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A Hybrid Fuzzy based DSTATCOM for Power Quality Improvement of Grid Connected Wind Energy System

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Abstract:

Power quality can be defined as any power quality problems manifested in voltage, current and frequency those results in failure or mal-operation of customer equipment. Injection of wind power into an electric grid affects the power quality. The work analyses the performance of Static Compensator (DSTATCOM) with a wind energy generating system at the point of common coupling to mitigate the power quality issues. In this work, D-STATCOM voltage source inverter (PWM-VSI) is connected between diesel generator and load which compensates harmonics in the AC grid. Implementation of the harmonics compensation by using D-STATCOM in the hybrid distribution system is used to attain the voltage stability. Here, Fuzzy logic algorithm with hysteresis loss current control method is used for harmonic reduction using D-STATCOM. The objective of this work is to show that with an adequate control, the converter not only can transfer the DC from hybrid solar wind energy system, but also can improve the power factor and quality power of electrical system. Here two control schemes for DSTATCOM are Fuzzy logic controller and hybrid Fuzzy logic controller. We can better response for hybrid fuzzy compare to fuzzy logic controller. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK.

Keywords:

STATCOM, power quality, wind generating system, Battery Energy Storage System (BESS), Bang –Bang current controller, Fuzzy logic controller.

I.INTRODUCTION:

Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the wind. Wind is the motion of air masses produced by the irregular heating of the earth's surface by sun. These differences consequently create forces that push air masses around for balancing the global temperature or, on a much smaller scale, the temperature between land and sea or between mountains. Wind energy is not a constant source of energy [4].It varies continuously and gives energy in sudden bursts. The widespread use of electronic equipment and electrical equipment susceptible to power quality or more appropriately lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems.

The electrical device might be an electrical motor, a transformer, a generator, a computer, a printer, communication equipment, or household appliances. Here proposing a STATCOM based control technology for mitigating the power quality issues when we are integrating wind farms to the grid. In the event of increasing grid disturbances, a battery energy storage system is required to compensate the fluctuation generated by wind turbine. Here two control schemes for STATCOM is designed and compared. Bang-Bang Current controller and fuzzy logic controller. PI controller plays an important role in reducing fluctuating voltage error signal efficiently. Simulation result shows that the proposed STATCOM with PI controller is efficient in mitigating voltage sags and thus improving the power quality of the power grid Fuzzy logic technique has been used as it has advantage of robustness, easily adaptive fast technology is also used and best results are achieved when compared to conventional PI technique.

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II.TOPOLOGY FOR POWER QUALITY IMPROVEMENT:

The STATCOM is a three- phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling [1]. Here the utility source, wind energy system and STATCOM with BESS are connected to the grid. The current controlled voltage source inverter based STATCOM injects the current into the grid in such a way that the source current (grid current) are harmonic free and they are in phase-angle with respect to source voltage. The injected current will cancel out the reactive part and harmonic part of the induction generator current and load current, thus it improves the power quality [4]. This injected current generation is by proper closing and opening of the switches of voltage source inverter of STATCOM and is different for the two control schemes proposed. For this the grid voltages are sensed and are synchronized in generating the current command for the inverter.

A. Wind Energy Generating System:

In this configuration, wind energy generation is based on constant speed topologies with pitch control turbine.

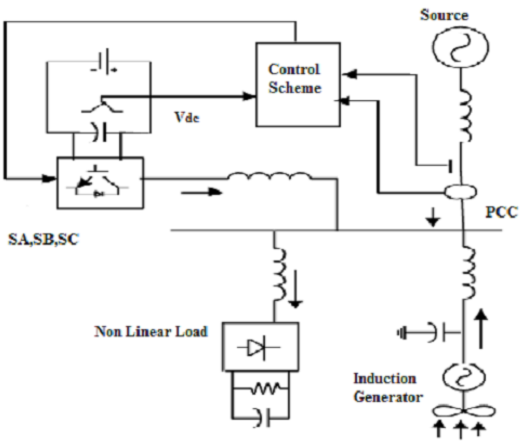

Fig.1.System operational scheme in grid system.

