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Mitigation of Harmonics using D-STATCOM with Fuzzy Logic

A Santosh Kumar [1] | Dr. B Srinivasa Rao [2]

[1]PG Scholar, Department of EEE, Sri Venkateswara College of Engineering and Technology, Srikakulam, India.
[2]Associate Professor, Department of EEE, Sri Venkateswara College of Engineering and Technology, Srikakulam, India.

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ABSTRACT

This paper presents the enhancement of voltage sags, Harmonic distortion and low power factor using Distribution Static Compensator (D-STATCOM) with LCL Passive Filter in Distribution system. Whenever there is a penetration of photovoltaic cell power to the low voltage distributed grid, there occur the problem of mismatch in voltage and frequency in the network, perhaps caused by non-linear loads, generating harmonics. The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags. LCL Passive Filter Was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK.

Keywords: *Fuzzy Logic Controller, D-Statcom, Harmonic Analysis, PI Controller.*

I. INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occur. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min.

Voltage sags is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Voltage sags are one of the most occurring power quality problems. For an industry voltage sags occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems.

Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. The development of power electronics devices such as Flexible AC Transmission System (FACTS) and customs power devices have introduced and emerging branch of technology providing the power system with versatile new control capabilities. There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices.

A new PWM-based control scheme has been implemented to control the electronic valves in the DSTATCOM. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage. In this paper, the configuration and design of the DSTATCOM with LCL Passive Filter are analyzed. It is connected in shunt or parallel to the 11 kV test distribution system. It also is design to enhance the power quality such as voltage sags, harmonic distortion and low power factor in distribution system.

The reactive power compensation is also one of the application of shunt converter devices [4]. Figure 1 shows the basic diagram for the shunt connected inverter based grid connected system.

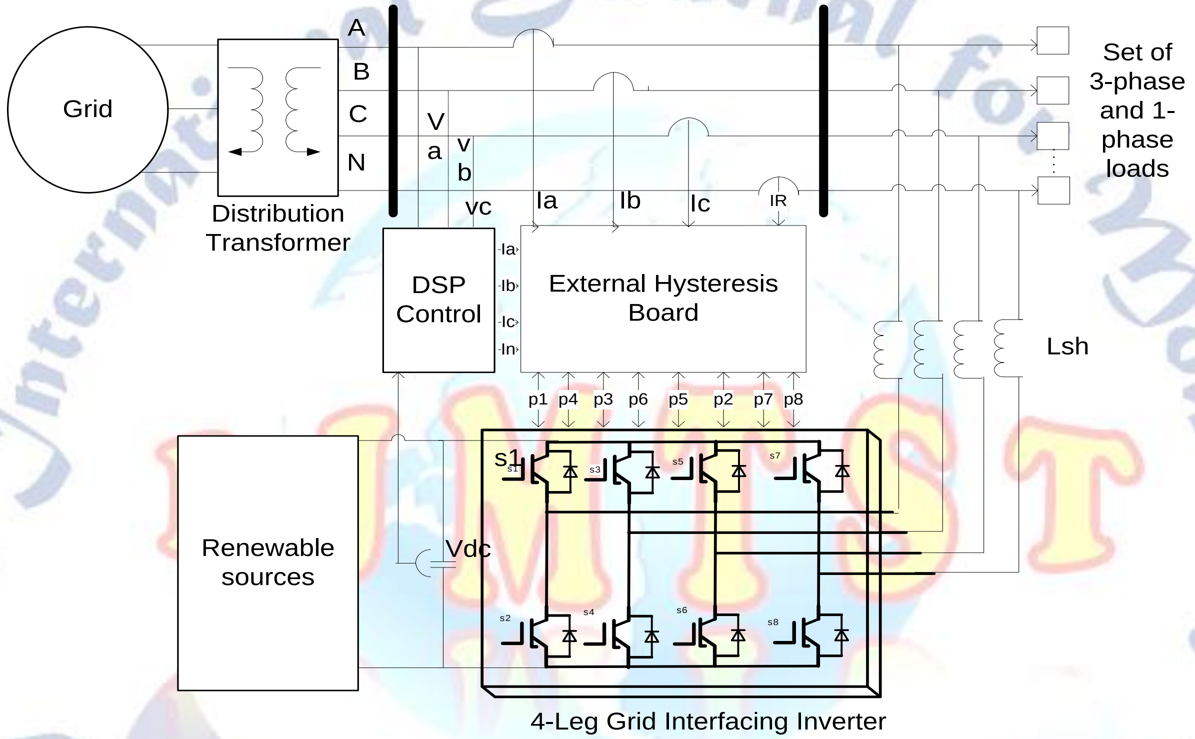

Figure 1: Diagram for Proposed System

II. STATCOM AND ITS CONTROL TECHNIQUE

A STATCOM is a one of the compensated device which is obtained from the FACTS family [11] and is a combination of power electronic converter along with reactor. Mostly, the converter is constructed by the use of fully controlled devices such as GTO, IGBT or MOSFET. The main purpose of this STATCOM converter control technique is used to compensate the deviations in power system for improving power quality. In this paper grid interfaced wind turbine based STATCOM control scheme is proposed for improving the reliability of electrical power [12].

