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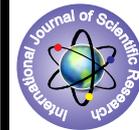
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# Analysis Of Power Transients In Transmission Devices For Stable Operation



## Engineering

KEYWORDS :

Sunil Kumar Mahapatro

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### ABSTRACT

Power industries worldwide move toward deregulation and competition. At the same time, electrical power systems are becoming more complicated. Even short interruptions in electrical supply can lead to serious consequences. The concept of AC Transmission devices technology has the ability to deal with many fields of both system and customer problems, where the power control can solve many of these problems with enhancing the quality of the performance. The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. Power-system stability is a term applied to alternating-current electric power systems, denoting a condition in which the various synchronous machines of the system remain in synchronism, or "in step," with each other. Fault occurrence in a power system is due to transients. In this paper, an approach has been done to stabilize the system load flow analysis. The transients have been analyzed and have obtained a better result in a simple approach.

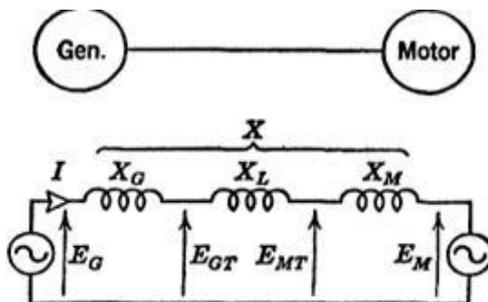
### Introduction:

The purpose of a power system is to transport and distribute the electrical energy generated in the power plants to the consumers in a safe and reliable way. Aluminium and copper conductors are used to carry the current, transformers are used to bring the electrical energy to the appropriate voltage level, and generators are used to take care of the conversion of mechanical energy into electrical energy. Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. Transient signals are one of the cause of instability. Transients occur when there is a sudden change in the voltage or the current in a power system. Transients are short-duration events, the characteristics of which are predominantly determined by the resistance, inductance, and capacitance of the power system network at the point of interest. Many different terms are associated with transients, such as spikes, bumps, power, pulses, impulses, and surges. While some of these terms may indeed describe a particular transient, such terms are not recommended due to their ambiguity. In this work analysis of power transients has been attempted.

### CAUSES OF TRANSIENTS:

Transients are disturbances that occur for a very short duration (less than a cycle), and the electrical circuit is quickly restored to original operation provided no damage has occurred due to the transient. An electrical transient is a cause-and-effect phenomenon. For transients to occur there must be a cause. While they may be many, this section will look at some of the more common causes of transients:

- Atmospheric phenomena (lightning, solar flares, geomagnetic disturbances)
- Switching loads on or off
- Interruption of fault currents
- Switching of power lines
- Switching of capacitor banks



(Fig-1: Simple two machine power system)

### Stability:

The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. With interconnected systems continually growing in size and extending over vast geographical regions, it is becoming increasingly more difficult to maintain synchronism between various parts of the power system. Random changes in load are taking place at all times, with subsequent adjustments of generation. If the oscillatory response of a power system during the transient period following a disturbance is damped and the system settles in a finite time to a new steady operating condition, we say the system is stable. If the system is not stable, it is considered unstable. This primitive definition of stability requires that the system oscillations be damped. This condition is sometimes called asymptotic stability and means that the system contains inherent forces that tend to reduce oscillations. This is a desirable feature in many systems and is considered necessary for power systems. The definition also excludes continuous oscillation from the family of stable systems, although oscillators are stable in a mathematical sense. The reason is practical since a continually oscillating system would be undesirable for both the supplier and the user of electric power.

Successful operation of a power system depends largely on the engineer's ability to provide reliable and uninterrupted service to the loads. The reliability of the power supply implies much more than merely being available. Ideally, the loads must be fed at constant voltage and frequency at all times. The first requirement of reliable service is to keep the synchronous generators running in parallel and with adequate capacity to meet the load demand. Synchronous machines do not easily fall out of step under normal conditions.

