

FREQUENCY STABILITY OF POWER SYSTEM WITH LARGE SHARE OF WIND AND SOLAR POWER UNDER STORM CONDITIONS

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Abstract - Storage Technology has emerged as main backup powers provider in the era of Smart Grid. Frequency stability analysis of a Hybrid Power System (HPS) based on Solar and Wind has been proposed. Generally, frequency instability problem occurs due to the abrupt variation in load demand growth and generated power variations from different renewable power sources. To Solve these fluctuating problem, renewable power generators are equipped with the various storage system. On the basis of frequency stability, HPS model has simulated in two different cases. First, one is the steady state analysis with the controller and another is the dynamic operation of the system throughout a day. Fuzzy Logic Algorithm is used for optimizing the controller's parameter. The MATLAB/ Simulink platform is used for analyzing the HPS model. From Simulation results, it is observed that the frequency fluctuations and improves system stability in both cases for variable PV power and uneven demand loads. This project proposes the frequency control scheme for a stand-alone hybrid power system in presence of different controllers. A case study on the impact of the frequency control of the integrated renewable power system has been carried out with PI and PID controllers. The hybrid system has been analyzed in MATLAB/ Simulink environment with load demand. A comparative evaluation of frequency deviation for proposed hybrid system in presence of different controlling techniques reflects the improvement in frequency stability in the presence of PID controller as compared to PI controller.

Keywords: Load demand, Storage system, Stability, Fuzzy Controller, Duty Cycle

1. INTRODUCTION

Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies. Among all renewable, PV systems are getting more attraction worldwide. A major application of the PV system to provide power facilities to satellite equipment, off grid application where the grid integration is not possible or not available and grid connected application. PV arrays can be installed in domestic locations such facades, rooftops of buildings, and shades of parking lots. Power coming from this type of plants can be injected to local grid or may be used to compensate domestic load demand. There are many projects going on worldwide based on solar power facilities with storage. Even though applications of PV system, increasing drastically, but this technology still facing many hurdles such as the intermittent nature of environmental concerns their high capital cost, and variable output power creates instability in the grid connected system. Another main concern that appears the global installation of grid-connected PV systems, operational problems in the distribution system, especially when a large megawatt PV system is connected to the electric grid. This is the area where researchers are about to focus.

2. LITERATURE REVIEW

[1] This paper describes a new method of photovoltaic energy sharing in standalone micro-grids using photovoltaic panels. This approach is based on automatic electrical energy sharing depending on the state of charge (SOC) of the electrical storage unit by each home and on the electrical power consumption of each home. The monitoring system is connected to each home in micro-grid, it manages each home's energy use, and assigns more energy to a large energy-consuming home.

[2] Proposed a design, mathematical analysis, and testing results of the architecture of a new all-digital phase-locked loop system for synchronizing a voltage source DC-AC single-phase inverter with the low voltage utility grid are presented. The system which is based on the time-delay digital lock loop was simulated using MATLAB/SIMULINK and was tested by subjecting the grid voltage to various perturbations similar to those which can occur in a real power system, such as voltage sags and nonlinear distortion of the grid voltage waveform. Results indicate that even in the presence of such perturbations the system achieved and / or re-gained synchronization within 100 ms. The proposed system is all-digital and can be readily implemented using a field programmable gate array and easily embedded into a power inverter.

[3] The paper proposes the frequency control scheme for a stand-alone hybrid power system in presence of different controllers. The hybrid isolated power system consist of a photovoltaic (PV) system, micro hydropower system (MHP) diesel engine generator (DEG) and fuel cell system. Assuming that power produced from PV and MHP system remains constant during a load disturbance. A case study on the impact of FC operation in the frequency control of the integrated renewable power system has been carried out with PI and PID controllers. The hybrid system has been analyzed in MATLAB/Simulink environment with step load demand. A comparative evaluation of frequency deviation for proposed hybrid system in presence of different controlling techniques reflects the improvement in frequency stability in the presence of PID controller as compared to PI controller.

[4] Storage Technology has emerged as main backup powers provider in the era of Smart Grid. Frequency stability analysis of a hybrid power system (HPS) based on solar PV and Superconducting Magnetic Energy Storage system (SMES) unit have discussed in this paper. Generally, frequency in stability problem occurs due to the abrupt variation in load demand growth and generated power variations from different renewable power sources. To Solve these fluctuating problem, renewable power generators are equipped with the various storage system.