The induction generator is used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. The available power of wind energy system is presented as:

$$P_{wind} = \frac{1}{2} \rho A V_{wind}^{3} \quad (1)$$

Where ρ= air density (kg/m3), A = area swept out by turbine blade (m), V wind= wind speed (m/s). It is not possible to extract all kinetic energy of wind. Thus extracts a fraction of the power called power coefficient 'Cp' of the wind turbine, and is given by:-

$$P_{mech} = C_p P_{wind} \quad (2)$$

The mechanical power produced by wind turbine is given by:-

$$P_{mech} = \frac{1}{2} \rho \Pi R^2 V_{wind}^{3} C_p \quad (3)$$

Where, R = Radius of the blade (m).

B. BESS-STATCOM:

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation [1]. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbs reactive power to stabilize the grid system. When power fluctuation occurs in the system, the BESS is used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM.

C. System Operation:

The shunt connected STATCOM with battery energy storage is connected at the interface of the induction generator and non-linear load at the PCC [4]. The Fig.1 represents the system operational scheme in grid system. The STATCOM output is varied according to the control strategy, so as to maintain the power quality norms in the grid system. The current control strategies for STATCOM are the Bang-Bang controller and fuzzy logic controller. A single STATCOM using insulated gate bipolar transistors is proposed to have a reactive power support to the induction generator and to the nonlinear load in the grid system. .

D. Control Scheme:

The first control scheme approach is based on injecting the currents into the grid using "bang-bang controller" [1].The controller uses a hysteresis current controlled technique as shown in Fig 2. Using such a technique, the controller keeps the control system variable between the boundaries of hysteresis area and gives correct switching signals for STATCOM operation.

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The current controller block receives reference current and actual current as inputs and are subtracted so as to activate the operation of STATCOM in current control mode [5]. The second control scheme is fuzzy logic controller. The inputs to the controller 'change in grid voltage (ΔV)' and 'change in grid current (ΔI)' and is represented as membership functions of the controller .The output is correct switching signals for IGBTs of STATCOM (ΔU).

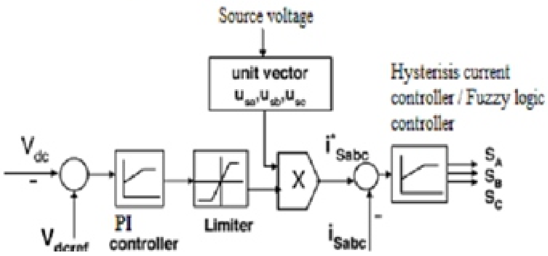

Fig.2.Control Scheme.

E Grid Synchronization:

In the three-phase balance system, the RMS source voltage amplitude is calculated from the source phase voltages (Vsa, Vsb, Vsc) and is expressed as sample template (sampled peak voltage),Vsm:

$$V_{sm} = \sqrt{\{2/3(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)\}} \quad (4)$$

The in-phase unit vectors are obtained from source voltage in each phases and the RMS value of unit vector is shown below

$$U_{sa} = V_{sa}/V_{sm}$$
$$U_{sb} = V_{sb}/V_{sm}$$
$$U_{sc} = V_{sc}/V_{sm} \quad (5)$$

Where 'I' is proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal [6].

F. Bang-Bang Current Controller :

It is implemented in the current control scheme. The reference current is generated as in equation (6) and actual current are detected by current sensors and are subtracted for obtaining a current error for a hysteresis based bang-bang controller. Thus the ON/OFF switching signals for IGBTs of STATCOM are derived from hysteresis controller [1] .The switching function SA for phase 'a' is expressed as:

$$(i_{sa} - i_{sa}^*) < HB = S_A = 1$$
$$(i_{sa} - i_{sa}^*) > HB = S_A = 0 \quad (7)$$

This is same for phases 'b' and 'c'.

