Statistical Analysis of Integration of renewable DGs in IEEE-9 Bus System using ETAP Simulation

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Abstract—**Due to the hybrid power system's benefit of integrating renewable energy with the conventional power grid, it is becoming more and more common nowadays. This work provides a thorough statistical analysis of voltage magnitude-based system stability in addition to a description of the composite power system. Using the IEEE- 9 bus system, a thorough study of this work has been conducted. The isolated hybrid system that has been presented is comprised a wind turbine and solar PV array to conduct system analysis. The hybrid electric generating station was modeled using the ETAP software tool. In a nutshell, the system behavior on voltage magnitude has been investigated under various cases while incorporating hybrid generation sources by keeping the one conventional generating unit out from the system topology.**

Keywords—WTG, PVDG, ETAP

I. Introduction

From the very scratch of power system, till date due to power industries different reasons of research on different methodologies gives us the legit "why" everyone is moving or relying more into the renewable power sources such as solar energy, wind energy and geothermal as well. All nations are making efforts to minimize greenhouse gas emissions and the usage of fossil fuels as a result of environmental damage and the implementation of energy conservation regulations. On the other hand, because fossil fuels are so widely dispersed over the planet, using renewable sources is somewhat simpler than using other types of energy. From this is, where the researchers are trying to mix up the renewable sources with non-renewable sources to make the best out of the system. There comes the name "Hybrid power system" [1] which contributes in providing continuous and uninterrupted power supply to full fill the desired power requirements. Hybrid power systems can employ a variety of power generation technologies, such as wind turbines, small hydro systems, solar PV Arrays, diesel engines, etc. The hybrid power system can deliver power irrespective to the size of the area and can deliver power from small areas to large areas out there. The modern power system of country like India, always have desired for an uninterrupted supply of power that would maintain the reliability and would make the power system secure as well [2].

One of the main issues as given in [3]–[5] have when employing a hybrid power system is that since solar and wind energy systems vary in a rapid manner, a continuous supply of reliable energy cannot be guaranteed [6]. As a result, hybrid grid occasionally needs to rely on fossil fuels when there are no renewable energy sources available. When fissile based generation is not there, this system combines sources and conserves energy to assure a constant supply of power whenever generation is necessary. In order to construct a hybrid power system that combines wind and solar energy, this research paper will create a variety of load scenarios and analyze the stability of the system while accounting for generating system availability and downtime. Even when fissile-based generation is not feasible, this system combines sources and conserves energy to provide a constant supply of power whenever generation is necessary. This paper's main goal is to investigate the statistical voltage magnitude of the IEEE-9 bus system after it has been powered by many hybrid producing sources. Several authors use the ETAP software to report on different stability analyses, including steady state and transient stability. [7]–[11].

The sections of the paper are organized as follows; the first section gives the introduction of the paper itself, the second section will depict the information about hybrid Power system, the third one shares the information about methodology adopted. The fourth section provides examples of the hybrid power system's intricate design, analysis, and case studies.

II. Hybrid Power System

A wind/solar controller, battery, PV array, inverter, and other ac loads are among the numerous parts that make up a hybrid. power system, which combines two different energy sources, such as wind and solar. By combining two or more generation sources and adding a type of energy storage, it is possible to improve overall supply patterns and increase efficiency. It is possible to obfuscate the issue of intermittent supply in the power system by depending on this approach of renewable energy and other energy. The installation of a sizable energy storage system is quite expensive in order to manage the most adverse conditions and provide enough power to meet demand at this weather. Peak demand periods are less expensive for supply. Applications for hybrid power systems include [12]– [16].Examples that are most frequently used include isolated or special purpose electrical loads, distributed generating applications in a traditional utility network, and remote AC networks. The distant AC network that is powered by diesel is the standard illustration of a hybrid energy system. The major goal is to reduce the amount of fuel and operating hours used by diesel generators. Incorporating a different form of generator, often one that use a renewable energy source, is the initial step towards hybridising a system. The following is a description of blended power system s' primary components:

