© September 2019 | IJIRT | Volume 6 Issue 4 | ISSN: 2349-6002

A Fuzzy Based Statcom Control Scheme is used in Wind Energy Generation Interface to Grid for Improving the Power Quality

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***Abstract*- Now a days customers are more aware of the seriousness that the power quality possesses, this prompt the utilities to assure good quality of power to their customer. The power quality is basically customer centric. Increased focus of utilities toward maintaining reliable power supply by employing power quality improvement tools has reduced the power outages and black out considerably. Capacitor banks, FACTS devices, harmonic filters, SVC's (static voltage compensators), STATCOM (Static Compensator) are the solutions to achieve the power quality. The performance of Wind turbine generators is affected by poor quality power, at the same time these wind power generating plant affects the power quality negatively. In this project we are using STATCOM-BESS (battery energy storage system) system and studies its impact on the power quality in a system which consists of wind turbine generator, non linear load, hysteresis controller for controlling the operation of STATCOM and grid. In this, BESS level out the imbalances caused in real power due to intermittent nature of wind power available due to varying wind speeds. Fuzzy based STATCOM control is simulated to improve the power quality.. This scheme mitigates the power quality issues, improves voltage profile and also reduces harmonic distortion of the waveforms.**

Index terms- STATCOM, EPQ, BESS, MATLAB, Low Power Factor, Harmonic pollution, Load balance

I. INTRODUCTION

Power is the very crucial input for the growth of any economy. Therefore, it is considered as a core industry as it facilitates development across various sectors, such as agriculture, manufacturing, railways, education, commercial etc. to expel economic development. To meet the high GDP rates the energy needs of the country are inevitable. Renewable energy (RE) is characterized as intermittent and variable which presents various challenges in its grid integration for maintaining grid stability and security. Intermittent/variable nature of RE source in an area of high penetration results in wide variation in quantum and direction of power flow on the inter-state high capacity transmission corridors. This requires placement of dynamic reactive compensation in the form of dynamic reactive compensation in the form of STATCOM/ SVC at strategic locations to provide dynamic support for smooth operation and maintaining grid security. The integration of wind energy into existing electrical power system induces power quality problems like voltage regulation, stability, harmonic distortion, voltage sag/swell and poor power factor. The power quality is mainly customer-focused measure and is greatly affected by the operation of a distribution and transmission network. In this proposed scheme one of the Flexible AC transmission system (FACTS) device i.e., STATCOM is connected at point of common coupling (PCC) with a battery energy storage system (BESS) to mitigate power quality problems. Since, STATCOM connected to the grid provides reactive power support to wind generator as well as to loads.

II.PROBLEMS RELATED TO POWER QUALITY

2.1 Power quality issues at grid side

At the grid side the power quality is the responsibility of utility. Utility should make sure that the power matches the customer requirements and should not violate the limits that are specified for the parameters which define the power quality. From the customer point of view the voltage variations and high content of harmonics in the grid power are highly undesired as they affect the performance of the end equipments. For the IIP's who have planned the wind power project, the voltage profile of evacuating substation and nearby substations is of prime concern.

2.1. a Voltage variation

Intermittent nature of wind power causes several problems and one is variation of voltage of buses in the region of high RE penetration. Wind generators mostly employed induction generators and power electronic circuits which demand reactive power for operation. Voltage sag/swell is observed where ineffective methods of reactive power management are employed. If voltage rises beyond the controllable limit, forced tripping of lines carried out, cascaded tripping may destabilize a weak power system. Generally the power factor of evacuating substation is maintained near to unity preferably slightly lagging.

2.1.b Voltage Transient

Fault in the power system network, capacitor switching and HVDC systems are the primary cause of voltage transients. Voltage transients are responded well by STATCOM.

2.2 Power quality issues of WTG side

In wind energy generating system the power quality primarily concerned with the quality of current waveform which is being drawn or generated by the wind turbine. Poor power quality affects the performance of the loads connected to the grid.

2.2. a Reactive Power Consumption

Induction generators draw reactive power to produce its working flux while generate active power at the same time. As induction generators are most widely preferred in wind turbine generators, collectively a wind farm demand huge amount of reactive power. As the wind speed is not constant, the use of electronic power conversion devices in wind turbine generators becomes inevitable to achieve a rotor speed for maximum extraction of energy from wind. The operation of power electronic devices also requires reactive power. To avoid voltage stability problem either STATCOM or capacitor arrangement is used to supply this demand of reactive power.

