Transient Stability on Power Flow using 9 Bus System

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Abstract – *The assurance of the strength of a power framework investigation. The target of this study is to comprehend and research the transient security of IEEE 9-transport framework that comprises of three generators and nine transports. For this, heap stream investigation is initially performed to decide the pre-shortcoming condition in the framework. Quick shortcoming clearing time and burden exchanging is then examined to decide the framework security. For the transient solidness examination, Euler and Runga technique are analyzed and varieties in rotor point and recurrence of the framework under various deficiency conditions are dissected. The reproductions are done on Power Word Simulator Software. It is presumed that power framework ought to have low basic clearing time to work the transfers if broken segment is confine inside extremely brief timeframe, consequently, the framework can acquire the solidness else it will leave synchronism.*

Key Words: Transient Stability, IEEE-9 Bus System, Rotor angle, Power Word Simulator, Critical time.

1.INTRODUCTION

Generally, generation, transmission, and distribution are the three steps in a power system. Supply continuous power is the main aim to design power system by maintaining voltage stability in presence of lightning, short circuit between transmission lines phase wires, and ground faults. One or many generators may be severely disturbed due to these above-listed faults, by causing a gap between demand and generation (Kundur, 1994, b).

Synchronization issues raising day by day in the installation of bigger systems as the escalation of power demand. Therefore, for upcoming development, demand forecasting has become, gradually, complex due to the increase in the use of electricity demand which results in overloading of the power lines. Due to overloading, the voltage at each bus gets reduce and the efficiency of the generator to supply active and reactive power decreases under an abnormal operation of a power system representing a contingency situation. By increasing the power generation and by constructing a new transmission line are may be useful to resolve the glitches of overhead transmission lines and increasing load demand to bring back the power system in safe operation.

The major concern in system operation is the stability of the power system. The analysis of transient stability is very important to design an electric power system. Transient stability is the capability of the power system to sustain large disturbances such as transmission line short circuit, losses of the generator, and load to persist in normal operating condition. The disturbances result in a large deviation of the generator rotor angle, effect on power flow, bus voltage, and other system variables causes the partial loss or loss of transmission network.

Steady-state stability handles the operating environments whereas transient stability analyzed operating environments as well as disturbances (Duan et al., 2016). For a good understanding of power reliability, the classification of power system stability becomes critical. Thus, the power system stability is classified according to the nature of system instability (voltage and frequency stability), the magnitude of disturbances (large and small disturbances), and long-term and short-term stability (time-frame stability). The complex issue for the power system is the instability since it can take many forms and can be relatable to many factors. Figure 1 shows a detailed classification of power system stability in which the three main categories are defined. The physical nature of the instability, loss of synchronization, low bus voltages, high-frequency deviation, size of the disturbances, and measures taken to enhance the power system stability included in the considerations to counter system instability.

Rotor angle stability is the competency to remain in synchronism after a disturbance has occurred. The synchronous machines start "swinging" to each other when a disturbance occurs in the system. The deviation in angular position will increase if one machine starts running faster than another and the fast machine will supply more loads. The other machine speed increase until equilibrium is reached to decrease system speed. Instability occurs when equilibrium is not reached and the speed of some machines increases until these machines are tripped (Machowski et al., 2011; Kundur et al., 2004). Rotor angle stability is a highly nonlinear, multi-dimensional problem (Kundur, 1994, b).

Instability can be categorized into two parts such as aperiodic or non-oscillatory instability which is caused by a lack of synchronizing torque that is associated with rotor angle deviation and periodic instability which is caused by a lack of damping torque associated with speed deviation. Instability problems are aperiodic and are mainly due to insufficient synchronizing torque (Custem, 2007; Taylor, 1994). Rotor angle stability consists only of the short-term phenomenon as the time frame is in the order of a few seconds to a few tens of seconds (Machowski et al., 2011; Kundur et al., 2004).

The subsection of rotor angle stability is the large disturbance angular stability (transient stability) which contains the function of the power system to keep angular stability after major disturbances (e.g., shorting or disconnecting of the transmission line). Critical Clearing Time (CCT) means the maximum time during which a disturbance can be applied without the system losing its stability. Time-domain simulation is used to solve the algebraic and differential equations in a power system due to the highly nonlinear characteristics of transient stability by using a step-by-step calculation procedure. To determine stability the direct method can also be used such as Newton Raphson's Second Method. This method is not often used due to the complication of finding an adequate function and instability of defining a practical stability domain (Kundur et al., 2004; Kundur, 1994 a, b). pattern recognition can also be a method for transient stability analysis by referring to experience and applying it to current stability properties (Kundur, 1994 a, b).

