A new STATCOM based Reactive power management in grid connected DFIG based wind farm

V Sharath Babu, Loveswara Rao Burthi

Abstract*: This paper displays control based on STATCOM conspire of PQ enlargement in grid associated DFIG (Doubly Fed Induction Generators).The fundamental purpose for utilizing the acceptance generators incorporated with a wind turbine is to excerpt max. Power. DFIG having a capability to operate at wider range of wind speeds and ability to produce more output with available energy , that's why it is being preferred well than SCIG (Squirrel Cage Induction Generator).The transient reaction is really a basic unique normal for DFIG-based breeze turbines, particularly within the sight of quick transient occasions, for example, power system fault ,abrupt change in load, and so on. Serious issue is found in profile of voltage and deviances in frequency with altering normal conditions, for example, speed of wind & load distincts. This paper shows a near investigation of stabilizing out a DFIG based wind-generating station utilizing its individual Converters for frequency & utilizing a STATCOM. By Simulation it shows a dynamic compensation of Q, when STATCOM utilized at a point of interconnection of WPS and keeping up its voltage level.

Index Terms*: Static Synchronous Compensator ; STATCOM; Double Fed Induction Generator; DFIG; Pulse Width Modulation-PWM.

I. INTRODUCTION

Due to rising demand of energy day to day, we need to generate adequate amount of power suitable for meeting the demand without sacrificing the consumer needs. But at the same time we need to concentrate on the energy resources available around us. In the previous decades huge amount of power was generated from conventional energy sources, but due to extinction of these resources, these is the time to move over other forms like wind energy, solar energy and many other renewable energy resources. With huge increasing interest towards the wind energy systems it should design in such a way that it can extracts max. Power from available energy. In order to generate the power it is preferable to use induction generators instead of synchronous generators because they require less maintenance, low cost, small in size[1]. Usually SCIG are used for fixed speed wind turbine application but due to variation of wind speed and also requirement of reactive power support for the grid we may not be able to use this SCIG much on this.So it is attractive over use DFIG as it can continue running at rates to some degree above or underneath their normal synchronous speed. In DFIG the converter, cost is very low as when differentiated and other adjustable speed courses of action in light of the fact that only a little measure of power at shaft, usually 25-30%, through a converter supports to Grid, the repose being sustained for network truly from stator. DFIG productivity is outstandingly helpful for a comparative reason.What's more, DFIG have demonstrated better conduct concerning system for stability amid SC faults in contrast with SCIG[2], as a result of this one ability that decoupling the P & Q output control. Then again, STATCOM can utilized to give reactive capacity for wind farm stabilization moreover. The Diverse voltage SI or Current SI centered FACTS components to versatile power damping control for Power framework and modification of generators run by a wind, anyway this paper has a STATCOM reliant on a Voltage SC Pulse width strategy adopted to stable out DFIG. This paper displays a relative examination of the utilization of DFIGs recurrence converters or STATCOM to balance out a breeze ranch. Reenactment model of wind turbine with DFIG created in MATLAB is introduced This paper exhibits a near examination of the utilization of DFIGs based frequency converters or STATCOM to balance out a WPS. Reenactment of wind turbine and DFIG modeled created in MATLAB is introduced.

Revised Manuscript Received on December 22, 2018.

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II. POTENTIAL OF A WIND AND IT'S TRANSFIGURATION

As of late, the natural contamination has turned into a noteworthy worry in every day life and a conceivable vitality emergency has driven individuals to grow new advances for producing perfect and sustainable energy. Wind control alongside solar power vitality, hydropower and tidal vitality are conceivable answers for an ecologically well disposed vitality creation. Europe, different nations, for example, China and USA likewise have promising seaward wind control assets and comparative designs for a wind farm establishment. India started in the 1990's, and has advanced consistently over the most recent couple of years. Starting at 2016 Aug 31 the introduced limit of a wind control 27,676.55 MW in India ,basically extent crosswise over North South and West locales. The principle necessity for wind control establishment is land and grid structure accessibility . In the year 2015, the Ministry of New and Renewable Energy (MNRE) set the goal for Wind Power age limit always 2022 at 60,000 MW. A. Aerodynamic Alteration The technique of how the breeze turbine structure makes electrical power [3] will be immediately sketched out as seeks after:

