wind turbine and power system components, as well as switching electronic devices, are necessarily to be monitored to keep these constraints within their permissible levels[6-7]. The wind turbine will generally operate in normal conditions with a voltage level between 90-105% and frequency between 49-51 Hz. The penetration of integrated distributed generation may violate these operational constraints. Therefore, the power supplied to the designed distribution network should be continuously monitored to regulate the voltage and frequency of the system. Under fault conditions, the wind turbine would experience significant voltage variations. The amplitude and duration of these variations will determine whether the wind turbine should be disconnected or kept operational during fault conditions. FACT devices such as STATCOM can provide the required reactive power for voltage regulation and assist wind farms to continue in supplying active power for a specific time during fault conditions[8]. The main objective of this paper is to simulate the integration of wind turbine and fuel cell stacks into the medium voltage distribution system and investigate the effect using STATCOM to stabilize the voltage levels in the studied system. The MATLAB/Simulink R2018a software package is used to model the distribution system, including the described distributed generators.

The fuel cell beak-up power supply is a desirable option to be used with an alternating power generation source like PV cell,since the fuel cell has many attractive features such as efficiency, fast load-response, modular production and fuel flexibility. Its feasibility with PV system has been successfully realized for both grid-connected and stand-alone applications. Due to the fast responding capability of the fuel cell power system, a photovoltaic-fuel cell (PVFC) hybrid system may be capable to solve the photovoltaic’ s inherent problem of intermittent power generation. Unlike a storage battery, which also signifies an attractive back-up option, such as fast response, flexible construction and flexibility, the fuel cell power can produce electricity for unlimited time to support the PV power generator.

2. Methodology

A. Motivation:

Energy management strategy is needed to control the power flow between the SOFC stack and battery in this type of active series hybrid. The energy management will calculate a control signal for the buck converter according to the actual states of the SOFC stack and the battery. The control signal for the buck converter is indicated by $I_{DCDC,d}$. The energy management strategy has three different aims. The first is related to the battery, whereas the other two concern the SOFC stack. (i)Battery: Constant state of charge (SOC) (ii)SOFC stack: Avoiding and identifying aging. The main goal for the battery is a constant state of charge. As shown inFig. 6, it is essential to operate the battery at a partial state of charge (PSoC). As an outcome, it is reasonable to store the maximum braking energy and to deliver the maximum acceleration energy at any time without violating defined voltage limits. To achieve a long lifetime for the system, it is essential to avoid operating conditions that might reduce the lifetime of the SOFC stack. Especially the SOFC stack voltage influences on the lifetime. One phenomenon, known as catalyst corrosion, occurs if the voltage is too low[11]. The energy management strategy should, therefore prevent aging of the SOFC stack and identify an aging process.

B. Control Structure:

1) Concept development in order to achieve this aim for the battery, a variable is needed which describes the actual state of charge ($SOC_{battery}$) of the battery. For a known battery capacity $K_{battery}$this can be calculated from the battery current $I_{battery}$ in a simple way:

$$SOC_{battery} = 1 - \frac{\int I_{battery}\, dt}{K_{battery}} \qquad (1)$$

The calculation in (1) is problematic since a measurement error for the battery current $I_{battery}$ will be accumulated over time. The result is a deviation of the calculated state of charge from the real state of charge, especially for long operating times of the system. This was demonstrated in an initial test with a PID controller and the state of charge as the control variable. The results of this test are described in Fig 4. Here, the state of charge is calculated in the battery management system of the lithium battery according to (1). The desired value for the control variable was set to 52.6 %. At the end of the test, which lasted 20 h, the calculated state of charge was 52.7 %, whereas the real state of charge calculated from the open circuit voltage was 37.5 %. The battery voltage $U_{battery}$ could be used as an alternate control variable. The stability of this control variable was demonstrated in a test with one single PID controller[4]. There are several possibilities for the topology of the control structure. As described, a PID controller with the battery voltage $U_{battery}$ as the control variable showed good results. The controller output is the desired value $I_{DCDC,d}$for the current at the output of the buck converter. Another possible topology is a two-level controller with the following parameters:

$$I_{DCDC,d} = \begin{cases} I_{DCDC,max} & \text{if } U_{battery} < U_{level,min} \\ 0 & \text{if } U_{battery} > U_{level,max} \end{cases} \qquad (2)$$

