CHAPTER 2

SYSTEM MODELLING

2.1 Introduction

The SIMPOW program system (APPENDIX A) enables modelling of most power system components, some of them with several models with different degrees of details. The models are based on engineering quantities, which are normally available to the user. The system elements can be combined in an arbitrary way. In this chapter, the author would like to introduce the method of representing the existing system for computor simulation study.

2.2 Optimal Power Flow Calculation

This analysis function can be characterized in general terms as static simulation of a power system under symmetrical, steady-state sinusoidal condition. Basically, the power systen is represented by a single phase model, employing positive sequence parameters. The state of the system is given by the complex node voltages, and variable quantities such as turns-ratios and phase shifts of transformers, active and reactive power injections.

Composite active and reactive loads can be represented by power injections proportional to the node voltage raised to an arbitrary exponent; constant power, constant impedance and constant current loads being special cases. Production sources for active and reactive power are modelled by variable injections, and a static var system by a variable susceptance.

Transformers and phase shifters are represented by their admittance polygon equivalent circuit, determined from the short circuit impedances of the windings taken pair-wise, and ideal tranformers with complex turns-ratios. This model allows explicit use of the turns-ratio as a control variable.

Shunt and series reactors and capacitors are represented by their susceptances.

A number of control functions in an AC network can be represented:

(i) The magnitude of a node voltage can be kept on a specified value by a variable reactive power injection, a static var system or a tap-changer of a transformer. The controlled node voltage can be located adjacent to or remote from the controlling device.

(ii) The reactive power through a transformer can be kept on a specified value by it tap-changer and the active power by its phase shifter.

(iii) The controlling variables can be constrained by minimum and maximum limits.

Because one quantity is controlled by another one, These type can be characterized as dedicated control functions.

2.3 Transient Stability Calculation

This analysis function can be characterized in general terms as a dynamic simulation of power system under symmetrical or unsymmetrical, transient condition with emphasis on electromechanical phenomena. A basic assumptiom is then that the electrical state in the AC transmission system is sinusoidal with a frequency close to the nominal one. In this thesis, the simulation under symmetrical condition is used.

For symmetrical conditions, the AC transmission system is represented with the same single phase model that is employed for the power flow calculation, i.e. basically the nodal, positive sequence, admittance matrix. The electrical state is described by the complex, positive sequence node voltages, with their magnitudes and phase angle varying with time. Currents, active and reactive powers in the network and to system elements connected at the nodes become functions of these state variables.

The simulation time of a transient stability calculation is normally less than ten seconds, and , therefore, slow control devices, e.g. LTC of transformers and phase shifters, are assumed to be constant. Thus, the modelling of the AC transmission system is reduced to its nodal admittance matrices for the positive sequence modes, i.e. it can be characterized as a static jw-model described by algebraic equations. The electrical state is described by the time varying, complex phase voltages, or their positive sequence components. Currents, active and reactive powers are functions of these state variables.

Static, composite loads are represented in the same way as for the power flow calculation, supplemented by an exponential frequency dependence, which may significantly influence the damping properties.

Except for the transmission system elements and the static loads, the remaining system components are represented by dynamic models, described by differential equation. The fundamental electromechanical dynamics are defined by the equation of motion of each rotating machine:

$$J \frac{dw}{dt} = T_m - T_e \qquad \ldots\ldots\ (1)$$

where

w is the angular speed of the roter
J is the moment of inertia
T_m is the mechanical torque on the rotor shaft
T_e is the electrical torque on the rotor shaft

The electrical torque, basically created by electromagnetic forces,can be determined with different degree of accuracy by a number of models of rotating machines for optional use. They are based on the well-known Park's transformation [ref 30] and the state is described by the speed and angle of the rotor, the dqo-components of the terminal voltages and the magnetic fluxes. The currents are dependent variables In transform, induced e.m.f. is disregarded, which is consistent with the basic assumption of the electrical state in the system being sinusoidal. In this thesis, a machine model without magnetic saturation model is used.

Static Var System (SVS) are finding increasing application for voltage control in transmission system. An SVS is modelled by a susceptance in the same manner as for a power flow calculation, but varying within its limits depending on the control performed by the voltage regulator of the SVS. Transfer functions of the P, I, PI and PID types can be represented.

2.4 System Network

The schematic diagram of system used in this thesis is shown in Figure A1.2 . The system consist of a large network connected through a step-down transformer, 115 kV/22 kV, a double circuit long distribution line, a composite load and large induction motors connected through a step-down transformer, 22 kV/3.15 kV.

Syetem parameters used in computer simulation are list as follow

Generation bus: Infinite Bus
Transformer 1: 25 MVA 115/22kV EX12 = 0.08pu.
line 1: R_1=0.04211pu. X_1=X_2=0.26764pu. R_0=0.13793pu. X_0=2.31576pu.
line 2: R_1=0.175713pu. X_1=X_2=0.356693pu. R_0=0.471713pu. X_0=2.68893pu.
Transformer 2: 5 MVA 22/3.15kV EX12 = 0.08pu.
Motor : 800kW V_{rated}= 3 kV R_1=0.002837pu. X_{1s}=0.118516pu. X_{2s}=0.02963pu.
X_m=4.96296pu. H=9.25