i. The wind strikes the breeze turbine sharp edges, makes them turn and further makes the lower-speed shaft rotate

ii. The rotating low-speed shaft trades the dynamic essentialness to the gearbox, which has the limit of wandering up the rotational speed and turning the quick shaft.
iii. The quick shaft makes the generator turn at quick which is close to the evaluated speed of the generator.
iv. The turning generator changes over the mechanical ability to electrical power.

B. Mechanical Drive train

The machine's rotor, and the gearbox, center and sharp edges of the propeller together make up the mechanical piece of the breeze turbine. They are coupled adaptably with one another, which conveys full developments into the structure. These showed up in Fig.1

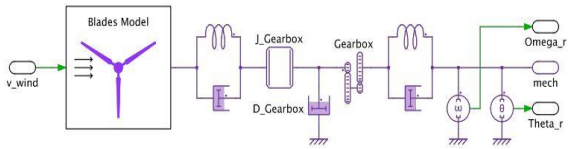

Fig-1. Driving mechanism for wind turbine

III. TURBINE MODELING FOR WIND TYPE

The power which is generated mostly be determined by an speed of wind. So available power of wind [4] is specified by the relation.

$$Pw = \frac{1}{2} \rho Vw^3 \qquad (1)$$

P_w is available power of wind,
ρ is densityof air,
Vw - wind velocity.

For the breeze (WT) turbine to begin producing force and speed of the breeze ought to be more noteworthy than the speed which is cut-in as 4 metre/sec, over an appraised speed 12 m/s contribute control comes to being and makes the edge pivot so that for further change in speed of wind and the speed of the turbine is made steady, so created intensity of these appeared in Fig.2.

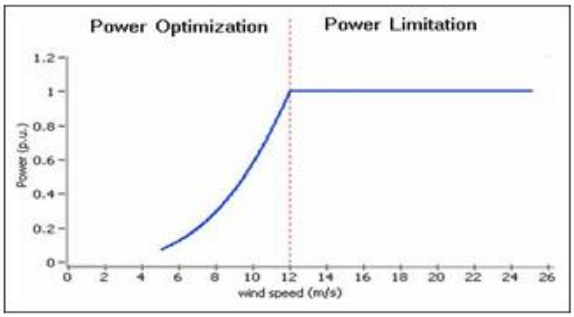

Fig-2: Power verse wind speed curve

In case of wind gust i.e speed above cut-out speed (24m/s) the turbine comes into standstill condition.

And turbine power, wind power are related as

$$Pt = Cp(\lambda, \beta) Pw \qquad (2)$$

Here Cp is defined as the power coefficient[8] which determines the amount of wind power being utilized, this can also be stated as the efficiency of wind turbine. Speed relation specified by

$$\lambda = \frac{R_{blade}\omega_r}{V_\omega}$$

The value of λ depends on blade length and velocity of wind. For diversed values of wind speeds the pitch angle (β) to be maintained by pitch angle controller can be determined from Fig.3

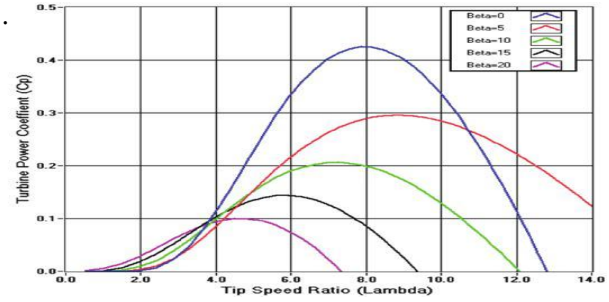

Fig.3: The power constant, Cp, when a function of the tip speed ratio, λ.

