Systematic Transient Stability Analysis of IEEE 5 Bus System using Power World Simulator

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Abstract: **Transient Stability Analysis is an important part of the Energy Systems Design. The strategy is that Power System must remain in a Steady State and Stable Condition. In this paper, the transient analysis of the IEEE 5 Bus System is done to manifest the system operation while a 3 phase fault is being set up. This practical approach to the Transient Stability Problem lists important severe disturbances to which the system is likely to be subjected.**

***Index Terms* –** Single Solution Full Newton Raphson Method **(SSFNRM),** Time Domain Transient Analysis **(TDTA),** Power Flow Conditions **(PFC),** Transient Stability Analysis **(TSA),** Power World Simulator **(PWS),** Transient Analysis **(TA).**

I. INTRODUCTION

As when branch currents and voltages in a synchronous AC network are not changing with respect to time resulting constant amplitude and frequency throughout the time interval we say the network is in **S**teady **S**tate. When currents and voltages change from their former values during a time period to new values it is transition period and circuit output during this extraordinary time interval is called Transient Response [1]. In this paper, step ahead work has been done in which new parameters of Voltage or Current, Voltage Angle, Real Power (**MW**), Reactive Power (**MVAr**), Generator Speed, and **G**enerator **R**otor **A**ngle are plotted against time using **SSFNRM** thereby giving **TDTA**. In this paper, the **TA** exactly shows the behavior of the **IEEE** 5 **B**us **N**etwork from **S**teady **S**tate to **U**nsteady **S**tate property and how to regain back the stable synchronism after being subjected to disturbances keeping different fixed points for fault clearance during the investigation.

II. TRANSIENT CASE STRATEGY ANALYSIS

Under this category transient behavior is systematically investigated for the **IEEE** 5 **B**us Power **S**ystem based on security analysis using **P**ower **F**low **C**onditions **(PFC)**. **PFC's** enable computational procedure for determining the operation of a Power System Network. The software used is **P**ower **W**orld **S**imulator **(PWS)** involving whole system procedure while working on **T**ransient **S**tability **A**nalysis **(TSA)**. The Goal is to solve a set of algebraic equations. We actually add the simple **GENCLS C**lassical **M**achine **D**ynamic **M**odel to an existing case by auctioning in the run mode through **G**enerator **I**nformation **D**ialog **B**ox using stability in which transient models are classified as they are critically undefined. Here the **I**nfinite **B**us case is assumed to have a fixed voltage magnitude and angle so its frequency will also be at the normal [3]. During **TSA**, **S**lack **B**us is usually kept an assumption the **I**nfinite **B**us as **PWS** does not treat **S**lack **B**us as an **I**nfinite **B**us. These buses are only used for case study purposes, as **F**igures 1 and 2 explain System Model and Contingency whereas Tables 1, 2 and 3 display various parameters.

