Grid Connected Wind Energy System for Power Quality Improvement by using STATCOM

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Abstract— **In this paper integration of wind power to grid introduces power quality issues, which mainly consist of voltage regulation and reactive power compensation. The most used unit to compensate for reactive power in the power systems are either synchronous condensers or shunt capacitors, the latter either with mechanical switches or with Thyristor switch, as in Static VAR Compensator (SVC). The disadvantage of using shunt Capacitor is that the reactive power supplied is proportional to the square of the voltage. To overcomes the above disadvantages; STATCOM is best suited for reactive power compensation and harmonic reduction. It is based on a controllable voltage source converter (VSC). By control of the voltage source converter output voltage in relation to the grid voltage, the voltage source converter will appear as a generator or absorber of reactive power. In this 3-phase separately excited induction generator feeding nonlinear load has been presented. A STATCOM is connected at the point of common coupling with this system in order to compensate the reactive power requirements of induction generator as well as load and also to reduce the harmonics produced by the nonlinear load. Reactive power compensation and harmonic reduction in a low voltage distribution networks for integration of wind power to the grid are the main issues. This Paper proposes a control scheme based on Fuzzy logic for compensating the reactive power requirement of a three phase grid connected wind driven induction generator as well as the harmonics produced by the non linear load connected to the PCC using STATCOM. The proposed control scheme is simulating using MATLAB/SIMULINK.**

Manuscript received July 18, 2014

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Index Terms— Static VAR Compensator (SVC), voltage source converter (VSC), STATCOM.

I. INTRODUCTION

To improve power quality, a power-electronics-based technology, also known as an active-power conditioner (APC), has been proposed. Based on their principles of operation, these APCs can be largely divided into the series, chopping, dual power conversion and parallel types. Rapid variation of reactive power generated by arc furnaces, and harmonics produced by diode or thyristor rectifiers have been serious as they have caused flicker or harmonic interference in industrial applications and transmission/distribution systems[1]. A shunt passive filter exhibits lower impedance at a tuned harmonic frequency than the source impedance to reduce the harmonic currents Rowing into the source. In principle, filtering characteristics of the shunt passive filter are determined by the impedance ratio of the source and the shunt passive filter[2]. The source impedance, which is not accurately known and varies with the system configuration, strongly influences filtering characteristics of the shunt passive filter. The shunt passive filter acts as a sink to the harmonic current flowing from the source. At a specific frequency, an anti resonance or parallel resonance occurs between the source impedance and the shunt passive filter, which is the so-called harmonic amplification [3]. Over the last five to ten years, remarkable progress of fast switching devices such as bipolar junction transistors and static induction thyristors has spurred interest in the study of shunt and series active power line conditioners for reactive power and harmonic compensation [4]. At present, the purpose of shunt active conditioners is to compensate for reactive power, negative- sequence, harmonics, and/or flicker. Moreover, attention is paid to the combined system of an active power line conditioner and a shunt passive filter to reduce initial costs and to improve efficiency [5]. The power quality of power supply of an ideal power system means to supply electric energy with perfect sinusoidal waveform at a constant frequency of a specified voltage with least amount of disturbances. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive equipment and non-linear loads are now more commonplace in both the industrial commercial sectors and the domestic environment. Harmonics are periodic sinusoidal distortions of the supply voltage or load current caused by non-linear loads. Harmonics are measured in integer multiples of the fundamental supply frequency [6]. Using Fourier series analysis the individual frequency components of the distorted waveform can be described in terms of the harmonic order, magnitude and phase of each component. The electricity is produced and distributed in its fundamental form as 50 Hz in India. A harmonics is defined as the content of signal who's frequency is integer multiple of the system fundamental frequency. Active power filters are powerful tools for compensating for not only the current harmonics produced by non-linear loads, but also the reactive power and unbalance of non-linear and fluctuating loads[7].

II. POWER QUALITY IMPROVEMENT BY USING STATCOM

The STATCOM based current control voltage source inverter injects the current into the grid in such a way that the source current are harmonic free and their phase angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter.

The control scheme approach is based on injecting the currents into the grid using "bang-bang controller." The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation. The control algorithm needs the measurements of several variables such as three-phase source current (i_{Sabc}), DC voltage (V_{dc}), inverter current (i_{iabc}) with the help of sensor in Fig.1. The current control block, receives an input of reference current (i^*_{Sabc}) and actual current (i_{Sabc}) are subtracted so as to activate the operation of STATCOM in current control mode.