For diverse speed of a wind in order to obtain max power the turbine should operate at the peak point corresponding to the wind speed i.e tracing the locus of Pmax as shown in Fig.4.

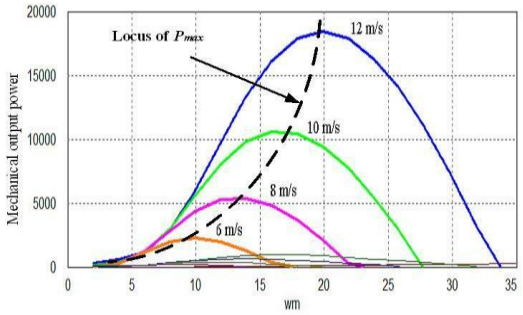

Fig4:characteristics of Turbine output power for different speeds

IV. DOUBLE FED INDUCTION GENERATOR

Double Fed IG contains wound type rotor IG and AC to DC as well as DC to AC PWM and IGBT based converters [5]. Twisting of a stator, which related genuinely to 50 HZ framework whereas rotor reinforced on flexible frequency from side to side of an AC to DC as well as DC to AC converter as showed up in Fig.5. Another favored viewpoint of the DFIG development is the limit with respect to control electronic converters to make or ingest receptive power, in this manner taking out the necessity for presenting capacitor banks as by virtue of squirrel-confine IG.

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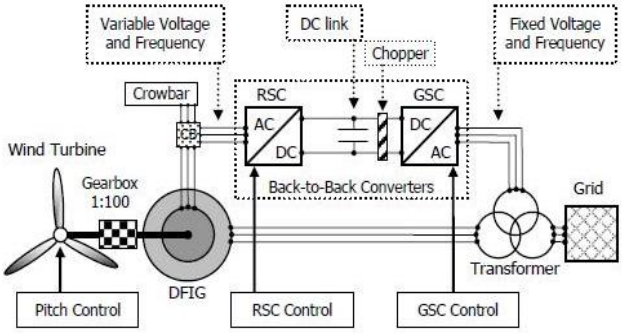

Fig.5: DFIG schematic diagram.