- *PV Array (PV Module):* A collection of photovoltaic (PV) panels that may produce direct current (DC) from incoming light and are linked in parallel, series, or both ways. These panels' tilt, location, and shadows from surrounding objects are all crucial design considerations.
- *A wind turbine :* A wind turbine is a device that uses the kinetic energy of the wind to generate electricity that can be used in a house. It is positioned on top of a tall tower.
- *Hybrid controller:* This is designed to integrate the three types of electricity (backup power, three-phase power, and solar array power).
- *Energy storage:*In hybrid energy systems, energy storage is frequently helpful. There are generally two uses for energy storage. It might be used, first and foremost, to balance out a disparity among the demand for electricity and the green energy supply. Second, it may be utilized to make the overall system's operation and control simpler. Convertible and end use energy storage are the two main types. Space that can be swiftly turned back into electrical power is referred to as convertible storage. Even though it might not be easily converted back to power, end-use storage can be used for a specific end-use function.
- *Inverter:* Solar panel DC electricity is converted into AC power via a power converter.

Hybrid systems provide the following benefits:

- They may circumvent restrictions in terms of mileage, dependability, flexibility, efficiency, and/or contamination.
- The opportunities for integrating more than one energy sources that are renewable based on the inherent environmental preservation potential of the local customers, notably in terms of minimising CO2 emissions.
- Low-cost, sources of energy like wind and solar can compete with nuclear, coal, and gas, especially in light of potential price trends for fossil and nuclear fuels in the future.
- Expenses are predictable and unaffected by changes in gasoline prices, albeit if batteries are used, changes in battery prices will have an impact.
- Energy storage and/or redundant technologies can help you achieve improved dependability. Both are often used in hybrid systems, which can simultaneously increase power quality and availability.

The next section elaborate the methodology adopted in this paper.

III. Methodology Adopted

The stability research needs to know the pre-fault voltage magnitude. One important piece of information in a power flow analysis is the bus voltage, bus voltage phase angle, transmission line actual and reactive power, generation bus actual and reactive power, and other factors.

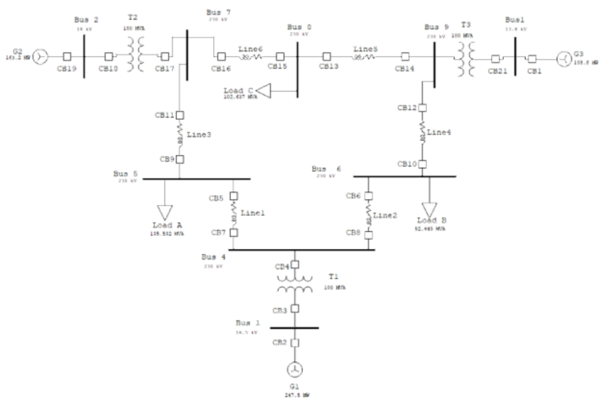

Fig. 1. Conventional 9 Bus System

With the use of load flow analysis and the Newton-Raphson approach, pre-fault circumstances may be discovered. The Newton-Raphson approach is a helpful technique that is unaffected by the convergence of large capacity load flow solutions for networking reserve bus selection. Starting with all unknown factors like voltage, the load bus's voltage angle, and the generator bus, this approach makes educated guesses.

