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Modeling & Analysis of Transient Stability of Thermal Power Station Jamshoro Using MATLAB Simulink Software

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Abstract In this paper the general ideas for transient stability analysis are given. Simulink based model of Thermal Power station Jamshoro is generated and its transient stability assessed, by considering three phase fault at one of the bus of system, with Time Domain Analysis(TDA). Simulation results are being reproduced and investigated before and after the fault.

Keywords: Transient stability, Fault Clearing Time (FCT), Simulations, MATLAB.

I. INTRODUCTION

Now-a-days the installations of big generating units and high tension tie lines and also their interactions make the modern power system to become more complex to analyze [1]. The need for the analysis of transient stability of power system arises when the system is under highly stressed condition due to the large number of operations [2]. Stability analysis of the power system lies within the domain of dynamic security assessment of electrical power system, which evaluates the capability of power system to return to the steady state condition after being subjected to a severe disturbance. An electrical power system is said to have dynamic stability if after the fault it is able to recover the synchronism and running near to initial state or over it completely. The results of these disturbances appear in the form of variation in tie-flows, bus voltages, rotor angles and other system variables [3]. Transient stability of power system is criteria that define the dynamic behavior of power system while considering the fault; the zero state initializing the fault is balanced one out [4-5]. The dynamic stability of the system is based on both abnormal severe disturbances and running conditions. Transient stability Analysis is complex in nature as the non-linear ties in the operation of power system cannot be ignored [6-7].

In power system stability analysis, Critical Clearing Time (CCT) plays vital role, as it is the maximum time during which fault may occur on the system without the loss of stability. Normally for the power system Fault Clearing Time is set arbitrarily. If the Fault Clearing Time FCT is more than Critical Clearing Time (CCT) then the rotor angles will swings away from equilibrium point and system will lose stability. For finding critical time, we find rotor angle as a function of time [8]. Critical Angle ( ) t ,is the maximum possible angle for clearing the fault without exceeding transient stability limit as shown in figure 01 [9] .The rotor angle as of function of time is calculated for a long period, to determine that whether rotor angle will increase without limit or reach a maximum value and starts decreasing [10]. The latter option indicates stability of power system. Standard interrupting periods for the circuit breakers and corresponding relays are usually 3sec, 5sec, 8sec or 2 cycles after the fault occurred. Simulink is an interactive tool for analyzing the behavior of non-linearity of power system and simulating the dynamics of system [11].

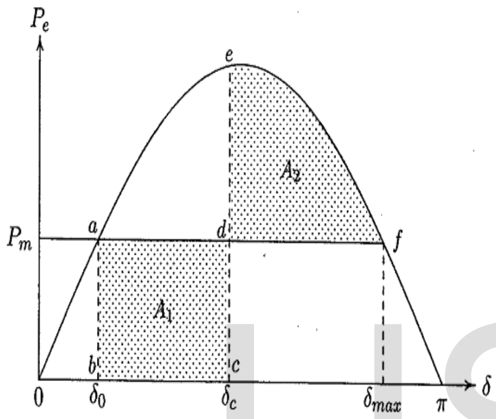

Figure.01. Critical Clearing Angle

II. DESCRIPTION & MODELING OF POWER SYSTEM

The one line diagram of Thermal Power Station Jamshoro is shown in Figure 02 , with four generating units, from which three are of 210 MW China based with generation voltage of 15.75 kV, 50 Hz, with ramping rate of 1.0 MW/min and require 6 hours to synchronize with system and one unit is of 250 MW Japan based with generation voltage of 16.5 kV, 50 Hz, with ramping rate of 2.0 MW/min and requires 12 hours to synchronize with system, fourteen transmission lines, eight load buses and four transformers.