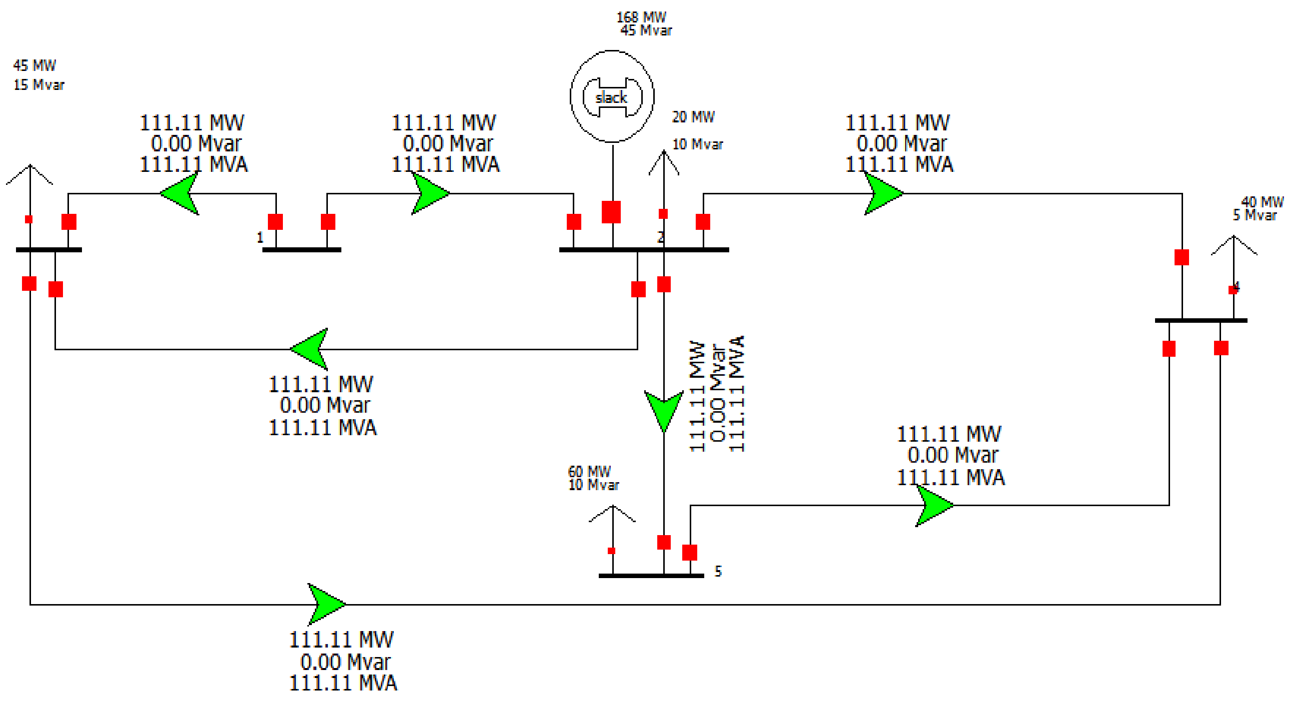

Figure 1 IEEE 5 Bus System Model

Table 1 Data for IEEE 5-Bus System under Model Running Condition

Number	Nominal Voltage **(KV)**	Pu **(Volt)**	Volt **(KV)**	Angle **(Degrees)**	Load **(MW)**	Load **(MVAr)**	Generator **(MW)**	Generator **(MVAr)**
1	138.00	0.99203	136.900	-3.55				
2	138.00	1.0000	138.000	-2.84	20	10	168.51	47.31
3	138.00	0.96180	132.729	-6.54	45	15		
4	138.00	0.96215	132.777	-6.62	40	5		
5	138.00	0.96080	132.590	-6.81	60	10		

Table 2 Y-Bus Data for the 5-Bus System

Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5
1	6.25 - j18.75	-5.00 + j 15.00	-1.25 + j 3.75		
2	-5.00 +j 15.00	10.07 + j 31.26	-0.91 + j 3.78	-1.67+ j 5.00	-2.50+ j 7.50
3	-1.25 + j 3.75	-0.91 + j 3.78	12.16 – j 37.52	-10.00+ j 30.00	
4		-1.67 + j 5.00	-10.00+ j 30.00	12.92 – j 38.74	-1.25 + j 3.75
5		-2.50+ j 7.50		- 1.25+ j 3.75	3.75 – j 11.25

Table 3 Minimum and Maximum Mismatch Values during Fault Clearing Time Interval of 10 seconds

Number	Bus	Original Volt	Minimum Volt	Time for Minimum Volt	Maximum Volt	Time for Maximum Volt	Max-Min Volt	Type of Bus	Mismatch MW	Mismatch MVAr	Mismatch MVA
1	1	0.9920	0.9920	10.000	0.9920	0.000	0.000	PQ	-.0.04	-0.00	0.04
2	2	1.0000	1.0000	0.000	1.0000	0.000	0.000	SLACK	0.02	0.01	0.02
3	3	0.9618	0.9618	10.000	0.9618	0.000	0.000	PQ	0.01	0.00	0.01
4	4	0.9621	0.9621	0.000	0.9621	10.000	0.000	PQ	-0.00	-0.00	0.00
5	5	0.9608	0.9608	0.000	0.9608	10.000	0.000	PQ	0.00	0.00	0.00