3. PROPOSED WORK

A hybrid PV-wind-battery-load distributed power generation system is proposed. The proposed topology is derived by simply adding two power switches based on the conventional half-bridge converter, and therefore high-power density of the system is achieved. With the equivalent conventional system, the utilization of the integrated topologies benefits, the system in terms of higher efficiency, higher power density and decreased cost. An integrated three-port DC-DC converter combining an buck-boost converter and a phase shift full-bridge converter for the PV/battery hybrid power generation system is proposed based on the concept of the symmetric boost-integrated three-port topology. The proposed PWM plus phase angle shift control scheme is verified as a suitable candidate for the PV/battery hybrid three port power generation system.

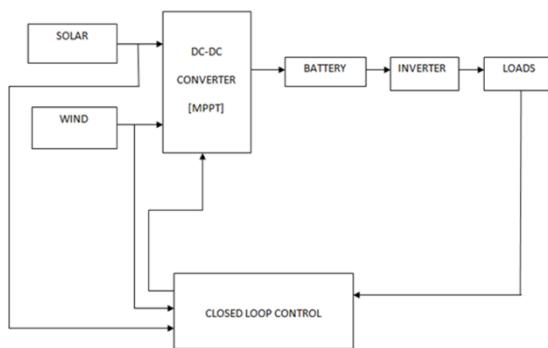


Figure -1: Block Diagram

The frequency control is performed by the battery only (BESS). The fluctuation behavior of frequency in the load bus is observed using both PID and fuzzy logic control. In addition, we also observed the fuzzy logic controller gives us more performing frequency (less transient time) compared to the PID controller. Here, the response of battery, dependent on its dynamics, can be slow (depending on the technology used) and can generate a large variation in frequency.

3.1 Photovoltaic System

A photovoltaic system makes use of one or more solar panel electricity. It consists of various components which include the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

3.2 Photovoltaic Module

Due to the low voltage generation in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. In case of partial or total shading, and at night there may be requirement of separate diodes to avoid reverse currents the p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. There is wastage of power because of reverse currents which directs to overheating of shaded cells. At higher temperatures solar cells provide less efficiency and installers aim to offer good ventilation behind solar panel. Usually there are of 36 / 72 cells in general PV modules. The modules consist of transparent front side, encapsulated PV cell and back side. The front side is usually made up of low-iron and tempered glass material. The efficiency of a PV module is less than a PV cell. This is because of some radiation is reflected by the glass cover and frame shadowing etc. The figure 2 shows the block diagram of Photovoltaic power generation.

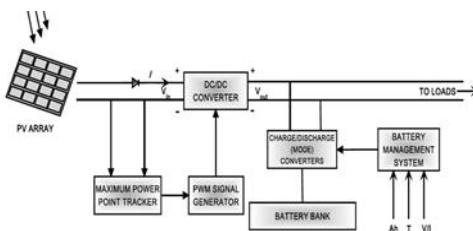


Figure – 2: Photovoltaic power generation

3.3 Maximum Power Point Tracking

As an electronic system maximum power point tracker (MPPT) functions the photovoltaic (PV) modules in a way that allows the PV modules to produce all the power they are capable of. It is not a mechanical tracking system which moves physically the modules to make them point more directly at the sun. Since MPPT is a fully electronic system, it varies the module's operating point so that the modules will be able to deliver maximum available power. As the outputs of PV system are dependent on the temperature, irradiation, and the load characteristic MPPT cannot deliver the output voltage perfectly. For this reason, MPPT is required to be implementing in the PV system to maximize the PV array output voltage.

3.4 Boost Converter

The buck converter is a commonly used in circuits that steps down the voltage level from the input voltage according to the requirement. It has the advantages of simplicity and low cost. Figure 3 shows a buck converter the operation of the Buck converters starts with a switch that is open (so no current flow through any part of circuit) When the switch is closed, the current flows through the inductor, slowly at first, but building up over time. When the switch is closed the inductor pulls current through the diode, and this means the voltage at the inductors "output" is lower than it first was. This is the very basic principle of operation of buck circuit.

3.5 Modeling of Battery

The battery is modelled as a nonlinear voltage source whose output voltage depend not only on the current but also on the battery state of charge (SOC), which is a nonlinear function of the current and time. Two parameters to represent state of a battery that is terminal voltage and state of charge can be written as:

