

Fuzzy based STATCOM Controller for Grid connected wind Farms with Fixed Speed Induction Generators

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Abstract:

The main aim of this project is STATCOM control structure with the capability to coordinate the control between the positive and the negative sequence of the grid voltage is proposed. The main using STATCOM to increase voltage stability by compensating the reactive power in the power system. This paper investigates the Static Synchronous Compensator (STATCOM) application to achieve continuous operation of wind turbine.

Wind turbines are of an variable-speed type using either a doubly fed induction generator (DFIG) or permanent-magnet synchronous generator, a non negligible percentage of 15% of the operating wind turbines is still of the fixed-speed induction generator (FSIG)-type connecting directly to the grid.

Because this generator type cannot provide reactive power control, it cannot fulfill the demanding grid code requirements without additional device. During voltage dips, the induction generators may consume a large amount of reactive power as their speed deviates from the synchronous speed. A STATCOM controller is connected to an FSIG-based wind turbine and used to control the positive- and the negative-sequence voltage during grid faults conditions.

While the positive-sequence voltage compensation leads to an increase the voltage stability level of the wind turbine, the negative sequence voltage compensation leads to a reducing of rippling torque, increasing the lifetime of the generator drive train. In this project control technique is PWM Technique with fuzzy logic controller in improving the performances of voltage stability and reducing the reactive power losses. The simulation work has been done in MATLAB/SIMULINK software.

Key words:

Induction generator, low-voltage ride through, STATCOM, wind energy.

Introduction:

The wind power penetration has enlarged dramatically in the past few years, hence it's become necessary to deal with issues associated with maintaining a stable power system that contains completely different sources of energy as well as hydro, thermal, coal, nuclear, wind, and solar. Within the past, the total installed wind power capacity was low fraction of the power system and continuous connection of the wind energy facility to the grid wasn't a serious concern.

With Associate in increasing share derived from alternative energy sources, continuous connection of wind farms to the system has compete Associate in increasing role in facultative uninterrupted power provide to the load, even within the case of minor disturbances. The wind energy facility capability is being continuously enlarged through the installation of a lot of and bigger wind turbines.

Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines need to be ready to continue uninterrupted operation underneath transient voltage conditions to be in accordance with the grid codes. Grid codes square measure sure standards set by control agencies. Alternative energy systems ought to meet these necessities for interconnection to the grid. But grid code standards square measure established by different control bodies however Nordic grid codes are getting more and more standard.

Although a significant part of the newly installed wind turbines are of the variable-speed type using either a doubly fed induction generator (DFIG) or permanent-magnet synchronous generator, a nonnegligible percentage of 15% of the in operation wind turbines in Europe in 2010 remains of the fixed-speed induction generator (FSIG)-type directly connected to the grid. As a result of this generator sort cannot give reactive power management, it cannot fulfill the demanded grid code needs while not further devices. Throughout voltage dips, the induction generators could consume an oversized quantity of reactive power as their speed deviates from the synchronous speed, which may cause a voltage collapse and additional fault propagation within the network. Completely different strategies are investigated to reinforce the fault-ride-through capability and to satisfy grid code needs. Besides using the pitch management of the rotary engine or putting in further instrumentation sort of a brake chopper or an energy storage system, the installation of a STATCOM has been known to produce the most effective dynamic stability improvement capabilities.

A STATCOM could be a voltage supply converter-based device providing dynamic reactive power support to the grid. Construction or star device topologies are typically chosen to implement the high-energy converters. Because of its versatile dynamic management capabilities, the STATCOM will facilitate to integrate alternative energy plants during a weak power grid. The capability of a static volt-ampere compensator compared to a STATCOM to extend the steadiness of FSIG-based wind turbines. The STATCOM can even perform an indirect force management for a similar reasonably generators to decrease the mechanical stress throughout grid voltage dip.

All of these investigations have been covered balanced grid faults, but the majority grid faults are of the unbalanced in nature. The unbalanced-voltage problems can cause the unbalanced heating in the machine windings and a pulsating torque, leading to mechanical vibration and additional acoustic noise. The STATCOM control structure can be adapted to these unbalanced voltage conditions, and the positive and the negative sequence of the voltage can be controlled independently. Different current injection methods are based on the symmetrical components can also be applied to the STATCOM, resulting in the different output-power distributions.

This paper proposes the application of a STATCOM that is connected to FSIG-based wind farm and used to control the positive- and the negative-sequence voltage during the grid faults. The novel contribution of this paper lies in the coordination with the positive- and the negative-sequence voltage control by the STATCOM and the related effect on the wind turbine behavior. While the positive sequence voltage compensation leads to an increased voltage stability of the wind farm and the negative sequence voltage compensation leads to a reduction of torque ripple, for increasing the lifetime of the generator drive train.

