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Statistical Impact Analysis of Integration of different types of WTG on Radial Distribution System

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***Abstract*—A nation's ability to obtain electrical energy determines its socio economic progress. While keeping in mind different operational and technological restrictions, planning for distribution system expansion considers the services that must be installed for the distribution networks to manage the expected load demand. When distributed generation sources (DGs) are integrated, distribution network efficiency is increased, power losses are decreased, and voltage magnitude is also enhanced. In this paper, Wind Turbine Generator (WTG) as renewable energy source of four different types are integrated under two unique control scheme in conventional radial distribution topology. A statistical analysis of WTG integration is carried out for conventional 34 bus radial distribution system using ETAP simulation package on single and multiple locations. Voltage magnitude were analyzed under critical, marginal and nominal level before and after integrating DGs in test system. In addition to this loss reduction is also noted and analyzed while incorporating different types of WTGs.**

***Index Terms*—WTG,ETAP,Distributed Generation(DGs)**

I. Introduction

The typical operation of an electric power distribution system involves low voltage levels and high current levels. Because the majority of distribution systems supply inductive loads, there are increased power losses in the distribution network and a weak power factor that is accompanied by voltage sags. According to reports, line losses in the low voltage distribution network account for around 13% of the overall generation [1]. Finding alternative solutions is therefore important in order to solve these issues and guarantee the stability, dependability, and quality of the supply of electricity. With the distribution generation (DG), several power companies are investing in renewable energy sources including wind, solar cells, and hydro-turbines with the main goal of reducing overall system power losses. Distributed generation is defined as a generating station that serves a client directly or supports a distribution network (DG). The usage of distributed generation (DG) can be either standalone or integrated. The most promising DG technology for renewable energy is the wind turbine. Electric losses, voltage profile, stability, and the operation of the power system are some of the system operational characteristics that are impacted by the integration of wind-based DG. By placing DGs in distributed systems in the best possible locations, system losses may be reduced overall and the voltage profile can be improved. In literature, various methodologies have been developed for optimum location and size of DG. The best DG size and position have been researched using a variety of computer approaches. These techniques are divided into single-objective and multi-objective (MO) optimization techniques. Network planners can choose the best optimal solutions rather than a single clear answer because to the benefits that MO optimization has over single objective optimization. Currently, a variety of distribution system applications employ evolutionary approaches (DSs). An approach to find the optimal location and sizing of DG to optimize power losses of the system using Harmony search algorithm (HSA) [2],Cuckoo search algorithm (CSA) [3],invasive weed optimization [4],Stud Krill herd technique [5],backtracking search optimization (BSO) technique [6],Ant Lion Optimization (ALO) algorithm [7],improved differential search algorithm [8] ,whale optimization algorithm (WOA) [9], [10] ,particle swarm optimization (PSO) [11] ,BAT Algorithm [12] are presented in respective literature. Other methods of positioning and sizing of DGs are given in [13]–[15]. In this work, position and location of WTG obtained by BAT algorithm in [12]is used to simulate the IEEE-34 bus system on ETAP software package and comparative analysis is performed to prove the supremacy of results. The rest of the paper is structured as follows: WTGs and their various types are explained in detail section-2. Simulation results are presented in section-3 and section-4 concluded the paper.

II. Wind Turbine Generators (WTGs)

The primary goals of the proposed study is to enhance voltage profile and minimize power losses (includes deviation and stability). The distribution network's optimization for proper planning (DG location and bank size, for example) is important. The ETAP Wind Turbine Generator is used to simulate and model the steady-state and dynamic power generation and operation of wind turbines. To understand the influence of wind penetration in the grid under wind variability, system

