Future Scope of Distribution Energy system using Wind Turbine

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Abstract:

Electrical energy is an essential element in aninclusiveassociation and the energy demand developing day by day. Electric power has been produced centrally in the previous few decades and then distributed across the country regions. But in centrally generated grids, there are numerous problemscause of overloading issues like load loss, transient response, voltage and frequency instability, concerns that makes the load flow analysis more substantial. This promptrise in load demand indicates the system becomes overwhelmed, resulting in other problems such as unreliable and uncertain of power systems. The DERs are implemented into the power system, and transient stability plays a keypart in the Power system effective, safe, and stable operation. In this paper, the transient stability analysed using a Power World Simulator on the standard IEEE 5 bus system using wind turbines and a comparative study of the standard IEEE 5 bus system using the conventional method for stability analysis based on the performance of wind turbines. The Newton-Raphson method used for steady-state analysis of load-flow study, and during-fault conditions, a three-phase balanced fault is considered. The wind turbine indicates from the DERs that it is presented using the Excitation, Governor, and Power System Stabilizer with the AVR to enhancement the transient stability response for a multi-machine operation.

Keywords – Transient Stability, three-phase balanced fault, Power World Simulator, PSS, AVR, Governor, Distribution Energy Resource, Wind turbine.

1. INTRODUCTION

Distributed Energy Resource has grown steadily in recent years. In the future development of the infrastructure, the DER provided and incorporated into the established distribution system. A large-scale DER penetration also creates some adversative things from the power grids, as an example this can cause voltage stability, line shift, net loss, protective relay, consistency, and other issues that can affect the stable operation of the grid operator ,Singh, A. K., &Parida, S. K. (2012).

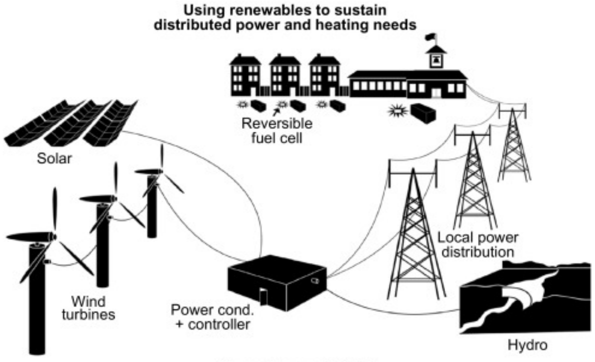


Figure 1: Distributed Energy Resource

DER contains renewables and non-renewables, power storing, inverters (ac-dc), electric vehicles, and other loads managed.The Distributed Energy Resource is playing a vital role in residential, commercial, and industrial sectors of the power grid. The DER is a dynamic system composed of solar, wind, photovoltaic panels, hydropower, etc. Also, DER comprises new developments includingdata services and smart meters. Earlier work based on specific system of excitation and governor control system. The current work is an integrator methodology that controls the voltage and frequency performance of generators based on the wind turbine, and the paper focuses on improving transient stability using wind turbines, Sun, Z., & Zhang, X. Y. (2012) and Martinez, J. A(2011).

Distribution Energy Resource (DER) systems as follows:

- **Biomass:**
  – It is an organic plant and animal elements which include trees, seeds, and wood waste.

– As biomass is heated, chemical energy is transported as fuel which can produceenergy with a steam turbine.

- **Solar:**
  – Photovoltaic (PV) cells are constructed of silicone substantial that directly transforms the sunlight into electricity.
  – It doesn't produce any greenhouse or atmospheric gases.
- **Wind:**
  – The wind power technology is important to renewable energy sources and it can work with variable velocity or constant velocity operations using different converters. Owing to the improvement of the wind energy output and the reduction of flicker issues, variable speed is also superior to constant speed,Islam, M., Javed,(2015).