Wind Turbine Fixed Speed Induction Generator:

1. Grid Connected Induction Generator:

The Grid connected induction generators develop their excitation from the Utility grid. The generated power is fed to the supply system when the induction generator is run above the synchronous speed. The machines with cage type rotor feed only through the stator and generally operate at low negative slip. But wound rotor machines can feed power through the stator as well as the rotor to the bus over a wide range known as the Doubly Fed Induction Machines.

2. Fixed Speed Grid Connected Wind Turbine Generator:

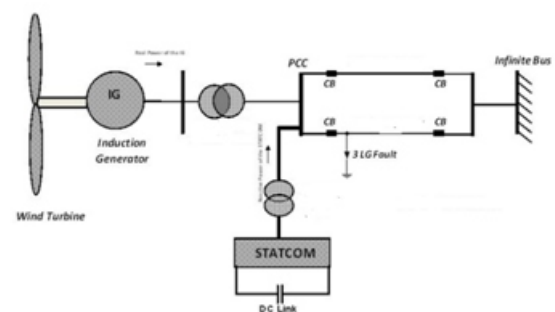


Fig 1 FSIG-based wind farm and STATCOM connected to the grid.

The structure and the performance of fixed-speed wind turbines as shown in Fig.1 depends on the features of mechanical sub-circuits, e.g., pitch control time constants etc. The reaction time of these mechanical circuits may lie in the range of tens of milliseconds.

As a result, each time a burst of wind hits the turbine, a rapid variation of electrical output power can be observed. The variations occurs in electric power generated not only require a power grid to enable stable operation, but also require a well-built mechanical design to absorb the high mechanical stress, which leads to an expensive mechanical structure ,especially at the high-rated power.

Static Compensator (STATCOM):

The block diagram of the STATCOM is shown in the figure 2. The STATCOM is connected to the ac system bus bar through a coupling transformer. In a STATCOM, the maximum compensating current is independent of the system voltage, so it operates at full capacity even at low voltages. A STATCOM advantages include flexible voltage control for the power quality improvement, fast response, applicability for use with high fluctuating loads and reactive power compensation.

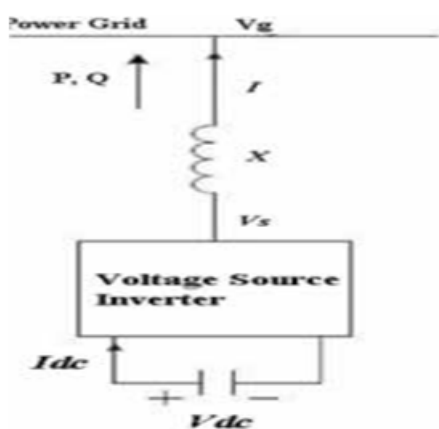


Fig 2 STATCOM structure

The shunt inverter, transformer and connection filter are the major components of a STATCOM. The control system employed in this system maintains the magnitude of the bus voltage constant by controlling the magnitude and/or phase shift of the voltage source Converter's output voltage. By properly controlling i_q , reactive power exchange is achieved. The DC capacitor voltage is maintained at a constant value and this voltage error is used to determine the reference for the active power to be exchanged by the inverter. The STATCOM is a static VAR generator whose output can be varied so as to maintain or control certain specific parameters of the electric power system.

It is a power electronic component that can be applied to the dynamic control of the reactive power and the grid voltage.

The reactive output power of the compensator is varied to control the voltage at given transmission network terminals, thus maintaining the desired power flows during possible system disturbances and contingencies.

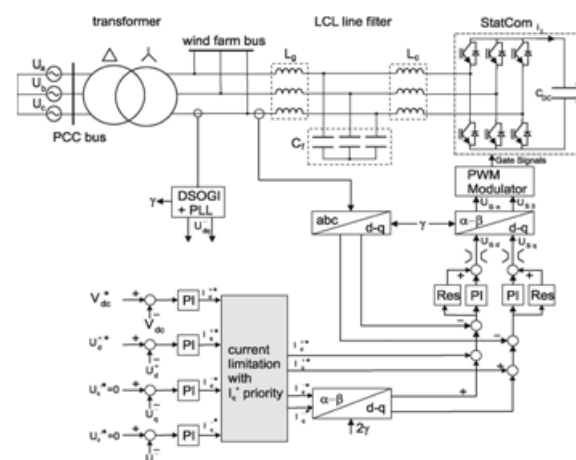


Fig.3. Proposed control structure of the STATCOM to control the positive- and the negative-sequence voltage independently.

