"DESIGN & SIMULATION OF MICROGRID FOR FREQUENCY STABILIZATION BY USING MOTOR-GENERATOR (DFIG AND SCIM) AND SUPERCAPACITOR"

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ABSTRACT: *This research introduces an energy storage system to deliver grid frequency response the coupling of a doubly fed induction generator and a squirrel cage induction machine as a motor/generator set to deliver an immediate inertial response to the change of frequency, as well as an inverter and super-capacitors to deliver short term energy response. This paper outlines the simulation and design of this system. A control system is created to monitor the grid frequency and activate an inverter to either charge or discharge a bank of capacitors depending on the measured conditions. For example, when the frequency is measured below 50 Hz, the system injects power into the grid to arrest the frequency deviation; above 50 Hz the energy storage system absorbs power. This system adds rotating inertia and short-term energy storage to stabilize the grid frequency.*

Keywords- AC Motor, Generator, Super capacitors, Electromechanical System, DC-DC Power Converter, AC-DC Power Converter, Power System Simulation

1. INTRODUCTION

The rotation of all generation units within a power grid interconnection is synchronized. Each interconnection can be thought of as being supplied by one massive generator whose speed sets the frequency, and whose equivalent inertia serves to stabilize fluctuations in the load. The frequency and the speed of the generators - is set by matching the supply of power with the demand. When there is balance between supply and demand then the frequency is stabilize. If customer demand (and losses) exceeds the power supplied by the generators, then the power signal will drop below the target frequency, (e.g. 50 Hz). As shown in fig.1.1.1 Vice-versa, the frequency will rise if the generation exceeds than the load supplied to the consumer.

There are two method to manipulate the [2] value of the frequency. It consists of two groups of methods:

• When the frequency is decline a certain portion of the load is motors that spin slower and therefore consume less power but when the frequency rises, motor spin faster thereby consuming more electricity.

• In grid the governor system is used to change the output of generator when the frequency is increases or decrease.

When renewable generation (or load) fluctuates the grid's primary control system will be actuated in order to pick up any difference between the new levels of generation and the load. That error could fall to a slack bus resource such as a diesel generator. The system proposed in this research can move energy into or out of its storage system quickly in order to keep the grid frequency stable frequency excursions. This can reduce not only the amount of stop/start cycles on the prime mover but also the amount of valuable dispatchable energy used - thereby leading to increased quality and reliability. As the there is imbalance between supply and demand, then there is frequency change . The National Grid has published a report on inertia that concludes that, "Machine inertia significantly affects the rate and rise and fall of system frequency," and are developing better methods to measure and control it [3]. Abad et. al [4] have published a tutorial that summarizes a comprehensive effort to mathematically model a doubly-fed induction machine. Mohan [5] delivers a focus on modeling a SCIM in Simulink. Giesselmann et al [6] demonstrate the sheer electrical force of AC machine inertia in high-current Electromagnetic Launch Applications. Syed et al [3] have implemented a supercapacitor based system to emulate inertial response for different wind conditions.

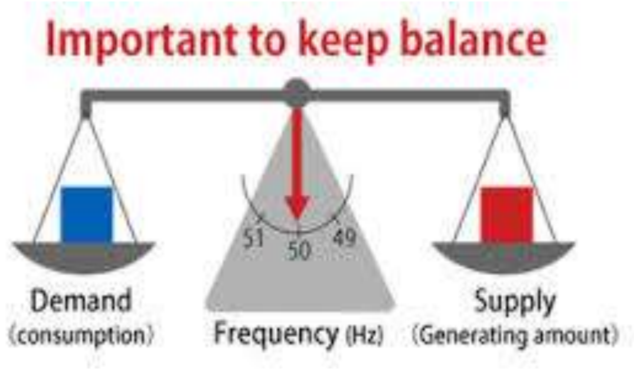

Figure 1: Demand/ Generation Balance

2. RELATED WORK

Ted K.A. Brekken, and Rick Crispo et. al. [1] discussed about When the frequency of microgrid is below 50 Hz then Supercapacitor injects power to grid to arrest the frequency deviation .The control system is created to monitor the charging and discharging of supercapacitor when the frequency is increase and decrease resp. A doubly fed induction generator (DFIG) and squirrel cage induction motor (SCIM)is use as motor generator set to deliver short term inertial response.When the frequency is below 50 Hz that time DFIG work as motor and SCIM work has a generator to provide short term energy response.

