FACTS Controller for Performance Optimization of Grid Connected Wind Farm

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Abstract- Wind is gaining more attention as an alternative mean for electricity generation. But integration of wind farm in power grid introduces new factor of uncertainty result in poor power quality. Power quality is key factor in today scenario. Custom power devices are extensively used for mitigation of power quality issues like harmonics and voltage unbalance. These papers demonstrate the utility of connecting STACOM with fuzzy logic controller at PCC for mitigation of power quality issues and for performance optimization. Effectiveness of Proposed control scheme is demonstrated and verified in MATLAB/SIMULINK in power system block set.

Key word— BESS- STATCOM, FACTS, custom power devices, fuzzy logic controller, power quality.

I. INTRODUCTION

Increased demand of electricity put stress in utility engg. And forces us to develop alternative mean for electricity generation. Renewable sources like solar, wind, biomass, and hydro are extensively used for electricity generation. With improved technology and reduced cost wind is gaining more attention as a alternative mean of electricity [1,2]. Wind as a source of electricity is proven and gaining more penetration in grid [3].Generated power of wind plant depend upon the availability and speed of wind. Integration of wind plant in power grid adversely affects the stability, reliability and power quality of grid. Fluctuating nature of wind introduces new factor of uncertainty and power quality issues like voltage unbalance, flicker, harmonic, power unbalance in grid [4]. Power quality is a key factor in today scenario causing damage to sensitive equipment. So it becomes essential for us to overcome these issues Custom power devices are effectively utilized for this purpose. Custom power devices are a family of power electronics based device provides value added, reliable and high quality power to consumer [5]. SVC, STATCOM and UPQC are member of FACTS controller which is used for this purpose. Section II of paper deal the power quality issues regarding wind farm section III describe the various devices which can be used to overcome these issues. In IV BESS-STATCOM is used for performance optimization of grid connected wind farm. Finally section V fuzzy logic controller for STATCOM is demonstrating in MATLAB/ SIMULINK. Section VI summaries the utility of fuzzy logic controlled STATCOM.

II. POWER QUALITY STANDARD & ISSUES OF GRID CONNECTED WIND FARM

Output power generated by wind power depends upon the available wind and wind speed. But wind speed and availability is not same during the all period. Therefore introduction of wind power plant in grid introduces new factor of uncertainty. This uncertainty causes adverse effect in power quality of grid. Power quality is one of the key concerns in today scenario. Some standard has been defined for power quality measure

IEC 61400-2 Design requirements for small wind turbines.

IEC 61400-12 Power performance measurements

IEC 61400-21: standard provides recommendations for preparing the measurements and assessment of power quality characteristics of wind turbines.[1,2]

IEC-61400-21: The measurement procedure the measurement procedures described in the IEC- 61400-21 standard are valid to test the power quality characteristic parameters for the full operational range measurement procedure is specified in the case of continuous operation

IEC 61400-25-1 Communications for monitoring and control of wind power plants

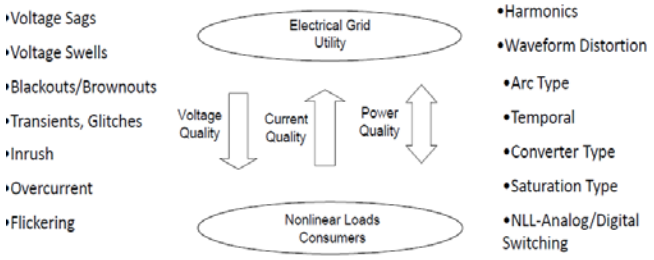


Figure 1 power quality issues [1]

It become essential to overcome the issues like harmonics, voltage unbalance, flickers because these issues result in poor power quality. Power quality is prolific buzzwords. Modern power electronics and microprocessor based equipment are very sensitive for quality supply.Poor quality power lead to damage to equipment. Poor power quality may cause to loss of consumer. Manufacturers want faster, more productive, more efficient machinery. Main reason for

increased attention in power quality concern is its economic concern basically power quality is voltage quality [6].

Harmonics-unwanted frequency component are termed as harmonics. It is the predominant cause of poor power quality. Wind farm have high capacitance there by suffer from the problem of resonance result in unacceptable level of harmonics current at capacitor band and consequent voltage harmonics at MW bus. So we conclude that integration of wind plant at PCC inject large amount of harmonics. Modern power electronics based equipment having non linear characteristic are main reason of harmonics [7]

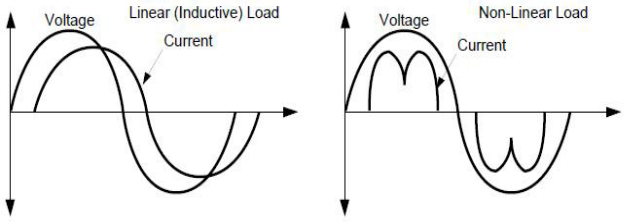


Fig2 Fundamental of Harmonics [6]

Voltage fluctuation- less than 5% variation in voltage is termed as voltage variation. It depends on real and reactive power variation. Voltage variation is of following types