The base MVA is 100 MVA and the system frequency is 50 Hz. The entire power system is modeled in simulink with reference to mathematical expressions. Expect the generator buses, all other buses are eliminated and internal nodes of machine units with multiport representations are obtained. With the help of self & transfer admittances of the simplified electrical network, power output of all generators can be obtained. The MATLAB coding to obtain the reduced admittance matrix is given in appendix

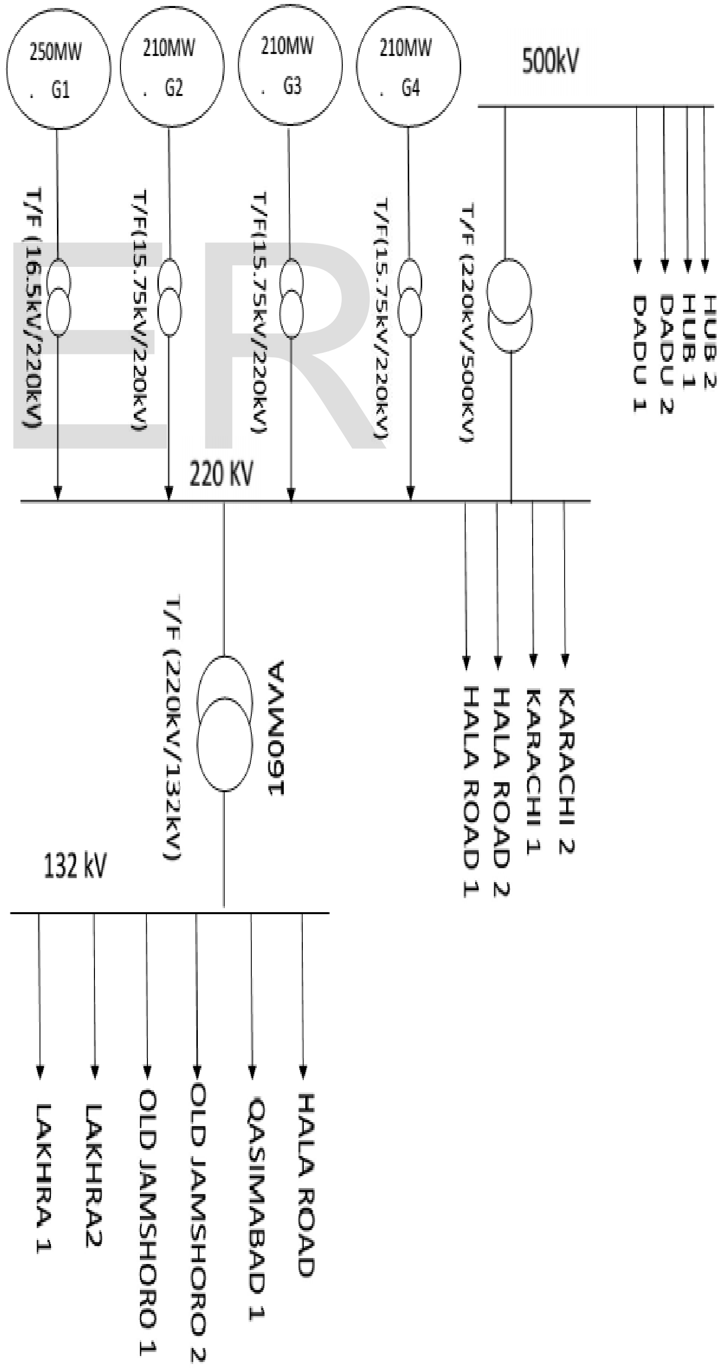

Figure.02. Main One Line Diagram of Jamshoro Thermal power station

The nodal admittance matrix $Y_{bus,\ nod}$,is augmented by adding the dynamic reactance of the generators. Let $Y_{bus,\ nod}$ after the addition of load impedances would become as

$$Y_{bus,\ nod} = \begin{pmatrix} Y1 & Y2 \\ Y3 & Y4 \end{pmatrix} \quad (1)$$

Where sub matrix Y1 is of order of m×n and corresponds to the generator buses and Y2, Y3 and Y4 are the other sub matrices.

