HYBRID DG PLACEMENT IN POWER DISTRIBUTION NETWORK TO ENHANCE SYSTEM STABILITY

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Abstract: This project proposes a distributed generator (DG) placement methodology based on newly defined term reactive power loadability for integration of cleaner and greener renewable energy sources in our emerging distribution networks. Firstly, the weak and strong buses of the system are determined by using reactive power loadability and simulation results shows the sensitivity of the location of renewable energy based DG on voltage profile and stability of the system. Then, a suitable location is identified for two principal types DG, i. e., wind and solar, separately to enhance the stability margin of the system. Voltage regulation is calculating to identify the best location for DG placement to reduce the power loss of the system and thereby increases overall system efficiency. Finally, a minimum value of capacitor size is also determined to improve the stability of the system as well as to reduce the cost of compensation with distributed wind generator.

Keywords: Distributed Generator (DG), Point Of Connection (POC), Concentrating Solar Power (CSP).

I. INTRODUCTION

Distributed generation (DG) based on renewable energy sources offers a promising solution to the problem of high greenhouse gas emissions, and is consequently the subject of increasing research efforts around the world. DG is more efficient as less power is lost through distribution lines as consumers are closer to the generation. However, integration of generation in distribution networks is not an easy task. To ensure the security and reliability of the grid with the new generation in distribution networks, a number of issues should be investigated before connecting large-scale DG units into existing systems. Different penetration levels and placement of DG will impact the distribution system. Moreover, inappropriate allocation of DG may lead to higher power loss than when there is no dispersed generation in the system at all. Other technical barrier is the voltage fluctuation issue. DG placement without proper planning can cause low or overvoltage at the point of connection (POC) and nearby area of the distribution system. Therefore, DG should be allocated in way such that it reduces system losses and enhances the system stability. Problems related to voltage instability in power systems are one of the major concerns in power system planning and operation.

If voltage limits and voltage stability are the determining factors for the system operation, additional sources of reactive power can be installed at critical location in order to smooth the Voltage profile and to increase the reserves against the loss of voltage stability with induction generator. However, DG placement without proper planningmay requires larger size compensating devices which involves significant cost. In practice, loadability of a distribution system is limited by voltage drop as most of the distribution feeders are long and operating at low voltage levels. The node which would experience the maximum rate of change of voltage with respect to load increase is called as the “Weakest Node” of the system. The weakest node will have the highest voltage gradient. By identifying this node and controlling the voltage at this node by DG will increase the loadability of the system. In, the authors have proposed a DG placement strategy based on real power loadability, which shows that placing DG which is capable of delivering reactive power and also real power at the weakest bus would allow the system to be loaded to the maximum point, as most of the distribution system feeders are voltage limited.

However, some DG units such as wind turbines which operate on induction machines principal are not suitable for this purpose, as it needs reactive power support for its operation. Most of the cases in distribution network propose DG placement strategy for synchronous generator based DG. As system behavior depends on the type of DG, location should be identified for different types of DG separately. Several studies proposed DG sitting and sizing strategy to improve the system power loss. One of the major concerns related to the distributed generations its impact on the system stability. However, DG placement strategy to increase the system stability has attracted much less attention. This case analyses the impact of location of wind and solar type DG in the distribution network stability. To enhance the system stability and to reduce the possibility of voltage collapse, a DG placement strategy is proposed based on there active power load ability for integration of cleaner and greener renewable energy sources in our emerging distribution networks. A minimum value of capacitor is also determined to enhance the system performance with wind generator.

II. DG-A DEFINITION

DG can be defined as electric power generation within distribution networks or on the customer side of the network as shown in Fig.1. The purpose of DG is to provide a source of active electric power located at the distribution side of the network or customer side [1]. The DGs are categorized as

- Micro DG:~ 1 W < 5 W;
- Small DG: 5kW < 5MW;
- Medium DG: 5MW< 50MW;
- Large DG: 50MW< ~300MW;

Reduction of transmission line losses, achieved by proper sitting. location and unit size.

- modes of operation: ownership.
- Penetration of DG.
- Distributed resources-2 aspects.
- DG located within the distributed system or on the customer side of the meter.
- Demand-side resources ie., load management systems, to move electricity use from peak to off peak periods, energy efficiency options.

A. Distributed Generation Types and Technology

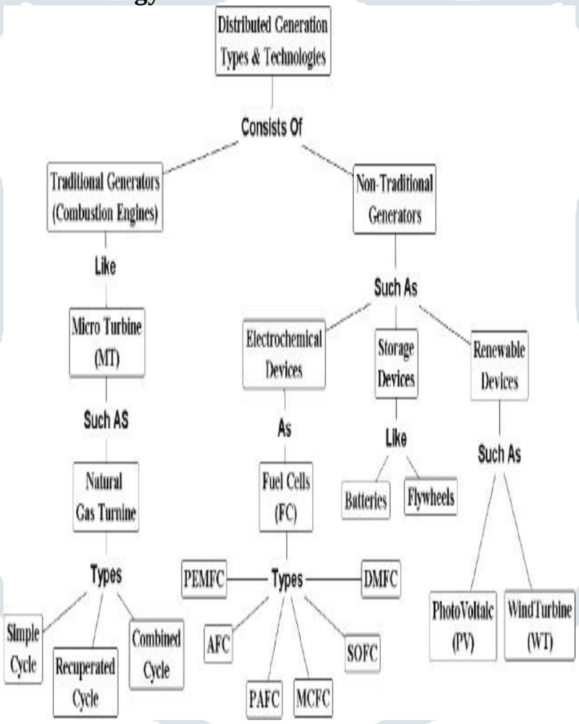


Fig .1. Distributed generation types and technology.