1.1 Power System stability:

Power system stability is an electrical system able to preserve a state of equilibrium operational after being disturbance for specified initial conditions that are important to keep the system stable with certain system variables. PSS is the drastic increase in people which origins a serious problem by growing the need for electricity or the load demand. This sudden increase in demand for loads is making the grid more overloaded or overwhelmed anddevice overloading make problems such as voltage fluctuation, transient reaction, and enables a more detailed study of the power flow. The Newton-Raphson is amongst the well-known analytical approaches. This strategy is comparatively better when it comes to accuracy and consistency, Kamna, S,(2019).In spite of the different types of disturbances that have been implemented, the power system stability can morecharacterize into appropriatetypes; rotor angle, frequency, and voltage stability. The Power system stabilityisconsidered, as seen in figure 1.1,Shetye, K. S,(2012).

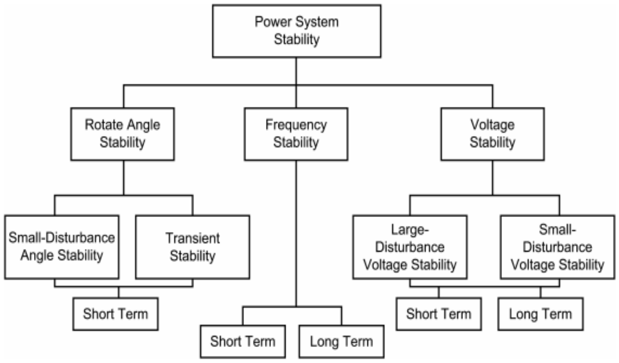


Figure 1.1: Categorizations of power system stability

- **Rotor angle stability** is defined as the capability to preserve power and torque synchronization. In general, the active power that the generator generates equal to the real power used by the loads; losses are also required.

Rotor angle stability is categorized into two sub-categories:

A. Small signal stability
B. Large signal stability

***A.* Small signal stability:**

It is defined as the power, after a minor slow disturbance, to sustain the synchronism between an outside tie-line and machines. The action of automatic voltage regulators, Natural load variations and governors may be the minor sluggish disruptions. The steady-state stability analysis is achieved by a linear version of the nonlinear method,Srikanth, P,(2013).

***B.* Large signal stability:**

Transient stability is the ability to sustain synchronism even after significant transient or severe disturbance. The transient stability of system linearization schemes does not require non-linear equations. This method relies on the perturbance magnitude and the initial operating state.

- **Frequency stability** may preserve frequency within an acceptable range. It involves the potential to reach equilibrium among manufacturing the system and loading it with the least unnecessary damage. Instability can cause constant fluctuations in frequencies.
- **Voltage stability**is the ability to sustain a relatively stable a balance voltage and reactive power. The primary factor improve to voltage stability is typically the drop in voltage resulting from actual and reactive power by analytic reaction connected to the transmission system; reactive losses increase as line currents rise under variable power flow conditions,Damor, M(2014).

In case that angle stability, it is effective to describe voltage stability by the size of the disturbance listed in the two subcategories below:

A. **Small-disturbance voltage stability** comprises the able to preserve steady voltages after minor disturbances, such as slight changes in load. Small disturbance analyses using linear methods provide valuable voltage-stability information from a system-wide perspective and classify areas with potential problems.

B. **Large-disturbance voltage stability** involves the ability to restore the steady voltages after severe conditions. Stability assessment generally includes an overview of the dynamic performance of the electric system over a reasonable period to identify device relationships such as generator tap changers under load transformer, induction motors, and field-current controllers. The systematic analysis time can modify from a few seconds to several minutes, Ingole, D. A.(2017).

The present paper focuses on the stability of the bus voltage, frequency and rotor angle which is a main consideration of the modern power system using Wind turbine and the result of the performance of the standard IEEE 5 bus system using a DER i.e. wind turbine is validated against the conventional method (Excitation, Governor Control method in conjunction with PSS with (AVR) simulated in Power World simulator.