2.2.b Current Harmonics Generation

Capacitors are used as an essential part of the wind turbine generators for supplying reactive power demand. Capacitor switching may cause large voltage transient. The frequency and amplitude of such transient are enormous, particularly when back to back switching is involved, for instance capacitor bank switching. The over voltages may damage the insulation, Moreover, electronic equipments such as controllers are very sensitive to these transients, may produce incorrect commands. In addition, lightning strikes will cause an over voltage in the electrical system of wind turbine.

III. BASIC TOPOLOGY FOR POWER QUALITY

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 proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), as shown in Figure 3. 1. The grid connected system in Figure3. 1, consists of wind energy generation system and battery energy storage system with STATCOM.

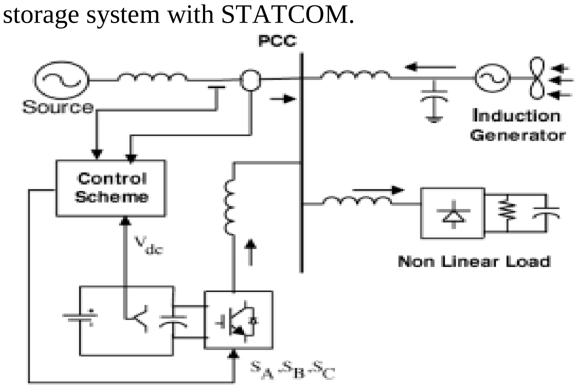

Figure3.1 **B**asic Operating Scheme

3.1. BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element to support the wind farm during intermittencies it also support grid during any disturbance and loss of generation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it readily manages demand and supply of real power and also injects or absorbed reactive power to stabilize the grid system.

It also controls the distribution and transmission system at a very fast rate. When power fluctuations occurs in the system, the BESS can be used to level the power fluctuations by charging and discharging operation. The BESS system is connected in parallel to the dc capacitor of STATCOM. STATCOM comes from the family of FACTS devices. These are basically solid-state devices which are having the capability to respond to the reactive power demand. STATCOM have the edge over the SVC's as the former have constant current characteristics while in the SVC's the capacitive current drops linearly with the voltage. STATCOM can easily be interfaced with real power sources like the battery systems, fuel cells etc. STATCOM effectively control the system voltage and avoid voltage collapse. STATCOM are solid state shunt connected devices. STATCOM's strategically placed in the power system to make the grid robust to the disturbances. STATCOM are finding applications in the renewable energy integration.

3.2. System operation

In the system under study STATCOM is interfaced with the BESS system. The STATCOM-BESS system is then connected to the PCC in the grid where non-linear loads and induction generator based wind turbine are also interfaced. Current control strategy is adopted to control the STATCOM -BESS system. The control strategy controls the output of STATCOM in such a manner so as to achieve power quality norms in the electrical grid. The STATCOM is intended here to support both reactive as well as real power demand of the other sub-systems.

IV. CONTORLLERS

4.1Hysteresis Controller

The current control scheme is implemented using a bang- bang current controller. In this control scheme, the source current are detected by a current sensor and these are compared with the reference current to obtain the current error for the hysteresis based bang-bang controller. Thus the ON/OFF switching signals for IGBT of STATCOM are derived from hysteresis controller. Hysteresis band controller is preferred for high dynamic applications since when the reference current changes due to some control action, then the hysteresis band also follows the reference current.

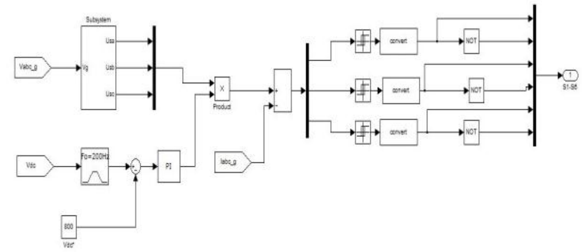

Fig.4.1Simulink Model for Power Quality Improvement with Hysteresis controller

The proposed control scheme is simulated using Simulink in power system block set. The system parameter for given system is given Table.

S.N.	Parameters	Ratings
1	Grid Voltage	3-phase ,415V,50 Hz
2	Induction Motor/Generator	3.35 kVA,415V, 50 Hz, P = 4, Speed = 1440 rpm, Rs = 0.01Ω, Rr=0.015Ω,Ls =0.06H,Lr=0.06H
3	Line Series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage = 800V, DC link Capacitance = 100 μF. Switching frequency = 2 kHz,
5	IGBT Rating	Collector Voltage =1200V, Forward Current =50A,Gate voltage =20V, Power dissipation = 310W
6	Load Parameter	Non-linear Load 25kW.