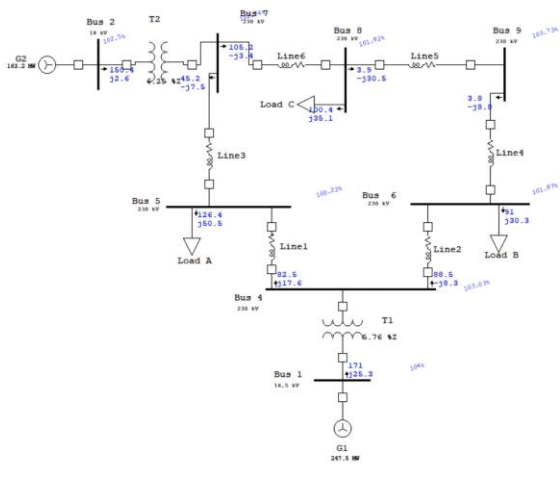

Fig. 2. Load flow analysis during G3 out

Using this Taylor series, it became possible to omit the higher-order terms in each power balance calculation. The creation and simulation of an integrated wind-solar system utilizing the ETAP programme are both addressed in this study. On a straightforward network, the Wind-Solar Composite electrical system was assessed. The first parts of the IEEE 9-Bus test system are three producers with an altogether power output of 519.50 MW, nine buses, and an integrated demand of 330.62 MW. A little amount of modifications is being applied to the IEEE 9-Bus system in an effort to imitate the Solar-Wind integrated system.

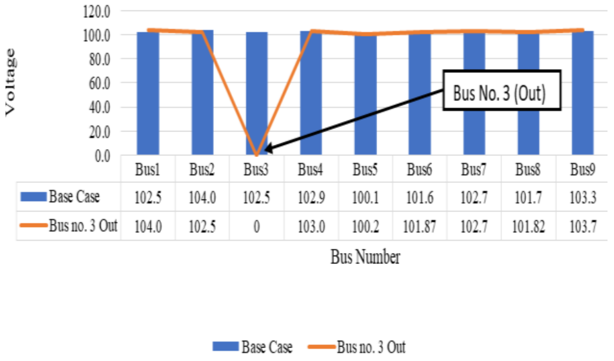

Fig. 3. Voltage profile of Case 1

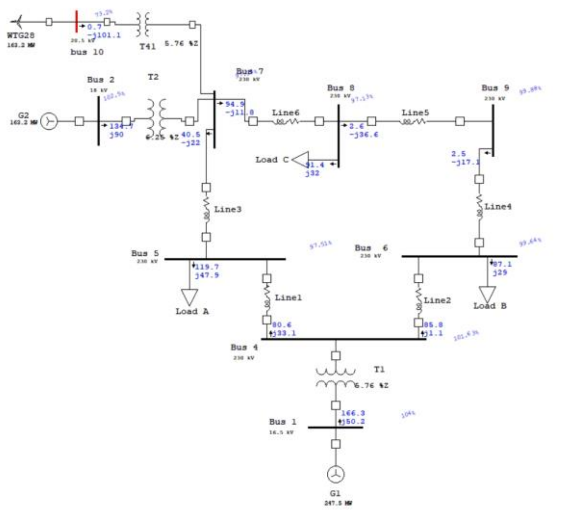

Fig. 4. Load flow analysis after WTG integration (Case 2)

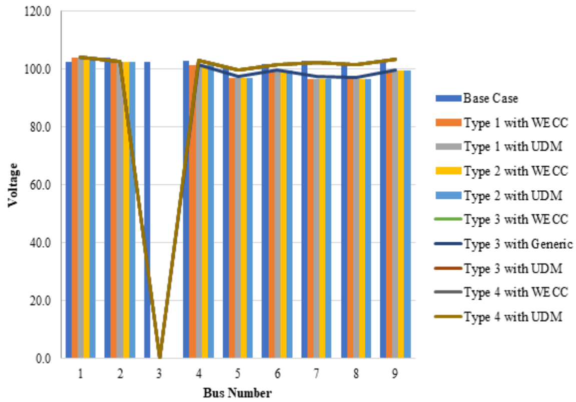

Fig. 5. Voltage profile of Case 2

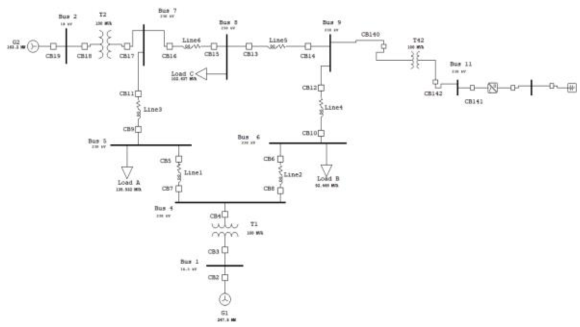

Fig. 6. Load flow analysis after solar PV array integration (Case 3)

The upgraded network is made up of a number of wind turbines, which are denoted by a single 163.20 MW wind turbine linked to bus 7 through 11, and solar panels, which are exclusively represented by a battery (143 V,2552 AH) connected to bus 7.