2. PROBLEM FORMULATION

The stability has continued to receive much attention through the years for suitability in assessing, gaining a greater understanding of the nature of the stability problems, and raising the solution to problems. Today the number of faults, distortion, frequency, and voltage drops will occur in the power system. The synchronization of voltage, frequencies, and inter-area oscillations has been more concerning than in the past. A clear understanding of the various form of instability for the proper design, operation of the system, and how to interconnect is important.

Therefore the load flow study using the Newton-Raphson method should be carried out to determine the reliability of the transient power system. During-fault conditions, the consequence of a balanced three-phase fault was considered, and the influence of uncertainty on the bus voltage and frequency is evaluated to improve the transient stability using DERs.

3. ALGORITHM FOR THE IMPROVEMENT OF THE TRANSIENT STABILITY

Step 1: Choose the standard IEEE 5 model.

Step 2: Load flow analysis is done on the standard IEEE 5 system using the Newton-Raphson method gives the accurate result as compared to other methods of load flow.

$$S_i = P_i + jQ_i = V_i\left(\sum_{j=1}^{n} Y_{ij}V_j\right)^* = \sum_{j=1}^{n}|V_i||V_j|e^{j\theta_{ik}}\left(G_{ij} - jB_{ij}\right)$$

$$S_i = \sum_{j=1}^{n}|V_i||V_j|\left(\cos\theta_{ij} + j\sin\theta_{ij}\right)\left(G_{ij} - jB_{ij}\right) \qquad \text{..... (1)}$$

Step 3: A balanced three-phase fault is executed on a bus 1 with clearing time 0.5 seconds during-fault condition.

Step 4: Analyse the IEEE 5 system during-fault condition after choosing a fault in such cases governor control, exciter and DERs i.e. Wind turbine.

Step 5: Run the transient stability analysis in the Power World Simulator. Then the results are occupied from Power World Simulator with the waveforms of bus voltage, and frequency in all the cases of pre-fault, during-fault and post-fault conditions.
Step 6: Compare the results obtained from the Conventional method with respect to the wind turbines.

4. TRANSIENT STABILITY ANALYSIS

Transient stability is the ability to preserve a state of equilibrium after a severe disturbance. Power system abnormal condition similar to the fault analysis is required for some other studies of the power system, such as voltage analyses, and transient stability, etc. The standard IEEE 5 bus system is considered using the DER system. In the present paper, a three-phase balanced fault is considered on bus 1 of the system, and a load flow study has been done by using the Newton-Raphson method,Fouad, A. A., &Vittal, V. (1991).
The distribution system includes specific voltage control devices and hardly includes the generator attached to a distribution system in regulating the voltage. Most widely used in the distribution system are voltage control devices. One example is the use of WTs in generating electricity increased. The purpose of AVR exists accomplished to boost stability via the system model, governor control, excitation, and stabilizer. Besides, a comparative study of the performance of the IEEE 5 bus system using the standard wind turbine efficiency approach for stability analysis.

4.1 Model of synchronous machine:

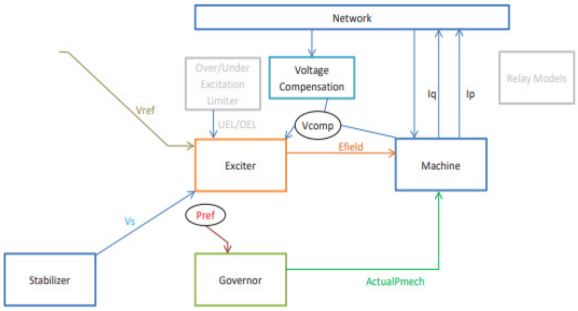


Figure 4: Machine model

The Machine Model is used in power plant modelling a generator, as normal with a solid rotor generator defined by equivalent modelling of the mutual inductance rotor. The base model for this analysis is the used by the IEEE form the GENCLS machine. When modelling a GENCLS model with H=0 and D=0 this is treated as an infinite bus.