Mallesham, Mishra, Jha et. al. [2] proposed the detail analysis Distributed Generation Systems (DGS) consisting of Wind, Solar and Diesel Generator. The Diesel Generator is controlled either by P or PI or PID controller to inject regulated amount of real power to the power system based on its rating. As a result it regulates the mismatch between the real power generation and the load which will lead to a minimum power and frequency deviations.
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Irtaza M. Syed, BalaVenkatesh, Bin Wu, Alexandre B. Nassif et. al. [4] discussed The flow of wind in atmosphere is not constant that effect to quality of power wind generator (WG). So to overcome this wind fluctuations doubely fed induction generator (DFIG) topology is used.
This technology can compensate for up to ±30% of the total WG rated power in an attempt to maintain power output constant. In order to extend this operating range we used supercapacitor energy storage system that couple to DFIG. The two layer supercapacitor scheme is able to effectively command the DFIG to supply optimal, smooth power output.

Yazhou Lei, Alan Mullane, Gordon Lightbody, and Robert Yacamini et. al. [5] Due to its many advantages such as the improved power quality, high energy efficiency and controllability, etc. the variable speed wind turbine using a doubly fed induction generator (DFIG) is becoming a popular concept and thus the modeling of the DFIG based wind turbine becomes an interesting research topic. This paper develops a simple DFIG wind turbine model in which the power converter is simulated as a controlled voltage source, regulating the rotor current to meet the command of real and reactive power production. This model has the form of traditional generator model and hence is easy to integrate into the power system simulation tool such as PSS/E. Considering the simplification adopted for the model development, the limitation and applicability of the model were also discussed in this paper.

3. PROPOSED MODEL OF MICROGRID FREQUENCY STABILIZATION USING DFIG- SCIM AND SUPERCAPACITOR

Main system model of microgrid frequency stabilization using DFIG- SCIM and Super capacitor. It consist of

1. Wind Turbine Doubly Fed Induction Generator system
2. Squirrel Cage Induction motor
3. Converter (AC/DC & DC/DC)

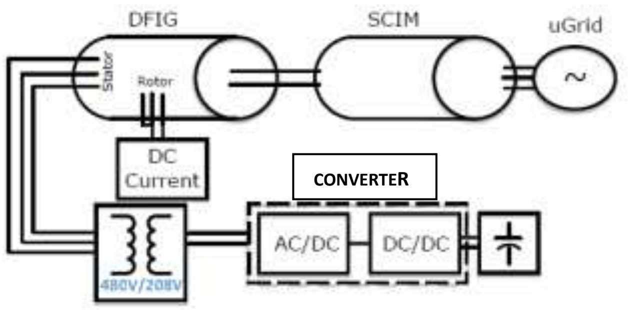

Figure 2: Proposed Circuit diagram

A control system is created to measure the grid frequency and then activate the inverter to either charge or discharge the supercapacitor bank.

- When the frequency rises above the target value (e.g. 50 Hz) the system takes power from the microgrid to charge the supercapacitors, thereby acting as a load to bring the system frequency down. Power now flows from the microgrid through the system to charge the supercapacitor bank.
- When the frequency drops below 50 Hz the system acts like a generator by taking energy from the supercapacitors, inverting it and injecting it into the microgrid to bring the system frequency back up.

The proposed control system block diagram is illustrated in Fig.2

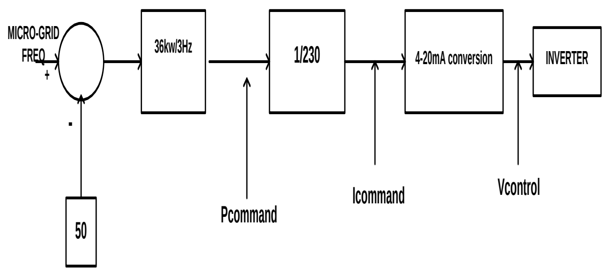

Figure 3: Block Diagram of Control System

3. SIMULATION MODEL AND RESULT

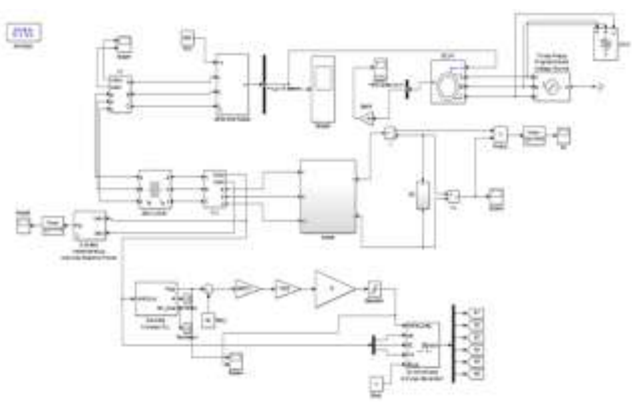

Figure 4: Microgrid frequency stabilization using DFIG-SCIM and supercapacitor

4. RESULT ANALYSIS

Frequency response measured at 50 Hz

Figure 4: Frequency Response at 50Hz

There is no power flow from supercapacitor to microgrid when the frequency is 50 Hz in microgrid is shown in fig 4

When the frequency measured at 50 Hz, the simulation result of speed of DFIG is shown in fig 5 . i.e 1500 rpm.

