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Fuzzy logic Control of FACTS Devices for Improving Voltage and Stability in DFIG Wind Energy System

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Abstract—Voltage and reactive power stability is an issue in wind energy system to achieve an uninterruptible operation. The continuous demand in power system network has caused the system to be heavily loaded insufficient reactive power and causing voltage instability, the external and internal faults also generate instabilities. FACTS devices such as SVC, STATCOM, SSSC, UPFC etc., are the best solution for the voltage and reactive power control. In this paper a fuzzy logic controller is implemented the FACTS devices for improving the voltage and reactive power disturbances in DFIG wind energy system . The performance of the system is presented by using real time voltage and current wave form using MATLAB software

Keywords— Flexible AC Transmission System(FACTS), Doubly Fed Induction Generator(DFIG), Fuzzy logic controller,

I. INTRODUCTION

Renewable energy sources like solar, wind, tidal, hybrid each contribute some amount of power to generate electricity. Earlier days fossil fuels are used largely to extract electricity. nowadays due to shortage of fuels and environmental pollution caused by green house gases, renewable energy has come to an effect. among these renewable energy sources, wind energy plays an important role in present scenario. at present wind energy is emerging at a faster rate because it's more cost effective, clean and easily sustainable and has remarkable growth ease of use.

With the recent progress in modern power electronics, the concept of a variable-speed wind turbine (VSWT) equipped with a doubly fed induction generator (DFIG) is receiving increasing attention because of its advantages over other wind turbine generator concepts. In the DFIG concept, the induction generator is grid-connected at the stator terminals; the rotor is connected to the utility grid via a partially rated variable frequency ac/dc/ac converter (VFC), which only needs to handle a fraction (25%–30%) of the total DFIG power to achieve full control of the generator. The VFC consists of a rotor-side converter (RSC) and a grid-side converter (GSC) connected back-to-back by a dc-link capacitor .

When connected to the grid and during a grid fault, the RSC of the DFIG may be blocked to protect it from overcurrent in the rotor circuit. The wind turbine typically trips shortly after the converter has blocked and automatically reconnects to the power network after the fault has cleared and the normal operation has been restored. In, the author proposed an uninterrupted operation feature of a DFIG wind turbine during grid faults. In this feature, the RSC is blocked, and the rotor circuit is short-circuited through an external resistor, the DFIG becomes a conventional induction generator and starts to absorb reactive power. The wind turbine continues its operation to produce some active power, and the GSC can be set to control the reactive power and voltage at the grid connection. The pitch angle controller might be activated to prevent the wind turbine from fatal over speeding. When the fault has cleared and when the voltage and the frequency in the utility grid have been re-established, the RSC will restart, and the wind turbine will return to normal operation. However, in the case of a weak power network and during a grid fault, the GSC cannot provide sufficient reactive power and voltage support due to its small power capacity, and there can be a risk of voltage instability. As a result, utilities, typically, immediately disconnect the wind turbines from the grid to prevent such a contingency and reconnect them when normal operation has been restored. Therefore, voltage stability is the crucial issue in maintaining uninterrupted operation of wind turbines equipped with DFIGs. With the rapid increase in penetration of wind power in power systems, tripping of many wind turbines in a large wind farm during grid faults may begin to influence the overall power system stability.

The problem of voltage instability can be solved by using dynamic reactive compensation. flexible ac transmission system (FACTS) devices, such as the static var compensator (SVC), the static synchronous compensator (STATCOM), Static Synchronous Series Compensator (SSSC) have been widely used to provide high-performance steady state and transient voltage control at the point of common coupling (PCC). Fuzzy logic control approach is an emerging tool for solving complex problems whose system behaviour is complex in nature. An attractive feature of fuzzy logic control is its robustness in system parameters and operating conditions changes .