B. Objective of The Project Work

Determining proper location of wind DG to enhance the system stability by newly proposed method reactive power loadability. Determining proper location of solar DG to enhance the system stability by newly reposed method reactive power load ability. Voltage regulation is calculating to identifying best location for DG to reduce the power loss of system and improve the overall system efficiency. A minimum value of capacitor size is also determined to improve the stability of the system as well as to reduce the cost of compensation with distributed wind generator.

C. Renewable Energy Source Type DG

The global requirement for sustainable energy provision will become increasingly important over the next years as the environmental effects of fossil fuels become apparent. Distributed Generation (DG) based on Renewable Energy Technologies (solar, wind, hydro and biomass) is becoming a more important energy option in the future generation system. Depending on the local conditions and energy potential, one or more of the widely used renewable energy sources can be exploited locally. Wind energy for electricity production, biogas from solid waste for heat and electricity production, solar for heat and electricity production, hydro for electricity production.

D. Wind Generator

Electricity from wind is generated by using turbines to convert the wind's kinetic energy into electrical energy. Wind turbines typically have two or three airfoils, which spin due to the aerodynamic lift that is created as wind passes over them. These airfoils are attached to a shaft that drives a generator, which in turn creates electricity. Most turbines are mounted at least 30 meters (m) above the ground to take advantage of wind resources that are faster and less turbulent than those closer to the ground A typical modern wind turbine has three airfoils that are 70-80 m in diameter mounted atop a tower 60-80 meters tall. Such a turbine can generate roughly 1.6 megawatts (MW) of electrical power. Although turbines with larger airfoils, higher towers, and greater generation capacity may be developed in the future, it is doubtful the airfoil diameter of land-based wind turbines will exceed 100 m, which corresponds to a power output of 3-6 MW. This is because the transportation costs of such large components present a significant economic barrier to widespread adoption.

E. Solar Generator

Solar power is generated by turning energy in the sun's light into electrical energy. Many technologies take advantage of solar energy, including Photovoltaic (PV) power systems and Concentrating Solar Power (CSP) systems, as well as passive solar heating, solar hot water, and solar process heating and cooling. The two main technologies used for solar electric power generation are PV and CSP.PV arrays use semiconductor devices called solar cells to convert sunlight to electricity. These solar cells are typically grouped into modules that hold about 40 cells, and about 10 of these modules are then combined to form the PV array, which is usually several meters to a side. PV arrays can be mounted at a fixed angle facing south, or on a tracking device that follows the motion of the sun across the sky. A household can be powered using 10-20 PV arrays, while utility-scale PV power generation requires hundreds of connected arrays. Most areas in the United States have enough sunlight for cost effective, small-scale, non-grid connected PV, but not all areas have sufficient sunlight for utility-scale PV power generation CSP systems focus the sun's light to produce high-temperature thermal energy, which is then converted into electricity. There are three main types of CSP systems: parabolic trough, dish-engine, and power tower.

In a parabolic trough system, long, U-shaped mirrors concentrate the sun's light onto a pipe that runs parallel to the bottom of the U. Oil flowing through this pipe is heated to extremely high temperatures and then is used to produce steam, which turns a turbine that drives a generator. The largest single trough system in existence currently produces 80 MW of electricity, but future troughs may produce as much as 250 MW. Multiple troughs are often combined in a single facility. In a dish-engine system, a dish is used to concentrate the sun's light. This concentrated light produces heat, which is transferred to a liquid that expands against a piston or turbine to produce mechanical power. This mechanical power can then be used to drive a generator or to perform other tasks. Dish engine systems produce less power than other types of CSP systems, typically generating 3 to 25 kW of electricity. In a power tower system, a large field of mirrors concentrates the sun's light at the top of a tower. This concentrated light heats molten salt that flows through a receiver at the top of the tower, and the molten salt is then used to produce steam. This steam turns a turbine that drives a generator, producing electricity. Power tower systems can produce up to 200 MW of electricity.

F. Reactive Power and Voltage Control

- For efficient and reliable operation of power system, the control of voltage and reactive power should satisfy the following objectives.
- Voltages at all terminals of all equipment in the system are within acceptable limits.
- System stability is enhanced to maximize utilization of the transmission system.
- The reactive power flow is minimized so as to reduce R I 2 and X I 2 losses. This ensures that the transmission system operates mainly for active power.

High angles are due to long lines and high power transfers Minimizing active and reactive power losses. Real losses should be minimized for economic reasons, reactive losses should be minimized to reduce investments in reactive power devices. Both active and reactive losses depend on reactive power transfer, Because: $\frac{P^2+Q^2}{V^2}R$ and $Q_{loss}=\frac{P^2+Q^2}{V^2}X$ to minimize losses we have to minimize reactive power transfer and keep voltage high.

