Journal of Advances in Science and Technology

Vol. VII, Issue No. XIII, May-2014, ISSN 2230-9659

STABILITY MODELLING AND RESEARCH STRATEGIES OF POWER SYSTEMS

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

www.ignited.in

Journal of Advances in Science and Technology
Vol. VII, Issue No. XIII, May-2014, ISSN 2230-9659

Stability Modelling and Research Strategies of Power Systems

Farah Diba[1] Lokesh Kumar[2]

[1]Bachelor of Technology Final Year Student

[2]Assistant Professor, Sityog Institute of Technology Aurangabad, Bihar

Abstract – In recent year, electric power demand has increased drastically due to superiority of electric energy to all other forms of energy and the expansion of power generation and transmission has been severely limited sequel to limited resources, environmental restrictions and lack of privatization as can be found in the developing countries.

After nearly four decades of research in power system stability via Lyapunov or energy functions, the method is now on the verge of being implemented for assessment of on-line dynamic security. The main bottleneck has been in the proper characterization of the stability boundary and defining the fault-dependent region of attraction locally around the controlling unstable equilibrium points. Now there is a better understanding of this issue and, hence, a number of algorithms have been proposed. Improved generating unit models and transmission network models are now being included in the technique.

---------------------------♦-----------------------------

INTRODUCTION

A Power System is predominantly in steady state operation or in a state that could with sufficient accuracy be regarded as steady state. In a power system there are always small load changes, switching actions, and other transients occurring so that in a strict mathematical sense most of the variables are varying with the time. However, these variations are most of the time so small that an algebraic, i.e. not time varying model of the power system is justified.

A short circuit in a power system is clearly not a steady state condition. Such an event can start a variety of different dynamic phenomena in the system, and to study these dynamic models are needed. However, when it comes to calculate the fault currents in the system, steady state (static) models with appropriate parameter values can be used. A fault current consists of two components, a transient part, and a steady state part, but since the transient part can be estimated from the steady state one, fault current analysis is commonly restricted to the calculation of the steady state fault currents.

The ongoing evolution of the electric power systems due to market liberalization and the integration of distributed generation is leading to increasingly complex and hard-to-predict interactions of technical components, relevant actors and the operating environments. Furthermore, recent large-area blackouts in North America and Europe demonstrated the potential consequences of inadequate operator response times to contingencies.

In recent years several advanced methods have been developed to assess the reliability of electric power systems in general and to model and analyze cascading blackouts. However, these approaches do not explicitly simulate the evolution of the events in time and represent the operator intervention to contingencies by using highly simplified models not taking into account the time needed for the corrective action. While Anghel et al. introduce a time-dependent probabilistic approach incorporating a model for the utility response to line overloads, the influence of the response time on the occurrence of cascading line outages remains neglected.

Various well documented tools are available to engineers for power system modelling and analysis. This chapter will describe the fundamental techniques required to complete studies on the stability of power systems including HVDC systems. Within this chapter, models are presented for all of the main components of electrical power systems, including synchronous generators, excitation systems, power system stabilisers, power transformers, transmission lines, systems loads and the electrical network. The modelling technique used to handle the time delays associated with wide area signals is also given. Following this, the techniques used to represent the HVDC system for power system stability analysis are presented, including relevant control schemes and converter controllers. The methods of modelling HVDC lines and multi-terminal HVDC grids are also provided.

An interconnected power system consists of generating units run by prime-movers (including turbine-governor and excitation control systems) plus transmission lines, loads, transformers, static reactive compensators, and high-voltage direct-current lines. The size of the interconnection varies depending on the system but the technical problems are the same. At the planning level, the planner would invariably study the stability of the system for a set of disturbances ranging from a three-phase-to-ground fault (whose probability of occurrence is rare) to single-phase faults, which constitute about 70 percent of the disturbances. The planner desires to determine if a potential fault has an adequate margin of safety without the system losing synchronism. A system is said to be synchronously stable (i.e., retain synchronism) for a given fault if the system variables settle down to some steady-state values as time approaches infinity after the fault is removed.

These simulation studies are called *transient stabiliry studies.* A typical transient stability study with detailed modeling for a 500-bus, 100-machine system might take up to an hour. Hence, the planner is limited to a few likely scenarios of fault occurrences.