Fuzzy Logic Controller:

The control system is based on fuzzy logic. Fuzzy logic controller is a one type non linear controller and automatic. This type of the control approaching the human reasoning that makes the use of the acceptance, uncertainty, imprecision and fuzziness in the decision-making process, manages to offer a very satisfactory performance, without the need of a detailed mathematical model of the system, just by incorporating the experts' knowledge into the fuzzy. Fig 5 shows the fuzzy logic controller block diagram.

The fuzzy logic control system is based on the MAM-DHANI fuzzy model. This system consists of four main parts. First, by using the input membership functions, inputs are Fuzzified then based on rule bases and the inferencing system, outputs are produced and finally the fuzzy outputs are Defuzzified and they are applied to the main control system.

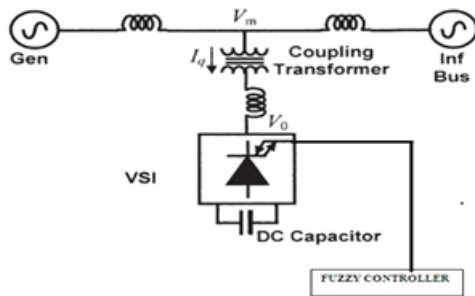


Fig 4: Extension circuit diagram STATCOM with fuzzy controller

Error of inputs from their references and error deviations in any time interval are chosen as MATLAB. The output of fuzzy controller is the value that should be added to the prior output to produce new reference output.

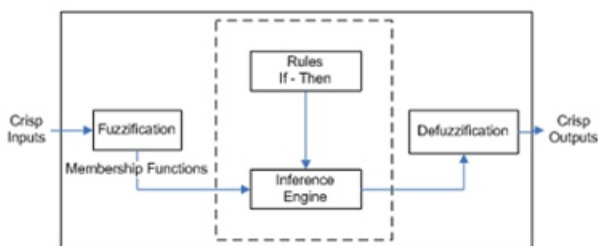


Fig 5: Block Diagram of fuzzy logic controller

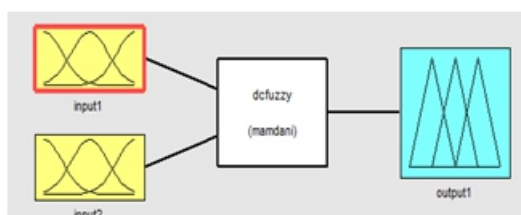


Fig 6: selection of input and output variables

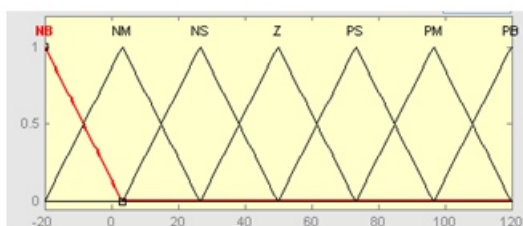


Fig 7: Input1 membership function

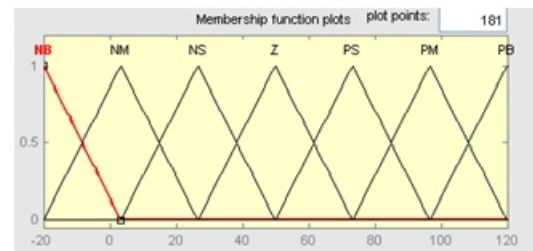


Fig 8: Input 2 membership function

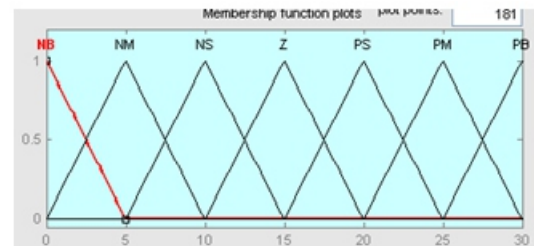


Fig 9: Output membership function

Simulation results:

The below figures shows the simulation diagrams of the proposed system and extension system.

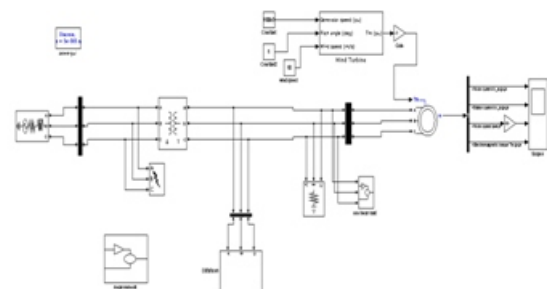


Fig 10: Simulation circuit diagram.