Doubly sustained sort generators resemble Alternating current generators, so far have extra features that empowers all to continue running on rates to some degree underneath or above its regular Ns. It is important on behalf of gigantic wind turbines with adjustable speed, since speed of a wind can be changed unexpectedly. Exactly once a hurricane touches a breeze turbine, so bleeding edges endeavors for quicken, yet an alternator dashed to main grid speed and can't quicken. Therefore reaching powers be there made inside, gearbox, and electrical machine as the structure of the power setup which drives back. So, this makes garb and mischief the mechanism [6]. In case a turbine will be permitted to quicken directly when hit by an air impact, Loads are lesser and power commences the WPS changes over for supportive power. One technique to manage permitting a speed of wind turbine for vacillates to recognize of any kind repeat the output of generator, converting into DC, then after that converting the same into AC by the perfect frequency output by using DC – AC converter. It is fundamental to the little firm & smallholding wind type turbines. In any case, the DC – AC converters requisites for megawatt measure wind type turbines are immense as well as exorbitant. This issue is because of one of the response of a doubly fed IG. As opposed to the standard field bending sustained by Direct current , and a winding at armature someplace the made power turns unavailable, so around 2 or 3 arrange windings, pivoting one and stationary one , two are freely joined with apparatus at external to the electrical machine. Thusly an articulation "Two ways exciting"[7]. In customary breeze turbines, the sharp edges turn a post that is related through a gearbox to the generator. The gearbox changes over the turning rate of the cutting edges 15 to 20 turns for every minute for a broad, one-megawatt turbine into the speedier 1,800 unrests for each minute that the generator needs to create control. Single winding directly joined with an output, which makes Three-arrange alternating control by the perfect system frequency. The other bending (generally named as field, anyway now the two windings could be an output) related with Three organize alternating current control at adjustable Fs . so, the given data control is attuned in frequency as well as stage to adjust the variations in speed of the modeled turbine. Changing Fs as well as stage needs an inverter and rectifier. It is commonly worked through extensive IGBTs. The said converter is have two way current flow , also be able to pass control in whichever heading. Power can spill out of this curving similarly as from the yield winding. The quality of the two way excited IG is that windings of a rotor relates to the network by means of methods on behalf of slip rings as well as back to backvoltage SC that regulates the flows of rotor as well as the matrix. As such rotor frequency can straightforwardly fluctuate from the recurrence of a network (50 or 60 Hz). By means of the power converters to regulate the rotational member streams, it's probable to change dynamic & open energy continued to a matrix since a stator uninhibitedly of the generator's rotational speedThe two way excited generator runs regularly curved with two onwards various occasions and amount of stator turns. This suggests that higher the rotor voltages and streams are lower independently. Consequently, the regular ± thirty percent working speed go about the Ns, then assessed converter current is as requirements be lower that prompts converter at lower cost. Load that regulates will be undertaking external the working speed stretch out at unimaginable due to greater than assessed voltage of the rotor. Additional, the potential vagabonds owed to the cross section agitating impacts (2-3 organize potential dives, especially) similarly it would intensified. For dodging, rotor voltages are higher and great streams impending about due to this voltage from terminating the diodes and IGBTs of the converter, and uses and affirmation circuit (called crowbar) . The crowbar would shorts the windings of rotor through a small deterrent once over the top streams or potentials are recognized. To have the ability to endure with an assignment as quick as probable a working crowbar must be implemented [8]. Dynamic crowbar be able to oust the short rotor in a regulated way & along these lines the converter at rotor side can starts just after twenty to sixty milli seconds from an earliest starting point of a lattice disrupting impact while the remainder of the potential stays more than 15% of an apparent voltage. Thusly it is probable to create system's reactive type current in a midst of rest of the potential dive and by this way; it helps the framework to recover since the fault. On behalf of zero potential ride through normally near hold up to the dive closes in light of the fact that with zero voltage it is past the domain of creative ability to hope to understand the stage edge where the responsive current should be mixed. The nitty gritty model of DFIG is appeared in Fig.6. PS,QS is given as reference to the RSC-Rotor Side Converter controller and voltage and recurrence is controlled in like manner. Pg, Qg is given as reference to Grid Side Converter(GSC) controller for keeping up steady Vdc..

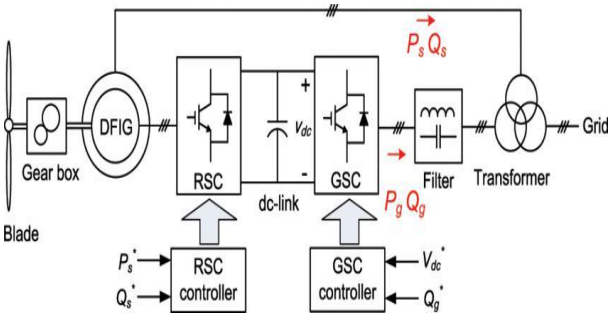

Fig.6: Detailed DFIG model.

V. REACTIVE POWER COMPENSATION USING FACTS DEVICES (STATCOM)

The arbitrary and discontinuous nature of wind control makes the huge scale wind ranches associated with the brace present some undesirable impacts at the association focuses. The most unmistakable is voltage variances, in serious case voltage breakdown. Voltage variance was essentially brought about by the sharp difference in responsive power request. To keep up the voltage delivered at the stator equivalent to the air conditioner control arrange voltage, a particular attractive transition esteem must be kept up in the machine (all the more exactly at the stator terminal) [9]. This can be accomplished by applying a voltage to the generator rotor winding that is relative to the recurrence of the voltage connected to the rotor winding (this guarantee the V/f proportion consistent and a steady extent motion an incentive in the machine). The estimation of the V/f proportion is commonly set with the goal that the responsive power at the stator Q stator is equivalent to zero.