Fuzzy logic controllers are capable of tolerating uncertainty and imprecision to a greater extent. In this paper investigates fuzzy controlled FACTS devices for improving the voltage and reactive power stability of DFIG wind energy system

II MODELING AND CONTROL OF DFIG

The basic configuration of a DFIG driven by a wind turbine is shown in Fig. 2. The wind turbine is connected to the DFIG through a mechanical shaft system, which consists of a low an a high-speed shaft with a gearbox in between. The wound rotor induction machine in this configuration is fed from both stator and rotor sides. The stator is directly connected to the grid while the rotor is connected to the grid through a VFC. In order to produce electrical power at constant voltage and frequency to the utility grid for a wide operating range from sub synchronous to super synchronous speeds, the power flow between the rotor circuit and the grid must be controlled both in magnitude and in direction. Therefore, the VFC consists of two four-quadrant insulated-gate bipolar transistor (IGBT) pulse width modulation (PWM) converters connected back-to back by a dc-link capacitor [10]. The crowbar is used to short circuit the RSC in order to protect it from overcurrent in the rotor circuit during transient grid disturbances.

Control of the DFIG is achieved by control of the VFC, which includes control of the RSC [4], [10]–[12] and control of the GSC [10]. The objective of the RSC is to independently

regulate the stator active and reactive powers, which are represented by P_s and Q_s, respectively. The reactive-power control using the RSC can be applied to keep the stator voltage V_s within the desired range, when the DFIG feeds into a weak power system without any local reactive compensation. When the DFIG feeds into a strong power system, the command of Q_s can be simply set to zero. Fig. 3 shows the overall vector control scheme of the RSC. In order to achieve independent control of the stator active power P_s and reactive power Q_s (Fig. 2) by means of rotor current regulation, the instantaneous three-phase rotor currents i_{rabc} are sampled and transformed to d–q components i_{dr} and i_{qr} in the stator-flux-oriented reference frame. The reference values of i_{dr} and i_{qr} can be determined directly from Q_s and P_s commands, respectively. The actual d–q current signals (i_{dr} and i_{qr}) are then compared with their reference signals ($i_{*\,dr}$ and $i_{*\,qr}$) to generate the error signals, which are passed through two PI controllers to form the voltage signals v_{dr1} and v_{qr1}. The two voltage signals (v_{dr1} and v_{qr1}) are compensated by the corresponding cross-coupling terms (v_{dr2} and v_{qr2}) to form the d–q voltage signals v_{dr} and v_{qr}.

These are then used by the PWM module to generate the IGBT gate control signals to drive the rotor-side IGBT converter

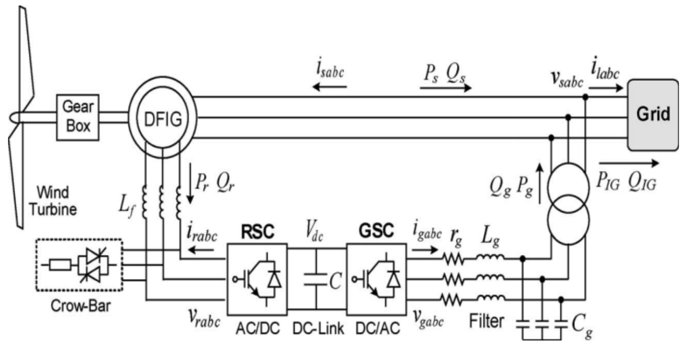

Fig. 1. Configuration of a DFIG wind turbine.

II FACTS DEVICES

A. Static VAR Compensator

Static VAR compensators, commonly known as SVCs and provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled reactive devices. An SVC is typically made up of the following major components: 1. Coupling transformer 2. Thyristor valves 3. Reactors 4. Capacitors (often tuned for harmonic filtering) They consist of conventional thyristors which have a faster control over the bus voltage and require more sophisticated controllers compared to the mechanical switched conventional devices. SVC_s are shunt connected devices capable of generating or absorbing reactive power

Figure 1 shows these configurations: the Thyristor Controlled Reactor (TCR), the Thyristor Switched Reactor (TSR) and the Thyristor Switched Capacitor (TSC) or a combination of all three in parallel configurations. The TCR uses firing angle control to continuously increase/decrease the inductive current whereas in the TSR the inductors connected are switched in and out stepwise, thus with no continuous control of firing angle. Usually SVC_s are connected to the transmission lines, thus having high voltage ratings . Therefore the SVC systems have a modular design with more thyristor valves connected in series/ parallel for extended voltage level capability.

