Power Quality Analysis of Wind generation System in Distributed Network

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ABSTRACT

The energy demand of developing countries like India is increasing day by day, in order to fulfil the energy demand fossil fuels are used more. The result of more usage of fossil fuels is global warming and climatic changes. So the world leaders came together for the Conference of Parties 21, i.e. Paris Climate Change Agreement. India has ratified the agreement and has set a target to install 175 GW of renewable energy plants by 2022. Which target from the wind generation system is 60GW and for MP target is 6.2 GW. An end user needs an electrical supply having good power quality, which means voltage and frequencies near to rated value. And as wind speed is fluctuating in nature the output power of the wind generator terminals is not constant. This fluctuation leads to various power quality issues like voltage sag, voltage swell and harmonics in the system. To address these issues, a machine that can run at variable speeds and provide almost constant power is needed. The machine that meets these conditions is the permanent magnet synchronous generator. The distributed generation system, with its unique feature of providing power to the local utility and the grid simultaneously, is a promising solution to these power quality issues.

To feed the power to grid system interfaces with the semiconductor devices, and combination of semiconductor devices and nonlinear load are the main reasons to produce the harmonics. In this thesis, analysis carried out on the IEEE 9 bus system consists of 3 generators and integration of wind generation is done based on the voltage regulation calculated on all buses and maximum voltage regulation bus provides the location to integrate the wind energy generation system and after integration, it is found that the voltage regulation improves on that bus and it impacts partially on others buses even. Before connecting the wind generation system to bus6 maximum voltage regulation is found at bus6 but after connecting the wind generation system voltage regulation at bus5 is higher.

Keywords: Wind Energy Conversion, IEEE bus, MATLAB, Simulink, Power quality.

[1]. INTRODUCTION

The requirement of energy is increasing day by day and the energy generated by electrical sources cannot store for a long time, so we have to select a system which is easily available and also meet the demand, hence it is the best way to adopt distributed generation system[1].The improvement in power quality of electrical accessories and the development of renewable energy are considered to be the most critical issues for the sustainable environment. Among different kinds of renewable energy sources, the solar energy and wind energy have been promoted highly in worldwide[2]. The power generated by wind energy system in India is 32.84GW at the end of November 2017. This makes India forth position (followed by China USA Germany) in wind energy generation in the world, this makes a record to increase generation level of 4 GW in a calendar year and secured fifth ranks in power generation[3]. They have sated a target to generate power from wind is 60GW by the end of 2022 and for M.P the target is 6.2 GW[4]

The energy generated by distributed generator system (DGs) has the feature to supply the power to the grid also to the local load. The DGs can increase the reliability and power qualities at the same time reduce the peak load demand and eliminate the reserve margin of the system. And the variation in either load side or wind speed causes many disturbances to the synchronized grid and arises many power quality issues like steady state voltage variation ratio, flicker, sag, swell, harmonics and fault

Power Quality

Electric power quality or simply power quality deals with the frequency, voltage and current waveform. Good power qualities mean the system should have steady supply voltage, current and AC supply frequency should be close to the rated value.

Power Quality Problems

There are numerous reasons which influence the power quality of grid connected wind generation system. Fluctuation in wind speed causes unstable voltage generation from wind generator which will lead to issues with voltage and during conversion process, uses rectifier, inverter, filter, and high-frequency power electronics devices, introduces harmonics, and ripples in voltage or current.

These power quality problems are as follow:

1. Voltage Sag
2. Voltage Swell
3. Flicker
4. Steady State Voltage variation ratio
5. Harmonics

1.3.1Voltage Sag

When there is drop in voltage by10% to 90% of nominal rms value or the network seems to be short-circuited for half cycle or more, then it is called as voltage sag.

There are various causes of voltage sag

1. It creates a fault in the power system network
2. During starting of the electrical machine, it draws more than the starting current, reflects voltage sag
3. When suddenly heavy load come is connection then it draws more than the rated current and causes the voltage dip in sources.

There are various consequences of Voltage Sag

1. Unwanted opening or closing of contractor protective devices like switchgear, circuit breaker
2. Due to the voltage sag for momentary, it gives the single to control of Adjustable Speed Drives (ADS) and cause unwanted operation

1.3.2 Voltage Swell

In a power system network, if the voltage level is increased by 10% to 80% of rated value for half cycle or more than it is termed as voltage swell

There are various causes of voltage swell

1. When a heavy load is disconnected it reflect huge current to the grid and at that point voltage will rise from normal value and reflect as a voltage swell
2. When capacitor bank energized it supply the reactive power and increase the voltage level in the system.
3. Interruption of current

There are various consequences of Voltage Swell

1. As the potential difference between the node more electrical appliances draw more current thus it get heated and increase the losses
2. Insulation of electrical appliance is provided based on the voltage strength as the voltage increases the breakdown of insulation may occur.

3. In the protection and control part of the system have a small rating and if the voltage rise occurs then it may happen to damage.

[2]. LITERATURE REVIEW

2.1Power Quality Analysis

Cheng-Ting Hsu et.al[9]worked on integrated DG system and suggested that reliability and power quality can be improved as well as reserve margin and peak load demand can be reduce by using distributed wind generation system. They used to redial network having 11 busses B_0 to B_{10}. In which voltage level is minimum at B_9, and maximum at B_0. When the wind generator having power factor unity and .8 are integrated to the system then the integrated system bus having maximum voltage and minimum voltage bus is change from previous case. This changesin bus voltage gives the information regarding integration of distributed generation system. to achieve this voltage profile of all the buses and voltage regulation is calculated with the help of IEC method at unity and .8 power factor are 3.6% and 9.2%. It was near to the practical condition which gives 4.6%and 11.20% respectively. Also reduces the pick margin of the system and need a very less reserve margin. Also with this integration, some harmonics are introduced in voltage and current, but the level of harmonic is small 2.28% and 1.35% respectively. And three-phase short circuit current and flicker produced by the system is 0.016% this is under a preset limit.

Outcome: - They suggested to integrate a wind system where maximum voltage regulation is present with this it is able to reduce the voltage regulation, reserve margin but introduces some harmonics and flicker in the system.