Then with ground reference the augmented matrix $Y_{bus,\ aug}$ of nodal matrix would be

$$Y_{bus,\ aug} = \begin{pmatrix} y & -y & 0 \\ -y & Y1+y & Y2 \\ 0 & Y3 & Y4 \end{pmatrix} \qquad (2)$$

The given matrix is reduced by applying Kron's reduction formula eliminating all the system except the buses to which generators are connected. For the three phase short circuit fault at the b bus, the row and column corresponding the b^{th} bus are assigned the zero value before applying Kron's formula. In the power system stability analysis these reduced matrices are used to calculate the performance of system before, during and after the fault.

Power output of the each generating unit can be calculated by the following expression

$$P_{out} = E_{i2}G_{ii} + \sum E_i E_j Y_{ij} \cos(Ø_{ij} - \delta_i + \delta_j) \quad (3)$$

Where,

$$Y_{ij} = Y_{ij} < Ø_{ij} = G_{ij} + j\,B_{ij}$$

$$Y_{ii} = Y_{ii} < Ø_{ii} = G_{ii} + j\,B_{ii}$$

The equation governing the dynamics of power system is given by

$$\frac{2Hidwi}{wRdt} + D_i W_i = P_{mi} - [E_{i2}G_{ii} + \sum E_i E_j Y_{ij} \cos(Ø_{ij} - \delta_i + \delta_j)] \quad (4)$$

And

$$\frac{d\delta}{dt} = w_i - w_R \qquad (6)$$

It should be pointed that before the fault (t=0) $P_{mi0} = P_{out0}$. The subscript 0 represents the initial condition.

When the network conditions change due to the fault, the corresponding variables would be changed in above expressions.

III. SIMULINK MODELING OF POWER SYSTEM

Since the entire system is consist of four generating units. In the simulink model 250 MW generating unit is simulated separately, while remaining three units of 210MW are simulated as a one whole unit of 630 MW for simplification in modeling and analysis as shown in figure 03.

We can see in Figure 03 that two generating units are connected in parallel and to the load centre through a long 500kV, 200 Km transmission line. The load center is modeled by a 5000 MW resistive load showing equivalent load of Dadu Grid Station. To maintain system stability after faults, the transmission line is sectionalized at its center. The fault has been simulated near the bus one and fault is cleared by opening the fault breaker. As we can see from the Figure 03 that there is stop, which stops the power flow and line voltage of the lines, when the synchronism is lost