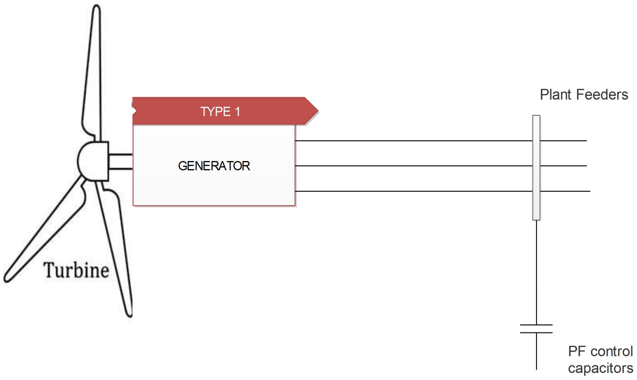

Fig. 1: TYPE-1 WTG

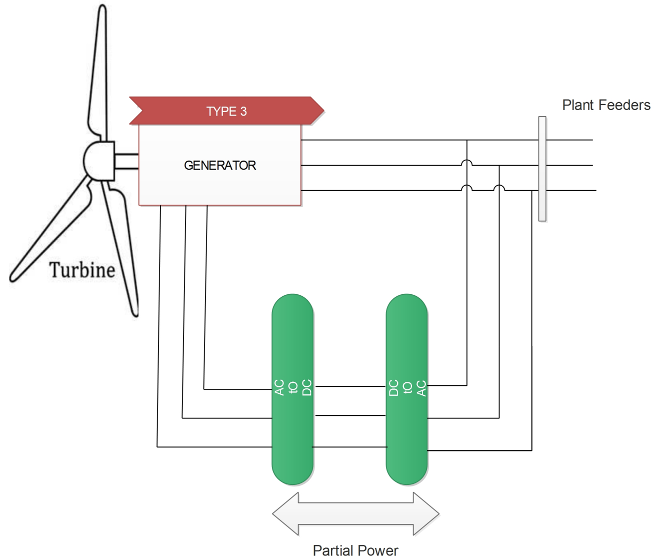

Fig. 3: TYPE-3 WTG

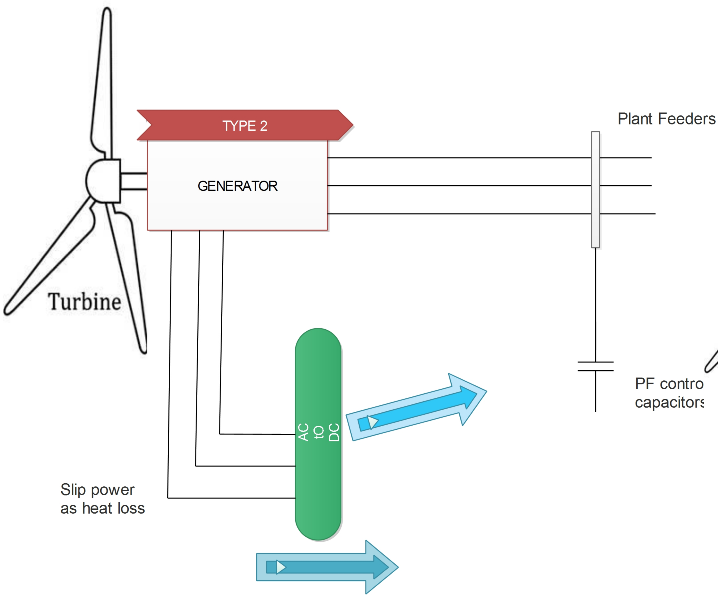

Fig. 2: TYPE-2 WTG

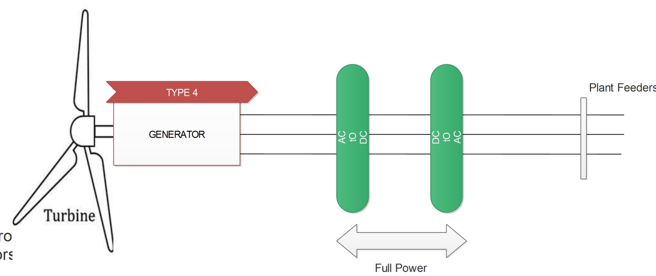

Fig. 4: TYPE-4 WTG

designers can mathematically describe each wind turbine generator as a separate unit. By varying wind speed (gust, ramp), tripping the wind farm, simulating system failures at wind turbines, or grid-connected buses, system dynamic behavior may be examined. The findings of the study establish the degree of system vulnerability with increased penetration and erratic wind power production. Relay operations and variants for wind turbine and grid transient recovery may be introduced as user-defined activities. Moreover, it forecasts how each particular wind turbine generator will behave dynamically. Generic dynamic models for grid interconnection based on WECC are as follows:-