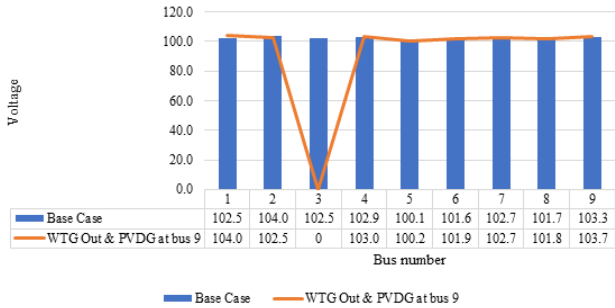

Fig. 7. Voltage profile of Case 3

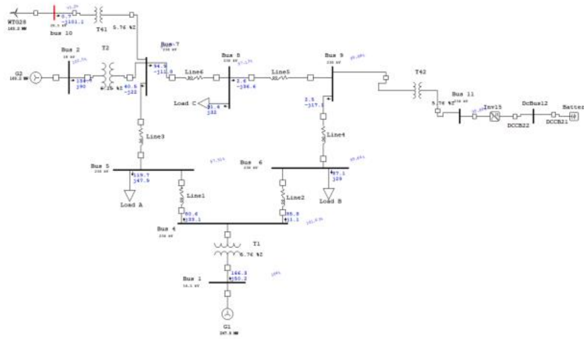

Fig. 8. Load flow analysis after solar PV array and WTG integration

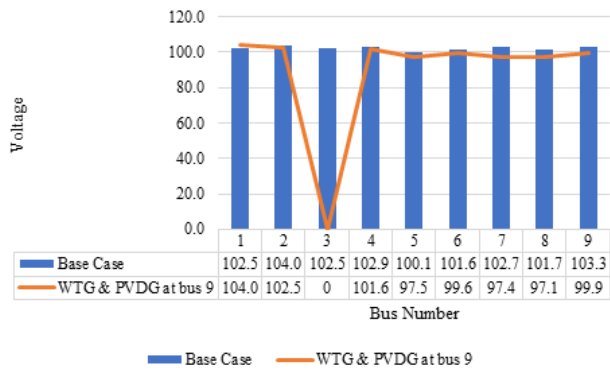

Fig. 9. Voltage profile of Case 4

G1 functions as the backup generator and voltage-controlled generator, duetothefactthatG2 is a swing generator, it acts as the battery bank. This simulation makes several assumptions, such as that the wind and solar power systems will run at full capacity. To represent the battery bank, it is assumed that Generator G2 is run as a swing generator. Simulations will be run under various generator operating conditions to analyze the intricate system.

IV. Simulation Results And Discussion

In this paper DG integration has been carried out with wind turbine generator (WTG) & Photo voltaic based solar array on the IEEE- 9 bus system by making it a hybrid Power system. On the ETAP program, the entire network (IEEE 9 Bus system) is emulated. But this hybrid network is regarded as an isolated one. WTG is a conventional squirrel cage induction generator with four different types and different controls in integrated in the test system topology.