Ns=120*F/P
=120*50/4 where, P=4
=1500

At that time speed of SCIM is 1460 rpm is shown in fig 6.

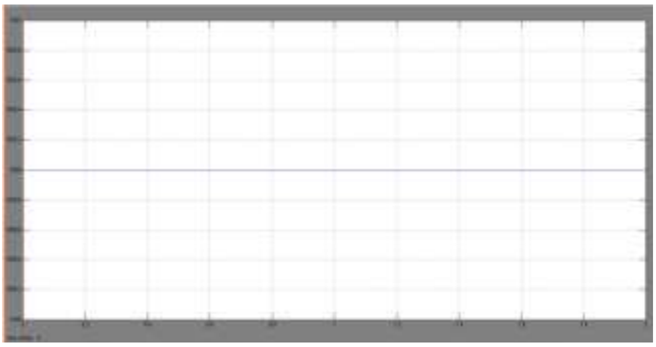

Figure 5: Speed of DFIG at 50Hz

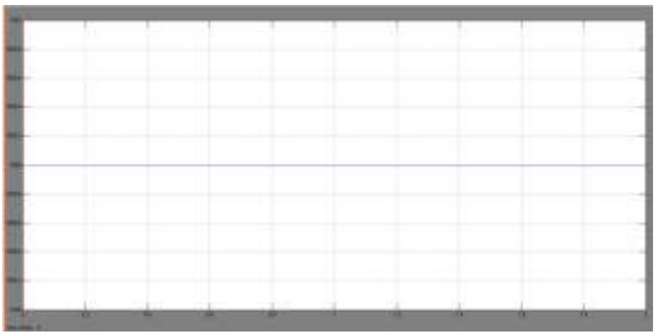

Figure 6: Speed of SCIM at 50Hz

When Frequency is 50 Hz, There is no need to inject power into microgrid from supercapacitor. But when frequency drop down for a moment at starting, that time supercapacitor inject some power into microgrid is shown in fig.7

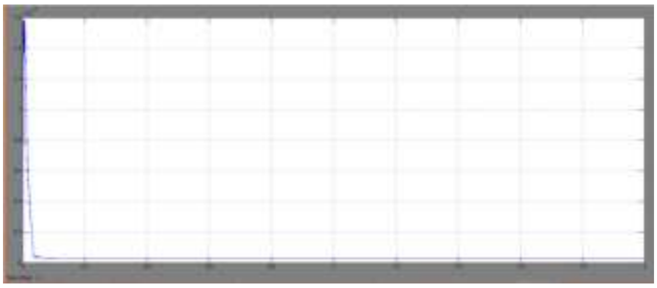

Figure 7: Response of supercapacitor Voltage at 50 Hz

When Frequency response measured at 47 Hz

The simulation result of frequency of microgrid is 47 Hz with load is as shown in fig.8 below. When the load increased at the microgrid, the frequency decreases from 50 Hz to 47 Hz. At that time supercapacitor start injecting power into microgrid and frequency goes near to 50 Hz