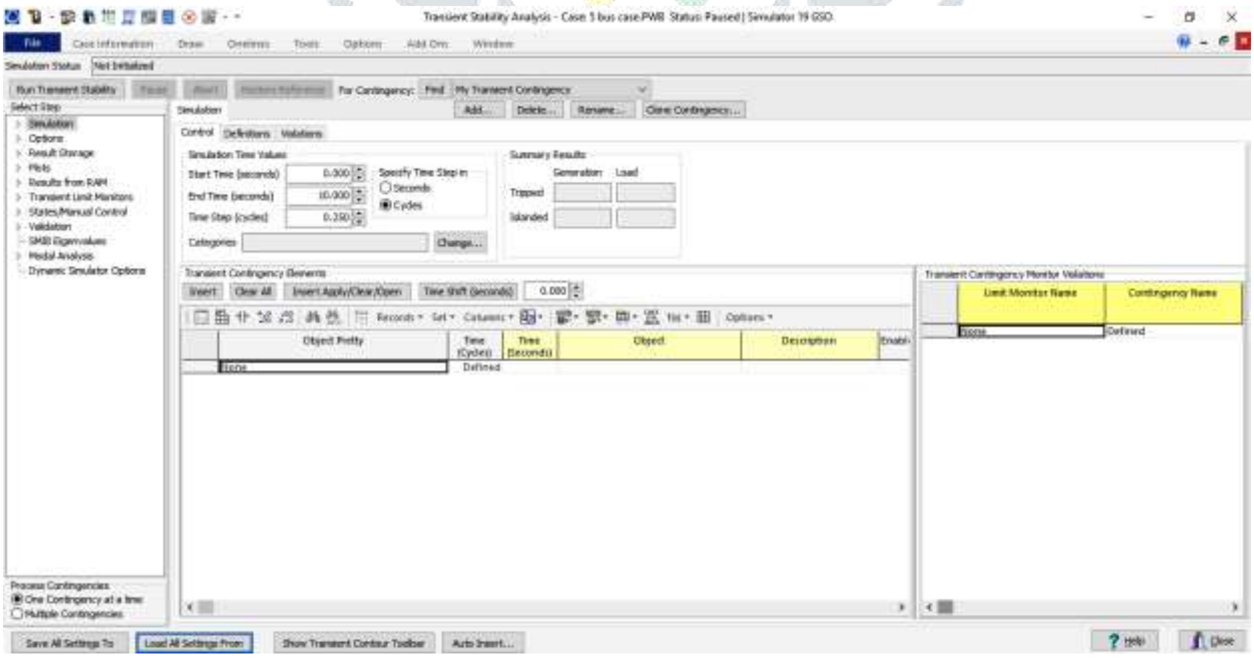

Figure 2 Simulation Results in setting Fault Points and Contingency

III. IDENTIFYING THE CONTINGENCY EVENT

In **PWS** contingency event is specified by **T**ransient **S**tability **C**ontingency **E**lement Dialog when simulation page is followed through "**I**nsert **E**lements **B**utton"

Case-I

Generator Model is used for all results

1) From Bus_2 to Bus _ 1

The Fault is initiated at the generator **Bus 2** and the settings involved are listed below:

During Transient Status: Closed
Gen **MW** = **168.51**
MVA Base = **100**
Machine = **GENCLS**
H (**S**ystem **B**ase) = **100**
Step **R** = 0.0000
Step **X** = 0.0000
Step **T**ap = **1.000**
R (Internal Resistance) = **1.0000**
X (Internal Resistance) = **1.0000**

2) Summary of Results

Model is Run with **SSFNRM** which defines the case as:

Bus 1 Fault Applied Time Seconds **(1.0000)**
Bus 2 Fault cleared **(1.05000)**
Frequency **50.00Hz (Apply)**
Frequency **52.5 Clearing Time**
The Fault set is 3 phase balanced type
Class of fault was **S**olid.