Minimizing over-voltage load rejection Reactive power transfer requires larger equipment sizes for transformers and cables Voltage stability and rotor angle stability are interlinked. Transient voltage stability is often interlinked with transient rotor angle stability, and slower forms of voltage stability are interlinked with small disturbance rotor angle stability. Off course, there are examples of pure voltage stability, like for instance a synchronous generator or large system connected by transmission line to asynchronous load and pure angle stability for example, a remote synchronous generator connected by transmission lines to a large system. However, rotor angle stability, as well as voltage stability, is affected by reactive power control. In particular, small disturbance instability involving a periodical increasing angle was major problem before continuously acting generator automatic voltage control regulators become available. We now can see the connection between small-disturbance angle stability and longer-term voltage stability: generator current limiting prevents normal automatic voltage regulation.

III. SYSTEM MODELING

A. Generator Modeling

A squirrel cage induction type wind generator is employed which consumes reactive power from system. A solar generator is used which has an inverter operating range of ±0.99pf. Reactive power capability of equivalent machine is determined by combined MVA rating of inverter and actual power level of solar plant such that,

$$Q_{max}=\sqrt{M_{Base}^2-P_{Gen}^2}=-Q_{min} \quad \text{----------} \; \textbf{(1)}$$

Where, M_{base} is base MVA of generator, P_{gen} is real power output, Q_{max} and Q_{min}- maximum and minimum reactive power output.

B. Load Modeling

Static loads can be classified as constant impedance, constant current or constant power loads. Common static load models for active and reactive power are expressed in polynomial or exponential forms and can include, if necessary, a frequency dependent term. In this project, we used the exponential form to represent static load as:

$$P(V)=P_O(V/V_0)\alpha \quad \text{---------} \; \textbf{(2)}$$

$$Q(V)=Q_0(V/V_0)\beta \quad \text{----------} \; \textbf{(3)}$$

Where, P and Q are active and reactive components of load, respectively. where bus voltage magnitude is V. The subscript 0 identifies the values of the respective variables at the initial operating condition. The parameters of this model are the exponents α and β. With these exponents equal to 0, 1or 2, the model represents the constant power, constant current or constant impedance characteristics of load components, respectively.

Where,

n=Total no. of buses

Total load=6.301MW, 0.446MVAr

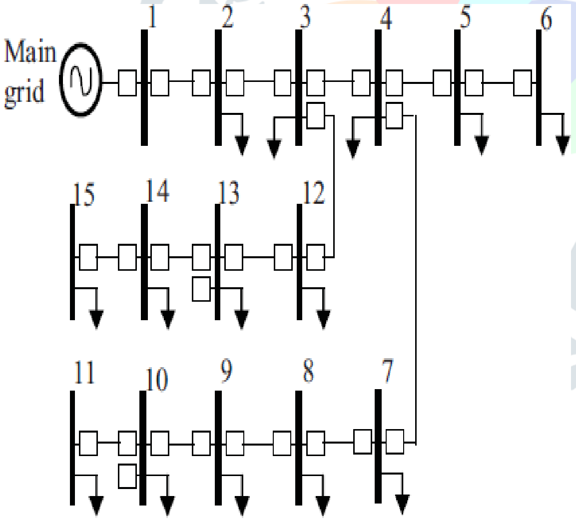


Fig.2: Single line diagram of 15 bus distribution system.

C. Proposed DG Placement Methodology

There are many ways to identify the weakest bus in power system, e. g., P-V analysis, L-index, Q-V analysis. The superiority of Q-V analysis compared to other methods is investigated in. In my project, to find out the static voltage stability limit of the distribution system Q-Analysis is performed with 40% wind and solar penetration, separately. Starting with existing reactive loading at a bus, the voltage of bus can be computed for a series of load flows as the reactive load is increased in steps, until power flow experiences convergence difficulties as system approaches voltage collapse point. Reactive power margin is measured as distance between lowest MVAr point of Q-V curve and voltage axis as shown in fig.3. Highest reactive power margin signifies strongest bus and lowest reactive power margin signifies weakest bus. Reactive power margin index can be used as a reliable stability index to identify critical node with all load uncertainties in a distribution system. After identifying weak and strong bus, to determine suitable location of DG, solar and wind generator is connected in different weak and strong buses to calculate the rate of increment of reactive power load ability (Q load ability) for different buses.

$$Q\ \text{load ability} = \frac{Q_{new}^{margin} - Q_{base}^{margin}}{Q_{base}^{margin}} \times 100 \qquad \text{------------ (4)}$$

V_i (max) = nodal voltage of bus for maximum demand case
V_i (min) = nodal voltage of bus for minimum demand case.

Assumed Maximum and minimum demand is +/- 10% of system nominal load. Respectively Determining voltage regulation: The load of a distribution network is always changing. Therefore for the correct operation of electrical equipment, it is essential that steady state voltage regulation i.e the difference in voltage profile between maximum and minimum demand cases should be as small as possible. Otherwise fluctuation of voltage may cause serious problem to utility which can reduce life time of equipment connected to it or damage them. Voltage regulation is minimum has much as possible.