$$V_b = V_0 + R_b i_b - K \frac{Q}{Q - \int i_b dt} + A * \exp(B \int i_b dt)$$

$$\text{SOC} = 100 \left(1 + \frac{\int i_b dt}{Q} \right)$$

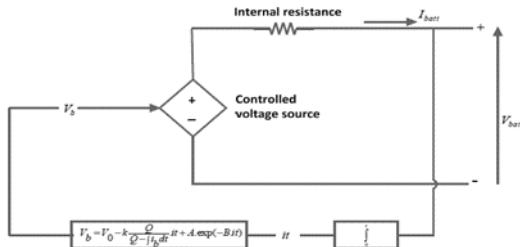


Figure - 3: Battery Equivalent Circuit

3.6 Wind Generation

Wind energy is produced by the force of wind that exerts on the blades of a wind turbine and turning them between 10 and 20 rpm. These blades are connected to a generator that converts mechanical energy into electrical energy. The amount of energy generated by a wind turbine mainly depends on wind velocity; the area swept by the air density and turbine blades. Wind turbines require a minimum amount of wind, usually 12 to 14 km/h, to start rotating and generate electricity. With winds of 50 to 60 km/h, the wind turbine produces full power. Wind speed beyond 90 km/h, wind production is interrupted to generate power from wind turbine. The energy of wind has several advantages including cleanliness because it is not fossil type, also produced by the wind and renewable source. Nevertheless, we can neither store the wind nor control its speed.

3.7 Conversion system of wind energy

The direct-drive configuration, where, the rotor of the turbine is directly coupled to the generator, is extremely reliable, requires minimal maintenance and often reduces costs. The turbines will be equipped with synchronous generators, synchronous permanent magnet generators or asynchronous generators, including models of squirrel cage and wound rotor. Permanent magnet generators and permanent squirrel cage induction generators are often used for small and medium turbines because of their reliability and lower cost. Various high-power turbines are currently equipped with induction generators or synchronous generators with permanent magnets. Most modern turbines are equipped with pulse width modulation (PWM) to produce quality power at fixed voltage and frequency. Both converters were used for wind turbines. Some adjustment of the high-power turbine is ensured by a double PWM converter, which provides power transmission in both directions between the generator of the turbine and the electric utilities.

3.8 Network stability

- The stability of the network is characterized by the fluctuations of power flow in the network and it's measured by the variations over time of voltages and frequency. It must be distinguished.
- Steady state stability: the network has a stable behaviour such as, subject to small disturbance, it returns to its initial operating point with possible damped oscillations utilities returns to the balance condition.
- Transient stability: when moving from one steady state to another state, due to a disturbance, this change in equilibrium is accompanied by a damped oscillatory variable considered acceptable with respect to predetermined ranges of ΔU (voltage), Δf (frequency) and Δt (time).

- Transient instability is observed when a major disturbance occurs and the damped oscillation is divergent. It causes a loss of power or a new unacceptable stable condition.
- Dynamic stability: the network is able to avoid any divergent oscillatory and return to an acceptable stable condition. Consider the main critical scenarios such as short circuit, loss of mechanical energy, loss of power source, load variation, process constraints.

3.9 Duty Cycle

The term describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. When a digital signal is on half of the time and off the other half of the time, the digital signal has a duty cycle of 50% and resembles a "square" wave. When a digital signal spends more time in the on state than the off state, it has a duty cycle of >50%. When a digital signal spends more time in the off state than the on state, it has a duty cycle of <50%. Here the figure 3.6 is a pictorial that illustrates these three scenarios of duty cycle.

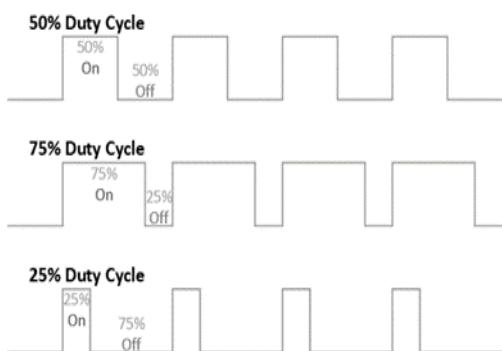


Figure - 4: Duty Cycle

3.10 Control of Frequency

The balance between the load and the output power determines the frequency of the power system. In large interconnected networks, output power increases with frequency drop and vice versa. The first frequency control line is the local governor, which provides "Reserve Power Flow" to the system. For DG, this type of control will be required for the operation of insulation. Frequency control in open loop always gives a constant value but in higher droop. For the case of closed loop control, the frequency is very sensitive with the actual energy (minimum droop), which requires control the governor to control the frequency. In the present time, many researchers proposed a lot of control techniques in their pioneer research to develop the frequency controllers.

3.11 Micro Grid Interface

Multiple sources of generation and the possibility of isolating the micro grid provide a highly reliable electric power. The heat produced from generation sources such as micro turbines could be used for heating. Marei and Mohamed proposed control strategies for the adaptation of decentralized generation units with autonomous micro-networks. They presented a model of a control system that coordinates the frequency and voltage of an inverter-based DG and an energy storage system. The interface of the DG not only used to control the flow of active power but to ensure the voltage regulation of the micro-network. Finally, the developed interface, DG and storage system ensured voltage regulation and frequency control for various disturbances.

4. SIMULATION RESULTS

Neuro Fuzzy controller is proposed to control inverter gating pulses which provides fast response to the correction.