N. Dizdarvic et.al[10]suggested that the limitation of integration of wind power plant in the grid is based on the short circuit capacity and power quality of the system with respect to the change in voltage and flicker emitted by them. This system is implemented in the island of Adriatic sea since 1996, where the average wind speed available of 3 to 10 m/s in the variation of height from 10 to 100 m. and it develops annual energy in a range of 18.5 to 28.2 GWh. They tested their system by applying the voltage of 110% of nominal voltage and checked the system for short circuit capacity of the induction generator, then they found that short circuit ratio (R/X) for the smaller generator is .2718 while for larger it was .1523 under the same coefficient of startup current. The flicker produced by the system was also observed and it was found that flicker emission by short time period is smaller compared to the long-term flicker emission by wind power plant injected into the system

Kai Yang et.al[11] analyzed on the harmonic generated by the wind power plant and suggested that the propagation of harmonics is counted as two groups first is a transfer of harmonic from one wind generation unit to another generation unit to the grid and then utility. Second is reverse of the first order that is from utility to wind generator. Also, the impact of a turbine filter on the propagation is studied. The study indicates that resonances of a wind power plant have a significant impact on the propagation. The lower-order harmonics tend to be synchronized to the fundamental voltage waveform with a small difference in phase angle, whereas the phase angles for high frequencies vary randomly. Primary emission penetrating from a WT for current harmonics is 100%. The inter harmonic voltages are relatively high compared to the harmonic voltages and from one turbine to another turbine is about 30 % and 20% from grid

2.2 The selection of machine

D. P. Kadam et.al[12] worked on the selection of machine in wind generation system. Induction generator is preferred that of the synchronous generator as they have some dominating feature like low cost, robust construction low maintenance cost, low power to weight ratio, and longer lifespan. Wind turbine integration has the direct impact on the system stability. For interconnection, we have to keep in mind two thing (A) fault rice through capability under the fault condition and (B) fulfillment of reactive power under operating condition. So need detail specification of grid and wind turbine for reactive power generation because it cannot be transmitted to long distance. The principle of power generation from induction generator depends on the consumption of reactive power. Also, step up transformer need reactive power in order to setup magnetizing current. This reactive power consumption introduces the distribution and transmission losses, overloading of transmission and distribution equipment, poor voltage profile blocked capacity and overloading reduces the lifetime of the equipment.

Sharma et.al[13]advised that when induction generator uses to generate power from the wind then they raise the issues of power quality. And they analyzed that frequency is increased at night and drop in the day and also in peak load period. They use electronics converter as a bridge between generator and grid

M. J. Ghorbanian et.al[14]suggested that the power quality of the wind generator connected system depends on the weather system connected to the grid or Standalone. In case of micro power grid mostly the uses DFIG, and for small grid power they use constant speed wind generator model. The distributed wind generation and photovoltaic power generation are largely influenced by ambient factors in nature and it might lead to the frequent switching of distributed power, which will severely influence voltage level in power distribution grid and lead to the transient impacted overvoltage around the grid-connected node. To establish the constant-speed wind turbine model based on common induction generator and studies its influence on loaded power quality in isolating status

2.3 Integration of distributed network to the grid

Sener Agalar et.al[1]suggested that, The demandfor energy is increasing day by day and also fluctuation in load is also varies either load connection or disconnection. At the same time, power generation from wind is somewhat fluctuating in nature because of fluctuation in wind speed. To reduce the fluctuation in output from wind generation system they suggested two methods. First, one is injecting a wind energy generation system by using static transfer switch parallel to the grid. The second one uses dynamic voltage restorer. That helps in the system to overcome fluctuation. They analyze the above system with the help of PSCAD and EMTDC program. With this help, they maintain the power the continuity of power supply and also improved the power quality of the system. They suggested that by using DVR method can achieve cost-effective and fastest control over voltage fluctuation and power quality improvement. Static transfer switches are used for providing the power to the highest sensitive load by fast switching mechanism from available two or more resources. That is either from wind or feeder. It generally applied in uninterrupted power supply or distributed wind generation system with grid-connected for providing power as an alternate source they implemented in 13.8 kV, 50 Hz system and the model was able to find the fault within .7 sec and rectified it. In case of DVR system provide the power to the sensitive load prevent the system from disturbance like voltage sag swell flicker and harmonics. It is consisting of voltage source inverter, capacitor bank, filter and injection transformer all are connected in series. DVR hasthe best feature it is neither delivered nor absorb real power under standby condition while in case of disturbance it absorbs or delivers the real power from/to the dc link. When they are using the DVR then the effect of fault does not forward in the grid line voltage and current.

Liljenfeldt et.al [6] research on the implementation of wind generation system based on the considering the socio-economic characteristics of the people living near the wind generation unit. The result show that the poor and unemployed people take more interest for implementation in his area while highly educated and wealthy people are not in favor.

Mahmoud Pesaran H.a et.al[15]suggested that**,** Optimal allocation of distributed wind generation system helps in improvements energy efficiency and power quality of the system. It also provides reliability and security of the system. For finding optimal allocation we use intelligence method or fuzzy control method and normal search methods. Most of the optimal allocation methods are based to reduce the real power losses of the system. They sated constrain for finding the optimal power allocation is based online current, node voltage power factor for balance power and capacity of power in inertia, short circuit, and no of distributed wind generator for maximum power production from distributed generation network. They suggested numerous algorithms for finding the optimal allocation of distributed generation system out of which weight factor method is most appropriate technique. And for finding accurate solution analytical method with an exhaustive search is the best way but it is not suitable for large networks because of its various disadvantages. The hybrid optimization method is suitable when various renewable energy sources are available for providing power to the grid.