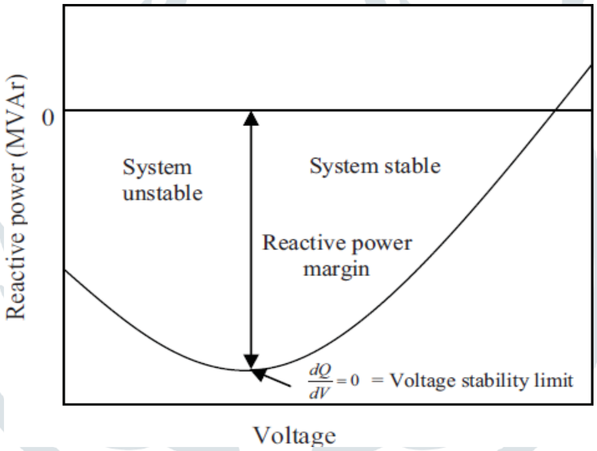


Fig.3. Typical reactive power-voltage (Q-V) curve.

SIMULATION RESULTS AND DISCUSSION

The reactive power margin for the load buses of the 15 bus test system under base case (without DG) is shown in Fig 4. It is seen that bus 15 has the lowest reactive power margin, which is the weakest bus of this test system. On the other hand, bus 2 has the highest reactive power margin, which is the strongest bus of this system. Ranking of the five weak and strong buses are listed in Table I.

TABLE I: Ranking of Buses

Weak bus		Strong bus	
Bus no.	Reactive power Margin in (MVAr)	Bus no.	Reactive power Margin in (MVAr)
15	6.10	2	32.10
14	6.19	3	31.31
13	8.48	4	22.13
11	8.48	5	19.38
10	9.98	7	16.36

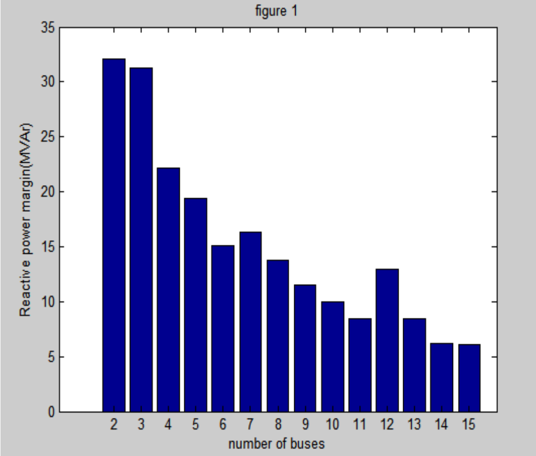


Fig.4.Reactive power margin of the load buses of the test System under base case.

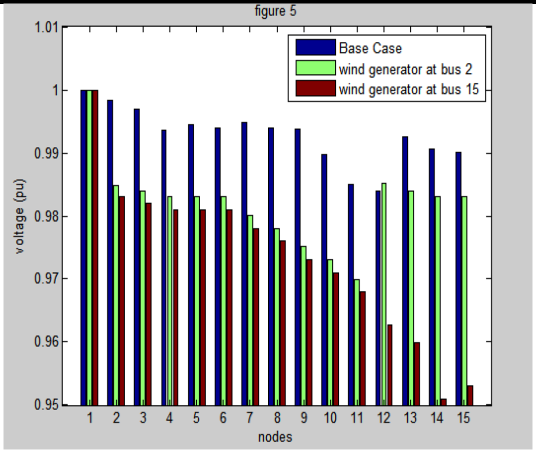
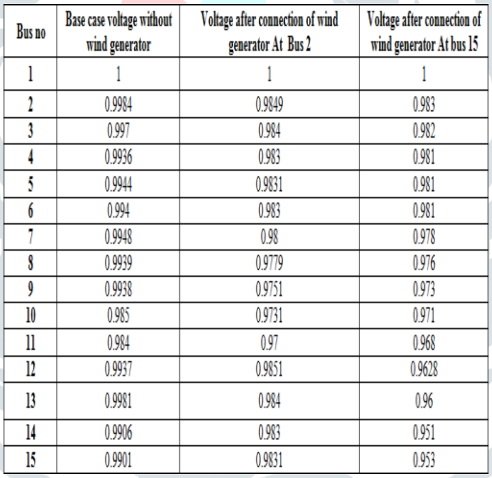


Fig 5: Nodal voltages of the test system for different location of wind generator.

A. Impact of DG Location On The Voltage Profile Of The System:

To see the impact of DG location on the system voltage profile, nodal voltages of the system are calculated from load flow study before and after integration of DG in different locations.