4.2 Excitation system:

The excitation system is used to improve the excitation system stable area of activity to allow the regulator to provide better outcomes. If the excitation system senses a sudden drop in voltage level, then the AVR receives a signal from the comparator and provides a proper voltage regulation signal to the exciter and finally improves the system terminal voltage,Varaiya, P et.al(1985).

4.1 Governor control:

A governor senses speed to control the fuel of the prime mover to maintain the speed at the appropriate level is called Governor. This response can be improved further if PSS is used to damp out the low-frequency oscillations with the high-speed governor.

4.2 Stabilizer:

The Power System Stabilizer (PSS) is used to small oscillations at lower frequency and raise the reliability of a power system and requires an exterior input signal to the excitation system to improve the power system's damping in terms of exciter control. The system speed, terminal frequency, or power-stabilizing signals, and it should be activated as a type of oscillation with low frequency Chiang, H. D.,(2017)..

5. TRANSIENT STABILITY OF THE STANDARD IEEE 5 BUS SYSTEM ANALYSIS

The desired power-flow simulation is a more stable generator model for the simulation of transient stability. The model contains the parameters of the power, voltage regulation (MW and MVAR),also stability parameters i.e. machine model, exciter, governor etc.

Wind turbines are characterized in the power flow as generator process:

- Type 1 and 2 run on active power generation system while consumes reactive power at a fixed amount.
- Type 3 and 4 are kept as a photovoltaic bus.
- There is no excitation system for the wind turbines.

Figure 5 shows the standard IEEE 5 bus system with the base values chosen as 100MVA, 138kV, 50Hz generators combined, and considered by a single line diagram in both cases. The pre-fault system condition 100MVA, 138kV base is as below:

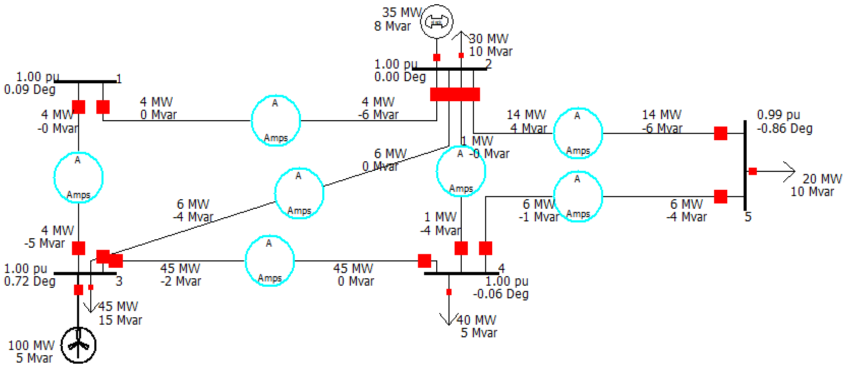


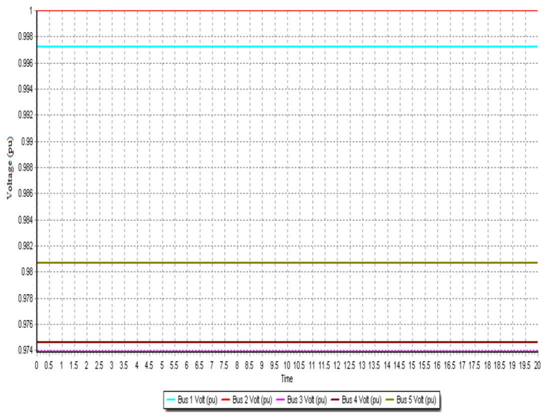
Figure 5: Standard IEEE 5 bus system with wind turbine

5.1 Simulation of the standard IEEE 5 bus system using the Conventional method:

The simulation of transient stability analysis is executed in three cases such as pre-fault, during-fault, and post-fault conditions:

Case (1) Pre-fault condition:

In the pre-fault condition, if all system parameters have standard stable conditions. The steady-state stability is shown in figure 5 above. Figures 5.1 (a, b) demonstrate the quantitative values for the voltage and frequency of the bus that it has under the conditions of a stable state.