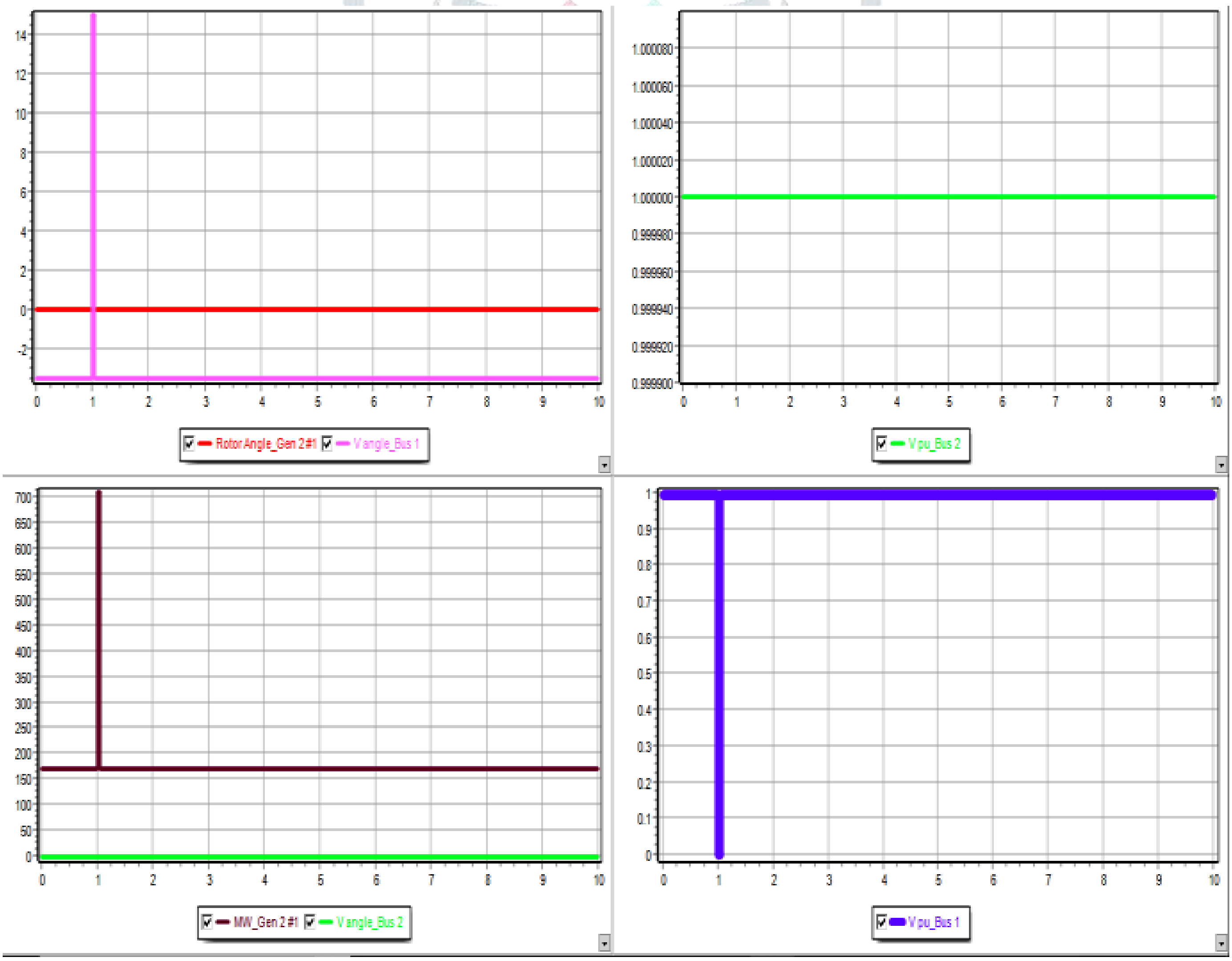

Figure 3 Subplots show the behavior of the system

Different case strategies as **F**igure 3 explains through subplots in which the generator **MW** goes maximum up to **700** from the time period of **0.9 Seconds** then strikes back to same generation value after the fault is cleared (Total Time Duration Allowed is **10 seconds**). **V**oltage **A**ngle of the **Bus 1** results in the change of **N**ominal **V**alue during Transient then regains back to its same value when a fault is cleared. Values of Per-Unit voltage at **Bus 1** also receives change at the specific point value during Transient Period and during this interval per unit system cannot absorb the large disturbance. For **V**oltage **A**ngle at **Bus 1** will go to zero at the time duration of **1 Second** due to the fault and then recovers to the same state after (damping) clearing the fault.

Case-II

The Investigation is followed from **Bus 2** to **Bus 5** and the **R**un **B**utton is pressed from a **SSFNRM**. Case second is set with balanced **3 P**hase **F**ault.