Somayeh Farhadkhani et.al[16]researched that, When wind generation unit is connected to the grid then coordination may be lost by fault and solution to overcome this problem can be broadly divided into two categories: preventive and remedial Fault Current Limiters (FCLs) use to limit the prospective short-circuit current when a fault occurs in a power transmission or distribution network. The effects of thesedevices on fault current level, transient stability and power quality on the system effects, utilization of FCL as an applicable and interesting solution has investigated the impact of various fault current limiters (FCLs) on electric distribution networks in presence of wind turbine power generation (WTPG). Generally, FCLs are classified into three different categories that are superconducting (SFCL), solid state (SSFCL) and hybrid types. Due to distributed generation, the system loses this radial configuration. Therefore, in case of a fault, DG sources will contribute to. The implementation of FCLs allows some other important performances such as power quality improvement, reliability increase, and transient stability enhancement. FCLs are classified in three different kinds as described in the following subsections 1) Resistive Superconducting Fault Current Limiter 2) Solid State Fault Current Limiter 3) Hybrid Fault Current Limiter using FCL could mitigate the drawback of installing distributed generation but each kind of FCL has its specific characteristic. The results show that resonance based hybrid FCL could make it possible to clear the fault with protection devices undersized with respect to the normal short-circuit level of the fault point without damaging the switchgear. Inductive type SSFCL could better restrict the voltage drop during fault so it is more effective in power quality improvement while RSFCL could better decrease the power drop during the fault so leading to a better influence in power stability enhancement.

2.4 Semi converter dives used in system

Lanfang Li et.al[17]The penetration of distributed wind generation system creates the power quality issues in the existing system. They focused on voltage fluctuation based on the direction of power flow, level of load and regularity in power injected by wind. The steady state voltage level depends on the reactive and active power along with strength of load. Deviation in voltage is calculated based on the vector analysis. The integration of distributed wind generation system in grid through power converter and PWM (which works on high frequency) interfacing cause the generation of flicker in the system. It also produces harmonics in the system. It was observed that the THD produced by a day is 14% by using PSW and switch of high frequency, filtering device and IGBT. If a system has more harmonics then the output generated is lesser than the nominal power and voltage is distorted and it may cause sometimes to trip the system. In case of unbalance in the system causes unstable of the distributed wind generation system which leads to disconnection of inverter, another unbalances is arises by the large amount of single phase power injected in the grid. If its strength is high then it may lead to collapse the grid. Also they provide to find the capacity of distributed generation is decided by two methods. First one is based on load capacity and second is based on transformer rating. If the penetration level is 40-50% the deviation in voltage may be more than 10%. Deviation of voltage also depends on the location of integration of the distributed wind generation system. The integrating point as well as deviation in the voltage of wind generation system in the grid is also depends on the value of short circuit capacity of the system. They suggested two methods to improve power quality of the system. 1) Use the power quality devices like SVC, DVR, APF, SVG, UPFC (unified power factor correction). 2) Uses the power quality compensation function with distributed wind generation system

M. Thirupathaiah et.al[18]When renewable energy sources are connected to the grid they raise the issues of power quality, to rectify these issues they suggested to adopt some supplementary devices to the system. These systems are reactive power injector, capacitor, and compensator. And compensator devices are distribution static compensation (DSTATCOM), dynamic voltage restorer (DVR) static var compensator, and unified power quality conditioner (UPQC). They implemented all the devices and analyzed the power quality issues like voltage swell, sag, and harmonics. And based on the performance they suggested that use of DSTATCOM for power quality improvement is the best option among DVR, UPQC, and DSTATCOM. They implemented in 3 phase, 300V, 50 Hz system when they analyze the power quality by all three methods then the by DVR maximum deviation observed after vanish of fault condition (265V) moderate with UPQC (285) but in case of DSTATCOM it reaches (290V) which is near to the nominal voltage level. Also, THD found the maximum in DVR and minimum in DSTATCOM.

Wajahat Ullah Tareen et.al[19]To integrate the distributed network with grid need some converter (AC/DC/AC), also there is the possibility of nonlinear load which produces harmonics(voltage or current) in the system to reduces these harmonics need to add reactive power compensating devices and filter (active or passive) like capacitor and high-frequency switch. While concerning on parameters like cost, weight, and size active power filter is best among passive filter, static var generator, the use of active power filter, it reduces the number of switching cycle, component, transformerless inverter, multilevel and multifunction inverter. Traditionally passive filter is used for reduction of series harmonics, but it has limited filtering range. Works on specific load and produces negative resonance between grid either in series or parallel. Thus it reduces the life of passive filters. The performance of filter depends upon converter control scheme, detection techniques based on reference current, instantaneous power theory, positive sequence methods and synchronous detection.

They suggested to use the active power filter because it consists of AC-to-AC inverters, Back-to-back inverter, and common-leg inverter configuration. It is mature technology which makes a bridge between grid-connected distributed generation system and harmonic generation. It also helps in improvement of power quality by reduction in voltage regulation, reduction in harmonics, power factor improvement and load balance, current compensation at neutral

Ashish Patel et.al[20]They suggested improving the power quality of distributed generation system when connected to three phase linear or nonlinear load with the help of distributed static compensation (DSTATCOM). They used kernel algorithm for finding the reactive power requirement for feeding for reference current and fluctuating step size in DSTATCOM for power quality improvement in the system. They tested the process in 7 kW wind turbine, 415, and 15m/s wind speed.

Divya Asija et.al [21]They performed the power quality analysis based on the outage of a different part of the system like Transmission line, Transformer, Generator which may lead to an overload of others branch of the system, voltage drop or rise and in the worst case, it may collapse the voltage. They perform the maximum parameter variation based on continuous power flow (CPF) method by disconnecting each line step by step. They perform power flow analysis based on the Newton Raphson Method. They perform the analysis on IEEE 9 bus system and found that the transmission line connected between bus no 4-5 have least loading parameter effect while the transmission line connected between 4-6 have highest loading parameter effect. They suggested using a proper protective system on that bus.