G. Fuzzy Logic Controller:

In a fuzzy logic controller, the control action is determined from the evaluation of a set of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The objectives include excellent rejection of input supply variations both in utility and in wind generating system and load transients.

Expert knowledge can also be participated with ease that is significant when the rules developed are intuitively inappropriate [7]. The rule base developed is reliable since it is complete and generated sophistically without using extrapolation. In this project, fuzzy control is used to control the firing angle for the switches of the VSI of STATCOM. In this design, the fuzzy logic based STATCOM has two inputs 'change in voltage(ΔV)' and 'change in current(ΔI)' and one control output(ΔU).

Firstly the input values will be converting to fuzzy variables. This is called fuzzification. After this, fuzzy inputs enter to rule base or interface engine and the outputs are sent to defuzzification to calculate the final outputs. These processes are demonstrated in Fig. 3. Here seven fuzzy subsets have been used for two inputs. These are: PB (positive big), PM (positive medium), PS (positive small), ZE (zero), NS (negative small), NM (negative medium) and NB (negative big).

We use Gaussian membership functions [8] and 49 control rules are developed, which are shown in table 1. Fuzzification: It is the process of representing the inputs as suitable linguistic variables .It is first block of controller and it converts each piece of input data to a degree of membership function. It matches the input data with conditions of rules and determines how well the particular input matches the conditions of each rule.

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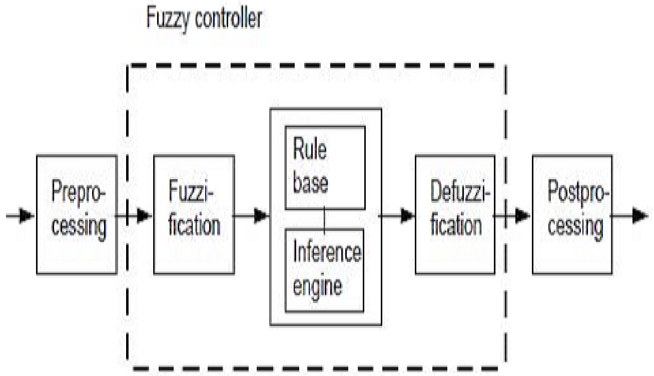

Fig.3. Fuzzy control block diagram.

Table I .Control Rules:

ΔI / ΔV	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

The membership functions for the inputs (for ΔV and ΔI) are shown in Fig.4 and Fig.5. The number of fuzzy levels is not fixed and it depends on the input resolution needed in an application. The larger the number of fuzzy levels, the higher is the input resolution. The fuzzy control implemented here uses sinusoidal fuzzy-set values Decision making:

The control rules that associate the fuzzy output to the fuzzy inputs are derived from general knowledge of the system behaviour. However, some of the control actions in the rule table are also developed using "trial and error" and from an "intuitive" feel of the process to be controlled. In this effort, the control rules for the STATCOM in Table 1 resulted from the understanding of STATCOM's behaviour and experimental tests of its VSI's performance.

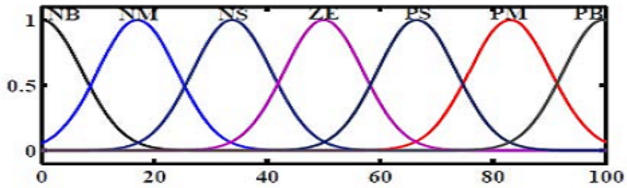

Fig.4. Membership function for ΔI.

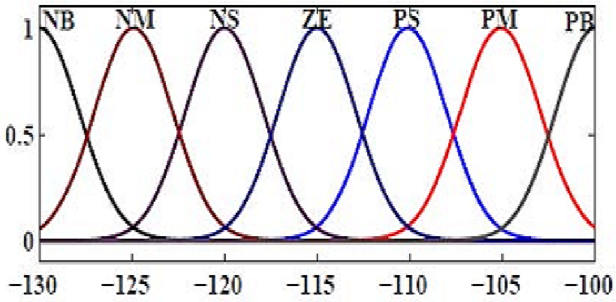

Fig.5. Membership functions for ΔV.