TABLE II: Voltage Value Before and After Connection of Wind Generator at Bus 2 and Bus 15

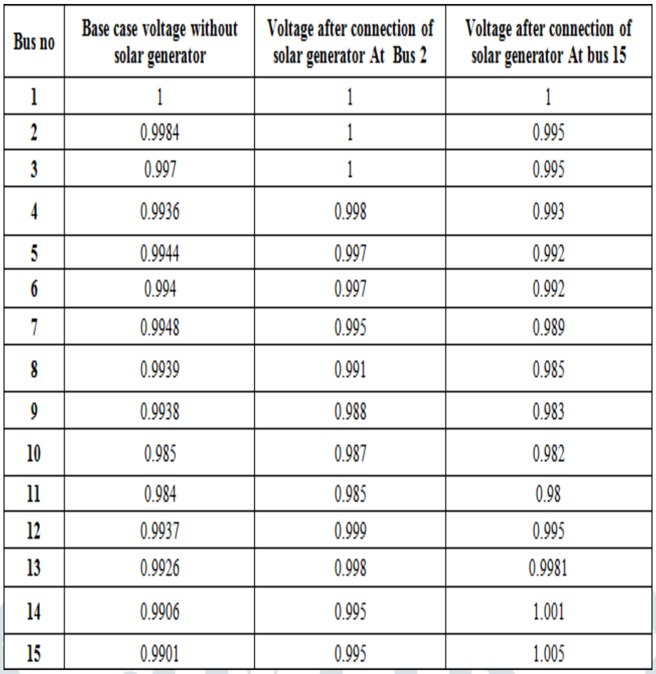


Bus no	Base case voltage without wind generator	Voltage after connection of wind generator At Bus 2	Voltage after connection of wind generator At bus 15
1	1	1	1
2	0.9984	0.9849	0.983
3	0.997	0.984	0.982
4	0.9936	0.983	0.981
5	0.9944	0.9831	0.981
6	0.994	0.983	0.981
7	0.9948	0.98	0.978
8	0.9939	0.9779	0.976
9	0.9938	0.9751	0.973
10	0.985	0.9731	0.971
11	0.984	0.97	0.968
12	0.9937	0.9851	0.9628
13	0.9981	0.984	0.96
14	0.9906	0.983	0.951
15	0.9901	0.9831	0.953

Case 1: The voltage profile of the system for connection of wind type DG at the weakest (bus 15)and strongest (bus 2) bus are shown in Fig.5 and voltage values after connection of wind type DG at the weakest (bus 15)and strongest (bus 2) bus are tabulated at table II.2 shows, respectively. It is seen that connection of wind generator at the weakest bus reduces the nodal voltages in the weak region significantly due to the inability of induction generator to produce reactive power to support the load.

Case 2: The voltage profile of the system for connection of solar type DG at the weakest (bus 15)and strongest (bus 2) bus are shown in Fig.6 and voltage values after connection of solar type DG at the weakest (bus 15)and strongest (bus 2) bus are tabulated at table III shows, respectively. The connection of solar generator in the weakest bus improves the bus voltages in the weak region as shown in Fig 6. So, proper location of generator is very important to well maintain the system voltage profile

TABLE III: Voltage Value Before And After Connection Of Wind Generator At Bus 2 And Bus



Bus no	Base case voltage without solar generator	Voltage after connection of solar generator At Bus 2	Voltage after connection of solar generator At bus 15
1	1	1	1
2	0.9984	1	0.995
3	0.997	1	0.995
4	0.9936	0.998	0.993
5	0.9944	0.997	0.992
6	0.994	0.997	0.992
7	0.9948	0.995	0.989
8	0.9939	0.991	0.985
9	0.9938	0.988	0.983
10	0.985	0.987	0.982
11	0.984	0.985	0.98
12	0.9937	0.999	0.995
13	0.9926	0.998	0.9981
14	0.9906	0.995	1.001
15	0.9901	0.995	1.005

A. Determining the Suitable Location To Improve Stability of The System

To determine the static voltage stability of the system with wind and solar generator Q-V analysis is performed for different location of these generators in the distribution network. As the weak buses are more vulnerable to voltage collapse, the reactive power margin of the weak region is calculated by several load flow studies.

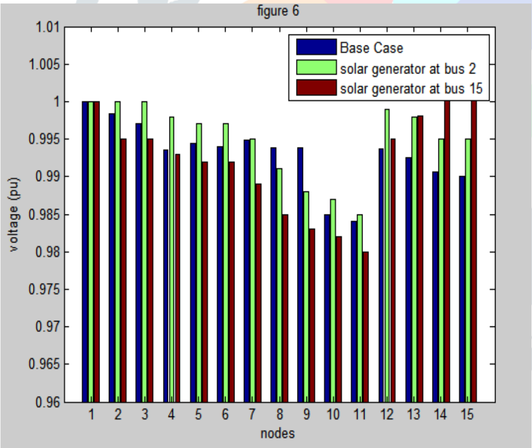


Fig.6: Nodal voltages of the test system for different location of solar generator

Case1: Connection Of Wind Generator At Weakest Buses Fig.7 show the reactive power margin of the system with the connection of wind generator in the weakest bus and Table IV gives the reactive power values of weak buses (15 14 13) after connection of wind DG at weak buses. From these figure, it is seen that connection of wind generator in the weakest bus reduces the static voltage stability limit in the weak area (Bus 15, 14, 13) of the system compared to base case.