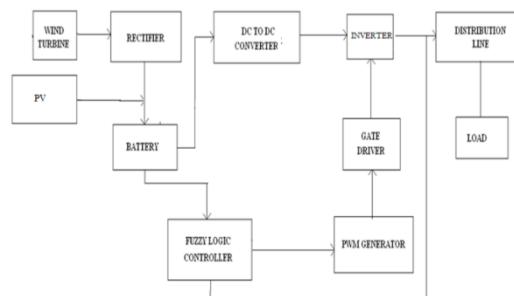


Figure - 5: Simulink Model of Proposed System

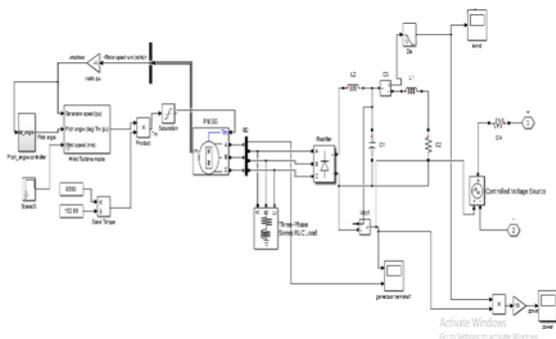


Figure - 6: Simulink Model of PMSG System

An integrated power converter as the interface for the PV/Wind hybrid distributed power generation system is proposed. Compared with the conventional system topology containing an independent DC-DC conversion stage, the proposed system has advantages in terms of higher power density and reliability. The phase shift angle of the full bridge and the switch duty cycle are adopted as two control variables to obtain the required DC bus voltage and realize the power balance and frequency stabilization. Different operating scenarios of the system under various power conditions are discussed in detail and a comprehensive energy management and control strategy is proposed accordingly. The PID controller can enable one of the control loops in different scenarios to optimize the whole system performance, taking both the MPPT benefit and the battery charging/discharging management requirements into consideration. The simulation results verify the performance of the proposed PV/battery hybrid distributed power generation system and the feasibility of the control algorithm.

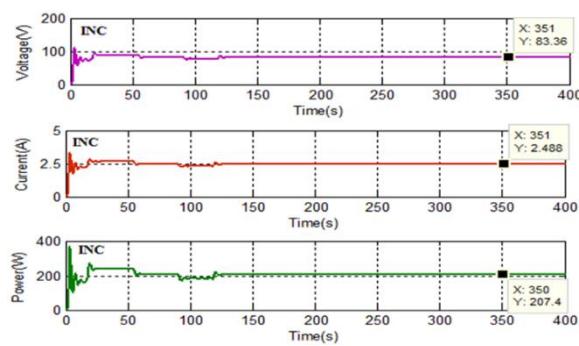


Figure - 7: Output Simulation MPPT

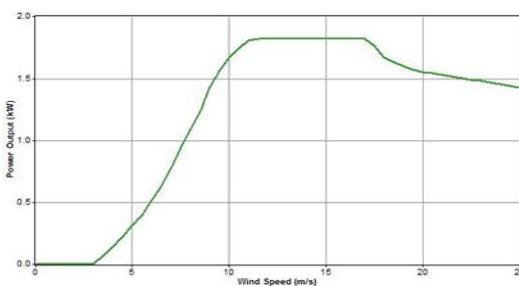


Figure - 8: Output of Wind Speed

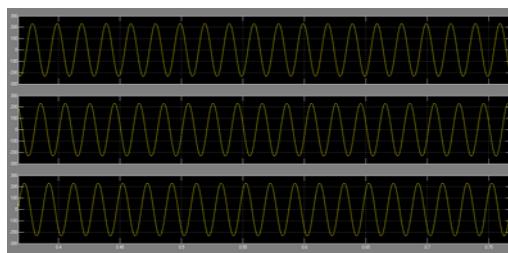


Figure - 9: Output of Wind Power

5. CONCLUSIONS

The proposed system frequency stability of power system with large share of Wind and Solar power under storm conditions has been analyzed in the steady and dynamic state with the performance of the micro-grid integrated hybrid solar system with has been examined by considering variable load demand. The impact of SMES of operation of the hybrid solar system has carried out. The frequency stability analyses of HPS under the micro grid connected simulation have presented. To improve the system's operation, the proposed system is necessary to share the load supply with the battery especially when the wind speed or photovoltaic power drops or the load increases. Also, the battery selection for applications is highly important in order to overcome the problems of dynamic instability of the electrical network based on such an energy storage system. As well, filters play a very important role in reducing the harmonics generated by the power electronics converter. For the future works, a larger power network could be developed using same technologies. To get more flexible results, fuzzy logic rules could be modified. The capacity of the battery could be increased with respect to the network load demand.

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