- Voltage sag/voltage dip
- Voltage swell
- Short interruption
- Long duration voltage variation[9]

Flicker-fluctuation in voltage result in observable changes is flicker. It is considered as problem of perception and measured with sensitivity of human eye. IEC 61000-4-15 provide the information regarding flicker it gives the idea of human discomfort causes due to voltage variation. Fluctuating load in power system are Maine cause of voltage flicker[8]. Since there is rapid variation in wind speed result in variable power causes the voltage flicker,

Tower shadow effect (periodic, f ≈ 1-2 Hz); Wind turbulence (stochastic, average frequency f < 0,1 Hz); Switching of windmills (single events per hour) [11]

These are the issues which result in poor power quality it become necessary to overcome these issues.

III. CUSTOM POWER DEVICES FOR POWER QUALITY IMPROVEMENT

Custom power devices are family of power electronics based devices which were used in order to overcome the power quality issues. For power quality improvement in transmission Shunt FACTS devices (SVC, STATCOM) are being extensively utilized. Use of FACTS devices facilitate the various benefits like Dynamic voltage control, increased power transmission capability and stability, facilitating connection of renewable generation [10]

SVC stands for static var compensator and it is a thyristor valve type FACTS controller preferred for use of low and medium power application.

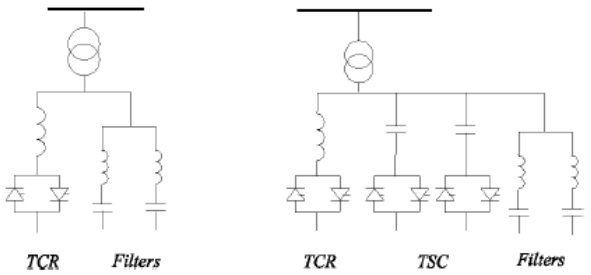


Figure 3 Configuration of thyristor valve SVC [10]

SVC is used widely it change its response according to change in operating condition by means of controlling its reactance there by changes the voltage result in performance optimization[12] STATCOM is VSC based shunt controller. STATCOM is connected in interface to wind generator and non linear load in order to facilitate the reactive power compensation result in power quality improvement. Current command is given to STATCOM and it injects the current at PCC so that source current with reduces harmonics. Current command is generate according to the grid voltage a controller is required to sense the grid voltage [13]

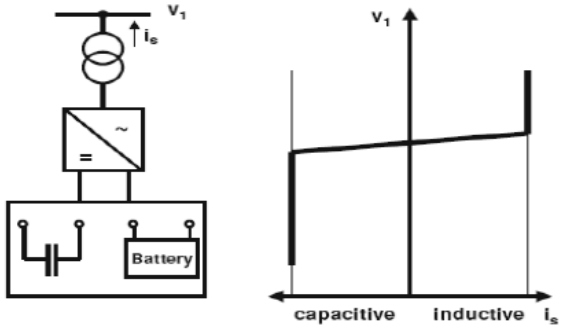


Figure 4 STATCOM structure and V-I characteristic [15]

Literature survey shows that as compare to SVC, STATCOM provide the fast response according to change in operating condition and it is capable of injecting capacitive current. At the same time STATCOM with battery storage provide 40% more storage [14] SVC is bulky require 3times more space as compare to STATCOM and thyrister valve can cause high switching losses on the other hand use of VSC based STATCOM result in less switching losses.

IV. BESS-STATCOM FOR PERFORMANCE OPTIMIZATION OF GRID CONNECTED WIND FARM

STATCOM is static synchronous compensator is used for integration of renewable energy sources. STATCOM with battery energy storage is connected at point of common coupling in order to facilitate the quality power to the load. During the normal operation battery store the active power generated by the load and inject the reactive power during the event when there is lack of power. STATCOM is shunt controllers which control the power by mean of current variation. STATCOM inject the current opposite to the polarity of injected harmonics therefore result in reduced total harmonics distortion. Prevent the system during transient and system collapse [16].STATCOM inject the capacitive and inductive current to the system and its operation is being independent of system performance and operate at its full. BESS storage provides the constant voltage across the capacitor.

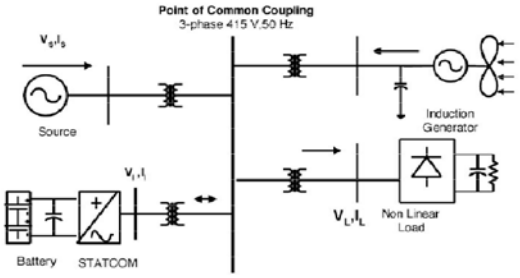


Figure 5 Connection of BESS-STATCOM at PCC [16]

V. CONTROL STRATEGY OF STATCOM

Control strategy is the main soul of STATCOM it provides the correct switching signal to STATCOM. Generation of unit vector and reference current is the main requirement of control strategy.PWM controlled PI controller is mostly used for STATCOM [17]. Bus voltage and grid voltage are compared and the corresponding error signal is processed. Bang -bang hysteresis controller is used which maintain the error signal within the boundaries. Narrow hysteresis band is maintained in order to reduce the error Inverter current and reference current are subtracted and STATCOM operate in the current control mode [8].