Table 4.1 System Parameters For Simulation

4.2 Fuzzy Logic Controller

One of the reasons for the popularity of Fuzzy Logic Controllers is its logical resemblance to a human operator. It operates on the foundations of a knowledge base which in turn rely upon the various if then rules, similar to a human operator. Unlike other control strategies, this is simpler as there is no complex mathematical knowledge required. The FLC requires only a qualitative knowledge of the system thereby making the controller not only easy to use, but also easy to design. The inputs to a Fuzzy Logic Controller are the processed with the help of linguistic variables which in turn are defined with the aid of membership functions. The membership functions are chosen in such a manner that they cover the whole of the universe of discourse. To avoid any discontinuity with respect to minor changes in the inputs, the adjacent fuzzy sets must overlap each other. Because of a small time constant in Fuzzy Logic Controllers, this criterion is very important in the design of the same.

There are basically three essential segments in Fuzzy Logic Controller viz.

1. Fuzzification block or Fuzzifier

2. Inference System
3. Defuzzification block or Defuzzifier

4.3 Rule Base

It consists of a number of If-Then rules. The If side of the rule is called the antecedent and the Then side is called the consequence. These rules are very much similar to the Human thought process and the computer uses the linguistic variables, derived after fuzzification for execution of the rules. They very simple to understand and write and hence the programming for the fuzzy logic controller becomes very simple. The control strategy is stored in more or less the normal language.