[3]. SIMULATION OF IEEE9 BUS SYSTEM

3.1. MATLAB model of IEEE9 bus system

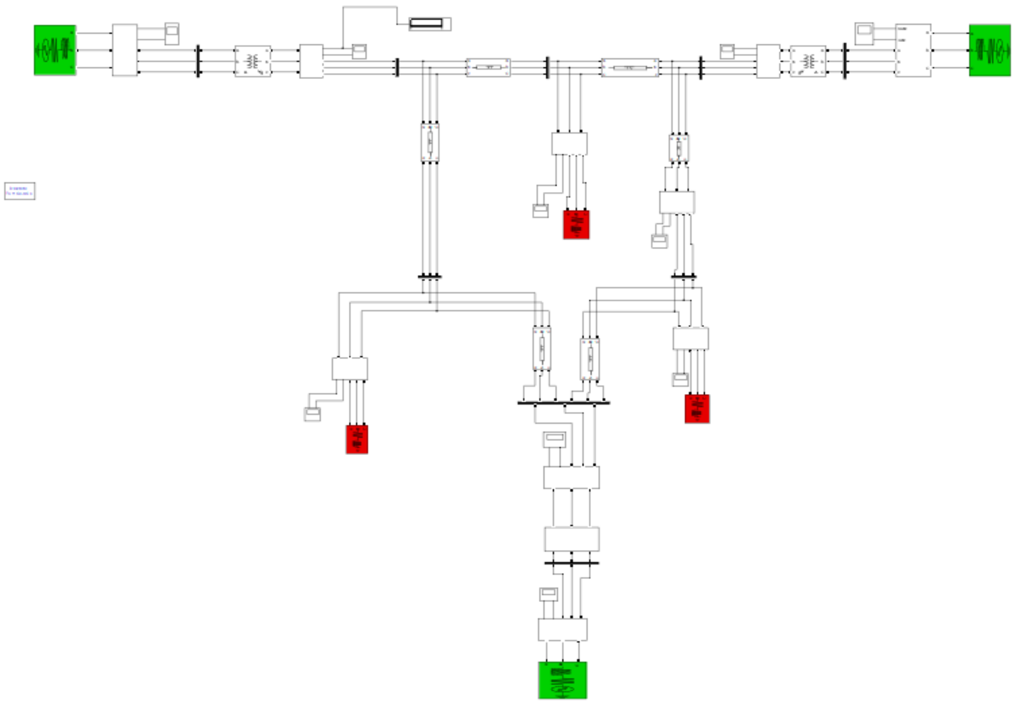

Fig. 2 MATLAB model of IEEE 9 bus system

3.2 Voltage Regulation of system

Voltage regulation of system is defined as change in terminal voltage when rated load is connected or disconnected with respect to terminal voltage.

3.2.1Voltage regulation at bus no5.

When load bus 5 connected

Table. 1 When load bus 5 connected

	load 5 connected	load 5 DIsconnected	loasd bus 5 connected voltage regulation
bus 1	34	34.2	0.5
bus2	25	25.9	3.6
bus3	22.5	23	2.22
bus4	325	336	3.4
bus5	310	335	7.35
bus6	318	330	5.9
bus7	320	338	5.63
bus8	322	335	4.3
bus9	328	338	3.1

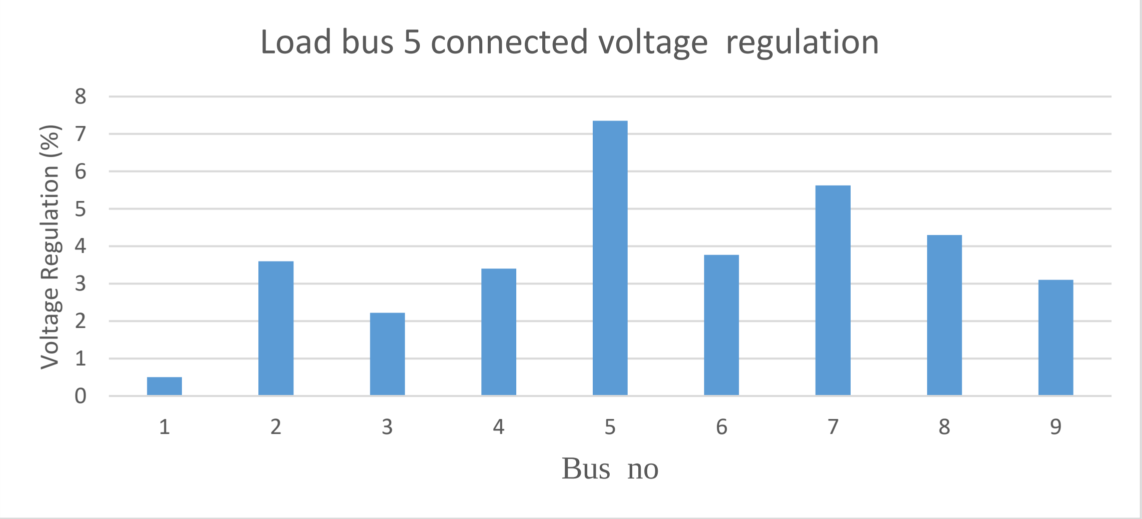

Fig. 3 Voltage regulation when load bus 5 connected

When load at bus 5 disconnected

Table.2 When load at bus 5 disconnected

	Disconnected	Connected	voltage regulation
bus 1	34.5	33.5	3
bus2	26.5	25.5	4
bus3	22.3	22	1.4
bus4	325	316	3
bus5	330	305	8.2
bus6	326	315	3.5
bus7	320	317	1
bus8	322	314	2.5
bus9	324	318	2