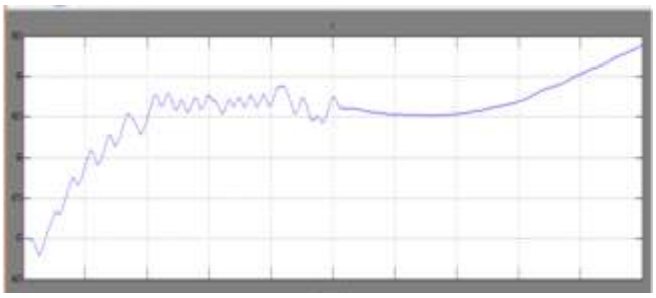

Figure 8: Frequency response at 47 Hz

When frequency is 47 Hz, speed of DFIG is 1410rpm is shown in fig.9

At that time speed of SCIM also go down i.e. 1360 rpm is shown in fig.10

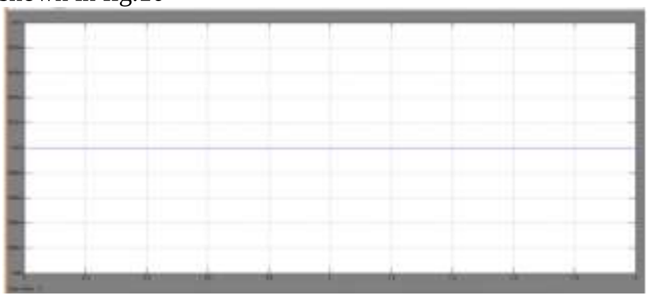

Figure 9: Speed of DFIG at 47 Hz

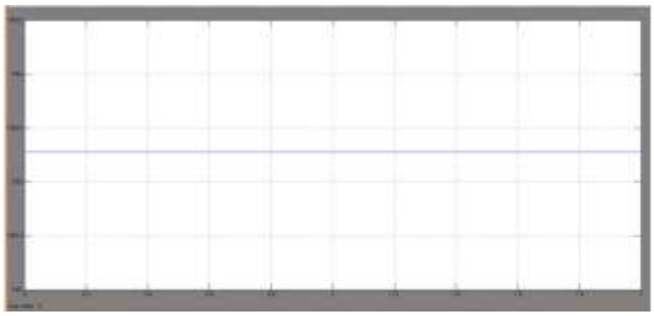

Figure 10: S peed of SCIM at 47Hz

The simulation result of power of supercapacitor when frequency of microgrid is 47 Hz is as shown in fig. 11 below. When load is connected to the microgrid, the frequency decreases from 50 Hz to 47 Hz. Here the power is providing from supercapacitor to microgrid for stabilizing the frequency i.e at 50 Hz.

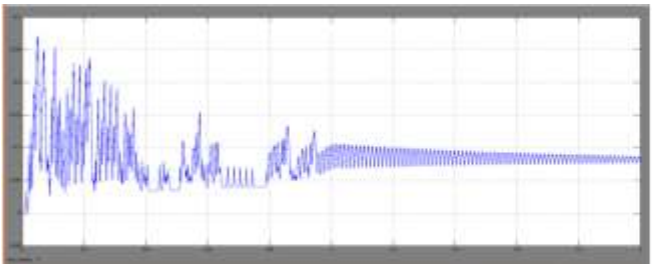

Figure 11: Response of supercapacitor Voltage at 47 Hz

5. SYSTEM PARAMETERS

Table 1: SCIM Parameter

Sr. No.	Parameter	Value
1	Power	20 HP
2	Voltage	400 v
3	Frequency	50 Hz
4	Speed	1460 rpm
5	Stator Resistance	0.2147 ohm
6	Rotor Resistance	0.2205 ohm
7	Stator Inductance	0.000291 H
8	Rotor Inductance	0.000291 H
9	Mutual Inductance	0.06419 H
10	Pole Pair	2

Table 2: DFIG Parameter

Sr. No.	Parameter	Value
1	Power	15 HP
2	Voltage	400 V
3	Frequency	50 Hz
4	Speed	1500 rpm
5	Stator Resistance	0.023pu
6	Rotor Resistance	0.016pu
7	Stator Inductance	0.18pu
8	Rotor Inductance	0.16pu
9	Magnetizing Inductance	2.9pu
10	Pole Pair	2

6. COMPARISON RESULT

The comparison result of Frequency, Synchronous speed & Rotor Speed is as shown Table 3. When the Frequency of Microgrid is at 50 Hz, the speed of SCIM is 1460 rpm. Now when the load is connected to the microgrid, thefrequency of microgrid decreases from 50 Hz to 47 Hz and the speed of SCIM also decreases from 1460 rpm to 1370 rpm.

Table 3: The comparison result of Frequency, Synchronous speed & Rotor Speed

Sr. No	Frequency	Synchronous Speed of DFIG	Speed of SCIM
1	47	1410 rpm	1370 rpm
2	50	1500 rpm	1460 rpm
3	52	1560 rpm	1510 rpm

The simulation Measurement of Frequency (Hz) & Supercapacitor power (KW) is as shown in Table 4 below. When the load is connected to the microgrid, the frequency decreases from 50 Hz to 47 Hz, but when the supercapacitor inject the power through the DFIG & SCIM to the microgrid, frequency of microgrid increase from 47 Hz to 50Hz.

Table 4: Measurement of Frequency (Hz) & Supercapacitor power (KW)

Sr, No.	Frequency (Hz)	Supercapacitor Power(KW)
1	47 Hz	1.1 KW
2	48 Hz	0.6 KW
3	49 Hz	0.154 KW
4	50 Hz	No power flow (zero)

7. CONCLUSION AND FUTURE SCOPE

This research creates a motor/generator and supercapacitor based system design and demonstrates its ability to deliver frequency response. The average model of the system is simulated and then the circuit is implemented in Matlab. The results demonstrate that the rotational inertia delivers immediate energy while the control system and supercapacitors achieve short-term response. This serves to stabilize frequency in order to improve microgrid service quality and reliability

The research presented in this thesis can be expanded in the following ways:

- The simulation in this research can be advanced by measuring the microgrid frequency above 50 Hz.
- The simulation can be expanded to include a power flow analysis and a fault study analysis. A single-line-to-ground fault in the transmission system, for example, will affect not only the frequency but the voltage of the generators.

Experimental implementation and testing of the proposed project schemes can be developed in hardware.

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