- The Dc voltage obtained for STATCOM is generated from Solar Cells. The schematic diagram of Static compensator is given in figure 2.

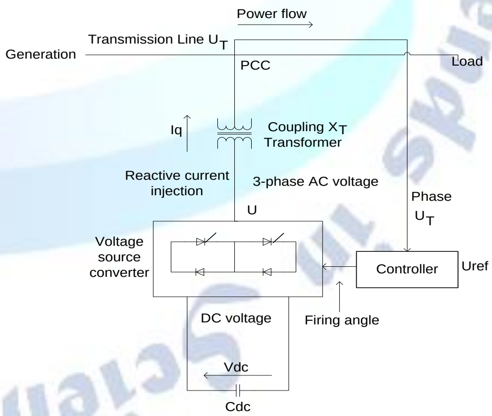

Figure 2: Basic block diagram for static compensator.

The utilization of different types of electrical loads in three phase system, produces an unbalances in current, which causes the unreliable power [13]. Thereby for maintaining the electrical reliability the statcom controller plays a key role. In this statcom control technique, the reference voltage and dc link capacitor voltages are compared and the result obtained from this is converted to two phase coordinators called as orthogonal vectors.

III. Control for Reactive Power Compensation

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load under system disturbances is connected. The control system only measures the root mean square (r.m.s) voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the fundamental frequency switching methods favored in FACTS applications. Apart from this, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

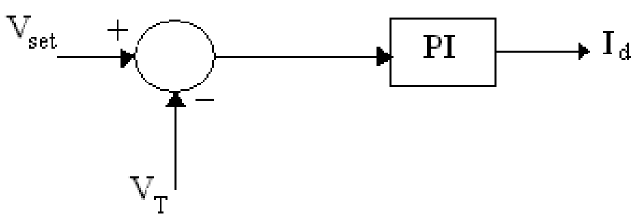

Fig. 3 PI Control Scheme

The controller input is an error signal obtained from the reference voltage and the r.m.s terminal voltage measured. Such error is processed by a PI controller; the output is the angle δ, which is provided to the PWM signal generator. It is important to note that in this case, of indirectly controlled converter, there is active and reactive power exchange with the network simultaneously. The PI controller processes the error signal and generates the required angle to drive the error to zero, i.e. the load r.m.s voltage is brought back to the reference voltage.

IV. FUZZY CONTROLLER

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 4. Generally, the FLC is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

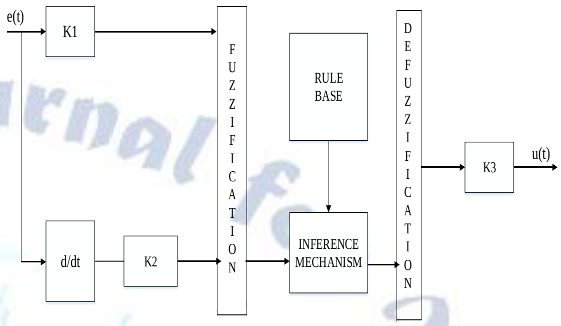

Figure 4: basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3.The numbers of rules are formed as 9. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the output as maximum value of input.

V. SIMULATION STUDY

The simulation is done based on the figure 1. The simulation diagram for the proposed grid interfaced wind energy system with STATCOM is shown in figure 2.