Another subsection of rotor stability is the small disturbance angular stability (small signal stability) which comprises functions of the power system and sustain stability after experiencing small disturbances. A small disturbance is considered if the linearized system still exhibits the kinetics of the original systems under this disturbance (Machowski et al., 2011; Kundur et al., 2004). When the system is linearized then the modal analysis method can be applied. The characteristics of modes such as mode shapes, transfer functions, and coupling coefficients are calculated by the modal analysis and are useful for improving damping. It uses the time-domain simulation to visualize the results (Potamianakis and Vournas, 2006). The branching method is another way to evaluate the effect of large changes in small-signal stability, unlike modal analysis where all system parameters are fixed (Van Custem, 2000; Chakravorty and Patra, 2016). The vibration instability is caused by the presence of complex conjugate eigenvalues with positive real parts as shown in Fig. 2. Instability becomes acyclic type if the eigenvalues are positive and real as shown in Fig. 3.

Frequency stability is defined as the ability of the power system to uphold stable frequencies following disturbances due to the discrepancy between generation and load. If the system can balance or restore power and load with minimal load trips then the system is said to have frequency stability. For frequency stability analysis mainly time-domain simulations are used as an appropriate representation of dynamic devices (Kundur et al., 2004).

In this study, the transient stability analysis is carried out with the help of a three-phase balance fault. For analyzing the swing behavior of the system, Runga and Euler methods are used. During the planning stage of the system, a large number of simulations are performed to obtain its accurate knowledge. In Power Word Simulator Software the simulation of the IEEE 9-Bus system model is carried out. The proposed work is tested on IEEE 9-bus power systems

under normal and abnormal operating conditions (Machowski et al., 2011).

2. LITERATURE REVIEW

Normally power system is running with stabilized operation. When sudden change in load any kind of earth fault occurs then the stabilization comes to the system. Basically, stabilization means the change in angle between stator and rotor angle & also the change in speed of the machine. ETAP is the most comprehensive analysis platform for the design, simulation, operation and automation of generation, distribution, and industrial power system. ETAP is developed under an established quality assurance program and is use worldwide as high impact software. It is completely localized in four languages with translated output reports in six languages ETAP is the Simulink software where we can draw a system. By using Power System Stabilizer, we can reduce the instability by providing signal to rotor.

In the given project, Power System Stability Analysis by Applying PSS in ETAP, we study the whole project work from different references. These are The abstract are help from C. L. Wadha , Electrical Power System where the PSS are existing AVR and governor for power system stability and the system is simulated phase and 1 phase fault by using ETAP. The PSS analysis may involve the calculation of critical clearing time (CCT) which define as the maximum allowable value for clearing time of fault and system remain stable. The whole ETAP software are learn and study from ETAP power station user guide and also User Define Dynamic Model (UDM) studied, chapter 20. The Power System Stability Analysis and Control are studied and guided us about PSS from- P. Kundur, Power System Stability & Control, Mc Graw Hill.inc The schematic diagram are inbuilt in the ETAP software and we analysis the transient stability of synchronous generation related this project from F. Selwa, L. Djmel, Transient Stability Analysis of Synchronous Generation of Electrical Work.

3. PROBLEM FORMULATION
3.1 Power Flow Study

Knowledge of pre-fault voltage magnitude is required for the transient stability study. Power flow study includes the bus voltage, phase angle of the bus voltage, the transmission line actual power and reactive power, the generation bus actual and reactive power, and other variables as a piece of key information. Pre-fault conditions can be obtained by using the Newton-Raphson method from load flow analysis.

Newton-Raphson method is a useful method and not affected by reserve bus selection of networking large capacity load flow solutions convergence. This method starts by guessing all unidentified variables such as voltage, voltage angle of the load bus, and generator bus. After this Taylor series obtained to ignore the higher-order term in the

equation system for every power balance equation. Firstly, the study is performed for the existence of a load bus and a distant PQ bus. For an ith bus:

$$Pi = \sum_{k=1}^{n} |Vi||Vk|\|Yik|\cos(\theta ik + \delta k - \delta i) = Pi(|V|, \delta)$$

$$Qi = \sum_{k=1}^{n} |Vi|\|Vk|\|Yik|\sin(\theta ik + \delta k - \delta i) = Qi(|V|, \delta)$$

$$|V| = (|v_1|, |v_2|\ldots\ldots, |v_n|)^t$$

$$Pi(|V|) = Pi(x)$$

$$Qi(|V|) = Qi(x)$$

$$x = \frac{\delta}{|V|}$$

$$Pi - Pi(x) = 0$$

$$Qi - Qi(x) = 0$$

$$f(x) = \begin{bmatrix} P(scheduled) - P(x) \\ Q(scheduled) - Q(x) \end{bmatrix} = \begin{bmatrix} \Delta P(x) \\ \Delta Q(x) \end{bmatrix} = 0$$