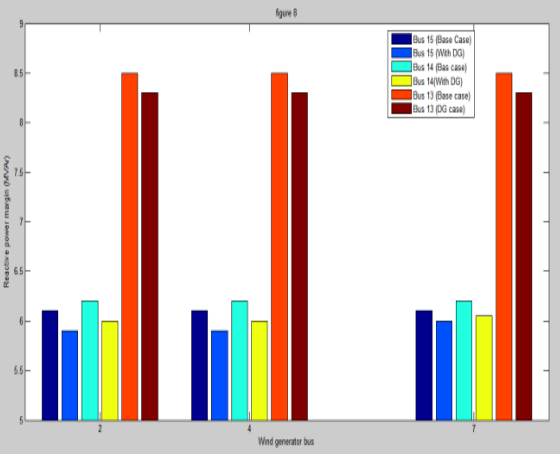


Fig.7. Reactive power margin in the weak region with wind generator connected in the weakest bus.

TABLE IV: Reactive Power Margin in the Weak Region When Wind Generator Connected At Weak Buses

Bus no	Base case reactive power In MVAr	Reactive power in (MVAr) after wind DG connected at weak buses		
		15	13	11
15	6.10	5.27	5.4	6.0
14	6.19	5.3	5.5	6.1
13	8.48	6.9	8.2	8.3

Case 2: Connection of Wind Generator at Strong Buses

Fig .8 show the reactive power margin of the system with the connection of wind generator in the strongest buses (2 4 7) and Table V gives the reactive power values of strongest buses after connection of wind DG at strong buses. It is seen that when wind DG connected to the strongest bus, it increases the stability limit in the weak region compared to its connection in the weakest bus.

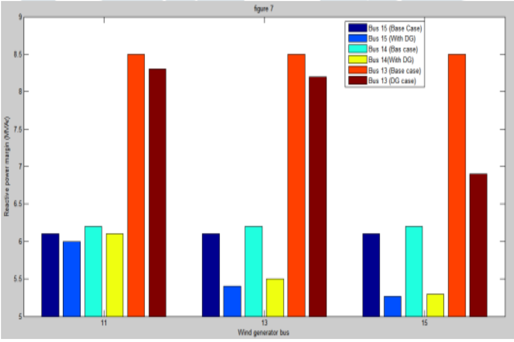
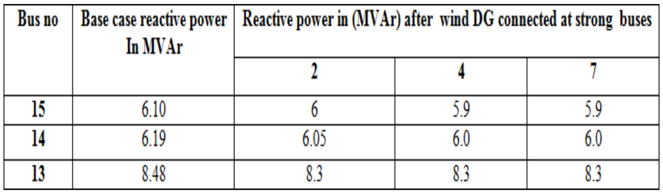


Fig.8. Reactive power margin in the weak region with wind generator connected in the strong bus.

TABLE V: Reactive Power Margin Of The System When Wind Generator Connected At Strong Buses



Bus no	Base case reactive power In MVAr	Reactive power in (MVAr) after wind DG connected at strong buses		
		2	4	7
15	6.10	6	5.9	5.9
14	6.19	6.05	6.0	6.0
13	8.48	8.3	8.3	8.3

Case 3: Connection of Solar Generator At Weak Buses

Fig.9 show the reactive power margin of the system with the connection of solar generator in the weakest bus and Table VI gives the reactive power values of weak buses (13 14 15) after connection of solar DG at weak buses.

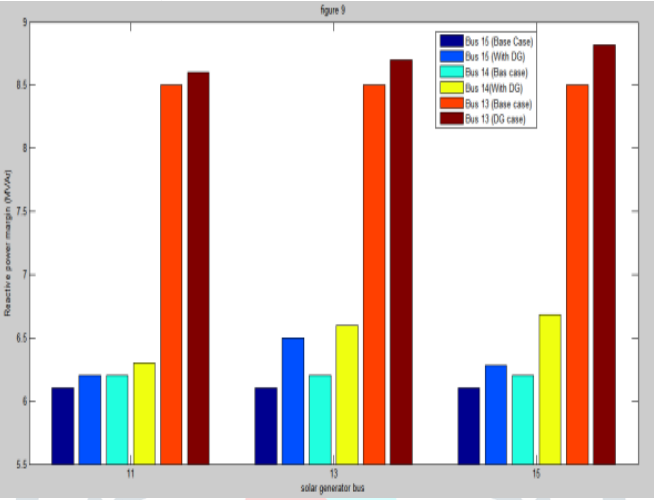
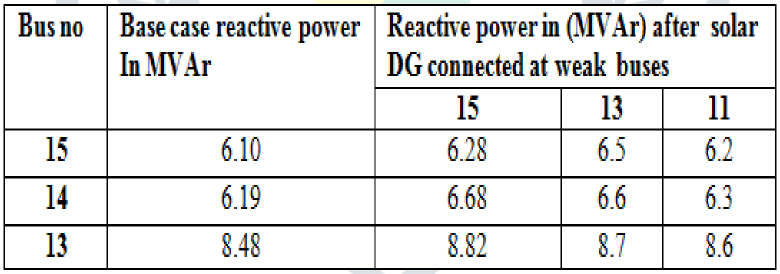


Fig.9.Reactive power margin in the weak region with solar generator connected in the weakest bus.

TABLE VI: Reactive Power Margin of the System When Wind Generator Connected At Weak Buses



Bus no	Base case reactive power In MVAr	Reactive power in (MVAr) after solar DG connected at weak buses		
		15	13	11
15	6.10	6.28	6.5	6.2
14	6.19	6.68	6.6	6.3
13	8.48	8.82	8.7	8.6

Case 4: Connection of Solar Generator At Strong Buses

Fig.10 show the reactive power margin of the system with the connection of solar generator in the strong bus and Table VII gives the reactive power values of strong buses (2 4 7) after connection of solar DG at strong buses.