The controller output $I_{DCDC,d}$, depends on the battery voltage $U_{battery}$. Two levels are defined. If the battery voltage is greater than the maximum level $U_{level,max}$, the controller output is set to zero. In this case, the SOFC stack is in a no-load state. For a battery voltage lower than $U_{level,min}$, the converter output current is set to the maximum possible converter current $I_{DCDC,max}$. Simulation result in Fig. 6 demonstrate the disadvantages of this controller compared to a PID controller. Firstly, the maximum SOFC stack power has to be higher in the case of the two-level controller. Secondly, it is possible for the SOFC stack to cool down in a no-load phase. This is the case if the difference between the two controller levels $U_{level,max}$ and $U_{level,min}$ is too significant. Therefore, the two-level controller is not an appropriate choice.

3. Test and Implementation

MATLAB/Simulink model is designed for the integrated distribution system. Fig. 1shows the MATLAB/Simulink model for the designed integrated distribution system. In this system, the three-phase ideal source is supplying power to the grid. We have considered PV as the ideal three phase source supplying power to the grid. This hybrid grid consists of IGBT based three-phase voltage source converter. This converter is controlled to supply needed reactive power and harmonic current into the system. To interface PV-Wind power system to the distribution system, inductor filters are used. These inductors are used to limit circulating current flowing in the system. To control the amount of power flow from battery/electrolyzer, its controller is designed in simulation. We have connected Fuel cell (SOFC) with PV-Wind to maintain the impedance in source and load.

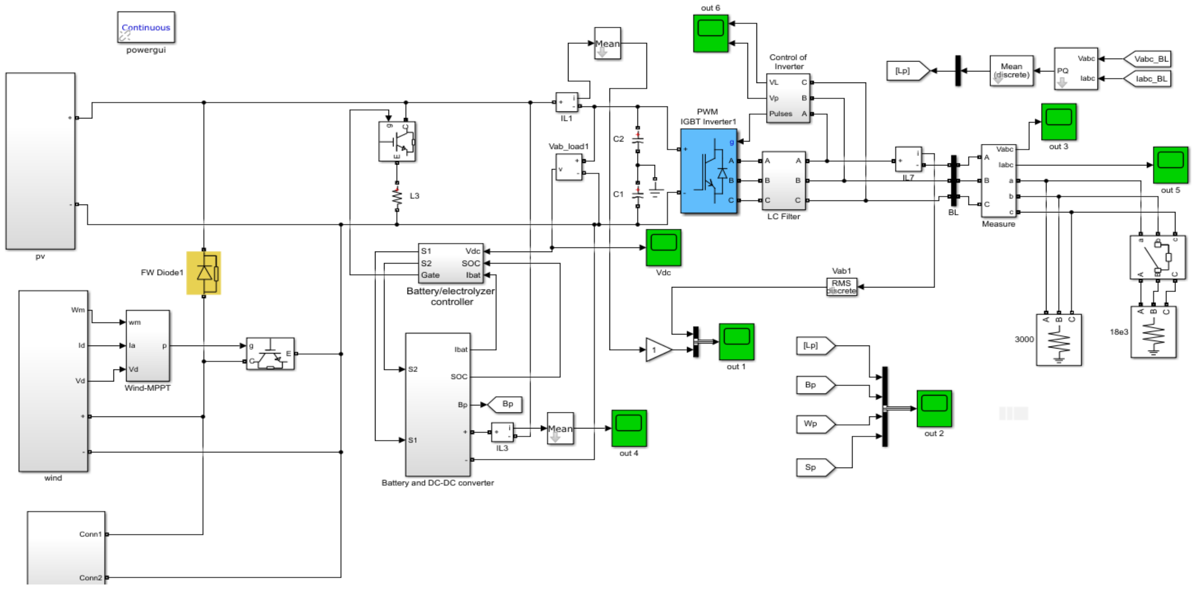

Figure 1: Simulated model of Fuel cell & PV-Wind Power based distribution network