Defuzzification: It is the Process of converting fuzzy flied output into a crisp value. In the defuzzification operation a logical sum of the results from each of the rules performed. This logical sum is the fuzzy representation of the change in firing angle (output). A crisp value for the change in firing angle is calculated. Correspondingly the grid current changes and improves the power quality.

III.HYBRID FUZZY CONTROLLER:

The objective of the hybrid controller is to utilize the best attributes of the PI and fuzzy logic controllers to provide a controller which will produce better response than either the PI or the fuzzy controller. There are two major differences between the tracking ability of the conventional PI controller and the fuzzy logic controller. Both the PI and fuzzy controller produce reasonably good tracking for steady-state or slowly varying operating conditions. However, when there is a step change in any of the operating conditions, such as may occur in the set point or load, the PI controller tends to exhibit some overshoot or oscillations. The fuzzy controller reduces both the overshoot and extent of oscillations under the same operating conditions. Although the fuzzy controller has a slower response by itself, it reduces both the overshoot and extent of oscillations under the same operating conditions. The desire is that, by combining the two controllers, one can get the quick response of the PI controller while eliminating the overshoot possibly associated with it. Switching Control Strategy the switching between the two controllers needs a reliable basis for determining which controller would be more effective.

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The answer could be derived by looking at the advantages of each controller. Both controllers yield good responses to steady-state or slowly changing conditions. To take advantage of the rapid response of the PI controller, one needs to keep the system responding under the PI controller for a majority of the time, and use the fuzzy controller only when the system behavior is oscillatory or tends to overshoot. Thus, after designing the best stand-alone PI and fuzzy controllers, one needs to develop a mechanism for switching from the PI to the fuzzy controllers, based on the following two conditions:

1) Switch when oscillations are detected;
2) Switch when overshoot is detected.

The switching strategy is then simply based on the following conditions: IF the system has an oscillatory behavior THEN fuzzy controller is activated, Otherwise PI controller is operated. IF the system has an overshoot THEN fuzzy controller is activated, Otherwise PI controller is operated. The system under study is considered as having an overshoot when the error is zero and the rate of change in error is any other value than zero. The system is considered oscillatory when the sum of the absolute values of the error taken over time does not equal the absolute values of the sum of the error over the same period of time. Since the system is expected to overshoot during oscillatory behavior, the only switching criterion that needs to be considered is overshoot. However, in practice, it is more convenient to directly implement the control signal according to the control actions delivered by the controller. Consequently, the fuzzy controller can be designed so that normal behavior (no oscillations or overshoot) results in a null fuzzy action. Accordingly, the switching between the two controllers reduces to using PI if the fuzzy has null value; otherwise, the fuzzy output is used. In particular, the fuzzy controller can be designed so that a normal behavior.

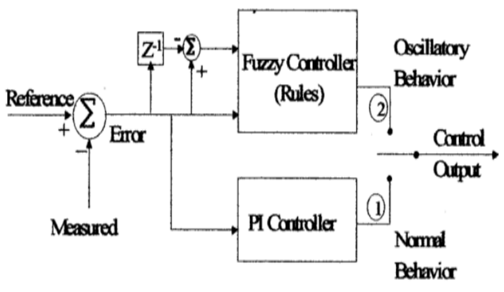

Fig.6. Structure of Switching Strategy Results in a Null Fuzzy Action.

IV.MATLAB/SIMULINK RESULTS:

Here simulation is carried out in several cases and the complete model of STATCOM with several control strategies are designed by using Matlab/Simulink platform.