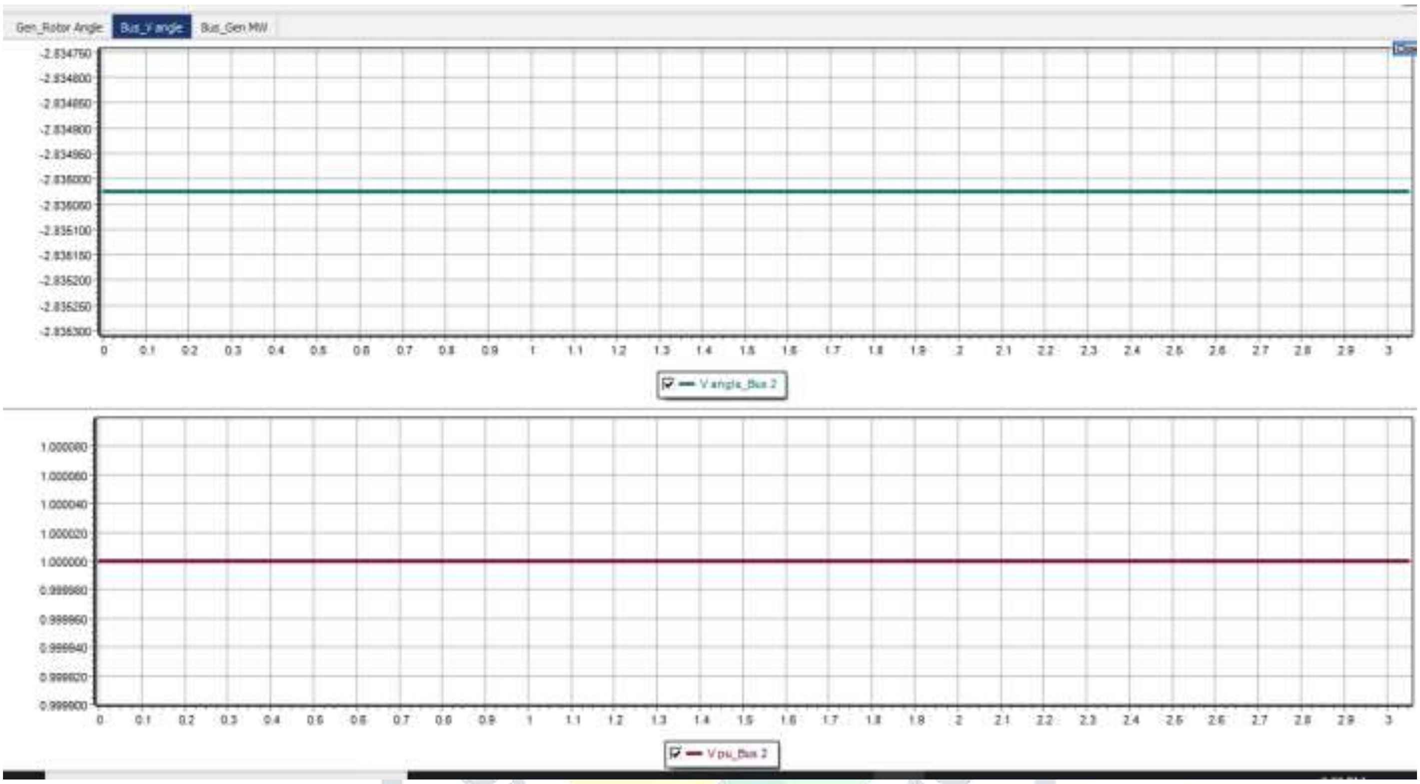

Figure 4 Behavior of Voltage Angle and Per-Unit voltage at Bus 2

Figure 4 percepts the First subplot as **V**oltage **A**ngle relies upon the constant level but during transient strikes at the **-2.835025 (V_ Angle)** value throughout the time interval of **3.050 seconds** and this undesired change is due to the occurrence