1) **TYPE-1:**The device operates a squirrel cage induction generator that is directly connected to the grid and is pitch-regulated. The generator model, drive train model, and pitch controller model make up the generic model as shown in fig.1
2) **TYPE-2:** Variable slip acts on the machine. It makes use of an induction generator with a wound rotor whose winding is removed using slip rings and brushes, as seen in fig.2. An external rotor resistance is electronically adjusted to effect dynamic variations in the machine's torque-speed characteristics. The drive train model, pitch controller, external resistance controller, and generator model are all components of the generic model.
3) **TYPE-3:** The device is a partial conversion, or doubly fed induction generator (DFIG). The turbine has a wound rotor induction generator and an AC/DC/AC power converter linked between the rotor terminals and grid, as illustrated in fig.3.The turbine is pitch-regulated. The grid is directly linked to the generator stator winding. With quick active and reactive power management across a wide range of generator speeds, the power converter in the rotor circuit enables independent control of generator torque and flux.
4) **TYPE-4:** The turbine, as indicated in fig.4 , is pitch-regulated and has an AC/DC/AC power converter that processes the full generator's power. Either an induction

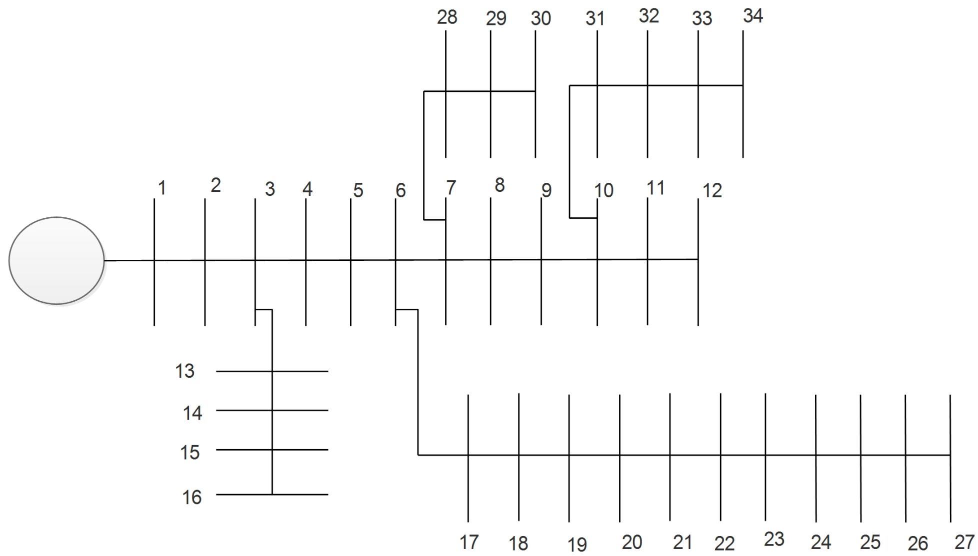

Fig. 5: 34 bus system

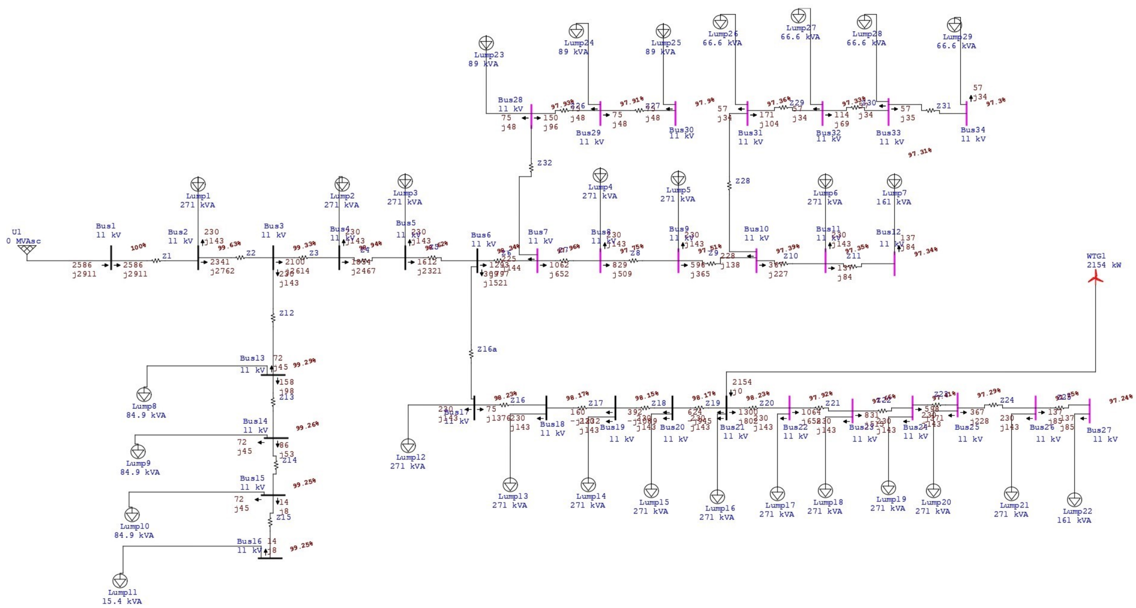

Fig. 6: Simulation of 34 bus system with WTG integration (case 1)

or synchronous kind of generator is possible. The power converter offers quick active and reactive power regulation across a wide range of generator speeds by enabling independent control of quadrature and direct axis output currents at the grid interface.

The two main industry groups currently working to create general models for use in power system simulations for wind turbine generators are the Western Electricity Coordinating Council (WECC) Renewable Energy Modeling Task Force (REMTF) and the International Electro technical Commission (IEC) Technical Committee (TC), Working Group (WG).

Wind turbine models were developed by the WECC Modeling & Validation Working Group & IEC Technical Committee Working Group and are present in ETAP. These simulations were developed to test the potential effects of large wind turbine arrays with a single network connection point on stability. These models have been applied in dynamic simulations, and the outcomes have been contrasted with those of higher-order models applied in manufacturer-specific representations of aero conversion and drive train dynamics.