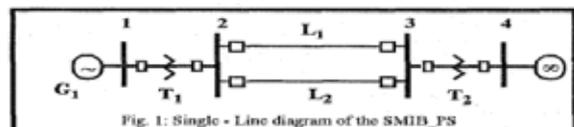


Fig. 1: Single-Line diagram of the SMIB\_PS

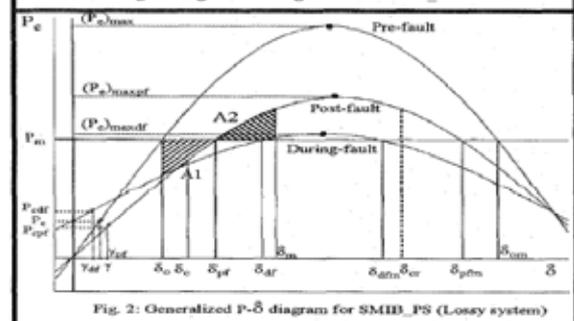


Fig. 2: Generalized P-δ diagram for SMIB\_PS (Lossy system)

(Fig-2: Condition showing fault in the transmission line and its effects on the swing equation.)

**TRANSIENT STABILITY ANALYSIS: A COMPUTING CHALLENGE**

Transient stability analysis is concerned with the electrical distribution network, electrical loads and the electro-mechanical equations of motion of the interconnected generators. Traditionally, power system transient stability analysis has been performed off-line to understand the system's ability to withstand specific disturbances and the system's response characteristics, such as damping of generator oscillations, as a system returns to normal operation. To date the computational complexity of transient stability problems have kept those from being run in real time to support the decision making at the time of a disturbance. If the transient stability program could run in a faster than real time then power system control room operators could be provided.

The linear design method considers only one particular operating point. Once the system operation point is varied, the controller parameters must be adjusted. Particularly in recent years, with the deregulation of the electricity market, the operating point of power system may be varied frequently to meet the needs according to power purchase contract. Therefore, the FACTS controllers must also be capable of being modified to incorporate with the new operating point. In recent years, energy, environment, right-of-way, and cost problems have delayed the

construction of both generation facilities and new transmission lines, while the demand for electric power has continued to grow. This situation has necessitated a review of the traditional power system concepts and practices to achieve greater operating flexibility and better utilization of existing power systems.

**STEADY STATE STABILITY**

The ability of power system to remain its synchronism and returns to its original state when subjected to small disturbances. Such stability is not affected by any control efforts such as voltage regulators or governor.

**Analysis of steady-state stability by swing equation**

- starting from swing equation

$$\frac{H}{\pi f_0} \frac{d^2\delta}{dt^2} = P_{m(pu)} - P_{e(pu)} = P_m - P_{max} \sin \delta \quad P_s = \left. \frac{dP}{d\delta} \right|_{\delta_0} = P_{max} \cos \delta_0$$

- introduce a small disturbance  $\Delta\delta$
- derivation is from  $\delta = \delta_0 + \Delta\delta$
- simplify the nonlinear function of power angle  $\delta$
- Analysis of steady-state stability by swing equation
- swing equation in terms of  $\Delta\delta$

$$\frac{H}{\pi f_0} \frac{d^2\Delta\delta}{dt^2} + P_m \cos \delta_0 \Delta\delta = 0$$

- PS =  $P_{max} \cos \delta_0$ : the slope of the power-angle curve at  $\delta_0$ , PS is positive when  $00 < \delta < 90$
- the second order differential equation

$$\frac{H}{\pi f_0} \frac{d^2\Delta\delta}{dt^2} + P_s \Delta\delta = 0$$

- Characteristic equation:

$$s^2 = -\frac{\pi f_0}{H} P_s$$

rule 1: if PS is negative, one root is in RHP and system is unstable

rule 2: if PS is positive, two roots in the  $j\omega$  axis and motion is oscillatory and undamped, system is marginally stable

The oscillatory frequency of the un-damped system. We have used Euler modified method. The swing equation can be transformed into state variable form as

$$\frac{d\delta}{dt} = \Delta\omega$$

$$\frac{d\Delta\omega}{dt} = \frac{\pi f_0}{H} P_a$$

We now apply modified Euler's method to the above equations as below

$$\frac{d\delta}{dt} \Big|_{\Delta\omega_{i+1}} = \Delta\omega_{i+1}, \text{ where } \Delta\omega_{i+1} = \Delta\omega_i + \frac{d\Delta\omega}{dt} \Big|_{\delta_i} \Delta t$$