POWER FLOW ANALYSIS

It is of utmost importance to be able to calculate the voltages and currents that different parts of the power system are exposed to. This is essential not only in order to design the different power system components such as generators, lines, transformers, shunt elements, etc. so that these can withstand the stresses they are exposed to during steady state operation without any risk of damages. Furthermore, for an economical operation of the system the losses should be kept at a low value taking various constraints into account, and the risk that the system enters into unstable modes of operation must be supervised. In order to do this in a satisfactory way the state of the system, i.e. all (complex) voltages of all nodes in the system, must be known. With these known, all currents, and hence all active and reactive power flows can be calculated, and other relevant quantities can be calculated in the system.

Generally the power flow, or load flow, problem is formulated as a nonlinear set of equations

$$f(x, u, p) = 0$$

where

f is an n-dimensional (non-linear) function

x is an n-dimensional vector containing the state variables, or states, as components. These are the unknown voltage magnitudes and voltage angles of nodes in the system u is a vector with (known) control outputs, e.g. voltages at generators with voltage control p is a vector with the parameters of the network components, e.g. line reactance's and resistances

The power flow problem consists in formulating the equations f in eq. and then solving these with respect to x. This will be the subject dealt with in the first part of these lectures. A necessary condition for eq. to have a physically meaningful solution is that f and x have the same dimension, i.e. that we have the same number of unknowns as equations. But in the general case there is no unique solution, and there are also cases when no solution exists.

MODELING FRAMEWORK

The conceptual modeling framework consists in the abstraction of the relevant technical and non-technical components of the electric power system as individual interacting objects. Each object is modeled by attributes and rules of behavior. An example for an attribute is a technical component constraint such as the rating of a transmission line. The rules of behavior are represented by using finite state machines (FSM) and include both deterministic and stochastic time-dependent, discrete events. A deterministic event is, for instance, the outage of a component when reaching a failure threshold, while stochastic processes are probabilistic component failure models using Monte Carlo techniques. The integration of nontechnical components is demonstrated by modeling the behavior of the grid operators in case of line overloads.

For the corresponding interactions between the operators and the technical components we make use of agent-based modeling techniques. Furthermore, we account for the possible division of the power system into several control areas. To each control area a distinct grid operator and a distinct control object are assigned. The control object is not an abstraction of a technical component as such but rather represents an implementation construct which controls the balance between generation and load within the corresponding control area.

MODELLING POWER SYSTEM COMPONENTS

Within this section, the models of all main power system components are presented. These models have been used throughout the research to provide the simulation results presented later. The power system, and all included components, are modelled using an orthogonal phase representation, under the assumption that all three phases are balanced .

Synchronous Generators - The synchronous generator is the fundamental source of energy within modern electrical power networks, and can be modelled with varying levels of complexity. Two different synchronous generator models are used within this research, a sixth order model including leakage reactance, and a fifth order model neglecting leakage reactance.

Generator Excitation Systems - Generators are reliant on excitation systems to provide direct current to the synchronous machine field winding. Furthermore, through controlling the field voltage E_{fd} (and therefore the field current), the excitation system is able to contribute towards maintaining power system stability. This control is provided by the AVR, which manipulates the field voltage in order to reach the generator stator terminal voltage reference set-point, E_t^{ref}, and to ensure the first-swing stability of the machine. A power system stabiliser may also be included in order to reduce rotor speed variations following disturbances. The functional relationship between the synchronous generator, excitation system, and PSS (if included) is shown in Fig. 1.

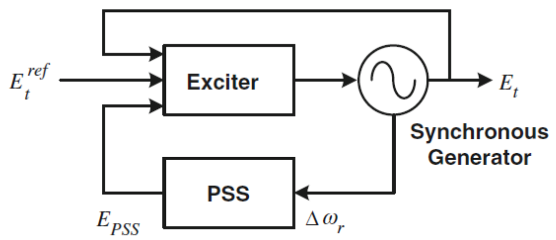

Fig. 1 Relationship and signals between the synchronous generator, excitation system, and power system stabilizer.

Transmission Lines - Throughout the work presented within this research, transmission lines are modeled using a lumped parameter model and the common p-representation. The lines are assumed to be short enough that this approach is applicable and that more complex p-section or distributed parameter representation is not required.

FAULT ANALYSIS

So FAR we have dealt with steady state behavior of power systems under normal operating conditions. This chapter is devoted to abnormal system behavior under conditions of faults. Such conditions are caused in the system accidentally through insulation failure of equipment or flashover of lines initiated by a lightning stroke or through accidental faulty operation.

In high voltage networks, short circuits are the most frequent type of faults. Short circuits may be solid or may involve an arc impedance. Figure 2 illustrates different types of short circuits.