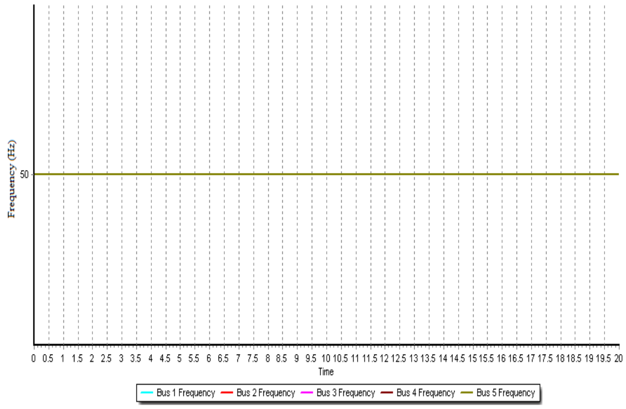
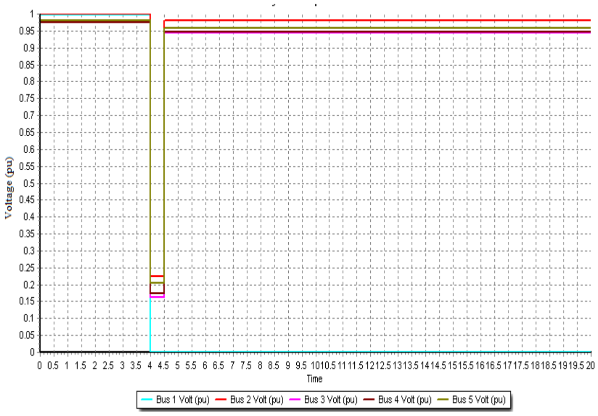


Figure 5.1 (a): Bus voltage (p.u) Vs time (sec) Figure 5.1 (b): Bus frequency (hz) Vs time (sec)

As seen in Figure 5 the transient stability for the standard IEEE 5 bus system tested and the Newton-Raphson method used to determine the initial load flow. In steady-state mode, power oscillations will not occur in the system output. The system is run on a steady-state during the pre-fault condition for 20 seconds as shown in figure 5.1 (a, b).

Case (2) During-fault condition:

A three-phase balanced fault is implemented on bus 1 at t= 4.0 seconds and resolved for the transient stability analysis after 0.5 seconds. During this condition, the simulation voltage variation, and frequency with respect to time for 20 seconds plotted in the following figures 5.1 (d, e).



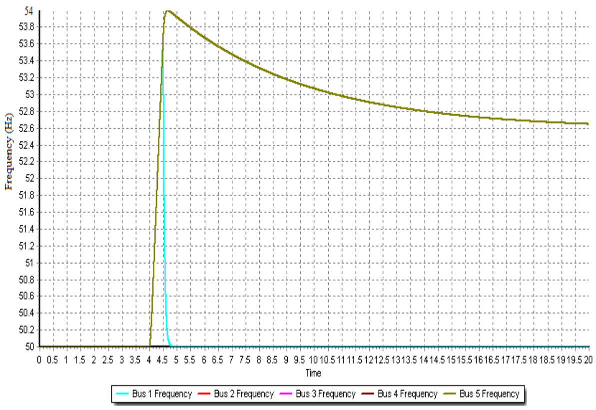


Figure 5.1 (d): Bus volt (p.u) Vs time (sec)Figure 5.1 (e): Bus frequency (Hz) Vs time (sec)

Figure 5.1 (d) shows that the voltage versus time for 20 seconds, the voltage (p.u) drops to zero, during a fault occurs on a bus 1, at t= 4.0 seconds and after 0.5 seconds it clears the fault and the voltage will rapidly rise.