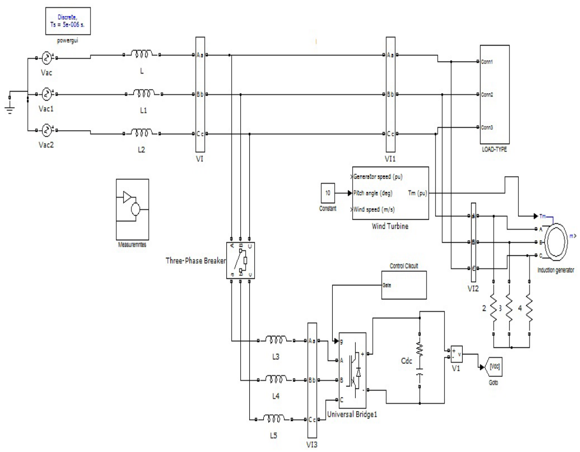

Fig.7.Matlab/Simulink of Proposed STATCOM-Power Circuit.

Fig.7. Matlab/Simulink Model of proposed power circuit, along with control circuit. The power circuit as well as control system are modeled using Power System Block set and Simulink. Here simulation is carried out at different control strategies, 1). Proposed converter with Conventional fuzzy Controller 2). Proposed converter with Conventional hybrid fuzzy Controller.

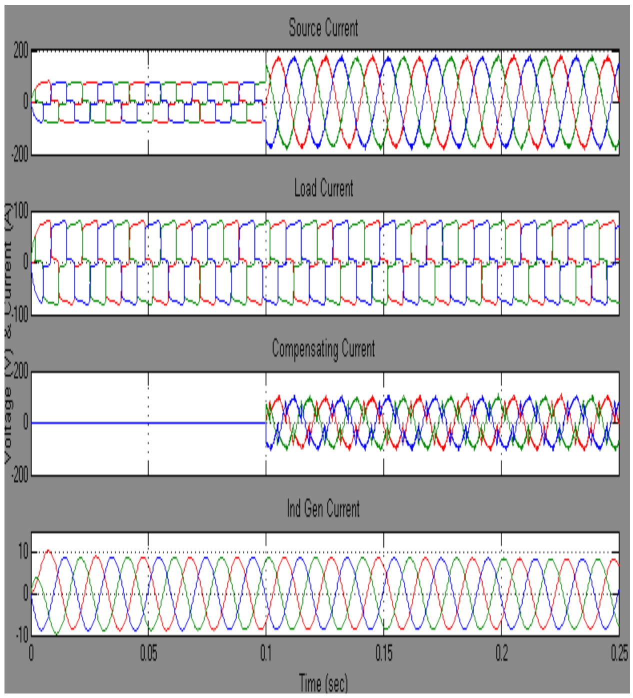

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Fig.8. Simulation results for Balanced Non Linear Load using fuzzy logic control (a) Source current. (b) Load current. (c) Compensator Current. (d) Wind Generator (Induction Generator) Current.

Fig.8.shows the source current, load current and compensator current and induction generator currents plots respectively with conventional fuzzy controller. Here compensator is turned on at 0.1 seconds, before we get some harmonics coming from non-linear load, then distorts our parameters and get sinusoidal when compensator is in on.

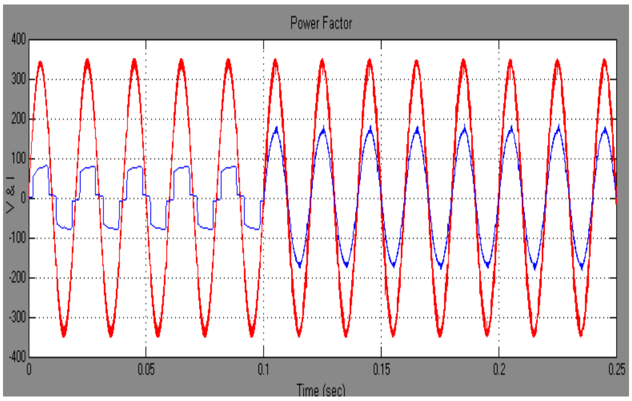

Fig.9.Power Factor for Balanced Non- Linear Load with Conventional Fuzzy Controller.