Depending on the location, the type, the duration, and the system grounding short circuits may lead to

- Electromagnetic interference with conductors in the vicinity (disturbance of communication lines),
- Stability problems,
- Mechanical and thermal stress (i.e. damage of equipment, personal danger)
- Danger for personnel

The system must be protected against flow of heavy short circuit currents by disconnecting the faulty part of the system by means of circuit breakers operated by protective relaying. The safe disconnection can only be guaranteed

if the current does not exceed the capability of the circuit breaker.

Therefore, the short circuit currents in the network must be computed and compared with the ratings of the circuit breakers at regular intervals as part of the normal operation planning. The short circuit currents at network nodes are generally increasing over the years due to

- More generators,
- New lines in existing networks,
- Interconnection of isolated networks to an integrated one.

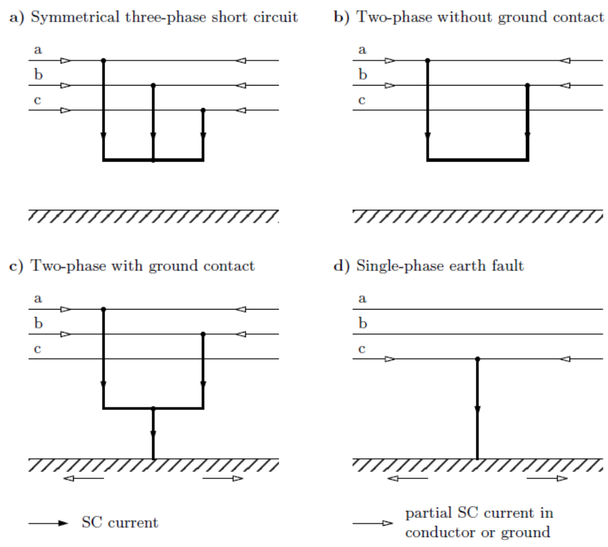

Figure 2. Examples for different types of short circuits.

Farah Diba[1] Lokesh Kumar[2]

This is primarily a problem for the expansion planning, where the impacts of long-term changes on the short circuit currents have to be assessed. If the short circuit current exceeds the admissible limit at a network node, the circuit breakers have to be replaced by breakers with higher ratings. Alternatively, the impedance between feeder and fault location can be increased in order to reduce the short circuit current.

CONCLUSION

Perhaps do other area in power engineering has brought control and power engineers together as in the case of power system stability. This is a healthy sign since both tend to benefit in the long run. What are the future issues? Dynamic security assessment (DSA) is far from being a reality. Taking the same time frame as in the case of steady-state security assessment, one can put DSA as being part of the Energy Management System software by the late 1990s.

The way in which non-linear power system models can be linearised in order to conduct small-disturbance stability analysis was then discussed. The modal analysis techniques introduced then formed the basis of the linear POD controller designs. The two controller structures described in this chapter will be used throughout the research and their impact on system stability and performance in the presence of uncertainties will be assessed. Finally, the test networks used throughout this research have been introduced.

The chosen level of modeling detail allows analyzing a multitude of different (time-dependent) reliability aspects such as the identification of weak points and the assessment of system upgrades. Although several model refinements need to be further developed, the results of the case studies performed on the IEEE RTS-96 and on a model of the Swiss high-voltage grid confirm the applicability of the approach with respect to mid-period power system planning purposes. Optimizing the technical implementation of the models together with the evolution of both hardand software will fasten up the simulation speed.

REFERENCES

- Billinton, R., Li, W., ”Reliability Assessment of Electric Power Systems Using Monte Carlo Methods”, Plenum Press, New York, 1994.
- ‘‘IEEE Recommended Practice for Excitation System Models for Power System Stability Studies,’’ IEEE Std 421.5-2005 (Revision of IEEE Std 421, 5-1992), 2006
- J. Machowski, J.W. Bialek, J.R. Bumby, Power System Dynamics and Stability (John Wiley and Sons, Inc., Chichester, 1997)
- J.H. Chow, J.J. Sanchez-Gasca, R. Haoxing, W. Shaopeng, Power system damping controller design-using multiple input signals. IEEE Control Syst. Mag. 20, 82–90 (2000)
- M. A. Pai, *Power System Stubiliy,* New York: North Holland, 1981
- Swiss Federal Office of Energy, ”Swiss Electricity Statistics 2006” (german), Bern 2007.
- Wood, A. J. and Wollenberg, B. F., ”Power Generation, Operation, and Control”, 2nd ed., John Wiley & Sons, New York, 1996.
- Zima, M. and Andersson, G., ”On security criteria in power systems operation”, Proc. IEEE Power Engineering Society General Meeting, San Francisco, June 2005.