$$f(x) = \begin{bmatrix} \Delta P(x) \\ \Delta Q(x) \end{bmatrix} = \begin{bmatrix} -J11(x) & -J12(x) \\ -J21(x) & -J22(x) \end{bmatrix} = \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$$

$$\Delta\delta = (\Delta\delta_2, \ldots\ldots, \Delta\delta_n)^T$$

$$\Delta|V| = (\Delta|V_2|, \ldots\ldots, \Delta|V_n|)^T$$

$$J(x) = \begin{bmatrix} -J11(x) & -J12(x) \\ -J21(x) & -J22(x) \end{bmatrix}$$

$$-J_{11}(x) = \frac{\partial P(x)}{\partial \delta}$$

$$-J_{12}(x) = \frac{\partial P(x)}{\partial |V|}$$

$$-J_{21}(x) = \frac{\partial Q(x)}{\partial \delta}$$

$$-J_{22}(x) = \frac{\partial Q(x)}{\partial |V|}$$

$$\frac{\partial Pi(x)}{\partial \delta k}, \frac{\partial Pi(x)}{\partial |Vk|}, \frac{\partial Qi(x)}{\partial \delta k}, \frac{\partial Qi(x)}{\partial |Vk|}$$

$$\frac{\partial Pi(x)}{\partial \delta k} = |Vi|\|Vk|\|Yik|\sin(\theta ik + \delta k - \delta i)(i = k)$$

$$\frac{\partial Pi(x)}{\partial \delta k} = \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vi|\|Vk|\|Yik|\sin(\theta ik + \delta k - \delta i)(i = k)$$

$$\frac{\partial Qi(x)}{\partial \delta k} = |Vi|\|Vk|\|Yik|\sin(\theta ik + \delta k - \delta i)(i \neq k)$$

$$\frac{\partial QPi(x)}{\partial \delta k} = \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vi|\|Vk|\|Yik|\sin(\theta ik + \delta k - \delta i)(i = k)$$

$$\frac{\partial Pi(x)}{\partial |Vk|} = |Vi|\|Yik|\sin(\theta ik + \delta k - \delta i)(i \neq k)$$

$$\frac{\partial Qi(x)}{\partial |Vk|} = 2|Vi|\|Yik|\sin\theta ii +$$

$$\sum_{\substack{k=1 \\ k \neq i}}^{n} |Vk|\|Yik|\sin(\theta ik + \delta k - \delta i)(i = k)$$

Jacobian matrix elements make important observations such as if ith bus and a kth bus is not linking then Yik=0 until the stop situation.

2.2 Materials and Methods

The effect of accidental outages addresses the transient stability such as sudden outages, the incidence of faults or abstraction, or the application of sudden loads. Transient stability analysis is performed to check the capability of the system to tolerate the transients (Kundur and Wang, 2002). By using Power Word Simulator Software transient stability analysis steps are given below:

Step 1 the standard IEEE-9 bus system given in Fig.4 is used (Makarov et al., 1998). To complete load flow the system model is applied. By using the adaptive Newton Raphson method the load flow analysis of the 9 bus system is performed which is shown in Table 1.

Step 2 initial parameters of the system are studied after the load flow such as the voltage at a bus, frequency of bus, bus power angle, and rotor angle of a generator as shown in Table 2.

Step 3 by applying multiple contingencies at different times the output results are obtained on Power Simulator Software using the Runga and Euler method.