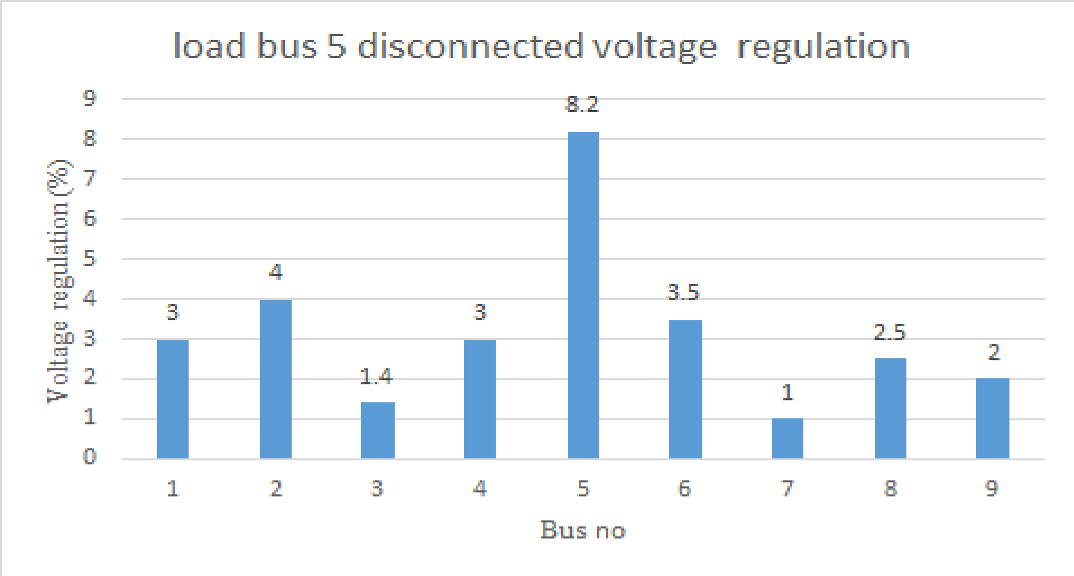

Fig.1 Voltage reregulation when load bus 5 disconnected

4.2.2. Voltage regulation at bus no 6

When load bus 6 is connected

Table. 4.3 When load bus 6 is connected

	Load 6 connected	Load6 disconnected	Voltage regulation
bus 1	34	33.9	0.2
bus2	25	25.5	2
bus3	22.5	22.8	1.33
bus4	325	335	3.07
bus5	328	315	3.22
bus6	308	340	10.38
bus7	320	334	4.3
bus8	322	333	3.1
bus9	328	335	2.13

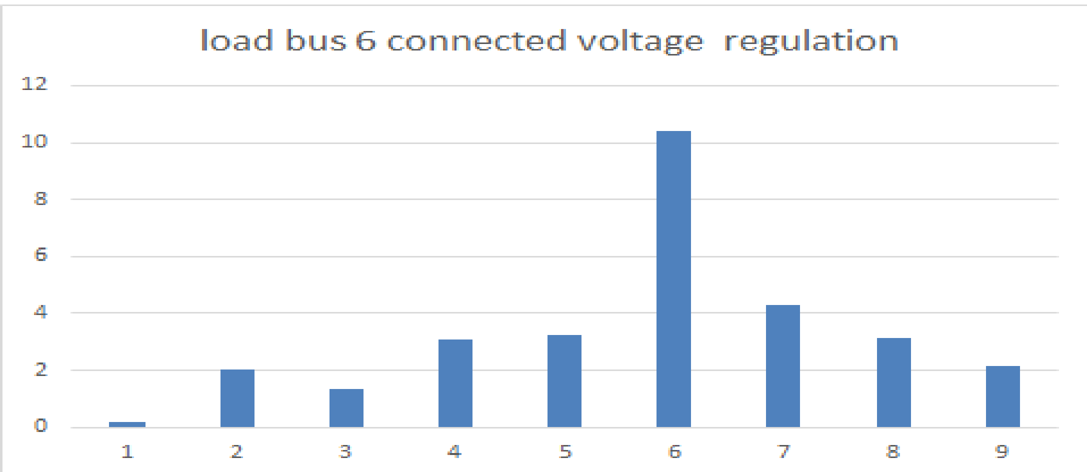

Fig.2 Voltage regulation when load bus 6 connected

When load bus 6 is disconnected

Table.4 When load bus 6 is disconnected

	Load 6 connected	Load 6 disconnected	Voltage regulation
bus 1	33.5	34	1.4
bus2	25.35	25.5	0.58
bus3	21.9	22.2	4.36
bus4	314	323	2.78
bus5	304	309	1.6
bus6	302	329	8.2
bus7	317	320	0.93
bus8	314	318	1.25
bus9	316	322	1.9

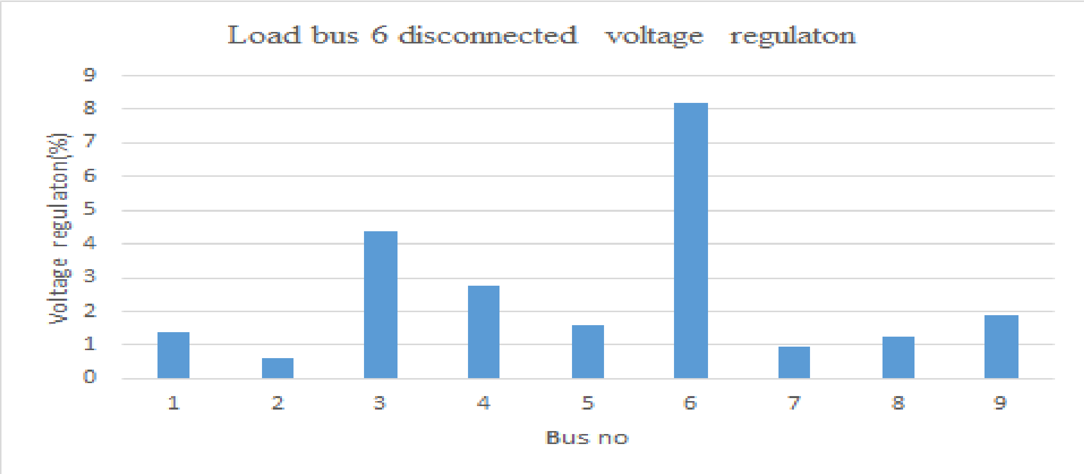

Fig.3 Voltage regulation when load bus 6 disconnected

4.2.3 Voltage regulation at bus no 8

When load bus 8 is connected

Table.4 When load bus 8 is connected

	Load 8 connected	Load 8 disconnected	Voltage regulation
bus 1	34	34.2	0.5
bus2	25	25.9	3.6
bus3	22.5	23	2.22
bus4	322	330	2.4
bus5	321	325	1.5
bus6	320	330	3.1
bus7	320	330	3.1
bus8	315	338	7.3
bus9	320	332	3.75