TABLE I Statsitical Analysis Of Voltage Magnitude Of Various Cases

Parameters		Bus Number								
Cases	***Condition***	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Base Case	***NA***	102.5	104.0	102.5	102.9	100.1	101.6	102.7	101.7	103.3
Case 1	***G3 Out***	104.0	102.5	0	103.0	100.2	101.87	102.7	101.82	103.7
Case 2	***WTG (Type 1 WECC)***	104.0	102.5	0	101.4	97	99.36	96.7	96.5	99.45
	WTG (Type 1 UDM)	104.0	102.5	0	101.40	97.0	99.36	96.7	96.5	99.45
	WTG (Type 2 WECC)	104.0	102.5	0	101.4	97.0	99.4	96.7	96.5	99.5
	WTG (Type 2 UDM)	104.0	102.5	0	101.4	97.0	99.4	96.7	96.5	99.5
	WTG (Type 3 WECC)	104.0	102.5	0	102.9	99.9	101.7	102.4	101.5	103.6
	WTG (Type 3 Generic)	104.0	102.5	0	101.6	97.5	99.6	97.4	97.1	99.8
	WTG (Type 3 UDM)	104.0	102.5	0	102.9	99.9	101.7	102.4	101.5	103.6
	WTG (Type 3 WECC)	104.0	102.5	0	102.9	99.9	101.7	102.4	101.5	103.6
	WTG (Type 3 UDM)	104.0	102.5	0	102.9	99.9	101.7	102.4	101.5	103.6
Case 3	***PV at Bus no. 9***	104.0	102.5	0	103.0	100.2	101.9	102.7	101.8	103.7
Case 4	***WTG at bus 7 + PV at bus 9***	104.0	102.5	0	101.6	97.5	99.6	97.4	97.1	99.9

PV system that is photovoltaic system with combined battery, inverter and other electrical hardware's that are used to generate electricity is integrated in the system. System behavior in terms of voltage magnitude has been accessed for four distinct cases. The Conventional IEEE 9 Bus system simulated in ETAP is depicted with the help of the fig. 1. 1.

- Case 1: Generator 3 out In Case 1,The system behavior after removing G3 from the system is studied and the impact on system by running the load flow of the system is depicted in fig. 2. Voltages of different buses are categorized under three different levels. Nominal Level: 95% -101% Marginal Level: 102% - 105% Critical level: Below 95%.As Table I shows the results of load flow of case 1 when G3 is detached from the system and comparison is done in terms of the voltage magnitude with the conventional base case. Results shows that there is a very slight difference in voltage as compared to base case that bus no. 5,6,8 lead to fall in Nominal category which are represented in the yellow color and rest of the buses 1,2,4,7,9 fall in Marginal category which are shown by red color. The graphical comparison with base case results are shown in fig.3.
- Case 2: Placement of Wind turbine Generator only with generator 3 out Under case 2, only WTG of different types are placed one by one at bus no 7. Four types and each type are analyzed for WECC and UDM control scheme. The ETAP simulation depicting case 2 is shown in fig.4.In addition to this, Generic control is also analyzed. The results are shown in Table I and the graphical comparison with base case results is shown in fig.5. It can be concluded from the table that type 3 WTG under generic control scheme gives nominal voltage profile as compared from the initial case for almost all the buses.
- Case 3: Placement of PV solar array only with generator 3 out Under case 3, only solar PV array is placed at bus no. 9 while keeping generator 3 out. The ETAP simulation depicting case 2 is shown in fig.6. The results of case 3 are shown in Table I. The performance of solar array integration is proved to be more promising in maintain nominal voltage profile. The comparative analysis of voltage with initial case and integration of PV solar array is depicted in fig.7.
- Case 4: : Placement of PV solar array and WTG simultaneously with generator 3 out under case 3, PV solar array and WTG is placed simultaneously with generator 3 out. The ETAP simulation depicting case 4 is shown in fig.8. The voltage outline in case 4 are seems to be more nominal as comparison to other cases. The figure depicting the comparative analysis is shown in fig.9.

V. Conclusion And Future Scope

This paper has provided a general overview of a hybrid power system, which comprises of solar PV, wind turbines, energy storage systems, and energy conversion systems, or converters. The entire network, which is built on a modified version of the IEEE-9 bus system. Several combinations of operation and fault location have been employed when using simulation and analysis. There is extensive discussion of the effects of generation addition and rejection. The study's overall conclusion is that the system's stability is unaffected by the renewable generation (solar and wind) units. Overall, the study found that the stability of the system is unaffected by the renewable generation (solar and wind) units. As was previously said, remote adoption of integrated power systems is possible.

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