Step 4 Calculate which technique is superior to the transient stability analysis after comparing the results of the three steps in both approaches.
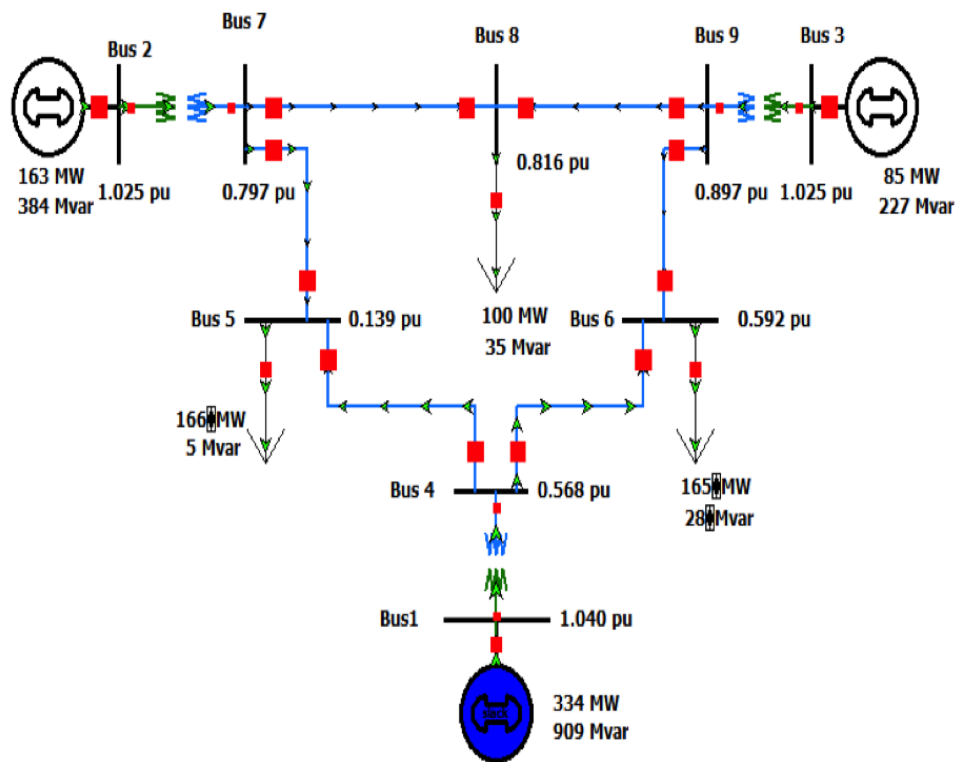
Fig -1: IEEE 9 Bus test System

Bus No	V pu	Angle Degree	Injection MW	Injection MVar	Generation MW	Generation Mvar	Load MW	Load MVar
1	1.0400	0.0000	71.64	27.05	71.64	27.05	0.00	0.00
2	1.0250	9.2800	163.00	6.65	163.00	6.65	0.00	0.00
3	1.0250	4.6648	85.00	-10.86	85.00	-10.86	0.00	0.00
4	1.0258	-2.2168	-0.00	-0.00	-0.00	-0.00	0.00	0.00
5	0.9956	-3.9888	-125.00	-50.00	-0.00	0.00	125.00	50.00
6	1.0127	-3.6874	-90.00	-30.00	-0.00	0.00	90.00	30.00
7	1.0258	3.7197	0.00	0.00	0.00	0.00	0.00	0.00
8	1.0159	0.7275	-100.00	-35.00	-0.00	0.00	100.00	35.00
9	1.0324	1.9667	0.00	-0.00	0.00	0.00	0.00	0.00
Total			4.641	-92.160	319.641	22.840	315.000	115.000

Table -1: Load Flow Analysis

```
---------------------------------------------------------------------------
                          Line Flow and Losses
---------------------------------------------------------------------------
|From|To |    P    |    Q    | From| To |    P    |    Q    |    Line Loss      |
|Bus |Bus|   MW    |   MVar  | Bus | Bus|   MW    |   MVar  |   MW    |   MVar  |
---------------------------------------------------------------------------
   1   4    71.64     27.05     4    1   -71.64    -23.92     0.00      3.12
---------------------------------------------------------------------------
   2   7   163.00      6.65     7    2  -163.00      9.18     0.00     15.83
---------------------------------------------------------------------------
   3   9    85.00    -10.86     9    3   -85.00     14.96     0.00      4.10
---------------------------------------------------------------------------
   4   5    50.20     32.15     5    4   -31.96    -29.96    18.24      2.19
---------------------------------------------------------------------------
   4   6    39.02      9.34     6    4   -22.44     -8.44    16.58      0.90
---------------------------------------------------------------------------
   5   7   -69.15      3.85     7    5   102.72      7.72    33.57     11.57
---------------------------------------------------------------------------
   6   9   -41.11      4.90     9    6    79.89      1.00    38.79      5.90
---------------------------------------------------------------------------
   7   8    84.22      7.04     8    7   -68.22     -3.02    16.00      4.03
---------------------------------------------------------------------------
   8   9   -13.31    -13.51     9    8    35.32     14.26    22.01      0.75
---------------------------------------------------------------------------
   Total Loss                                              145.185    48.384
---------------------------------------------------------------------------
```

Table -1: Line Flow and Losses

3. CONCLUSIONS

The simulation model of the IEEE 9- bus system has been build to analyze the system behavior and related simulation results have been presented. It is concluded that power should have a very low critical time. Due to low critical time relays of faulty sections operate in a very short time so that system can obtain stability otherwise it will go out of synchronism. In this research work, the transient stability analysis of the system, performed by load studies. Also, this study investigates the behavior of three-phase balanced fault and load switching impact. That reveals that the protection system provided for the system should have a fast response. Accordingly, system stability adopts the fast fault clearing and load shedding methodologies.

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