Figure 5.1 (e) shows that the frequency versus time for 20 seconds, once a fault arises, the oscillations of frequency are high, after the 0.5 second clearing time resolved the fault, the frequency dropped to 52.7 Hz. The frequency starts to rise exponentially at t=4.0 seconds until the maximum limit is 54 Hz, and never returns to an initial state, and it shows the instability of the system.

Case (3) Post-fault condition:

This case for improve transient stability for the excitation process. GENCLS System Model, AC7B Exciter, WESGOV Governor, and AVR PSSSH Stabilizer are used in the connected generator on bus 2 and simulation results for the bus voltage, frequency is shown below:

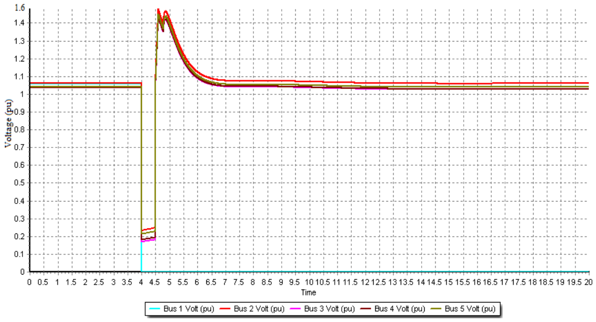


Figure 5.1 (f): Bus volt (p.u) Vs time (sec)

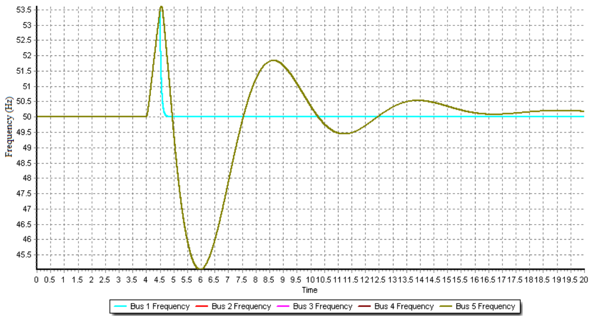


Figure 5.1 (g): Bus frequency (hz) Vs time (sec)

Figure 5.1 (f) indicates that the voltage per unit significantly decreases from typical value of 1.6 per unit to 0.0 per unit, after three-phase balanced fault executed. The fault reached at t= 4.5 seconds, the voltage keeps increasing rapidly, and the voltage falls with small damped oscillations to its original state at t= 7 seconds.

Figure 5.1 (g) indicates that the frequency of buses increased abruptly from 50 Hz to 50.17 Hz from regular operation. After the fault was resolved, the frequency fell to 53.6 Hertz after 0.5 seconds till it reduced again after 9 seconds to synchronize operating Hz, and at t=16 seconds the frequency returns to its initial state of 50.17 Hz.

5.2 Simulation of the standard IEEE 5 bus system using the Wind Turbine:

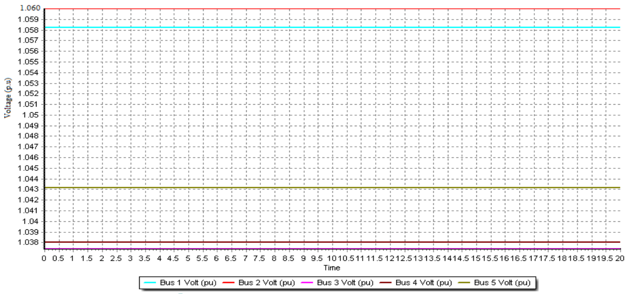
TheDERs subsequentfigures are shown below and as well here weget a balanced three-phase fault that arisen on bus 1 at t= 4.0 seconds and since resolving the fault after 0.5 seconds. The transient stability of the DER system performed by using the WT1G machine model, WT1T governor, and WT1P stabilizer, are considered as a generator of wind turbine which is connected to bus 3 for the fault.