5.1. Static Synchronous Compensator (STATCOM)

STATCOM made out of the accompanying segments:

A. Voltage (VSC) Source Converter

The voltage (vsc) source converter changes the dc voltage input to an output alternating voltage. Two of the utmost widely recognized Voltage SC types depicted underneath.

Inverters with square wave utilizing GTO Thyristors, usually, 4 3level inverters would be used to make a voltage waveform with 48-stepped. Thusly, it regulates 'Q' stream by varying the DC input voltage of capacitor, in light of the fact that the major segment of an output of converter voltage corresponding to the Direct current potential.

Likewise, unique transformers inter-connection utilized near kill sounds limited in a square wave delivered by singled inverters.Pulse width modulated dc to ac converters utilizing Transistors IGBT It uses PWM system to make a waveform having a nature sinusoidal from a source voltage DC type with a run of the mill hacking recurrence of a couple of kHz. Rather than the GTO dependent sort, the VSC based on IGBT uses a fixed voltage value with dc type, shifts, and this yields AC voltage on varying the tweak list of the modulator with PWM method. Additionally, consonant voltages relieved on introducing channels with parallel of the VSC at an AC side.

B. DC Capacitor

The given segment gives the voltage of dc type to the DC-AC converter. The voltage over this DC connect is to be kept up steady esteem.

C.XL- Inductive Reactance

This one interfaces the DC to AC converter yield to the Electrical Power system. Which is normally the spillage of a coupling transformer's Inductance.

D. Harmonic filters

Harmonics Mitigating and other some more frequency segments because of the inverters The essential circuit graph demonstrating every one of the segments of STATCOM is appeared in Fig.7.

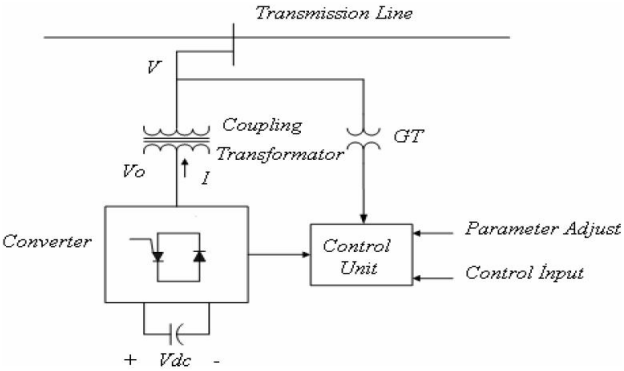

Fig.7. STATCOM circuit diagram.

5.2 STATCOM Operation

A. Simple Standard Operation

On account of two Alternating sources, they have a similar frequency and associates over an reactance arrangement, the power streams would be:

i. P or Q streams on or after the main source to a slacking source.

ii. Q streams from higher level to a lower level voltage extents source. Subsequently, the phase edge contrast among the sources selects the stream of dynamic power, though the difference of voltage among the sources resolves the flow of Reactive nature power. Regarding this guideline, the device STATCOM could be utilize for controlling a flow of reactive type power on changing the voltage at the output side of the voltage VSC source converter as for a voltage of system.

B. Different Operational Modes

The STATCOM device can works with two unique modes:

1. Voltage Regulation

The static device used for a synchronous compensator manages voltage with the association of a device and point of regulating the Reactive type power measure which ingested on or after or infused keen on the given power system through a voltage (VSC) source converter [10]. Now the consistent mode , the obtained voltage V_2 produced on a voltage (VSC) source converter over the capacitor with dc type will be in stage with a given system voltage V_1 at $\delta=0$, therefore just reactive type power would flows so ,P=0.

i. Once voltage at a given system is high, the STATCOM would retain reactive type power at inductive conduct

ii. While the voltage at a given system is low, the device STATCOM would be produced also infuses the reactive type power keens on the system at capacitive nature.

In this manner, measuring the reactive type power flowing can be given on the condition:

$$Q = (V_1 (V_1 - V_2)) / X \quad (4)$$

2 . *Control of VAR*

In this approach, the STATCOM output of Q kept at persistent and will not depends on the other parameters of system.