Using inverter, we generate required AC voltage from fuel cell. The inverter uses hysteresis switching and controls active power by management of direct-axis current while holding reactive power at 0 MVar. The measurement blocks are rated at 50kW. Thus, an active power reference of 1pu =50kW. Ode23tb solver with the configuration parameter discrete sampled at 1e-005s is used. This model undertakes the following: (i)The fuel cell gases are ideal. (ii)Only one pressure is well-defined in the interior of the electrodes. (iii)The fuel cell temperature is invariant. There is reverse in pressure of all the reactants after 0.4s.Due to which reactive power output of the fuel cell also increases. Simulation can be extended for dynamic study of fuel cell. After 0.4 s fuel cell is able to provide the 50kw active power.

4. Result and Discussions

In this integrated distribution network, we have considered PV as the 3-pahse input voltage supply which maintains the constant voltage and frequency at the power grid. These constant voltage and frequency are the constraints used when the power is injected from wind and fuel cell into the grid.Shown below are the graphs of the simulated model of the designed distribution system.

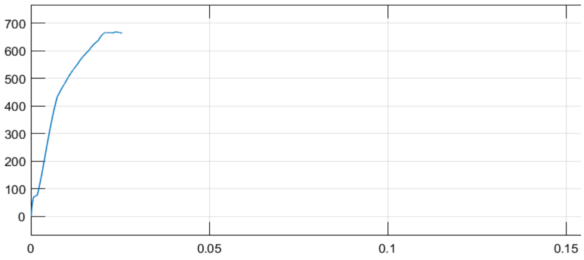

Fig.2: Source Voltage

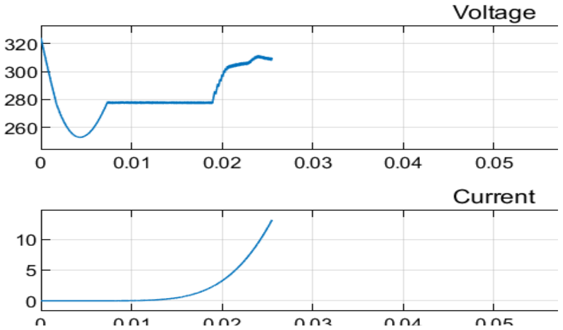

Fig. 3: DC-DC Boost converter Voltage and Current with battery

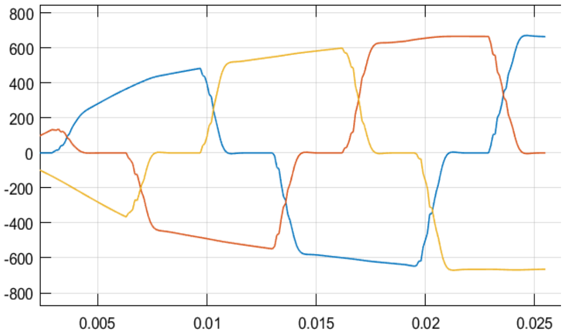

Fig.4:Three phase Line-Line Load Voltage

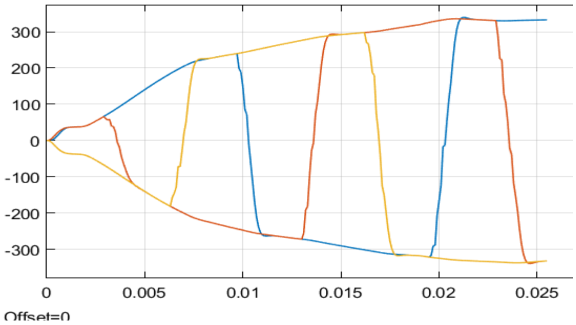

Fig.5: Three phase Load Voltage

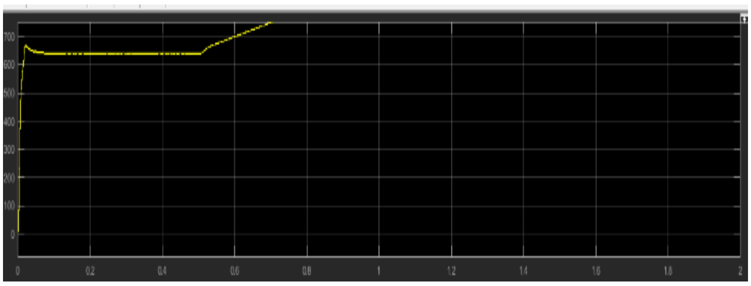

Fig. 6: Battery Electrolyzer Voltage

The stability of the fuel cell system will make sure the continuous power is provided throughout the day as compare to traditional energy source. Fuel cells have a promising demand within the field of renewable energy. This paper describes the autonomous control strategies of inverters connected in parallel, especially load share for isolated operation of a micro grid configured with various new energy generators. In the verification test, the system was isolated from the utility grid, and inverters connected in parallel and determined the micro grid bus voltage and frequency. Various renewable energy generators PV-Wind turbine and the fuel cell were operated synchronously. The system proved stable controllability even with various loads and generation power change for around three weeks. When the fuel cell system is sufficient enough to supply the load then the system is operated on the islanded mode of operation. In this mode ofoperation, the controller must regulate the output voltage at the reference bus voltage and the frequency at the grid frequency. The reference values can be got by taking as a grid voltage magnitude and phase angle as reference frequency of grid. This paper implements the design of hybrid cascaded multilevel inverter for the hybrid power sources. The