advantages are fundamental to maintaining frequency.

III. PROPOSED ARCHITECTURE

Motor-Generator Pair consists of two synchronous machines, one operates as a motor and the other as a generator. Shafts of two machines are coupled so they can rotate at the same speed. Power generated by renewable energies are converged to drive the motor. The motor replaces steam turbine or hydro-turbine a primary mover of the generator, which is the main difference from traditional power generation unit.

Moment of inertia is inherently provided by two electric machines and stability control can be achieved by two excitation systems. In addition, short circuit capacity of the whole system is enhanced by this way. It can be seen that the MGP system is actually a new approach for renewable energy sources to achieve grid-connection. Converters of different kinds of renewable energies remain the same, which means that there is no need to add a high power converter to drive the MGP. With the proposed MGP system, depicts a possible configuration of the future power grid with high penetration of renewable energies. One part of renewable energies is still connected to the grid in the traditional way and another part can use MGP to provide inertia, damping, and other related stability control.

Time response of small disturbance and transient events shows that Motor generator pair (MGP) can effectively damp rotor angle oscillation and limit the rate of change of frequency and use the fuel cell implemented the power voltage vector generated from the current control loop is sent to the space vector shift modulation to control the active power using the fuzzy controller.

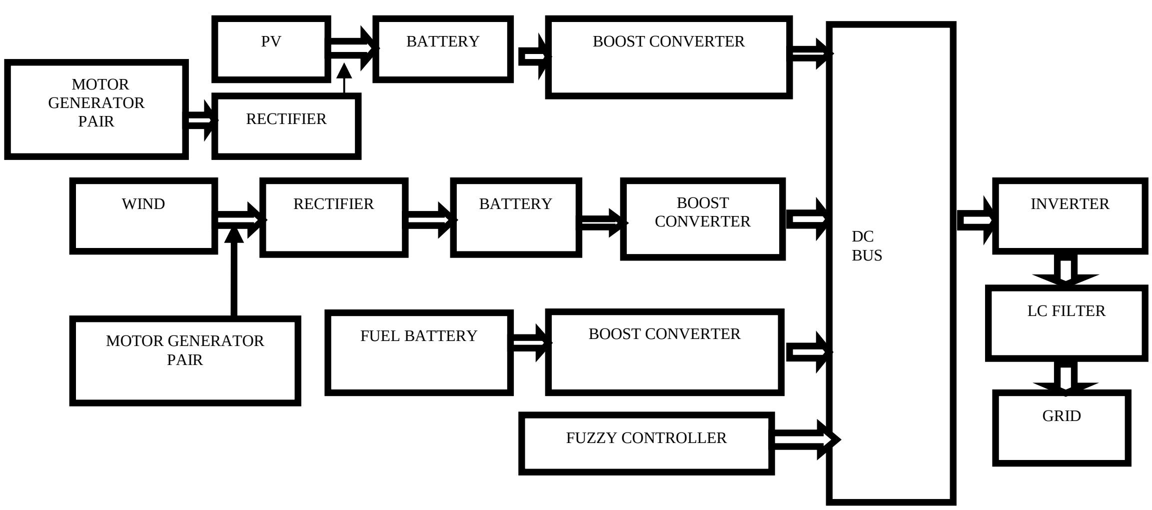

Fig. 1: Proposed Architecture

Photovoltaic Energy

The word photovoltaic combines two terms – photo means light and voltaic means voltage. The Photovoltaic energy is obtained from sunlight in the form of solar energy. The sunlight is made to be focused on solar panels which have the ability to convert the solar energy into an electrical energy. The conversion of solar energy to an electrical energy is done by solar cells of the solar panel. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230-watt module will have twice the area of a 16% efficient 230-watt module. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and solar tracker and interconnection wiring.

Wind Energy

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses the little land. The net effects on the environment are far less problematic than those of non-renewable power sources. Wind farms consist of many individual wind turbines which are connected to the transmission network.

Fuel Cell

A fuel cell produces electricity through a chemical reaction, but without combustion. It converts hydrogen and oxygen into water and in the process also creates electricity. It's an electrochemical energy conversion device that produces electricity, water, and heat. Fuel cells operate much like a battery, except they don't require electrical recharging.