VI. PROPOSED MODEL

The network of a power system examined for study presented in Fig.8, which entails of wind farm, traditional grid, FACTS based compensation of reactive power devices & Load.

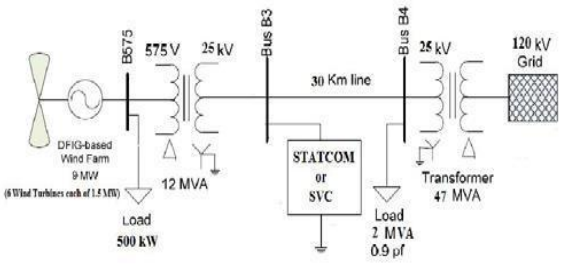

Fig.8. Experimental setup of a Single line diagram of power system

The single line chart of the framework to be tried utilized for this investigation appeared in Fig.8.The model of a network comprises of a 120 kV ,50hz, supply purpose of matrix, giving a 25 kV dissemination framework more than 120/25kV,47 MV venture down transformer,

encouraging a 575V framework over 25kV/575V, 12 MVA venture down transformer.A 2 MVA load, 0.9 pf slacking is associated at 25 km from a transmission line. The 25kV and 25Km long queue meant as nominal- π line. The breeze ranch dependent on DFIG comprises of 6 wind turbines to each with 1.5mw and aggregate of 9 MW. The parameters of the given framework segments given in Table.1

Wind Turbine		Generator Parameters		Transmission Line Parameters (π Model)	
Rated Capacity	(6 Turbines ×1.5MW) 9 MW	P_{rated}	6G×1.5 MW	r_1	0.1153 Ω/km
Cut–in Wind speed	3.5 m/s	V_{rated}	575 V	r_0	0.413 Ω/km
Cut-out Wind speed	25 m/s	r_s	0.00706	l_1	0.00105 H/km
Rated Wind speed	14 m/s	r_r	0.005	l_0	0.00332 H/km
No. of Blades	3	l_{ls}	0.171	C_1	11.33e-9 F/km
Rotor Diameter	82.5 m	l_{lr}	0.156	C_0	5.01e-9 F/km
Swept area	5346 m^2	L_m	2.9		
Rotor speed	10.1-18.7 rpm	pf	0.9		

Table.1: Parameters of simulated DFIG

The proposed model uses wind-turbines with 1.5MW utilizing DFIG these are appeared in Fig.9. The shunt associated STATCOM is at the sending end side transport with 25kV to bear the cost of receptive power dynamic remuneration .The stator winding is connected legitimately to organize. The ingested Reactive power by the DFIGs is somewhat remunerated by consistent V/f proportion and extent transition steady an incentive in the machine.. The V/f proportion esteem is commonly fixed so that at the stator the responsive power Q stator equivalent to 0. The staying responsive power important to keep the transport voltage near 1pu is given by a STATCOM with 3MVAR. The breeze speed ostensible yielding the mechanical power ostensible esteem 1pu is 11 m/s. The model of wind turbine and STATCOM are unmistakable models that license transient steadiness kind investigations with high recreation times.