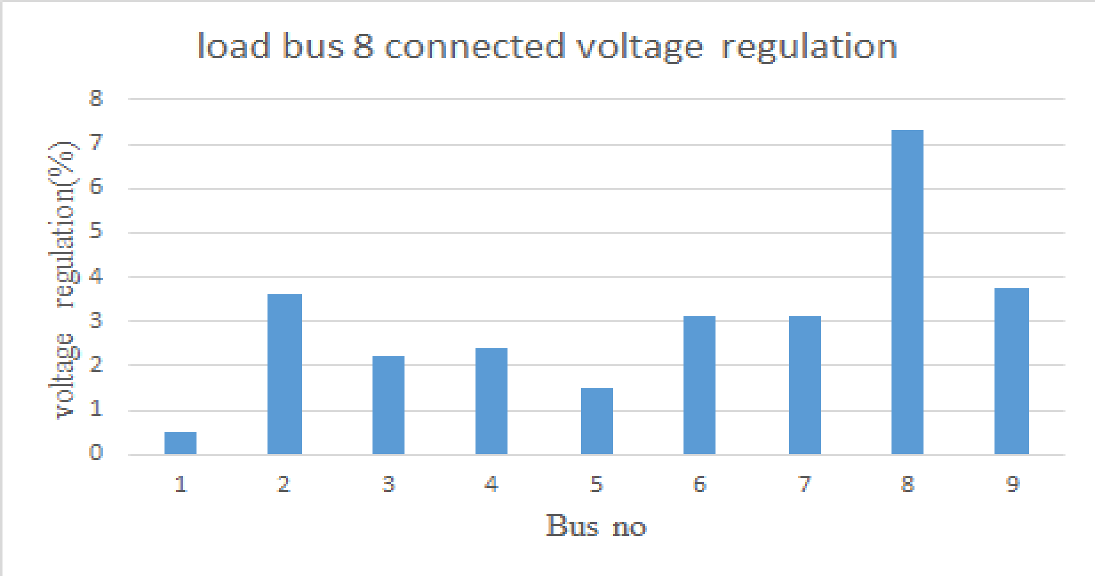

Fig. 4 Voltage regulation when load bus 8 connected

When load bus 8 is disconnected

Table. 5 When load bus 8 is disconnected

	Load 8 connected	Load 8 disconnected	Voltage regulation
bus 1	34.5	34	1.5
bus2	26.5	25.5	4
bus3	22.3	21.5	1
bus4	325	316	3.5
bus5	330	319	3.4
bus6	326	318	2.5
bus7	326	319	2.2
bus8	330	305	7.6
bus9	328	318	3

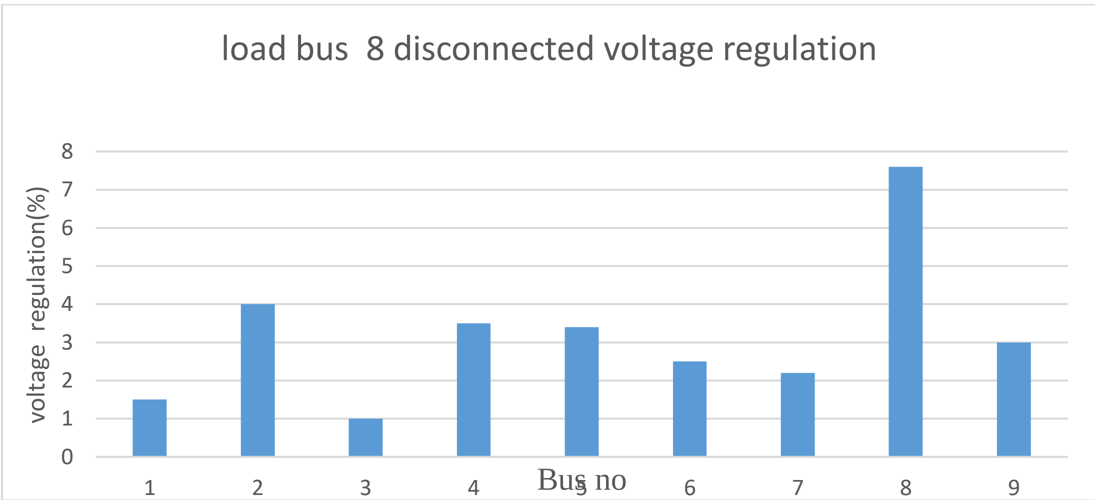

Fig. 4. 5 Voltage regulation when load bus 8 disconnected

4.2.4 Comparative voltage regulation

When all load disconnected

Table. 4.6 Overall voltage regulation when all load disconnected

	Load 5 disconnected Voltage regulation	Load 6 disconnected Voltage regulation	Load 8 disconnected Voltage regulation
bus 1	3	1.4	1.5
bus2	4	0.58	4
bus3	1.4	4.36	1
bus4	3	2.78	3.5
bus5	8.1	1.6	3.4
bus6	3.5	8.2	2.5
bus7	1	0.93	2.2
bus8	2.5	1.25	7.6
bus9	2	1.9	3