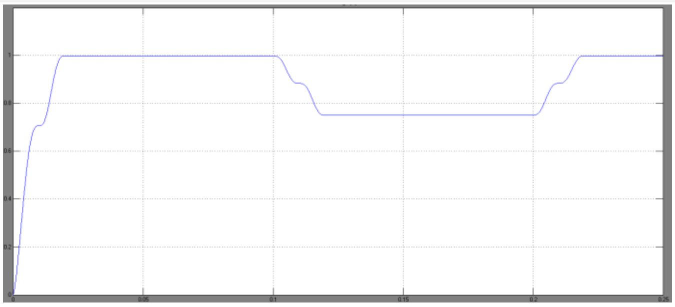

Figure 5: Simulation Result for Line Voltage under RMS without DSTATCOM

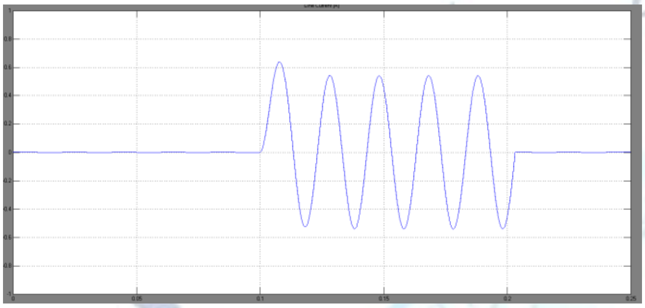

Figure 6: Simulation Result for Line Current under RMS without DSTATCOM

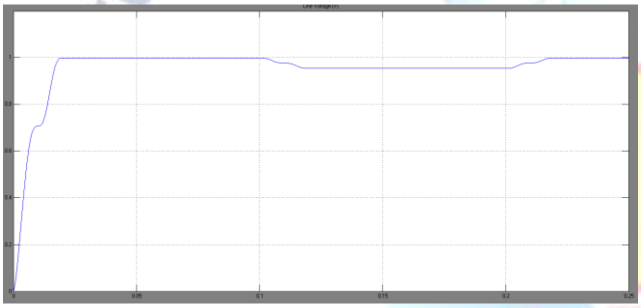

Figure 7: Simulation Result for Line Voltage under RMS with DSTATCOM

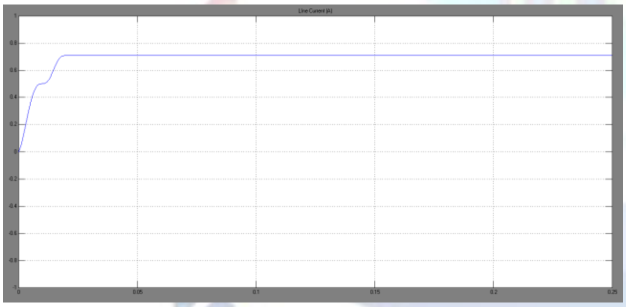

Figure 7: Simulation Result for Line Current under RMS with DSTATCOM

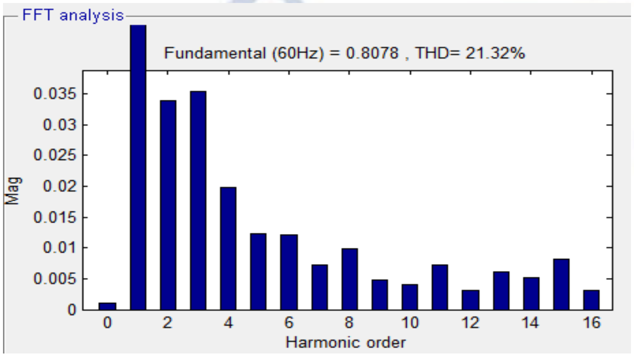

Figure 7: THD value for Line Current without FUZZY

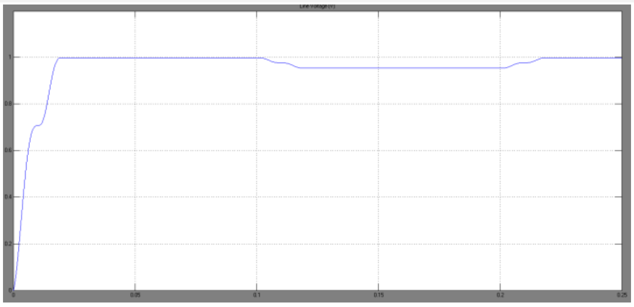

Figure 8: Simulation Result for Line Voltage under RMS with DSTATCOM and FUZZY

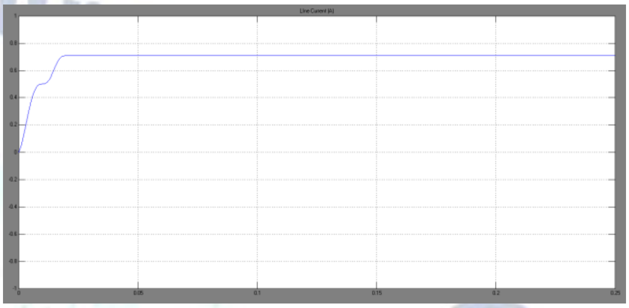

Figure 9: Simulation Result for Line Current under RMS with DSTATCOM and FUZZY

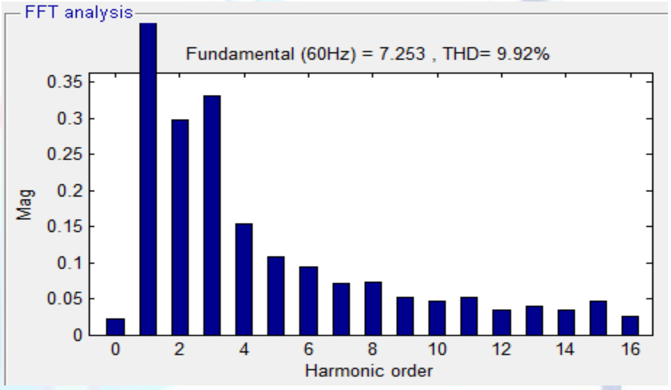

Figure 10: THD value for Line Current with FUZZY

VI. CONCLUSION

The paper presents a novel concept of integration of fuzzy based DSTATCOM with grid inter faced wind energy system for power quality improvement. The paper also presents effects of power quality on consumer and power utility systems. The shunt devices proposed here, while reducing the distortions in currents, improved the power factor thus reducing the reducing the reactive power demand from the wind generator and the load at point of common coupling. Thus, the integration of FACTS devices maintains the desired power quality requirements. The operation of STATCOM and their control strategies are simulated in MATLAB/SIMULINK.

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