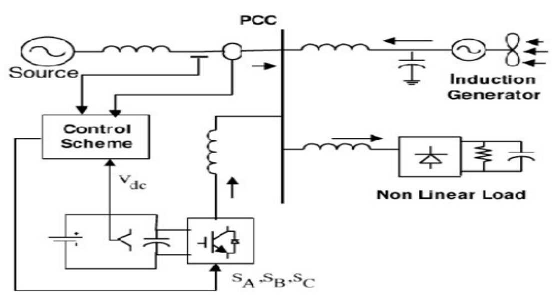

Fig. 1: power quality improvement by using statcom with control scheme

Fuzzy logic controller

Fuzzy logic is a method of rule-based decision making used for expert systems and process control that emulates the rule-of-thumb thought process used by human beings. The basis of fuzzy logic is fuzzy set theory which was developed by LotfiZadeh in the 1960s. Fuzzy set theory differs from traditional Boolean (or two-valued) set theory in that partial membership in a set is allowed [10]. Traditional Boolean set theory is two-valued in the sense that a member belongs to a set or does not and is represented by 1 or 0, respectively. Fuzzy set theory allows for partial membership, or a degree of membership, which might be any value along the continuum of 0 to 1. A linguistic term can be defined quantitatively by a type of fuzzy set known as a membership function [11].

The membership function specifically defines degrees of membership based on a property such as temperature or pressure. With membership functions defined for controller or expert system inputs and outputs, the formulation of a rule base of IF-THEN type conditional rules is done. Such a rule base and the corresponding membership functions are employed to analyze controller inputs and determine controller outputs by the process of fuzzy logic inference [12]. By defining such a fuzzy controller, process control can be implemented quickly and easily. Many such systems are difficult or impossible to model mathematically, which is required for the design of most traditional control algorithms. In addition, many processes that might or might not be modeled mathematically are too complex or nonlinear to be controlled with traditional strategies. However, if a control strategy can be described qualitatively by an expert, fuzzy logic can be used to define a controller that emulates the heuristic rule-of-thumb strategies of the expert. Therefore, fuzzy logic can be used to control a process that a human can control manually with expertise gained from experience. The linguistic control rules that a human expert can describe in an intuitive and general manner can be directly translated to a rule base for a fuzzy logic controller. Developing a FIS and applying it to a control problem involves several steps[12]:

1. Fuzzification

2. Fuzzy rule evaluation (fuzzy inference engine)

3. Defuzzification.

The total fuzzy inference system is a mechanism that relates the inputs to a specific output or set of outputs in Fig.2. First, the inputs are categorized linguistically (fuzzification), then the linguistic inputs are related to outputs (fuzzy inference) and, finally, all the different outputs are combined to produce a single output (defuzzification)[13][14].

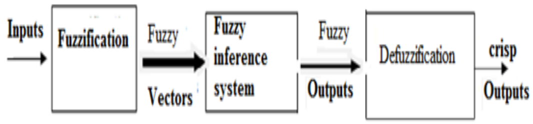

Fig .2: Fuzzy inference system

III. MATLAB/SIMULINK Model without STATCOM

The Simulation circuit of grid connected system is shown in the Fig 3. In this 3-phase induction generator feeding nonlinear load has been presented. The integration of wind power to grid introduces power quality issues, which mainly consist of voltage regulation and reactive power compensation. Iinduction generator draws reactive power from the grid for its magnetization and Nonlinear load distorts the grid current waveform and also increase the harmonic component [15][16].

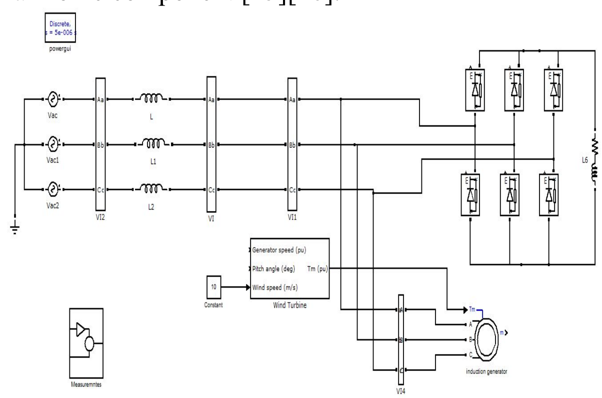

Fig. 3: MATLAB/Simulink Model of the power without STATCOM

MATLAB/Simulink Result of 3-Phase Source current, load current, and Source Voltage waveforms without STATCOM

The simulation is performed using MATLAB/Simulink and the output of 3-Phase Source current, load current, Source Voltage waveforms are shown in the Fig 4.The grid current is not in phase with the grid voltage and its wave shape is also different from sine wave. Hence the power factor is not unity.