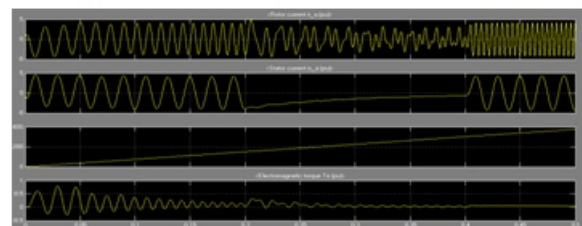


Fig 11: Motor specifications

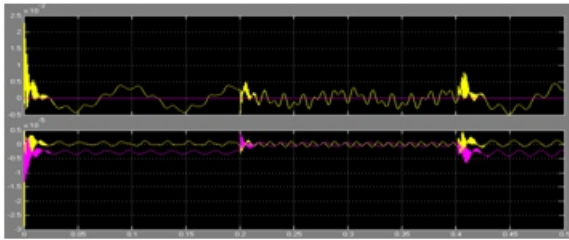


Fig 12: Active and reactive power

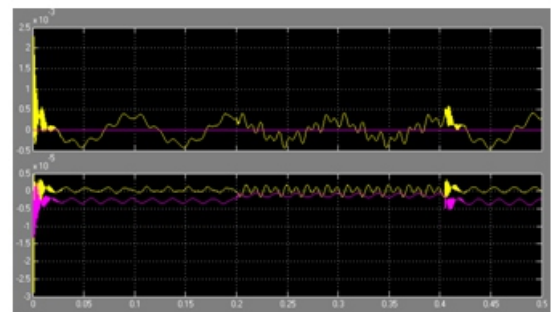


Fig 16: Synchronous frame calculations like active and reactive power

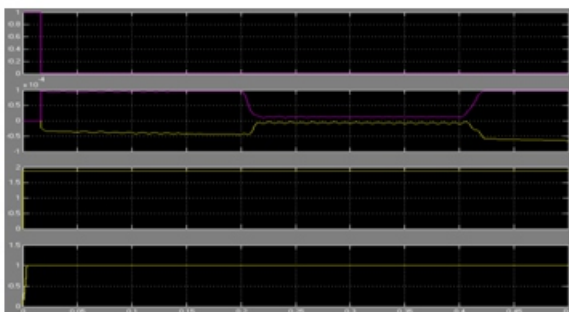


Fig 13: Bus3 voltage and current , Vdc, modulation index

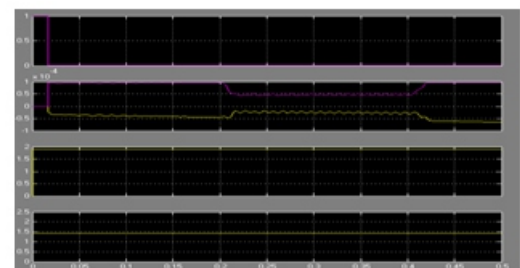


Fig 17: Voltage, current of bus1 and Vdc and modulation index

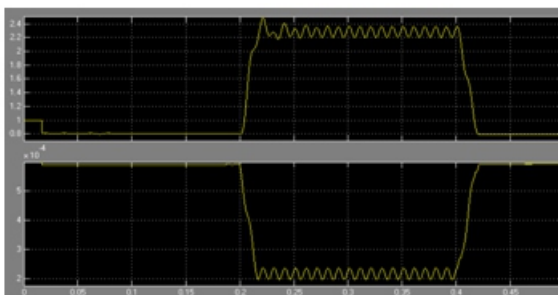


Fig 14: Bus B1 voltage and current

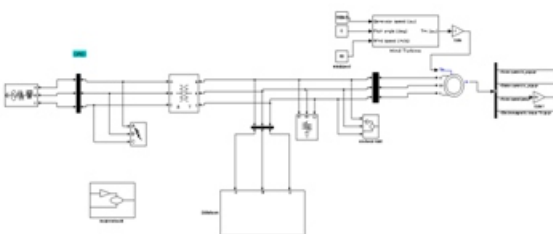


Fig 15: Extension circuit diagram

CONCLUSION:

A voltage control structure for a STATCOM at an FSIG-based on the wind farm under unbalanced grid voltage condition has been implemented. The proposed structure controls the positive and the negative sequence of the voltage independently with priority on the positive-sequence voltage. The new contribution of this paper lies in the coordination of the positive- and the negative sequence voltage control by the STATCOM and the related effect on the wind turbine behavior. While the positive-sequence voltage compensation leads to an increased the voltage stability of the wind farm, the negative-sequence voltage compensation leads to the reduction of the torque ripple, increasing the lifetime of the generator drive train. The coordination is realized by prioritizing the positive-sequence voltage control. If there is remaining STATCOM current capability, the STATCOM is controlled to compensate the negative-sequence voltage additionally, in order to reduce the torque ripple during the grid fault. Hence the Fuzzy logic controllers surpass the traditional PI control during the non linear variations and it gives better performance than PI in wind turbine fed FSIG under different asymmetric faults.