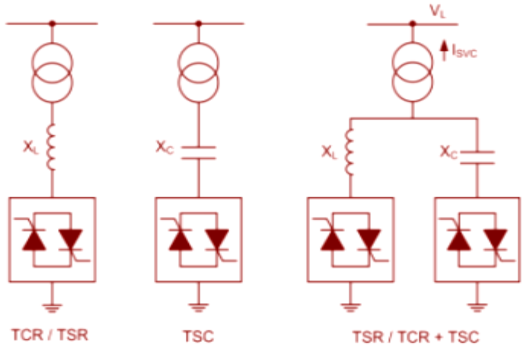

Fig.2.Basic structure of TSC/TCR (SVC)

B Static Compensator (STATCOM)

STATCOM is installed at the MV bus in the wind farm. Its aim is to help the wind farm in situations of voltage dips, voltage regulation, power factor control and power flow stabilizing. A general scheme of a STATCOM connected to an AC system has been presented in Fig.2. If the primary voltage of the inverter side becomes larger than the system side, the current passes the AC power system through the leakage reactance (X) of the transformer, and inverter generates reactive power for the power system (capacitive case). If the secondary voltage of the inverter side becomes larger than the system side, the reactive current passes from AC system to the inverter and inverter observes reactive power.

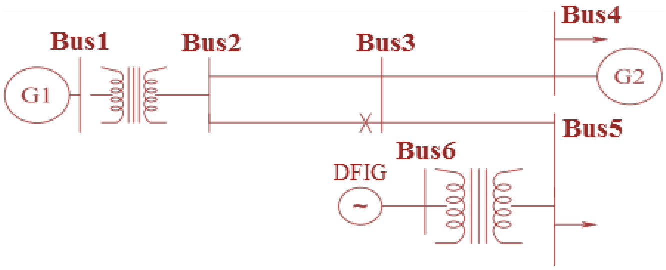

Fig.3. Basic structure of STATCOM at grid connected wind turbines

C. Unified Power Flow Controller (UPFC)

This FACT device is consisted of two converters. As presented in Fig.3 the converter-1 is to supply or absorb the real power demanded by converter-2 at the common dc link to support the real power exchange resulting from the series voltage injection. Converter-1 can generate or absorb controllable reactive power if desired, and thereby provide independent shunt reactive compensation for the line. The superior operating characteristic of UPFCConverter-2 provides the main function the UPFC by injecting a voltage Vpq with controllable magnitude and phase angle ρ in series with the line via an insertion transformer finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar

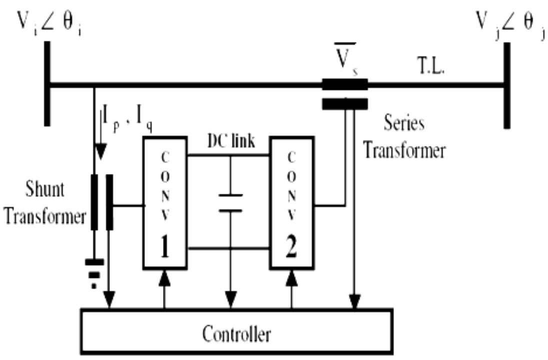

Fig.4.Basic structure of UPFC

D. Static synchronous series compensator (SSSC)

It is FACTS controllers connecting in series with a power transmission lines. It consists of a solid state voltage source converter (*VSC*) which generates a controllable alternating current voltage at fundamental frequency. When the injected voltage is kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as influence the power flow through the transmission line