A battery stores all of its chemicals inside and coverts the chemicals into electricity. Once those chemicals run out, the battery dies. A fuel cell, on the other hand, receives the chemicals it uses from the outside, therefore, it won't run out. Fuel cells can generate power almost indefinitely, as long as they have fuel to use. The reactions that produce electricity happen at the electrodes. Every fuel cell has two electrodes, one positive, called the anode, and one negative called the cathode. These are separated by an electrolyte barrier.

Fuel cells are electrochemical devices. A fuel cell system generally consists of three main parts namely a fuel processor (reformer) which converts fuels such as natural gas to hydrogen, the fuel cell itself, where the electrochemical processes take place and the power is generated and the power conditioner, which converts the DC voltage to AC and enables grid-connection. The positively charged hydrogen cells move between the two electrodes to create a flow of electricity which is directed outside the cell to provide electricity. The electric power created is known as the load. A fuel cell is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen to create electricity by an electrochemical process. A single fuel cell consists of an electrolyte sandwiched between two thin electrodes (a porous anode and cathode) Hydrogen, or a hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen's negatively charged electrons from positively charged ions (protons) At the cathode, oxygen combines with electrons and, in some cases, with species such as protons or water, resulting in water or hydroxide ions, respectively. The electrons from the anode side of the cell cannot pass through the membrane to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell. This movement of electrons is an electrical current. The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell Still, a single fuel cell produces enough electricity for only the smallest applications.

Therefore, individual fuel cells are typically combined in series into a fuel cell stack. A typical fuel cell stack may consist of hundreds of fuel cells. Fuel cells are classified primarily by the kind of electrolyte they employ. This determines the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors.

Boost Converter

The dc-to-dc converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It the switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators.

Multilevel Inverter

An inverter converts the DC voltage to an AC voltage. In most cases, the input DC voltage is usually lower while the output AC is equal to the grid supply voltage of either 120 volts, or 240 Volts depending on the country. The inverter may be built as standalone equipment for applications such as solar power, or to work as a backup power supply from batteries which are charged separately. There are different types of inverters based on the shape of the switching waveform. These have varying circuit configurations, efficiencies, advantages, and disadvantages. An inverter provides an ac voltage from dc power sources and is useful in power electronics and electrical.

IV. SIMULATION RESULTS

The proposed system that is going to be described in this phase is done using the Mat Lab Simulink model. In order to get the desired output, the simulation circuit has been designed in Mat Lab software by using the respective components that are present in the Mat Lab Simulink. This simulation circuit will be described in detail below.

MATLAB a high-performance language for technical computing integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. It is a prototyping environment, meaning it focuses on the ease of development with language flexibility, interactive debugging, and other conveniences lacking in performance-oriented languages like C and FORTRAN. While Matlab may not be as fast as C, there are ways to bring it closer. We want to spend less time total from developing, debugging, running, and until obtaining results.

A Simulink Circuit Model

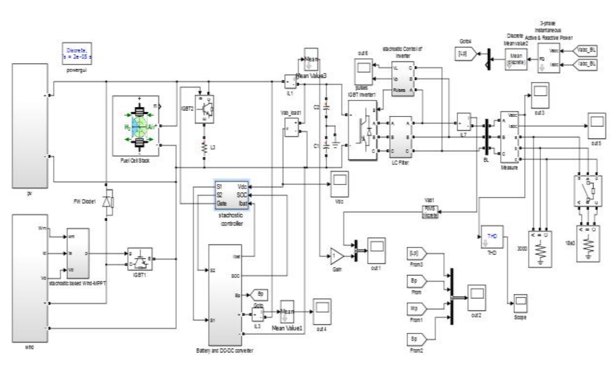

Fig. 2: Simulation Circuit Model

A Simulation Output Results

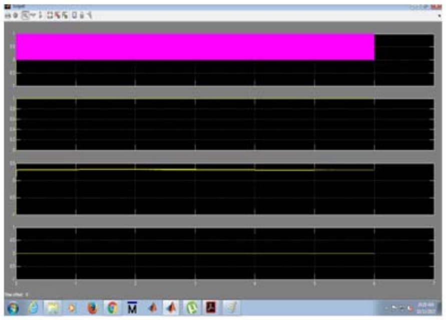

Fig. 3: Motor Generator Output Waveform

Fig 3 the generated output switch pulses for each switches in the power control circuit. In switch one the variation of voltage is (0-1) v .by using switch two during starting time period the voltage is zero. Next switch operation time is (0-0.3) voltage.