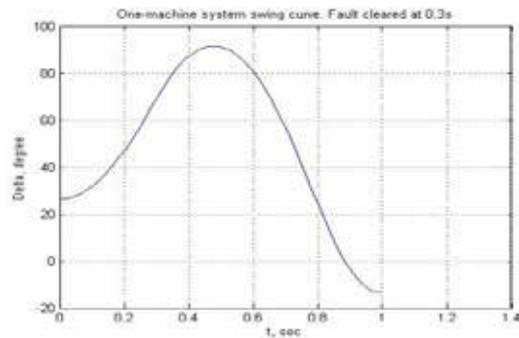
$$\frac{d\Delta\omega}{dt} \Big|_{\delta_{i+1}} = \frac{\pi f_0}{H} P_a \Big|_{\delta_{i+1}} \text{ where } \delta_{i+1} = \delta_i + \frac{d\delta}{dt} \Big|_{\Delta\omega_i} \Delta t$$

Then the average value of the two derivatives is used to find the corrected values.

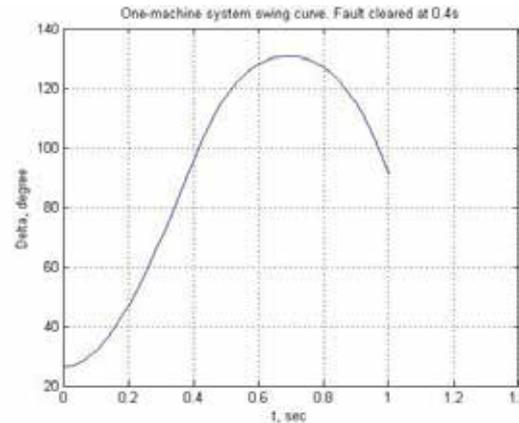
$$\delta_{i+1}^c = \delta_i + \left( \frac{\frac{d\delta}{dt} \Big|_{\Delta\omega_i} + \frac{d\delta}{dt} \Big|_{\Delta\omega_{i+1}}}{2} \right) \Delta t, \text{ where } \Delta\omega_{i+1}^c = \Delta\omega_i + \left( \frac{\frac{d\Delta\omega}{dt} \Big|_{\delta_i} + \frac{d\Delta\omega}{dt} \Big|_{\delta_{i+1}}}{2} \right) \Delta t$$

This is illustrated in the following design.

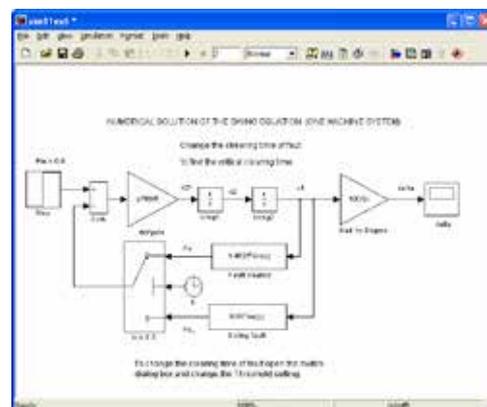
**Result :**



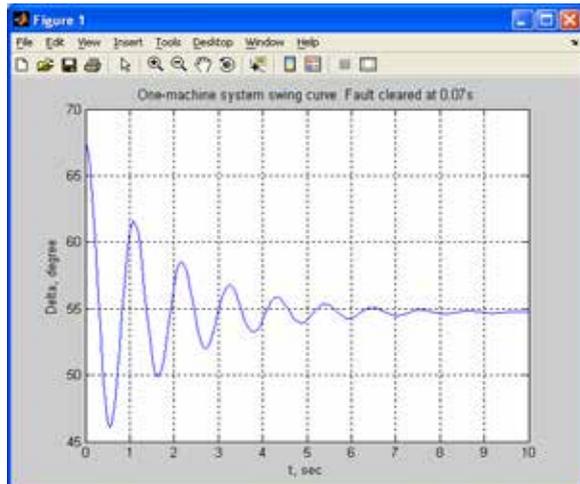
(Fig-3: Swing Curve using Modified Euler Method for fault cleared at 0.3s)



(Fig-4: Swing Curve using Modified Euler Method for fault cleared at 0.4s)



(Fig-5: Numerical solution of the swing equation(one machine system))



(Fig-6: One machine system swing curve-Fault cleared at 0.07s)

Conclusion: In this way we have analysed the stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance.

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