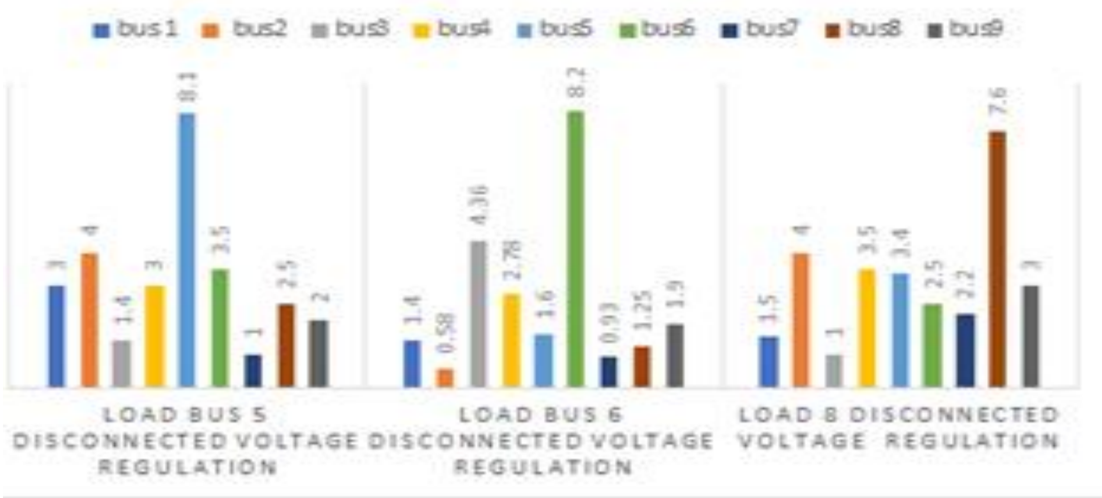

Fig. 6 Overall voltage regulation when all load disconnected

When all load connected

Table.7 Overall voltage regulation when all load connected

	Load 5 connected Voltage regulation	Load 6 connected Voltage regulation	Load 8 connected Voltage regulation
bus 1	0.5	0.2	0.5
bus2	3.6	2	3.6
bus3	2.22	1.33	2.22
bus4	3.4	3.07	2.4
bus5	9.67	3.22	1.5
bus6	3.77	10.38	3.1

bus7	5.63	4.3	3.1
bus8	4.3	3.1	7.3
bus9	3.1	2.13	3.75

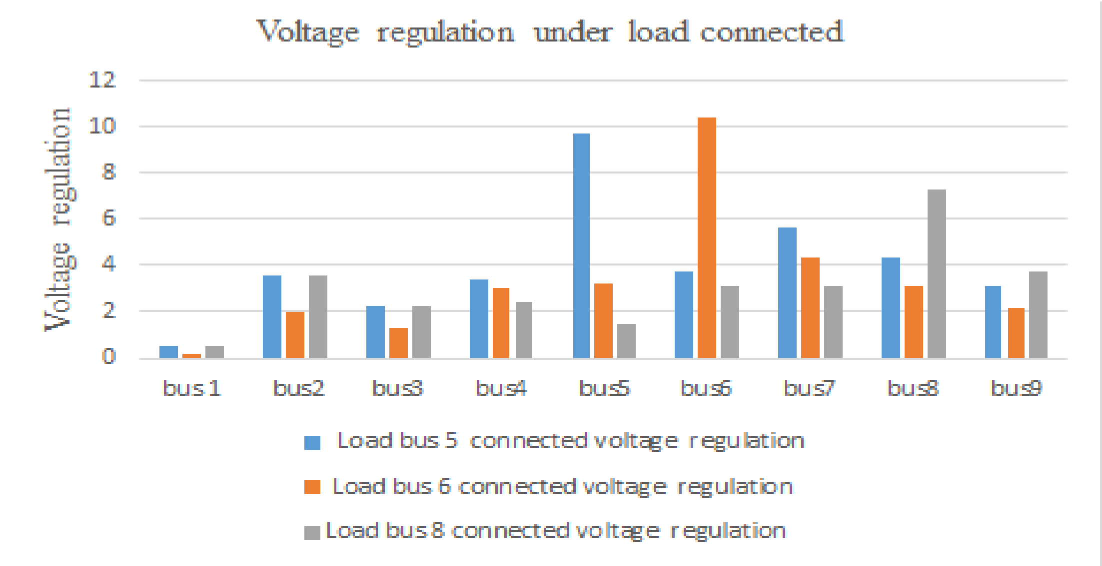

Fig. 7 Overall voltage regulation when all load connected

From the comparative analysis provides the location of wind generation system in the IEEE 9 bus system which is on the bus no 6, because the maximum voltage regulation is observed on that bus under connection and disconnection.

4. SIMULATION OF WIND GENERATION SYSTEM

Wind power is generated by conversion of kinetic energy to the mechanical energy and them mechanical energy to the electrical energy. The wind turbine is used to convert kinetic energy to mechanical energy, and for conversion of this mechanical energy to electrical use shaft. And this shaft is coupled through gearbox mechanism to transfer mechanical power to the prime mover of the electrical generator.

The input of wind generator is wind and as the wind speed changes the input kinetic energy changes that change the mechanical energy, which effect change in output electrical energy. This output change in electrical energy in the form of change in voltage which effects voltage sag swell flicker. This change affects the speed of the machine and procures changes in frequency. That’s result in the form of harmonics.

To extract the power on variable speed uses either permanent magnet synchronous generator or double fed induction generator. For maximum power extraction and provides almost constant power needs a converter (AC/DC/AC)

And the converter and generator are nonlinear devices which are the main cause of generation of harmonics in the system to reduces these harmonic use compensator devices like a capacitor, DVR, STATCOM etc. then connect the whole system to the grid for better utilization or fed the power to local utility depends on need.