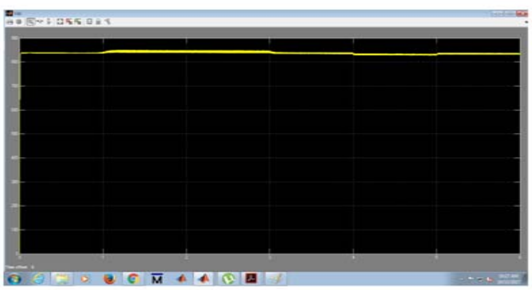

Fig. 4: Boost Converter Output Waveform

Fig 4 shows the improved the boost converter using stochastic control algorithm .it shows the improved output voltage of 820 v with respect to the simulation time range between(0-6 seconds).

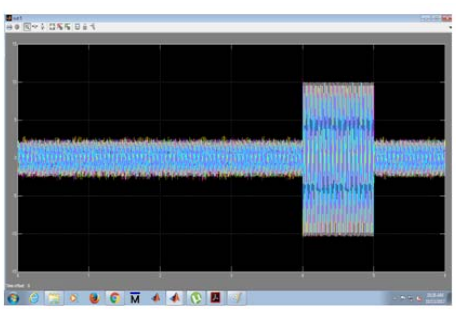

Fig. 5: Current Output Waveform

Fig 5 shows the improved output current using stochastic control algorithm .it shows the improved output current of 5x10-4 amps with respect to the simulation time range between (0-6 seconds). The current waveform may swing between 4 seconds to 5 second due to the non linear conditions

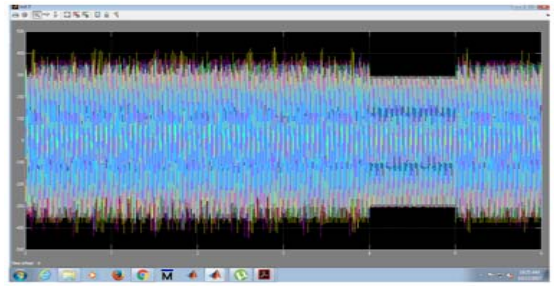

Fig. 6: Voltage Output Waveform

Fig 6 shows the improved output voltage of boost converter using stochastic control algorithm .it shows the improved output voltage of 400 v with respect to the simulation time range between (0-6 seconds). The current waveform may swing between 4 seconds to 5 second due to the non linear conditions zero.

Table I: Wind Turbine Data

Power Rating (W)	1000
Vr(m/s)	30
Vci (m/s)	15
Vco (m/s)	40
Life of WTG	5
Installation cost(rs/m)	17
Operation and maintenance (rs/yr)	34

Table II: PV Array Data

Voc(v)	12500
Isc(A)	30
Lifetime of the PV panel(year)	5
Installation cost(Rs/m)	5.5
Operation and maintenance	0.65

Table III: Battery Specification

Nominal Capacity(Ah)	640
Voltage(V)	12
DOD (%)	80
Efficiency (%)	90
Life of PV years	5
Installation cost (Rs/m)	13
Operation and maintenance	2.6

V. CONCLUSION

In this project, the Motor-Generator pair (MGP) system based synchronous machines to provide a possible future power grid solution with high penetration of renewable energy and to enhance its stability. The damping level and efficiency of the Motor-Generator pair (MGP) are discussed. The stochastic Fuzzy controller is used for analyzing rotor angle relation, active power regulation, small signal stability, and frequency response are verified through simulation results and reduced the THD value to the grid.

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