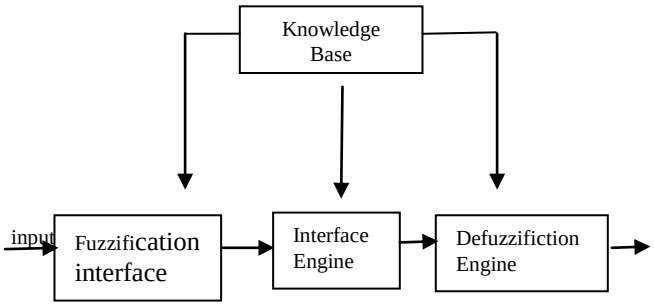
Equation for Generation of unit vector

$$Vsm = \{\frac{2}{3}(Vsa^2 + Vsb^2 + Vsc^2\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

In above equation

$$U_{sa} - \frac{V_{SA}}{V\,sm} \quad , \quad U_{sa} - \frac{v\,SB}{V\,sm}, \quad U_{sa} - \frac{v\,SC}{V\,sm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

PI controller is a single input single output control but once We provide the input to PI controller we cannot change it. There for its operation is not satisfactory during the system disturbance therefore in this project work fuzzy logic controller is used. Fuzzy logic controller has three main step Fuzzification interface, interface engine and Defuzzification[19.20].

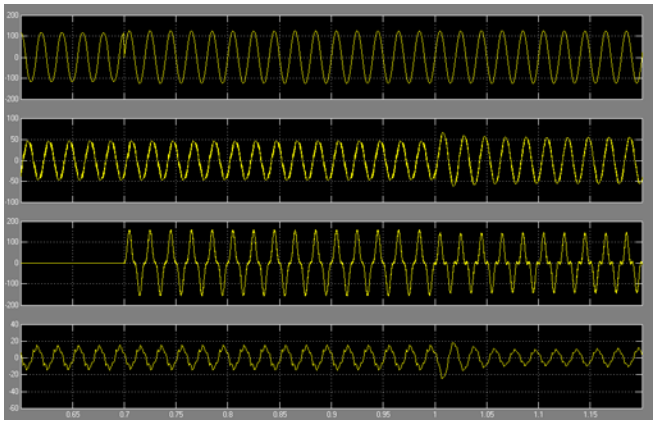


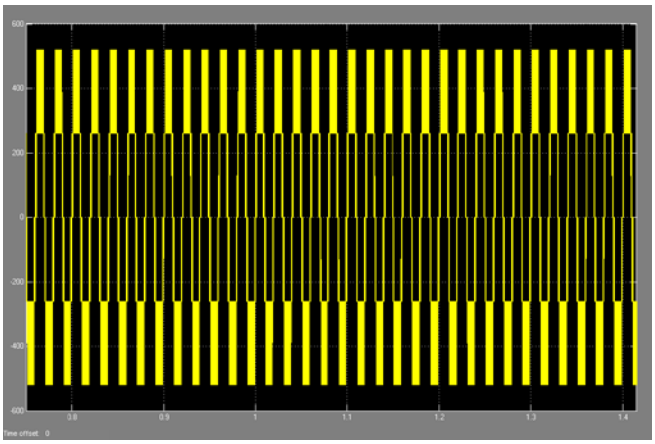
In this project work error e and change in error de are two inputs and it is being subdivided in seven input linguistic variable NB,NM,NS,ZE,PB,PM,PS degree of membership is being one trigonometric and trapezoidal membership function are being used.

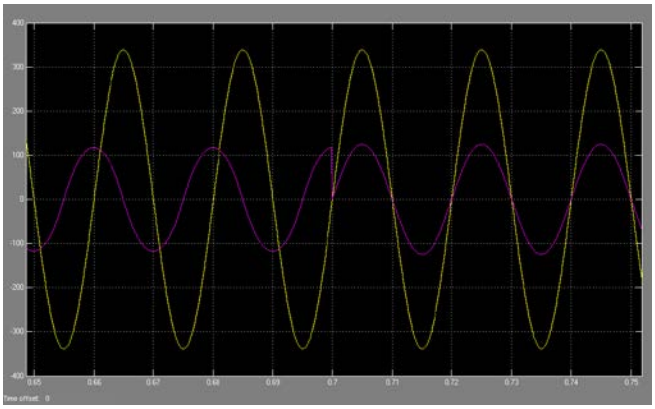
Rule base for this table

e/ de	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Utility of fuzzy logic control for grid connected wind farm is being assessed in fuzzy logic tool box of matlab/ simulink model







VI. RESULT AND CONCLUSION

Mat lab/ simulink result shows that fuzzy logic controller for STATCOM is proven to be more effective FFT analysis shows that fuzzy logic controller result in reduced THD of 0.16%. Fuzzy logic controller is proven to be more effective for varying operating condition overcome the drawback of conventional PI controller.

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