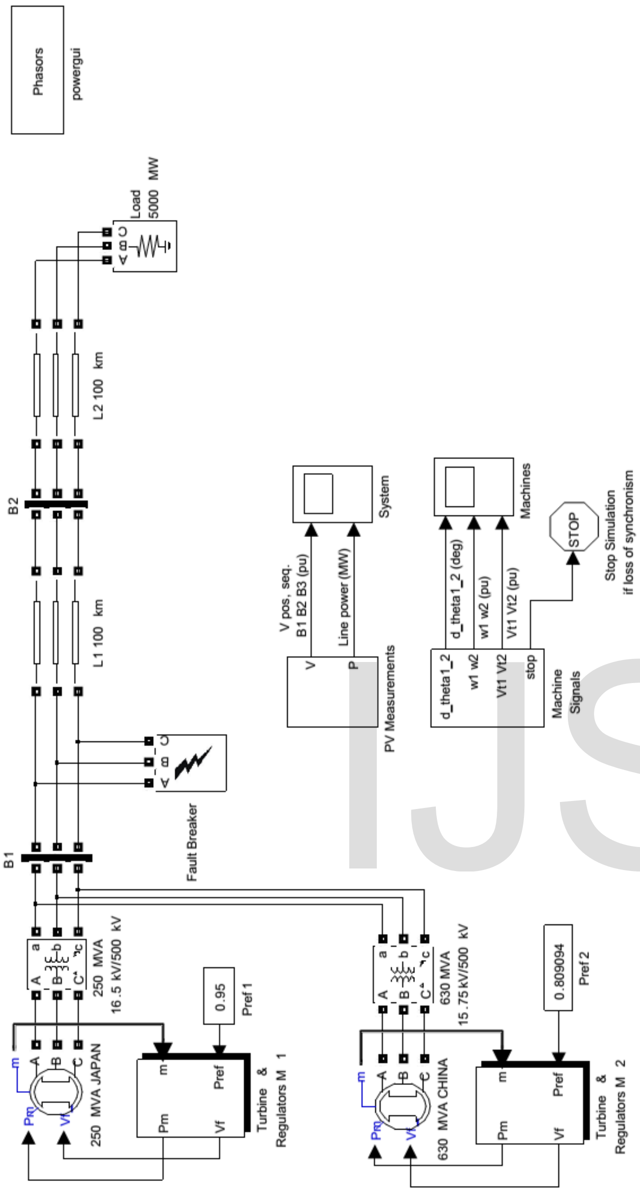

Figure.03. Simulink Model of Jamshoro Thermal power station

IV. SIMULINK RESULTS

Different system responses are given, which shows their condition before and after the fault. When the fault has been cleared, the 0.6 Hz oscillation is immediately damped out. This oscillation mode is normally the part of inter area oscillations in a large electrical power system. First variable on the scope of machines shows the rotor angle difference (d_theta1_2) between the two machines. Maximum power would be transferred when this difference reaches around 90 degrees. This condition is an indication of system stability. If difference between the angles exceeds 90 degrees for so long a period of time, the machines will lose synchronism and the system becomes unstable. Second variable on the scope shows speeds of the machines. Notice that machine1 speed increases during the fault because during that period its electrical power is lower than its mechanical power as shown in Figure 05. By simulating over a long period of time (5 cycles) we will also notice that the speeds of the machines oscillate together at a low frequency of about 0.025 Hz after the fault has been cleared by fault breaker as shown in Figure 05. The fault near the bus 1 is continued for one cycle (50sec), and then cut off by the fault breaker

Figure 04 shows the position of line power. Since before the fault, the power in all the phases is according to the line, but when the fault occurs at 0.2 sec, there is shooting up in the power, which is continued until the fault is sustained. At the interval of 1 sec, the fault is removed by the fault breaker and again the line power is normalized after the fault.

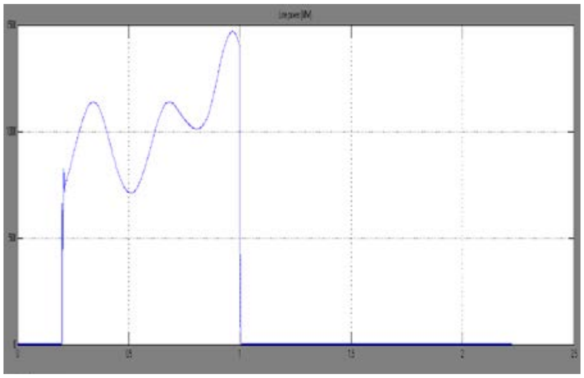

Figure.04. Simulation of Line Power before and after fault

Figure 05 shows the rotor angle positions for two generating units. From the figure 04 we can see that before the fault the rotor angles are at steady state position, but when fault occurs at 0.2 sec of supply frequency, then rotors angles slightly increased up, but when the fault removed by circuit breaker at 1sec, then both the rotor angles, continuously goes on increasing and hence finally the synchronism is lost and system is shut down by stop function shown in figure 03, which is set to cut off at 5sec of supply frequency.