e/Δe	ZE	NS	PS	NB	PB
ZE	ZE	PS	NS	PB	NB
NS	ZE	PS	ZE	PB	NS
PS	ZE	ZE	NS	PS	NB
NB	PS	PS	ZE	ZE	NS
PB	NS	ZE	NS	PS	ZE

Table4.2 Rule base of FLC

V.RESULTS

5.1 WITHOUT FUZZY

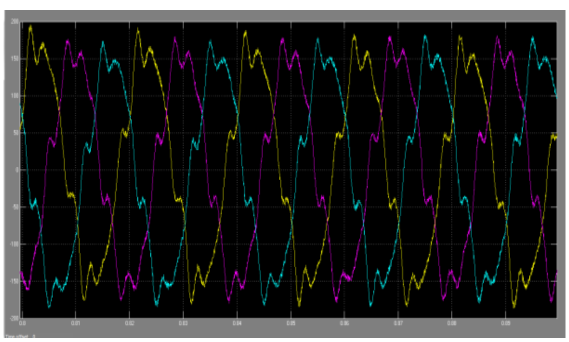

Figure 5.1. Three phase injected inverter Current

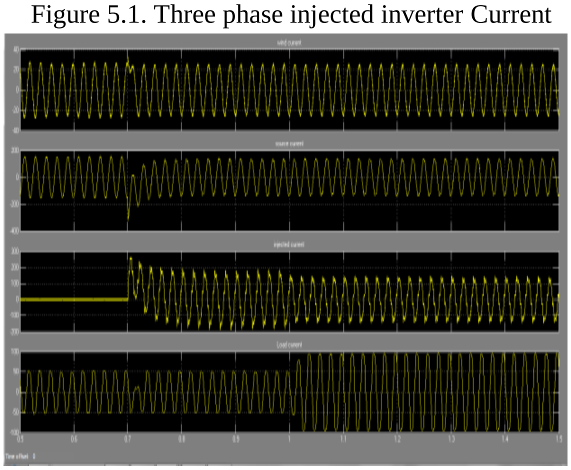

Figure 5.2 Source current, Load current, Inverter Injected Current, Wind current

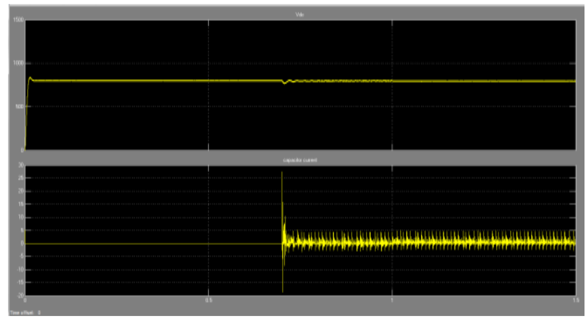

Figure 5.3. (a) DC link voltage. (b) Current through Capacitor

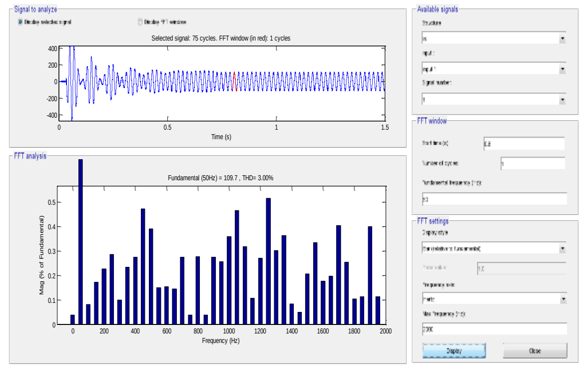

Fig.5.4 FFT Analysis For Power Quality Improvement Without Fuzzy Logic Controller.

5.2 FUZZY RESULTS

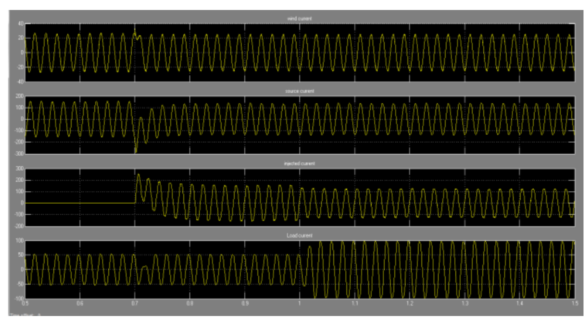

Figure5.5 Source current, Load current, Inverter Injected current, Wind generator current

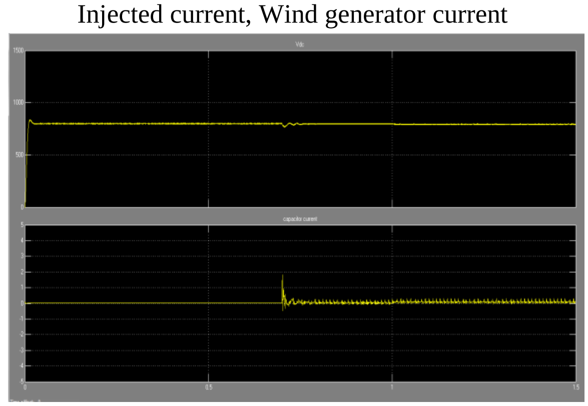

Fig5.6 (a) DC link voltage. (b) Current through Capacitor

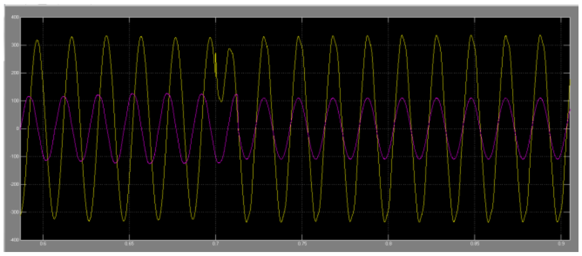

Figure 5.7. Supply Voltage and Current at PCC

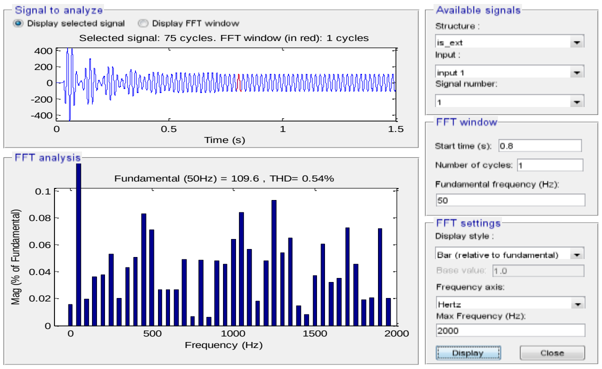

Fig.5.8 FFT Analysis For Power quality Improvement With Fuzzy Logic Controller

VI.CONCLUSION

The project presents STATCOM based battery energy storage system. The entire STACOM-BESS system is modeled in MATLAB/Simulink. When STATCOM is in operation significant improvement in power quality is observed. Issues harmonic distortion, power factor, voltage profile are properly tackled. The current and voltage at source side are observed in phase after the STACOM is made on into the system. Therefore, a near unity power factor therefore can be maintained at the evacuating substation (PCC). A Fuzzy based STATCOM controller Improves power quality norms nearby substations of the wind generating farm. Therefore, forced tripping of connecting lines between pooling substation and evacuating substation can be avoided which improves the plant load factor and in term revenues.

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