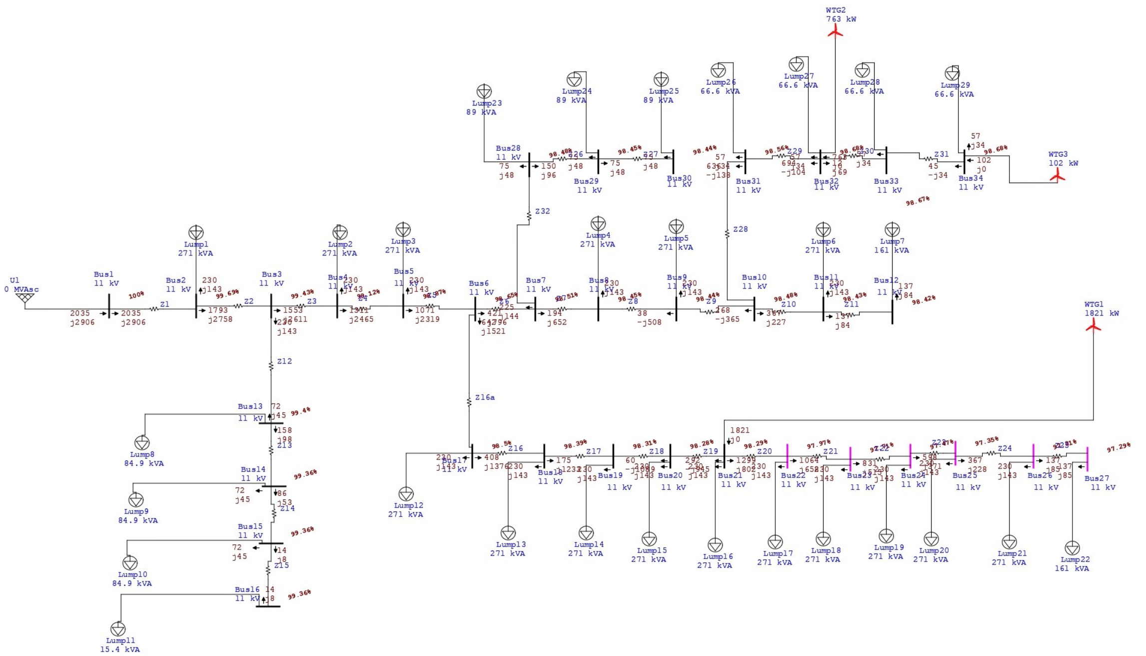

Fig. 7: Simulation of 34 bus system with WTG integration (case 2)

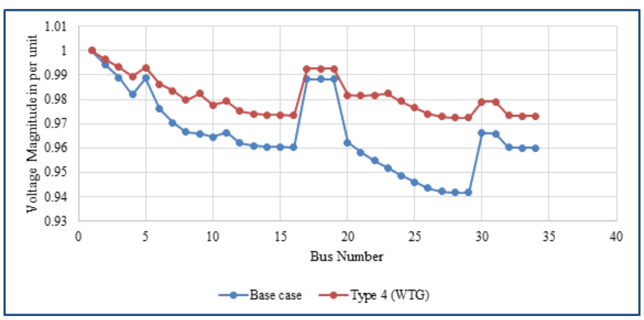

Fig. 8: Voltage Magnitude for Case 1

III. Simulation Results and Discussion

The IEEE 34 test system is adopted in this paper to analyze the effect of integration of Wind turbine Generator of different types as mentioned earlier in section 2 under distinct control schemes in radial distribution scheme. The single line diagram of conventional 34-bus system is shown in fig.5

The system is simulated in Electronic transient analyzer program (ETAP). The parameters (informative, rating, turbine, pitch control) of WTG considered are exhibited in table I. Without placing any compensatory devices, the losses in the system are obtained as 221.67 kW (active power losses), 65.1 kVAr (reactive power losses) and the minimum voltage is found to be 0.9417 per unit at bus no.28. The efficacy is evaluated by considering two cases for different types of WTG. The case description is as follows:-

TABLE I: Parameter Description

Informative Parameters	
Description	Types/value
Type of WTG	Type 1, Type 2, Type 3, Type 4
Control	WECC, UDM
Generator	Induction Generator
Rating Parameters	
Power factor	0.85 lagging
Efficiency	95%
Poles	4
RPM	1800
FLA	133.1
Wind Speed	5 m/s
Turbine Parameters	
V Rated	15
Swept Area	2828
Air Density	1.225
Cut in Speed	4
Cut out speed	25
Pitch Control parameters	
Kdroop	300
Kp	0.5
Ki	3
Pimax	.01
Pimin	30

TABLE II: Performance of WTG integration (Case 1)

Parameters	Base values	Type 1		Type 2		Type 3		Type 4	
		WECC	UDM	WECC	UDM	WECC	UDM	WECC	UDM
Active power loss in kW	222.1	197.5	197.5	197.49	197.49	103.09	103.09	103.09	103.09
Reactive power loss in kVAr	62.5	56.5	56.5	56.50	56.50	29.04	29.04	29.04	29.04
Size in kW and location of DG	NA	2154.75(21)							
Minimal voltage magnitude in per unit with bus no.	0.942 (28)	0.966 (28)	0.966 (28)	0.9704 (28)	0.966 (28)	0.972 (28)	0.972 (28)	0.972 (28)	0.972 (28))
Active power losses Reduction	NA	11.07%	11.07%	11.07%	11.07%	53.58%	53.58%	53.58%	53.58%
Reactive power losses Reduction	NA	9.60%	9.60%	9.60%	9.60%	53.53%	53.53%	53.53%	53.53%