Fig. 9 shows the power factor it is clear from the figure after compensation power factor is unity.

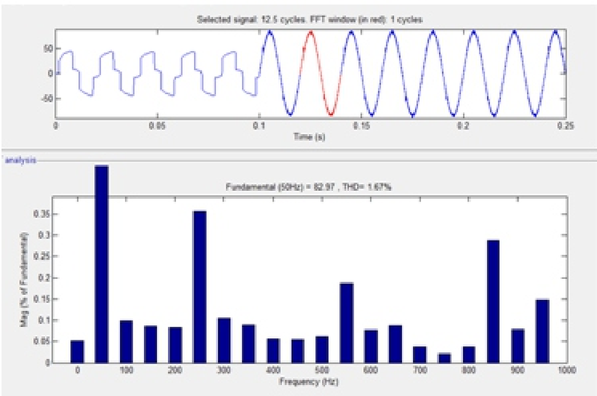

Fig.10.THD Analysis of Source Current with Fuzzy Logic Control.

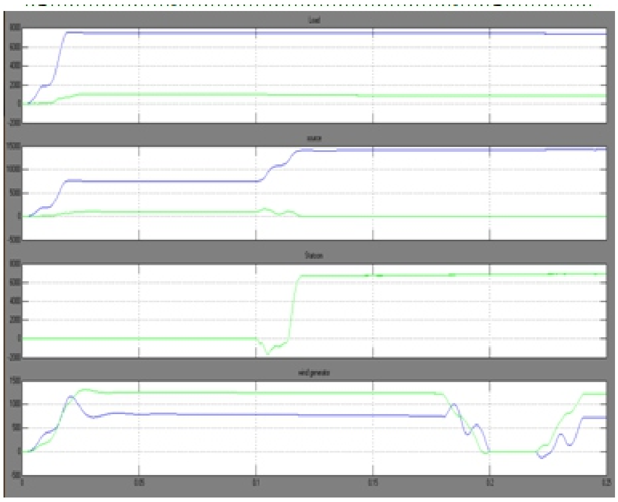

Fig.11.Real and Reactive Power for (A) Load (B) Source (C) STATCOM (D) Wind Energy Generating System.

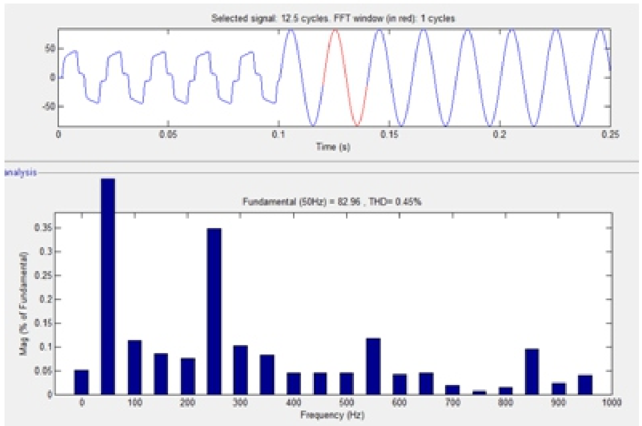

Fig.12.THD Analysis of Source Current with Hybrid Fuzzy Logic Control.

V.CONCLUSION:

The paper presents the DSTATCOM-based control scheme for power quality improvement in grid connected wind generating system with non linear loads. The operation of the DSTATCOM is simulated using two controllers: fuzzy controller and hybrid Fuzzy controller .DSTATCOM injects current to the grid and it cancel out the reactive and harmonic parts of the induction generator current and load current .When we are reducing the wind generating system output ,it will not affect the source current magnitude. The THD analysis revealed that the hybrid fuzzy logic controller is good compared to fuzzy logic controller. The hybrid fuzzy logic controller is simpler and has faster response.

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