This instance as well as the excitation and governor control systems, but the output capacity is taken 100 MW by default while using wind turbine contact,since a predetermined area is generally the most severe output power. In both cases, the generator output power is discussed in the generator device, voltage, and frequency at the buses.

The simulation results indicate wind turbine device stability as seen below:

Case (1) Pre fault condition:

The pre-fault condition all the system parameters have normal state values and this stable-state analysis is seen in figure 5 above. The quantitative values for bus voltage and frequency with respect to time for 20 seconds is shown in figure 5.2 (a, b) which have been during steady-state conditions.



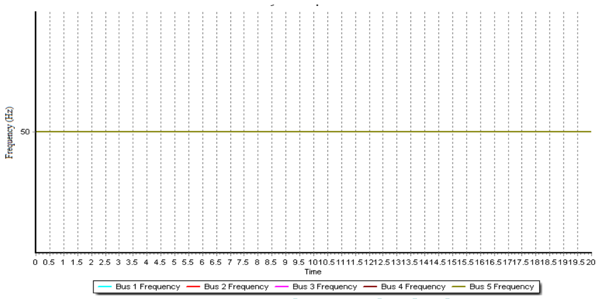
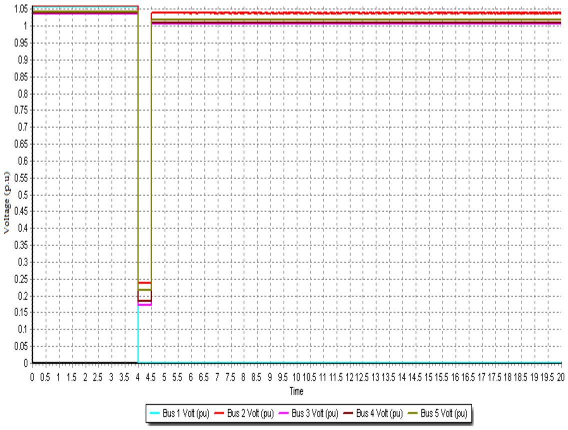


Figure 5.2 (a): Bus volt (p.u) Vs time (sec)Figure 5.2 (b): Bus frequency (Hz) Vs time (sec)

Case (2) During-fault condition:

In this case, a three-phase balanced fault is implemented on bus 1 of the system at t= 4.0 second is studied. During this condition, the bus voltage, and frequency with respect to time for 20 seconds using wind turbine as a generator is plotted in the following figures 5.2 (c, d).