of the transient. The second subplot directly shows that Per-Unit value is not changed from its initial value and remains the same at **1 Pu** during the time interval of **3.050 seconds**.

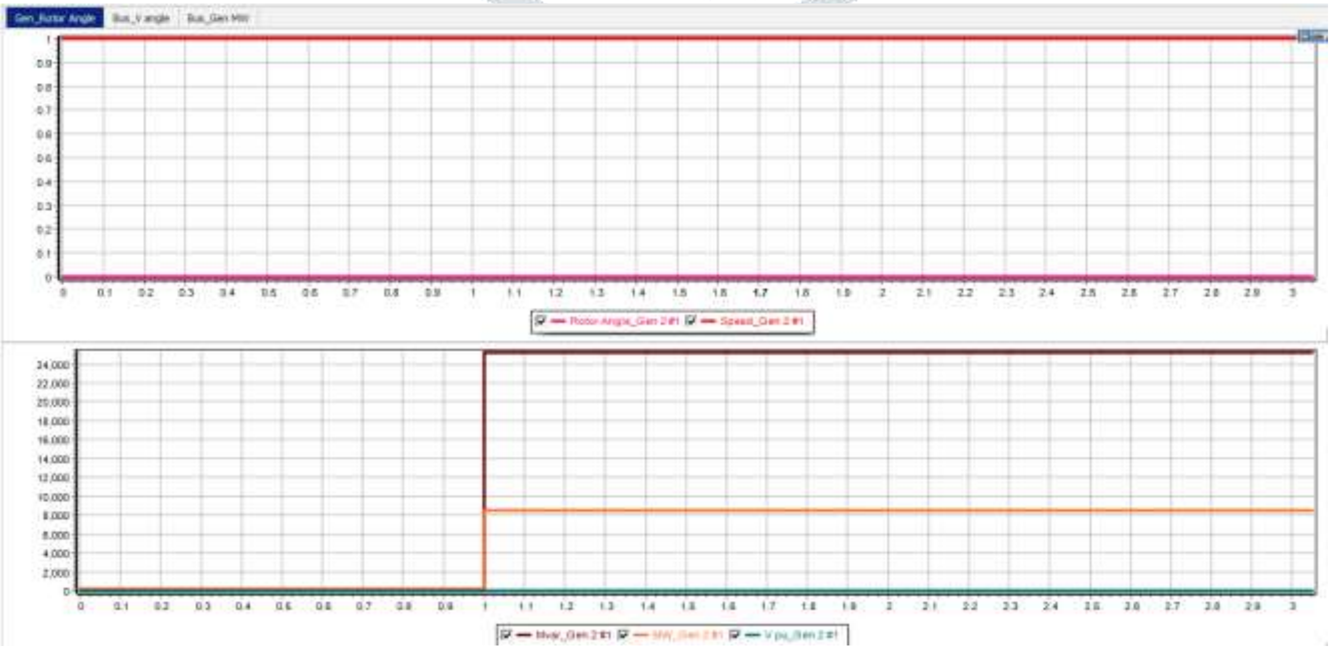

Figure 5 Gives Speed of the generator during Mismatch, Rotor Angle Swing, MVAr rise, MW step change during Fault Occurrence