Fig 10: Reactive power margin in the weak region with solar generator connected in the strong bus.

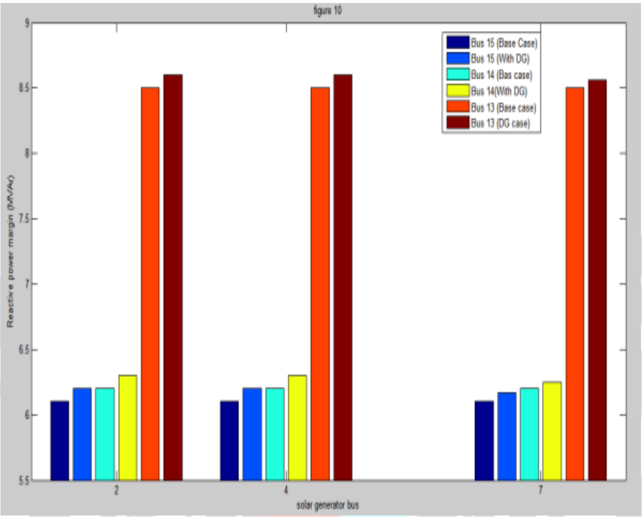
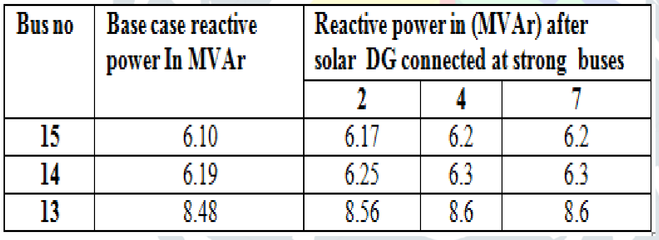
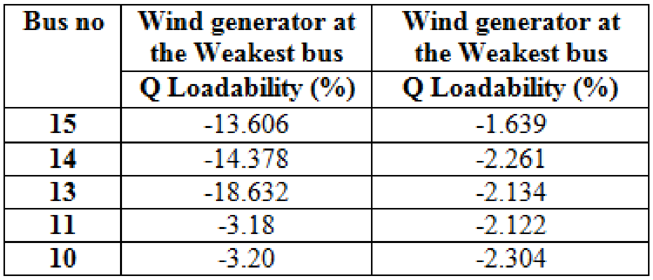


TABLE VII: Reactive Power Margin of the System When Wind Generator Connected At Weak Buses



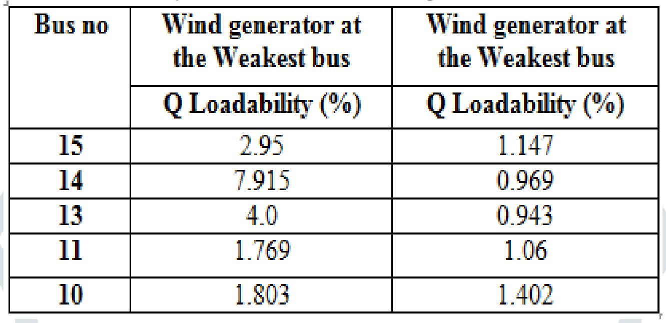
Bus no	Base case reactive power In MVAr	Reactive power in (MVAr) after solar DG connected at strong buses		
		2	4	7
15	6.10	6.17	6.2	6.2
14	6.19	6.25	6.3	6.3
13	8.48	8.56	8.6	8.6

TABLE VIII: Q Loadability of Weak and Strong Buses With Wind Generator



Bus no	Wind generator at the Weakest bus	Wind generator at the Weakest bus
	Q Loadability (%)	Q Loadability (%)
15	-13.606	-1.639
14	-14.378	-2.261
13	-18.632	-2.134
11	-3.18	-2.122
10	-3.20	-2.304

TABLE IX: Q Loadability Of Weak And Strong Buses With Solar Generator

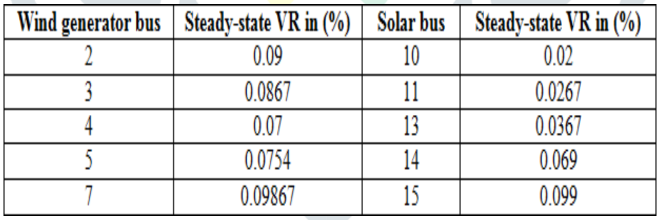


Bus no	Wind generator at the Weakest bus	Wind generator at the Weakest bus
	Q Loadability (%)	Q Loadability (%)
15	2.95	1.147
14	7.915	0.969
13	4.0	0.943
11	1.769	1.06
10	1.803	1.402

B. Determining Voltage Regulation for DG Placement

The placement of DG in power distribution system the voltage regulation should be minimum. The load of a distribution network is always changing. To work electrical equipments properly, it is desirable that steady-state voltage regulation, i. e., the difference in the voltage profile between the maximum and minimum demand cases, should be as small as possible. Otherwise, the fluctuation of voltage may cause a serious problem to the distribution utility, which can reduce the life time of the equipments connected to it or damage them. Voltage regulation (VR) is calculated frogmen
(5) for connection of wind and solar generator in the strong and weak area, respectively. The values of VR for both generators are given in Table X. It is seen that voltage regulation is minimum for the connection of wind generator at bus 4 and that for solar at bus 10. Therefore, to improve the loadability of the system and to reduce the voltage regulation, bus 4 and bus 10 are the best location for wind and solar generator, respectively.