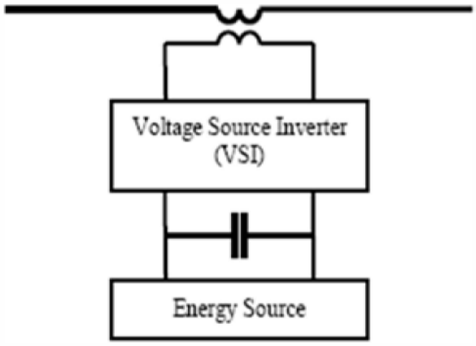

Fig.5. Basic configuration of SSSC

III FUZZY LOGIC CONTROLLER

A new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig.7 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action

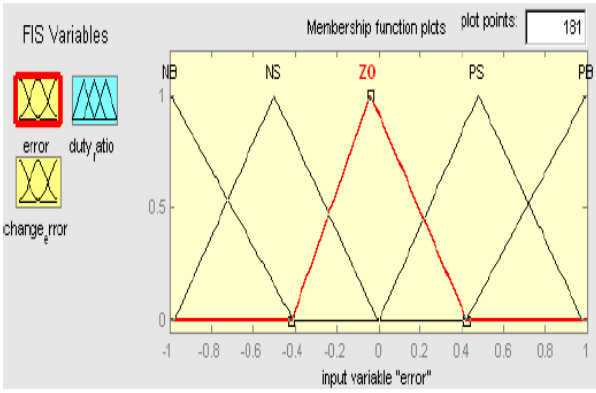

Fig. 6.The Membership Function

IV. SSSC CONTROL SYSTEM

To respond the dynamic and transient changes caused in system, SSSC utilizes the series converter as shown in Figure 7. One side of the converter is connected to the AC system while the other side is connected to a capacitor and battery. If a change (large load entrance or three phase faults and etc) occurs in system, SSSC control system works such that according to the control system in the energy of battery to be converted to the AC form by converter, and then injecting this voltage to the transmission line causes that the spontaneous demand to be met and properly damping occurs.

Fuzzy controller which is in control system of Figure 7 is shown in Figure 8. To control the active and reactive powers, first, sampling from the voltage and current is done and then it is transformed to the dq0 values. Active and reactive powers of bus-2 are calculated using their voltage and current in dq0 references and compared with the determined reference and the produced error signal is sent to the Fuzzy controllers. Then, the output of the controllers are transformed to the abc reference and given to the PWM so as to adjust properly the IGBTs firing angles.

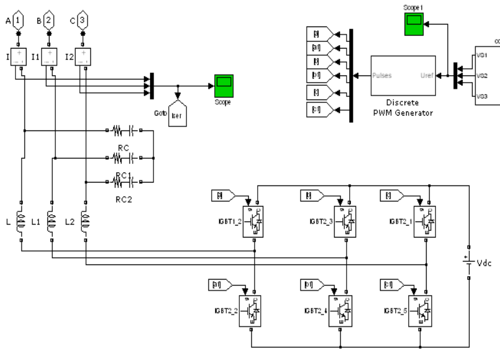

Fig: 7. The Converter of SSSC

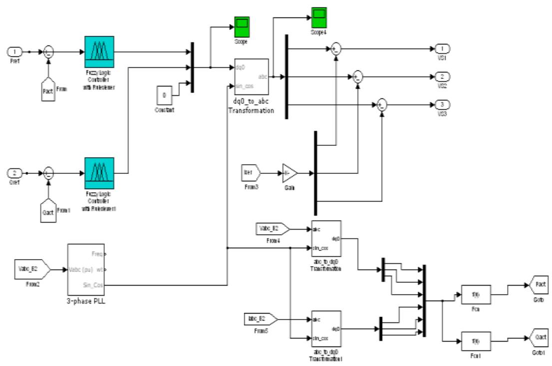

Fig: 8.Control circuit of SSSC

V. MATLAB/SIMULINK RESULTS

To assess the effectiveness of the proposed controller,
simulation studies are carried out for both WITH and without SSSC and the FACTS device with fuzzy logic controller