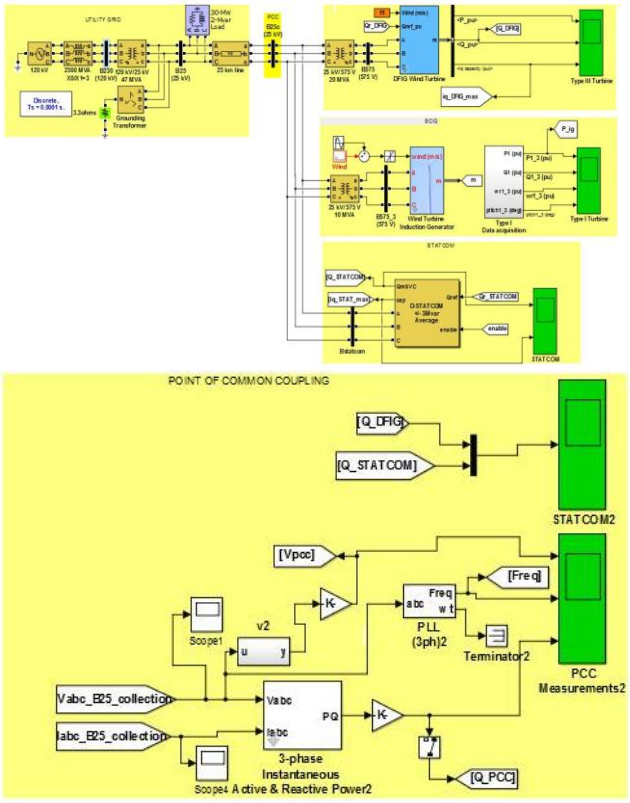

Fig.9. DFIG connected to utility grid

VII. SIMULATION RESULTS

The investigated power system network modeled and simulated in SIMULINK as given in Fig.9. to study behavior with STATCOM and DFIG. All the parameters are given in appendix.

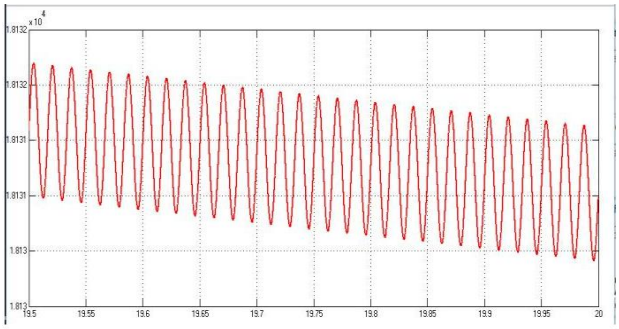

Fig.10. Voltage profile at PCC without reactive power compensation.

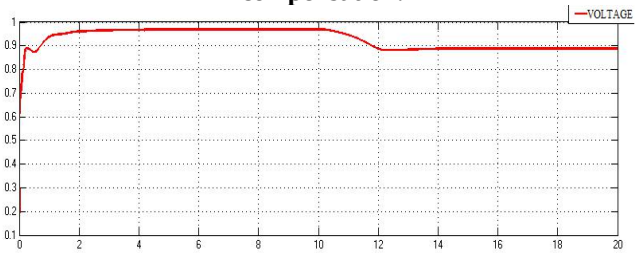

Fig.11. Voltage profile (p.u) at PCC without reactive power compensation.

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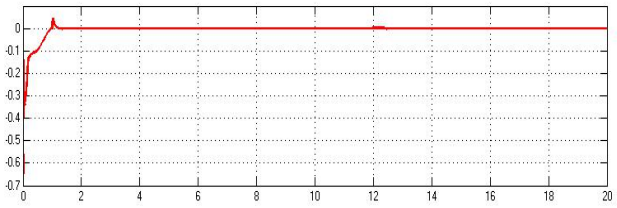

Fig.12. Zero Q supplied to Grid.

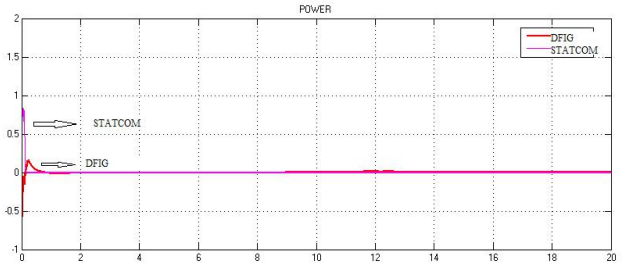

Fig.13. NO Q compensation by STATCOM and DFIG.