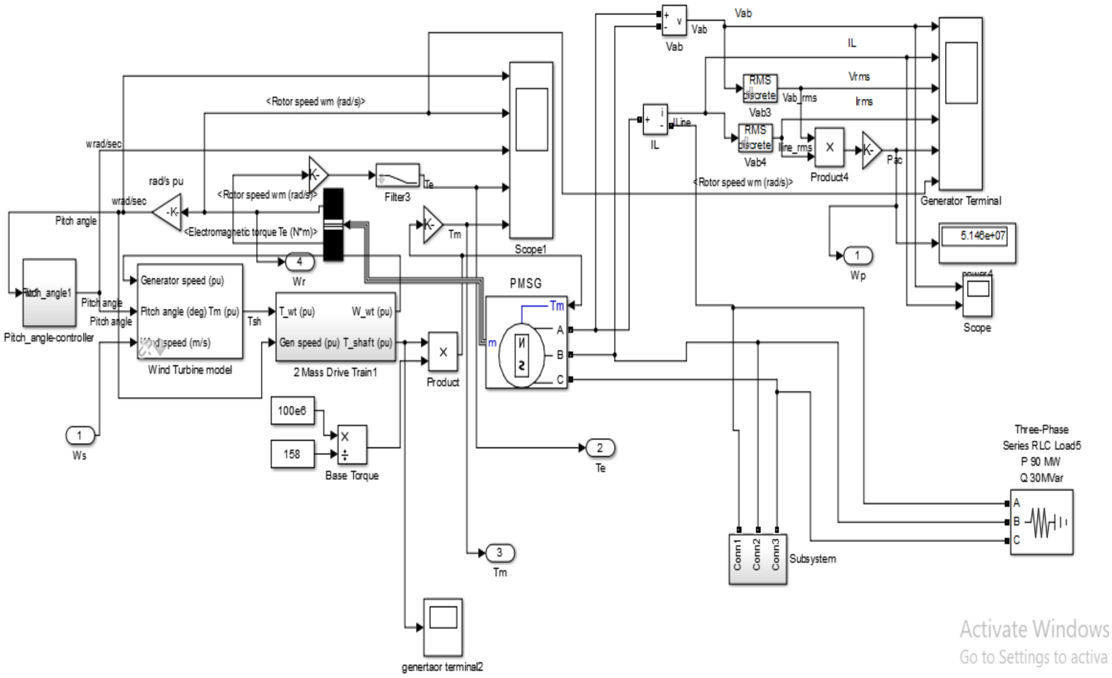

Fig. 5.1 MATLAB model of wind generation system

Wind generator generate 72 MW power at 15.5 kV line to line rms voltage and working frequency is 50 Hz

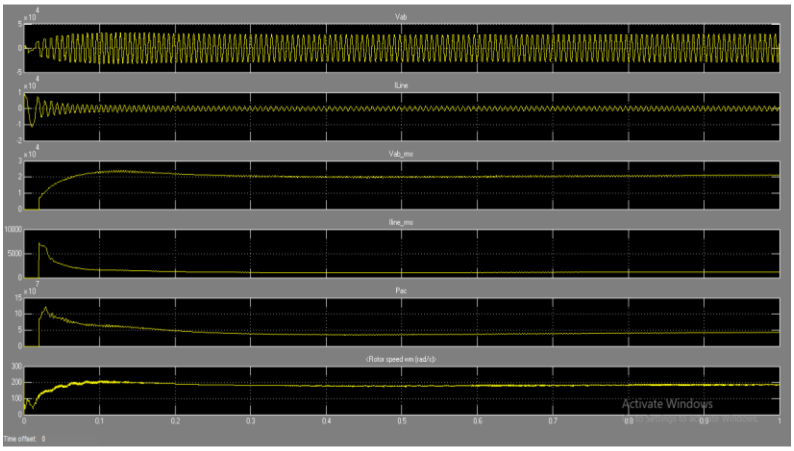

Fig. 5.2 Voltage, current, power and rotor speed profile

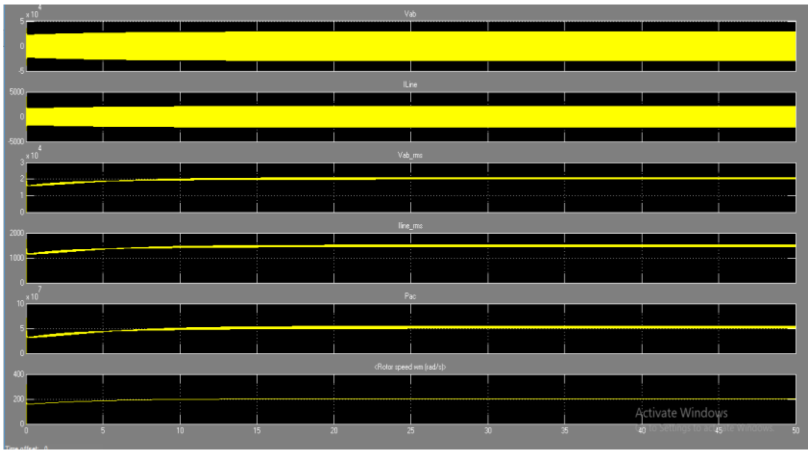

Fig. 5.3 Voltage, current, power and rotor speed profile under steady state

Output torque available from wind generation system

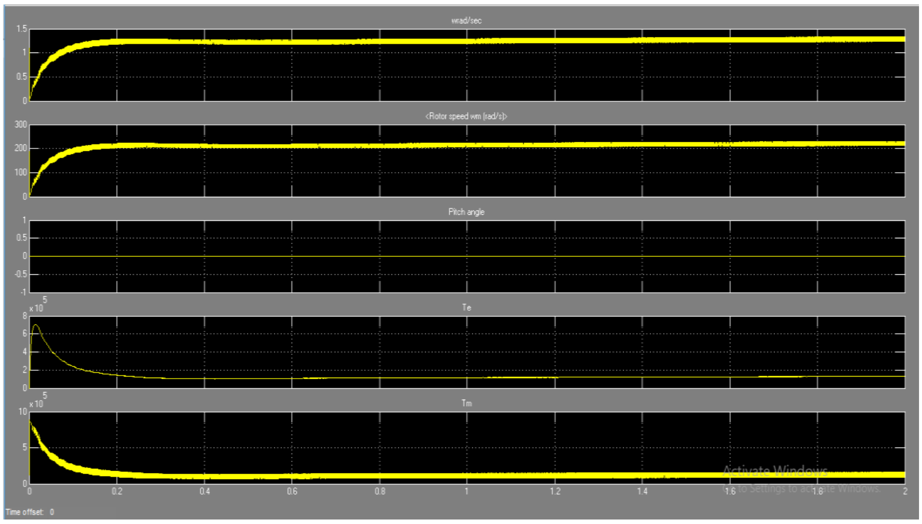

Fig. 5.4 Output torque available from wind generation system

5. CONCLUSION

It can be concluded that with the integration of wind generation system, power can be provides to local load as well as the grid simultaneously, and voltage profile also improved by the integration distributed generation system, but integration of wind generation system with power electronics devices introduces some harmonics in the system. According to MNRE report government focusing to generate more power from wind, for that they selected location in western coastal line and also in TAMIL NADU and coastal region of GUJRAT.

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