hybrid cascaded multilevel inverter reduces the harmonics in the output voltage. The harmonics are decreased relatively increasing the voltage levels of inverter. The effectiveness of the strategy for the cascaded multilevel inverter is studied based on the simulation results. The implemented PV-wind turbine and fuel cell provide the supply continuously and the experimental result shows the output voltage of the hybrid cascaded fed by fuel cell, PV cell and wind turbine. In this topology the non triplen lower order harmonics are reduced.

5. Conclusion

The design and control of fuel cell and PV-wind power system have been carried out for a three-phase distribution system. A control algorithm based on correlation and cross-correlation function has been found suitable for generating the switching signals of fuel cell in a three-phase power system. In this project, algorithms are implemented for the operation of fuel cell to eliminate harmonics in source current due to non-linear load, pulse load, and reactive load. Fuel cells convert the chemical energy of a fuel and an oxidant directly into electrical power and heat using electrochemical processes, not combustion. In fuel cell, water could be split into the hydrogen and oxygen by sending an electric current through process of electrolysis technique. A Proton Exchange Membrane Fuel Cell (PEMFC), combines hydrogen fuel with oxygen from the air to produce electricity, water, and heat. A Basic Proton Exchange Membrane Fuel Cell consists of 3 components: (i)Anode (a negative electrode that resists electrons) (ii)An electrolyte in center (iii)Cathode (a positive electrode that attracts electron). As hydrogen flows into the fuel cell anode, a catalyst, often a platinum coating on the anode helps to separate the gas into protons (hydrogen ions) and electrons. The MATLAB simulation model is designed for all power loads, and simulated results are analyzed. This system is implemented and compared for harmonic elimination, power factor correction and tracking capability to maintain DC bus voltage. With the effect of source distortion, these three algorithms are analyzed. The next step in the research is to consider Microgrid as a system. It is essential to know more about how the sources interact with each other. More specifically, their relationship to each other needs to be defined. If all goes as anticipated and the Microgrid system is developed, the control of the order will likely be embedded within the electronics. It is possible to use specialized controllers to get a more stable response and to use each power source more efficiently. This should undoubtedly be researched and considered once the power sources interaction and relationship with each other and the mains have been defined. Other aspects that could be developed further are the original sources within the Microgrid.

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