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Analysis of Power System Network Using Step by Step Method

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Abstract

The power system network can be analyzed based on the solution of swing equation. In case of a Synchronous generator connected to an infinite bus bar, the solution of swing equation can be determined by Elliptical Integral method. However, a graphical technique known as Equal Area Criterion Technique can be used to determine the solution of Swing equation for Two Machine System where a Synchronous Generator is connected to Synchronous Motor. In practice, most of the power system networks consist of Multi Machine System where the solution of swing equation can be determined by Step-by-Step method.

Keywords: Power System Network, Step by Step method and Critical Clearing Angle

INTRODUCTION

In large power networks, transient disturbances such as three-phase faults, sudden load changes, or generator tripping can lead to instability in multi-machine systems. The challenge lies in analysing the ability of the interconnected generators to maintain synchronism during and after such disturbances [1]. The primary objective of analysing transient stability in multi-machine systems using MATLAB is to assess the ability of the system to maintain synchronism during and after large disturbances. This involves simulating scenarios such as faults, sudden load changes, or generator tripping, and evaluating the system's response. Ensuring transient stability is critical for preventing cascading failures that can lead to widespread power outages and disruptions [2].

Transient stability refers to the system's ability to maintain synchronism when subjected to sudden and large disturbances like faults, line outages, or generator trips[3]. Transient Stability is a fast-occurring phenomenon that happens within seconds of a disturbance. In multi-machine systems, multiple generators are interconnected. The goal is to evaluate whether the system remains stable or becomes unstable after a three-phase fault and how Critical Clearing Time (CCT) affects system behaviour[4]. The study uses simulation tools to examine machine rotor angle deviations (swing curves) to determine stability. The system is modelled as a three-generator setup.

This focuses on transient stability in power systems—how a power grid behaves after major disturbances (like faults or line failures) and whether it can return to normal operation. Single Machine System: A generator connected to a large power network (called an "infinite bus").MATLAB was used to simulate different fault clearing times (e.g., 0.125s vs. 0.5s).Longer fault clearing times led to instability. Multi-Machine System: A 3-generator, 6-bus power system was modelled[5].

MATHEMATICAL MODELLING

The following are the methods generally employed for analysing transient stability for multi-machine power systems.

1. Equal area Criterion.
2. Solution of swing equation

Equal Area Criterion is a graphical method for determination of transient stability and is used for either single machine infinite bus systems or two finite systems. It involves errors since this method is graphical.

Multi-machine systems transient stability is analysed mostly by solving its swing equation for the machines and algebraic equations for the network by adopting suitable numerical method. The transient stability analysis requires the solution of a system of coupled non-linear differential equations. In general, no analytical solution of these equations exists. However, techniques are available to obtain approximate solution of such differential equations by numerical methods and one must therefore resort to numerical computation techniques commonly known as digital simulation. Some of the commonly used numerical techniques for the solution of the swing equation are:

- Point by point method
- Euler modified method
- Runge-Kutta method

The point-by-point method is used for the solution of critical clearing time associated with critical clearing angle and also for the solution of multi-machine system. The step-by-step of point-by-point method is the conventional, approximate but proven method. This involves the calculation of the rotor angle as time is incremented. The accuracy of the solution depends upon the time increment used in the analysis.

Euler's Method is a numerical technique for solving differential equations step-by-step over time. In power systems, we use it to simulate how generator rotor angles and speeds change after a disturbance, such as a short circuit. In a multi-machine system (with more than one generator), we want to:

- Track the rotor angle of each generator (δ)
- See if generators stay in synchronism (i.e., swing together)
- If they go out of sync, the system is unstable

The Runge-Kutta method is a powerful and accurate numerical technique for solving ordinary differential equations (ODEs).In power systems, we use it to simulate how generators behave (especially rotor angles and speeds) after a disturbance like a fault. It's widely used in multi-machine systems because it provides higher accuracy than basic methods like Euler's.

Power system stability is a subject of great interest to power system planners and operations in recent times. In practical power systems, it is expected that power generation must be equal to power demand including losses to ensure constant speed and frequency of operation. Successful operation of a power system depends largely on the engineer's ability to provide reliable and interrupted service to the load.

REALIZATION OF PROPOSED METHOD

Infinite Grid

An infinite grid is a theoretical power system that has constant voltage magnitude and frequency, regardless of how much power is drawn from or supplied to it. An infinite grid is an idealized power source that:

- Maintains a constant voltage (magnitude and phase)
- Maintains a constant frequency (usually 50 Hz or 60 Hz)
- Has infinite capacity to absorb or supply active and reactive power without any change in its operating conditions.

Specifications

Phase-to-Phase Voltage: 230kV
Frequency: 50Hz
Source inductance: 16.58Mh

Circuit Breakers

A circuit breaker is a switching device designed to interrupt the flow of electrical current during abnormal conditions (like faults) and reconnect the system once it's safe.

- CB1 and CB2 are placed on key transmission lines
- Used to simulate line switching, fault isolation, or transient events

The specifications of the circuit breaker used in the system are tabulated as follows:

Table 1: Specifications of Circuit Breakers

Specification	Circuit Breaker-1	Circuit Breaker-2
Breaker Resistance	0.01Ω	0.01Ω
Snubber Resistance	1MΩ	1MΩ
Snubber Capacitance	Infinite	Infinite

CONCLUSION

The power system stability problem is considered and effective ideas are introduce for efficient analysis of power system behaviour for various types of operating condition. The result is occurring fault between generator and infinite bus can be fully protected by using point-by-point method. Through analysis it can be determined whether the system is stable or unstable for a particular fault clearing time when subjected to a three phase fault. It can be seen from the phase angle characteristic that the relative swing between the generator phase angles is less when the fault clearing time is less. In order for the system to be unstable the fault should be cleared within minimum time for system stability.

Declaration of Conflicting Interests

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