TABLE III: Performance of WTG integration (Case 2)

Parameters	Base values	Type 1		Type 2		Type 3		Type 4	
		WECC	UDM	WECC	UDM	WECC	UDM	WECC	UDM
Active power loss in kW	222.1	195.543	195.543	195.543	195.543	84.401	84.401	84.401	84.401
Reactive power loss in kVAr	62.5	56.0862	56.0862	56.0862	56.0862	24.049	24.049	24.049	24.049
Size in kW and location of DG	NA	1820.53 (21)							
		763.11(32)							
		102.07(34)							
Minimal voltage magnitude in per unit with bus no.	.9415 (28)	0.9669 (28)	0.9669 (28)	0.9669 (28)	0.9669 (28)	0.972917 (28)	0.9729 (28)	0.9729 (28)	0.9729 (28)
Active power losses Reduction	NA	11.90%	11.90%	11.90%	11.90%	61.99%	61.99%	61.99%	61.99%
Reactive power losses Reduction	NA	10.27%	10.27%	10.27%	10.27%	61.53%	61.53%	61.53%	61.53%

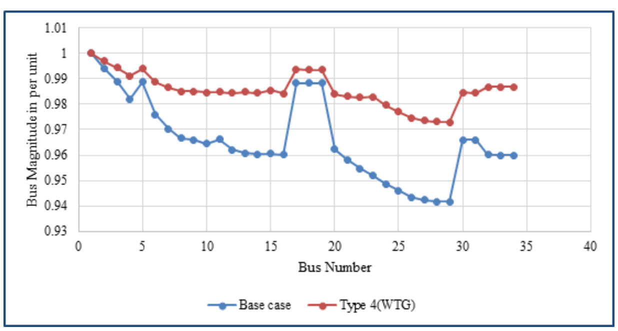

Fig. 9: Voltage Magnitude for Case 2

1) **Case 1: Allocation of WTG at one load bus**
Under case 1, wind turbine generator is placed at one load bus. The candidate bus no 21 is identified with optimal size of 2154.75 kW. Table II indicates performance of insertion of WTG on bus no 21 for 34 bus system. It can be clearly seen from the table that losses have been reduced after placing WTG on the candidate bus. Type 3 and type 4 WTG are giving significant reduction in system losses with improvement in voltage magnitude. The system after WTG integration in ETAP is shown in fig 6. The system minimal voltage is improved to 0.97 per unit from 0.942 per unit. A reduction of 53.58%is noted in losses when type 3 WTG is integrated into the system. The voltage magnitude of base case and type 4 WTG integration is shown in fig 8.

2) **Case 2: Allocation of WTG at Multiple load buses**
Under case 2, WTGs are placed at multiple load buses. The system after multiple WTG integration in ETAP is shown in fig 7. The desired locations of the WTG are bus no 21, 32 and 34 with size of 1820.53 kW, 763.11 kW and 102.07 kW respectively. The performance of integration of WTG at aforesaid locations is presented in table III. It can be seen from the table, a noticeable reduction of 61.99% is obtained in integrating WTG

(type 3 or 4) at desired locations. Additionally, the voltage has increased from 0.941 to 0.972 per unit. It can be seen from the table that the type 1 & 2 WTG and type 3 &4 gives similar results on integration to distribution network. The voltage comparison is shown in fig 9.

IV. Conclusion and Future Scope

The most effective planning of renewable distributed generation (DGs), such as solar photovoltaic, wind energy, and biomass coupled with capacitor banks in distribution networks, is the best option to not only improve the existing network parameter but also allow renewable energy access to the network. This study optimized the size and location of DG to lower system losses and enhance the voltage profile of radial distribution networks (RDSs).

This leads to the conclusion that wind-based DG improves voltage profile and decreases losses when compared to DG without wind. This reduces power loss in both the wind-based DG scenario and the alternative. The mesh distribution systems study may be extended in the future to include both solar- and wind-based DGs.

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