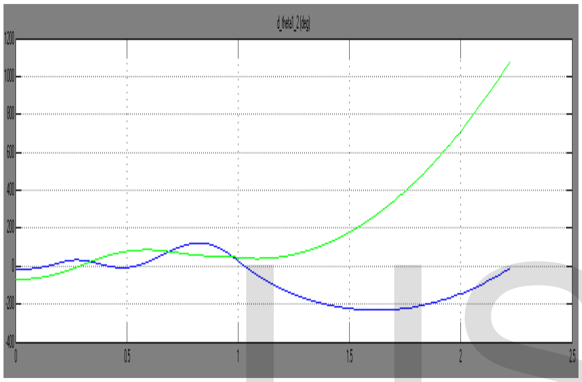

Figure.05. Simulation showing the different rotor angle positions for two generating units

Figure 06 represents the difference between the rotor angle positions of two generating units. From Figure 06 we can see that there is a big difference between the rotor angles before the fault and during the fault, it is somewhat increasing and after the fault the difference goes on decreasing and become zero when synchronism is lost.

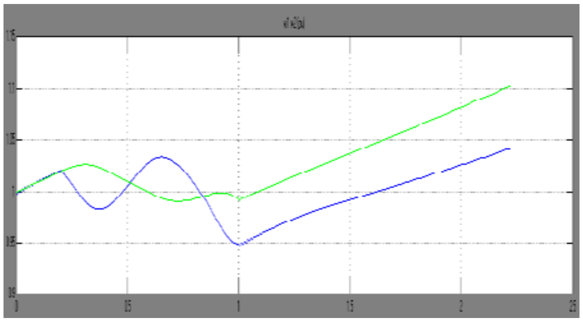

Figure.07. Simulation of Speeds of two generating units

Figure 08 represents the generated voltage of two generating units. From Figure 08 we can see that before the fault, the generated voltages of two units are at their designated value. When the fault occurs at 0.2 sec of the supply frequency, the voltages of units shoots up and after the interval of 1sec when the fault is cleared, then voltages of two units try to stabilize but due the loss of synchronism the frequency at which the voltages of two machines oscillates becomes and voltages are linearized at some value.

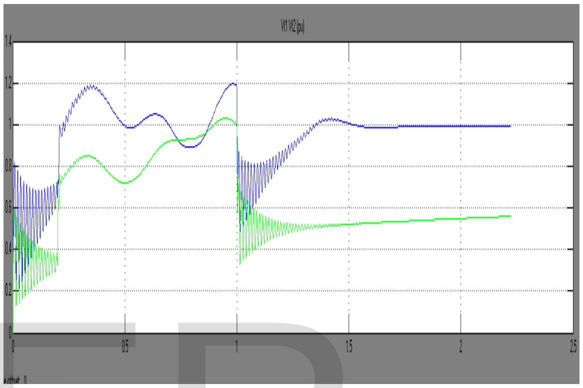

Figure.08. Simulation of Voltages of two generating units

CONCLUSION

In this paper we have simulated the power system stability of Jamshoro Thermal Power Station. We have seen that after the fault the system is unable to maintain its stability, as the rotor angles and speeds of the generating units goes on increasing after the fault and at last the system lost its stability. This system is naturally unstable without power system stabilizers (PSS). If you remove the fault (by deselecting phase A in the Fault Breaker) ,you will see the instability slowly building up at approximately 1 Hz after a few seconds. So to make the system to maintain its stability after the fault we should design such controller which cause the rotor angles to decrease after reaching the maximum critical value and also the controller should be designed in such a way that the fault should be cleared before reaching the critical clearing time.

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Appendix

```
n=12;
Y=zeros(k);
k=k-1;
i=1;
b=1;
forii=1:locs;
add=loc(ii+1)-loc(ii);
forbb=1:add;
L=c(b);
Y(i,i)=Y(i,i)+1/e(b);
ifL==0;
disp('branch')
b=b+1;
else
Y(L,L)=Y(L,L) +1/e(b);
Y(i,L)=Y(i,L) -1/e(b);
Y(L,i)=Y(i,L);
b=b+1;
end
end
i=i+1;
end
Y
```

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