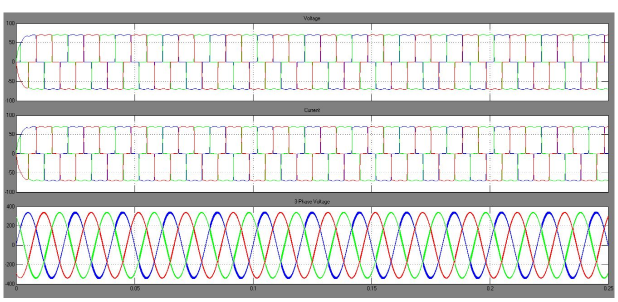

Fig. 4: 3-Phase Source current, load current, Source Voltage waveforms without STATCOM

MATLAB/Simulink THD results without STATCOM THD Performance:

Power Factor wave form without STATCOM is shown in Fig.5.

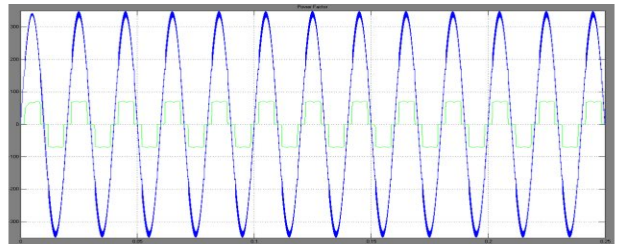

Fig. 5: Power Factor wave form without STATCOM

Total Harmonic Distortion Value of the Source Current Is 25.53% shown in Fig .6

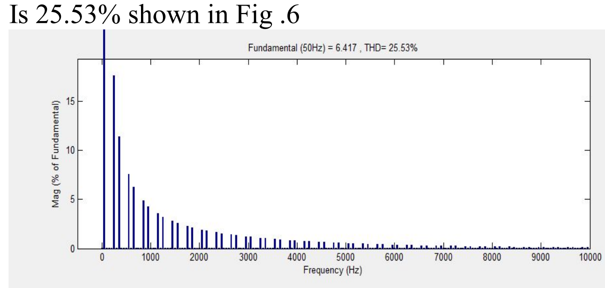

Fig. 6: Total Harmonic Distortion Value of the Source Current Is 25.53%

MATLAB/Simulink Model with STATCOM and with different load:

MATLAB/Simulink Model of the power quality improvement With the Fuzzy Logic Controller at different load conditions is shown in Fig.7.

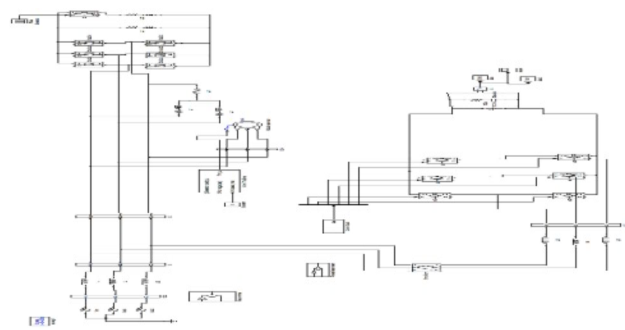

Fig.7: MATLAB/Simulink Model of the power quality improvement With the Fuzzy Logic Controller at Different Load Conditions

MATLAB/Simulink Model of the Control Circuit with the Fuzzy Logic Controller

MATLAB/Simulink Model of the Control Circuit with the Fuzzy Logic Controller is shown in Fig.8.

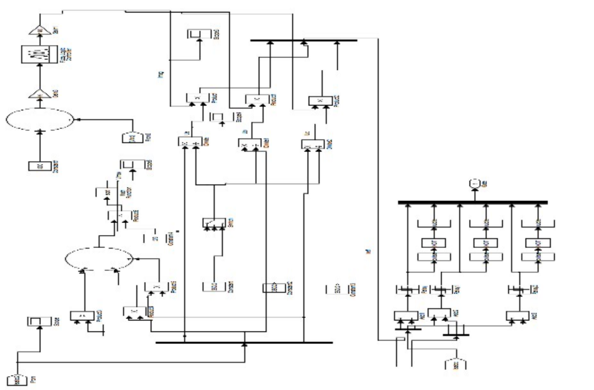

Fig. 8: MATLAB/Simulink Model of the Control Circuit with the Fuzzy Logic Controller

Simulated Output with the Fuzzy Logic Controller:
Output Wave Forms of the Single Phase Source Current, Load Current and Compensating Current is shown in Fig.9.