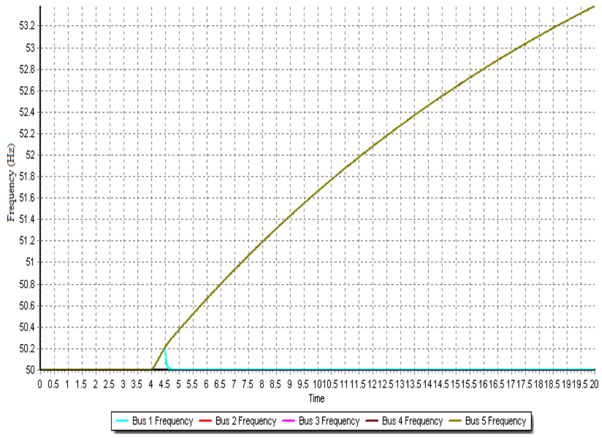


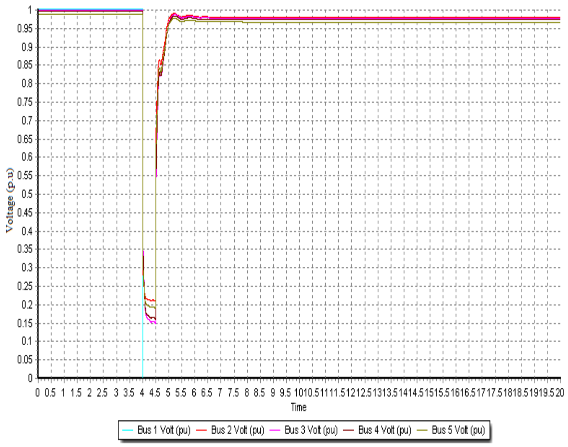
Figure 5.2 (c): Bus volt (p.u) Vs time (sec) Figure 5.2 (d): Bus Frequency (Hz) Vs time (sec)

Figure 5.2 (c) shows that the voltage versus time for 20 seconds, a fault occurs on a bus 1, at t= 4.0 seconds the voltage (p.u) drops to zero and after 0.5 seconds it clears the fault and the voltage will rapidly rise.

Figure 5.2 (d) shows that the frequency versus time for 20 seconds, once a fault arises, the frequency oscillations are high, since resolving the fault after 0.5 seconds clearing time, the frequency fell to 50 Hz to 53.8 Hz. The frequency starts to rise exponentially at t=4.0 seconds, until the full limit is 53.8 Hz, and never returns to an initial state, and it shows the instability of the system.

Case (3) Post-fault condition:

In post-fault condition, the WT1G machine model, WT1T governor, and WT1P stabilizer are implemented in the wind turbine as a generator, which is associated on bus 3 to boost the system response. The simulation for the bus voltage and frequency as shown below:



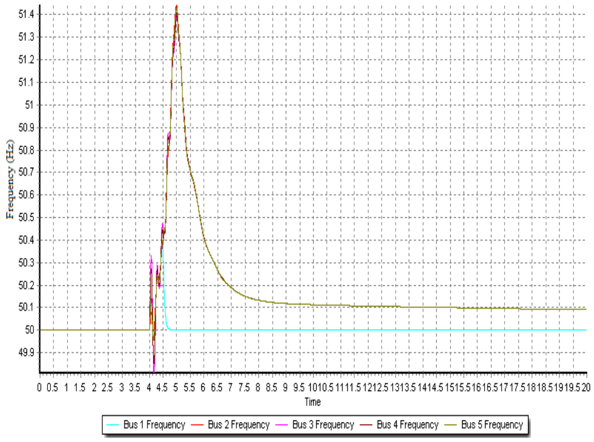


Figure 5.3 (e): Bus volt (p.u) Vs time (sec)Figure 5.3 (f): Bus frequency (hz) Vs time (sec)

Figure 5.3(e) indicates that the voltage per unit gradually decreases from typical value of 1.0 per unit to 0.00 per unit after being a balanced three-phase fault. Since determining a fault after 0.5 seconds voltage will be increase exponentially, the voltage in the wind case has no oscillations after t= 4.5 seconds and which are taking less time to stable in wind case as compared to the conventional method.

Figure 5.3 (f) shows that the frequency versus time for 20 seconds. The frequency after t= 6.5 seconds is in the initial state i.e. 50.1 Hz using the wind turbines. The frequency of the system also has small damped oscillations instead of it was in the standard IEEE 5 bus system using the Conventional method.

6. CONCLUSION

In conclusion, the transient stability study for the standard IEEE 5 bus in pre-fault, during-fault, and post-fault conditions are analysed using a conventional method that is excitation and governor control in conjunction with the PSS with AVR and Wind turbine system. It has been examined that the system regains its original position after t= 7 seconds using a conventional method. Though the system regains its original position with the use of the wind turbine in around 6.5 seconds, the bus voltage and frequency responses are better instead of the conventional method. DERs have more stability margins and have small damped oscillations instead of the conventional method. To sum up, the transient stability improved with the use of DERs in lesser time with more stability margins.

Conflict of interest: The authors confirm that there is no conflict of interest to declare for this publication.

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