Figure 5 explains that in subplot first Speed of the generator remains constant during mismatch between mechanical and electrical powers. But in the initial state, it flies from **0** to **1** value giving new constant response across time which is **3.050 seconds** it means the machine has selected the new value for synchronous operation after the fault clearance while the **G**enerator **R**otor **A**ngle continues to remain in synchronism after a disturbance. Due to an increase of current in the rotor field, the graph steadily shows the **MVAr** rise blink at the time scale of **1 second** on **x-axis** which at the same time marks **y-axis** scale at somewhere above **2400**. This causes the magnetic coupling of the rotor to the stator and increases the **MVAr** output during this instant. In second subplot **MW** of the Generator receives a step blink at **1 second** time scale which marks up to somewhere **8300** on the **y-axis** and finally chooses the new increased and damped **MW** value. During the mentioned transient, Per-Unit voltage of the generator remains almost constant throughout. **G**enerator **R**otor **A**ngle will swing at zero relatives during transient of **3.050 seconds** and speed will also remain constant. As generator Reactive Power rises abruptly above **24000** up to **25000** at the time period of **1 second** and remains at the same value during the clearing time period of **3.050 seconds**.

Figure 6 Gives the MW representation, MVAr, Per unit Voltage at Bus 5, Bus voltage angle

As Figure 6 displays the generator **MW** is zero and its **MVAr** value is constant throughout time duration of **3.050 seconds**. Per unit voltage at **Bus 5** receives change from **1 V Pu** to less up to **0.5 Pu** and remains the same for rest of the system. The voltage angle at **Bus 5** results decrease in angle from **-6.81** to **-9.50** at a time period of **1 second** and remains the same throughout the rest of the time clearing interval of **3.050 seconds**. But when the fault occurs across the buses parameters of impedance are considered as:

Percent Location (near to fault) **------ 3.00**
PU Resistance **(5 Pu)**
PU Reactance **(1 Pu)**
Observance of **Bus 2** and **5**
As the results are given and the scale of the plot is provided as per Plot Designer options.
Using Generator information for the current case with the option from stability in which Machine Model is using **GENCLS** Active mode that possesses values along with
H (System **B**ase) = **3.000**
D = 0.00
Ra = 0.00
Xdp = **0.2000**
R Comp = 0.0000
X Comp = 0.0000
PU values are entered with using device base of **100 MVA**

Simulation has resulted from the control window
Start Time 0.000
End Time **(Seconds) = 3.050**
Time set **(cycles) = 0.250**
Description is **[Line -2 To Line-5 CKT Fault 33PB SOLID]**
Power **S**ystem **V**alues:
Normal System Frequency **50Hz**
Initial System Frequency **50Hz**

System **MVA Base 100**
Network Equation Solution:
Solution Tolerance **(MVA) 0.0100**
Maximum Iteration **25**

For case consideration, we need to set the generator Rotor Angle, Speed, **MW** terminal power, and **MVAr** terminal power.

IV. CONCLUSION

The **IEEE** 5 **B**us **P**ower **S**ystem is analyzed and two different transient case strategies are calculated and the results show how the response of the system changes from normal **S**teady **S**tate value to **U**nstable **S**tate during the specific set of time intervals. The waveform results clearly show how the power system behaves during Transient and what happens to the system parameters. The graphical values are also mentioned giving a clear understanding of the system response, changes from initial system conditions up to final state after being subjected to disturbances. So with these results, we can make the better potential design of any **P**ower **S**ystem in order to withstand against faults like a short circuit on a Transmission line, loss of a generator, loss of a load, gain of load or loss of a portion of the transmission network.

REFERENCES

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