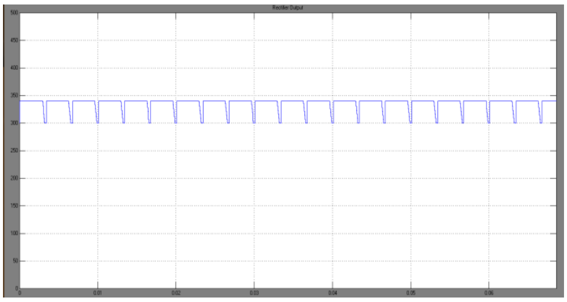

Fig.9.Simulation results for DC output for three phase rectifier using Thyristors

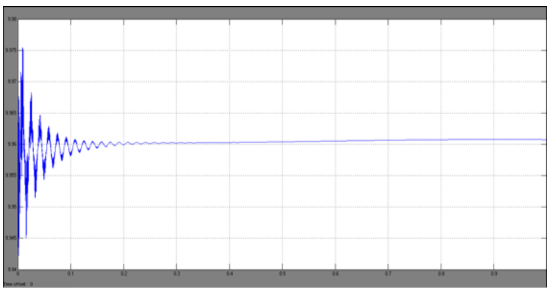

Fig .10 Active power without SSSC

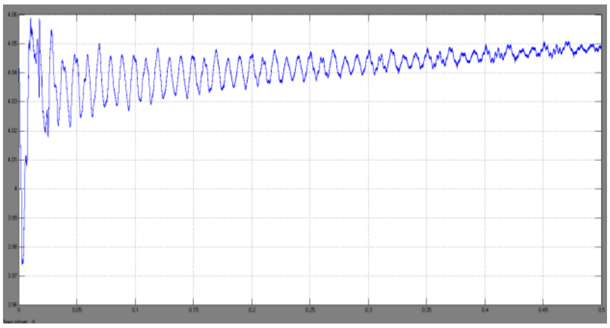

Fig 11. Active power with SSSC

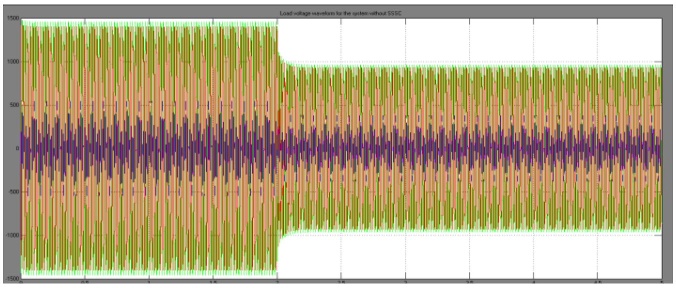

Fig.12.Simulation results for Load voltage waveform for the system without SSSC.

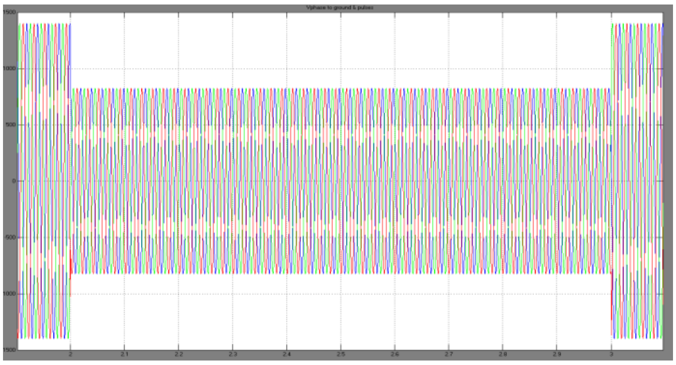

Fig.13.Simulation results for Load voltage waveform for the system with SSSC

VI. CONCLUSION

This paper discusses about the new concept of Wind based SSSC for power flow enhancement in distributed generation system. It deals with the approach of utilizing the wind farm itself as SSSC for providing a flexible control over the power flow in transmission lines simultaneously. On this account the simulation of wind energy based SSSC is performed and interfaced to the transmission system. The loads are added to the system and subsequent compensation is provided by Wind based SSSC. Here in this paper fuzzy based controller is used, and it is one of the most useful controller was utilized in SSSC control system

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