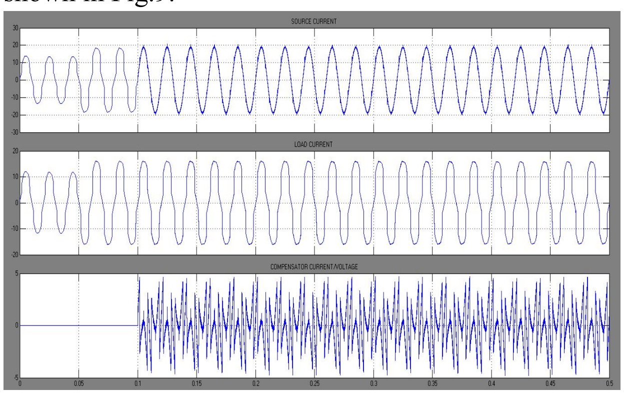

Fig.9: Output Wave Forms of the Single Phase Source Current, Load Current and Compensating Current

Simulated Output Result of Voltage & Current with the Fuzzy Logic Controller:
Waveform of Voltage & Currents indicating Unity power factor at the source side is shown in Fig.10.

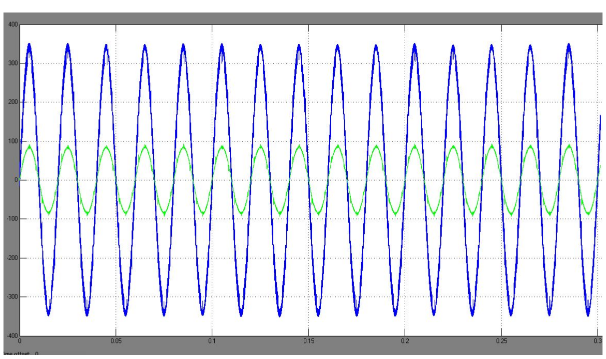

Fig.10: Waveform of Voltage & Currents indicating Unity power factor at the source side

Simulated Output Result of Three Phase Source Current, Load Current and Compensating Current with the Fuzzy Logic Controller:

The performance of the system is analyzed with and without STATCOM by switching ON the ST ATCOM at time t=0.1s. Initially the STATCOM current is zero after 0.1 seconds the STATCOM starts tracking the reference current within the hysteresis band. Grid current is not in phase with voltage during STATCOM OFF condition.
During the STATCOM ON condition grid current is in phase with voltage, which signifies that the excess power after feeding the nonlinear load is fed back to the source.

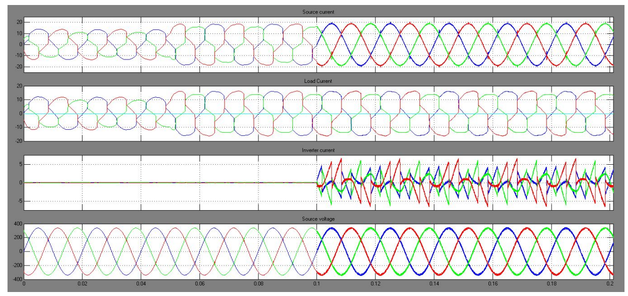

Fig.11: Simulated Output Wave Forms of the Three Phase Source Current, Load Current and Compensating Current.

Simulated Output Result of THD with the Fuzzy Logic Controller for STATCOM:
Fig. 12 shows THD value of a Fuzzy Based STATCOM Control Scheme For Grid Connected Wind Energy System is 2.58%.

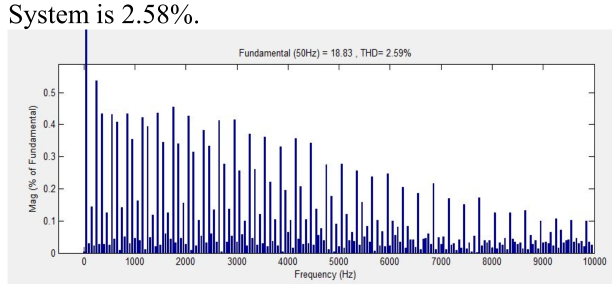

Fig.12: Total Harmonic Distortion Value of the Source Current with Fuzzy Logic Controller is 2.58%

Comparison for non-linear unbalanced load for without and with STATCOM:
Comparison for non-linear unbalanced load for without and with STATCOM

Parameters	Without STATCOM	With STATCOM
THD	25.53%	2.58%
Power factor	Not unity	Unity
Source current	Non sinusoidal	Sinusoidal
Load current	Non sinusoidal (unbalanced)	sinusoidal (balanced)

Source voltage	Sinusoidal	Sinusoidal

Table .1: comparison for non-linear unbalanced load for without and with STATCOM

IV. CONCLUSION

In this paper, Fuzzy based STATCOM control scheme for power quality improvement in grid connected wind generating system and with non linear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and STATCOM with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21

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