TABLE X: Steady State Voltage Regulation



Wind generator bus	Steady-state VR in (%)	Solar bus	Steady-state VR in (%)
2	0.09	10	0.02
3	0.0867	11	0.0267
4	0.07	13	0.0367
5	0.0754	14	0.069
7	0.09867	15	0.099

It is also seen that connection of wind generator at bus 4and solar type DG at bus 10 improves the total system power loss by 29.44% and 74.14%, respectively compared to the base case has shown in table 4.12. However, in practice these buses (bus 4 and bus 10) might not be always suitable for DG installation as the location of DG depends on environmental constraints and availability of primary resources.

C. DG Location

TABLE XI: DG Location

Dg type	Bus number
Wind DG	4
Solar DG	10

TABLE XII: Power Loss Before and After DG and Power Loss Improvement

DG type	Power loss in pu		
	Before DG	After DG	Power loss improvement
Wind DG	1.5435	1.08902	29.44%
Solar DG	1.5435	0.39902	74.14%

Five best locations for wind and solar type DG are given in Table 4.13 by doing the similar analysis for other buses also. Depending on operational requirements, distribution utility will decide proper site for DG installation among these buses. The flowchart of the proposed planning to maximize the distribution system stability and to minimize the voltage regulation with renewable generation is shown in earlier Fig 4.

TABLE XIII: Suitable Location of DG

DG type	Suitable location
Wind	Bus 4,7,5,3,2,respectively
Solar	Bus10,11,13,14,15, Respectively

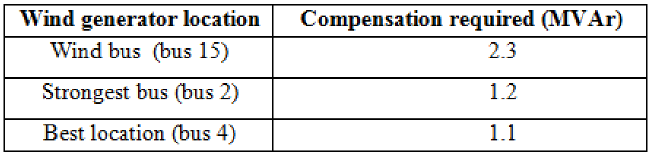
D. Determining the Size of Compensator for Wind Type DG

It is found that wind generator reduces the system stability compared to the base case. As our objective is to increase the system stability, we have determined the minimum value of capacitor that must be connected with the wind generator to get the stability margin equal to the base case. A series of load flows are performed with an increase of the value of capacitor from 0 to 3 MVAr. The value of the required compensator size to keep the stability margin of the weakest bus equal to base case is given in Table 4.14for different locations of wind generator. It is found that placement of wind type DG in our determined location (bus 4) needs almost half compensation compared to its location in the weakest bus, which reduces the cost of compensation significantly (cost of capacitor varies $10-$20 per kVAr).

TABLE XIV: Compensation Size of Capacitor for Wind Generator to Keep Stability Margin Equal to the Base Case

Bus no	Base case reactive power margin in MVAr	Reactive power when wind at bus 15 and capacitor is 2.3 MVAr	Reactive power when wind at bus 2 and capacitor is 1.2 MVAr	Reactive power when wind at bus 4 and capacitor is 1.1MVAr
2	32.10	31.5	31.9	32.02
3	31.31	30.2	30.2	31.01
4	22.13	21.5	22.10	22.02
5	19.38	18.9	19.1	19.1
6	15.11	14.08	14.89	14.98
7	16.36	15.5	16.12	16.11
8	13.73	12.8	13.12	13.12
9	11.56	10.82	11.24	11.32
10	9.98	9.11	9.32	9.66
11	8.48	7.98	8.12	8.23
12	12.96	12.16	12.5	12.4
13	8.48	8.01	8.301	8.38
14	6.19	5.9	6.051	6.10
15	6.10	5.8	6.002	5.95

TABLE XV: Compensation Required For Wind Generator



Wind generator location	Compensation required (MVAr)
Wind bus (bus 15)	2.3
Strongest bus (bus 2)	1.2
Best location (bus 4)	1.1

• CONCLUSION

The analysis shows that location of DG has a significant impact on the system stability which strongly depends on DG technology. It is found that induction type wind generator reduces the system stability and solar energy based DG enhances the stability margin of the system compared to the base case. A new index, Q loadability, is used in this project to find out the suitable location of DG in the system. To enhance the system stability margin, it is recommended to place the wind generator in the strong region and solar generator in the weak region. Voltage regulation is calculated to identify the best location for DG to minimize the system voltage fluctuation due to the change of load demand. It is seen that proper placement of DG reduces the total system power loss, thereby increasing the overall system efficiency. Finally, a minimum value of capacitor size is also determined to improve the stability of the system as well as to reduce the cost of compensation with distributed wind generator.

A. Scope for the Future Work

In this project 40% wind and solar penetration are consider to enhance the system stability. There is scope for the same work considering following. This work can be extended by considering time varying load or different levels of wind and solar penetration like 30%, 50% , 80%.

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