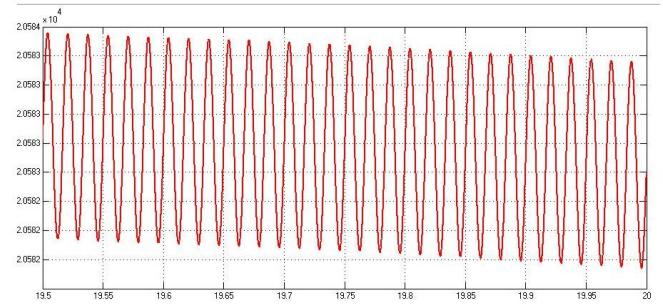

Fig.14. Improved Voltage profile at PCC with reactive power compensation provided.

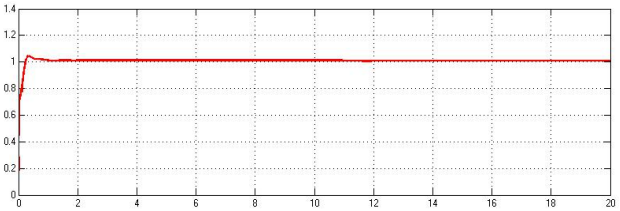

Fig.15. Improved Voltage profile (p.u) at PCC with reactive power compensation provided.

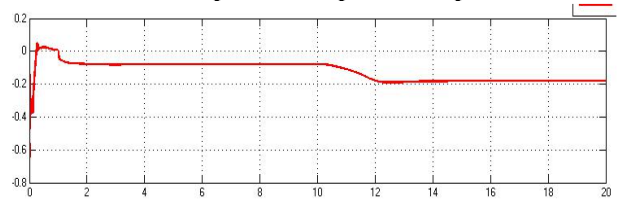

Fig.16. Reactive power supplied to the grid during disturbance.

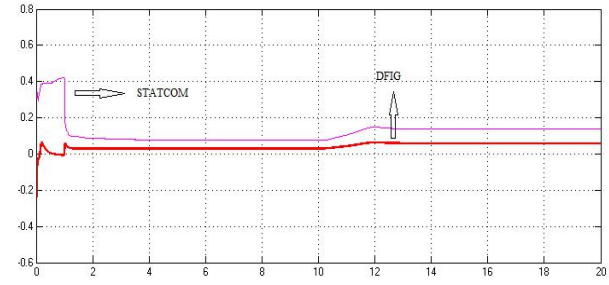

Fig.17. Reactive power from STATCOM and DFIG.

VIII. RESULTS AND DISCUSSIONS

For the proposed system all the values are studied in per unit values taking 25kV, 1MVA as base, for easier analysis. All tests examined here afterward steady state is reaching by the system to i.e. 14 seconds after. Here in this case the voltage profile at PCC (Fig.14) is improved by employing reactive power management system, which uses a coordinated system between STATCOM and DFIG.However analyzing the reactive power flow for stabilizing the system voltage, then it is quite clear from Fig.17 that under the same condition of voltage instability, the reactive power to be compensated will be shared between STATCOM and DFIG according to their capabilities. The numerical values of the graphical results of the proposed model is given in Table.2.

Parameter	Without STATCOM	With STATCOM
Voltage at PCC (p.u)	0.882	1.008
Voltage at PCC (rms)	18×10^3	20.6×10^3
Current at PCC (rms)	706	605
Power factor	0.85	0.9
Reactive power supplied to grid (MVAR)	0	1.8

Table.2. Numerical values of graphical results.

IX. CONCLUSION

The Compensation of a Dynamic responsive power is the best framework to organize the breeze ranch dependent on DFIG to the Grid in the midst of Grid agitating impacts. This paper has analyzed the usage of a STATCOM to accomplish nonstop action of wind ranch dependent on DFIG in the midst of blame conditions. The STATCOM is related at the Point of (PCC) basic coupling where the breeze ranch dependent on DFIG is related with matrix, to give a voltage backing and shield the under voltage security from bumbling the Wind ranch. Nevertheless, without STATCOM the voltage at PCC will fall underneath 0.88 pu, so the Wind turbine must be lurched from the power sort out. It was surmised that the STATCOM produces the required responsive ability to keep up the Wind farm in organization and produces a predominant voltage profile. Additionally STATCOM has a brisk and smooth response due to sort of switches used.

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