3. A TRANSIENT STABILITY SIMULATION PACKAGE

3.1 Introduction

Time domain simulation of power systems has been a classical tool for various purposes of stability studies for decades [13,14,15]. Various digital simulation packages [16,17] are in wide use as complementary tools in research. Many other computer softwares are also reported in the literature [18,19,20].

It is felt that every simulation package has its own advantages and shortcomings. A package available to one may not have all the feature and flexibility that one needs. The possibility of changing the capability of the package is often limited if not impossible. With the increased power of micro computers in recent years, there has been a need of a new package that has the capacity of fulfilling most requirements in transient simulation studies of power systems. In answering this call, a transient stability simulation package (TSSP) implemented on an IBM PC has been developed at the University of Saskatchewan. It is written in FORTRAN language. A minimum of 410K conventional memory is required to perform a stability study for a system of 100 buses and a CGA, EGA or VGA graphics card to run the plotting utility. This package has been tested on the WSCC system [8] and the New England Test system. It has been also used to conduct the stability investigations reported in this thesis.

The following is a list of tasks that can be performed with TSSP:

a) Machine modeling of varying complexity

b) Transients of induction motors

c) Modeling of symmetrical and asymmetrical disturbances

d) Various load representations

e) Modeling of AVR, AGC and PSS

f) Interfacing of user-defined modules

e) Load flow studies

g) Short circuit calculations

3.2 Description of Modules within TSSP

The transient behavior of a power component or a controller is modeled by a set of first order differential equations. On the basis of the implicit integration method [10], this set of differential equations can be simulated by building a block of integrators. Each such block forms an independent module to be called upon by a coordinator in TSSP.

TSSP has modules for four different synchronous machine models, one induction motor model, all IEEE recommended excitation system models [5], speed governing and turbine system models [6] and the standard model for a power system stabilizer. Different load models can also be included. For most of the studies, these modules are sufficient. In cases where the module of a component is not available in TSSP, a user-defined module can be written and easily interfaced to the simulation package. Descriptions of the modules provided in TSSP are given in this section.

3.2.1 Machine Modules

As discussed in Chapter 2, a synchronous machine can be modeled with varying complexity. Each machine model is programmed into a module that is designated by a one-digit identifying number as illustrated in Table 3.1. Specifically, modules for the following machine representations are available:

a) Two-axis subtransient model
b) Two-axis transient model
c) One-axis transient model
d) Constant voltage behind $x_d^{'}$ model
e) Infinite-bus
f) Induction motor

The differential equations describing the two-axis subtransient model of a synchronous generator are given by (2.1) ~ (2.5) in Chapter 2. Detailed derivation of these equations is given in Appendix D. A block diagram for this model is also given in Chapter 2. Generation saturation has been taken into account by approximating the open circuit curve of the generator terminal voltage as an exponential function [8] and by modifying the reactances, x_{ad} and x_{aq}, and the three time constants according to (D.33) ~ (D.42), respectively, as illustrated in Appendix D.

A large induction motor is modeled by its transient models.

3.2.2 Modules for Excitation Systems

Any excitation including their nonlinearities can be simulated in TSSP. Modules for all IEEE recommended excitation systems [5] and other three excitation systems given in Chapter 2 are included. Each system is designated by a two-digit model identifying number as shown in Table 3.1. Specifically, the following models are available in the package:

1. The following excitation systems use direct current generators as the source of power supply to the exciters:

   a) DC type 1
   b) DC type 2
   c) DC type 3
   d) DC type 2 modified

2. The following excitation systems use an alternator and either stationary or rotating rectifiers to produce the direct current for the exciters:

   e) AC type 1
   f) AC type 2
   g) AC type 3
   h) AC type 4

3. The following excitation systems use transformers and rectifiers to provide the direct current for the exciters:

   i) ST type 1
   j) ST type 2
   k) ST type 3

4. The following excitation systems are solid state types:
   l) SCRX, Figure 2.4 of Chapter 2
   m) SCRXIL (SCRX with maximum field current limitation)

5. User - defined modules for excitation systems not listed above with the identifying numbers from 51 to 55 can be interfaced into the package.

3.2.3 Modules for Speed Governing and Turbine Systems

Modules of the speed governing and turbine systems for all steam and hydro generator models recommended by IEEE [6] are available in TSSP. Each module is designated by a three-digit identifying number, as per Table 3.1:

1. For steam turbine systems, they are:
   A) speed governing and turbine system for Non-Reheat configuration (NR)
   B) speed governing and turbine system for Tandem-Compound, Single-Reheat configuration (TCSR)
   C) speed governing and turbine system for Tandem-Compound, Double-Reheat configuration (TCDR)
   D) speed governing and turbine system for Cross-Compound, Single-Reheat configuration A (CCSR-A)
   E) speed governing and turbine system for Cross-Compound, Single-Reheat configuration B (CCSR-B)
   F) speed governing and turbine system for Cross-Compound, Double-Reheat configuration (CCDR)
2. For hydro turbine systems, they are:

   A) Speed governing and hydro turbine system with a detailed representation
   B) Speed governing and hydro turbine system with a simplified representation
3. User - defined modules for speed governing and turbine systems not listed above with the identifying numbers from 231 to 235 can be interfaced into the package.

3.2.4 Modules for Power system stabilizers

Modules for the two specific PSS models, i.e., IEEESN and IEEEST, utilized in the studies reported in this thesis and one IEEE standard model [5] utilized to design new PSSs are incorporated in TSSP. The block diagrams of these models are given in Chapter 2. For each PSS module, different input signals can be chosen by specifying the corresponding identifying numbers as listed in Table 3.1.

1. Available modules are:
   A) IEEESN
   B) IEEEST
   C) IEEE standard

2. User - defined modules for PSSs not listed above with the identifying numbers from 51 to 55 can be interfaced into the package.

3.2.5 Disturbances

Special attention is given to the modeling of various disturbances, as they are significant in influencing the stability of a system. To conduct a stability study, a disturbance, small or large, symmetrical or not, must be created and applied to the system under study. The common practice is that a symmetrical disturbance such as three phase fault is used as the most severe disturbance under certain operating conditions. The stability margin obtained under such a fault is quite conservative and pessimistic. Moreover, the frequency of occurrence of such disturbances is much lower than that of asymmetrical ones such as single phase faults. Therefore, it is desirable to conduct transient stability investigations under asymmetrical disturbances at planning and operation stages.

As has been explained in Chapter 2, symmetrical disturbances can be modeled by using only the positive sequence network as the disturbed system remains symmetrical. Asymmetrical disturbances can be modeled by incorporating the negative and zero sequence networks into the positive sequence network at the fault point. The following disturbances can be modeled in TSSP. Provision is made to allow the use of fault and/or grounding impedance.

A) Three phase to ground
B) One phase to ground
C) Two phase to ground
D) Phase to phase
E) One phase open

F) Two phases open

Table 3.1: Module Identifying Numbers in TSSP

Generator	AVR	AGC	PSS
0 - Infinite-bus	11 - DC 1 12 - DC 2	211 - NR 212 - TCSR	311 - IEEEST 312 - IEEESN
1 - Classic	13 - DC 3 14 - EXDC2B	213 - TCDR 214 - CCSR-A	313 - IEEE standard
2 - Eq'		215 - CCSR-B	Input Identifier:
	21 - AC 1	216 - CCDR	1 - Deviation of speed
3 - Ed', Eq'	22 - AC 2 23 - AC 3	221 - Hydro A	2 - Deviation of terminal frequency
4 - Ed", Eq"	24 - AC 4 31 - ST 1	222 - Hydro B	3 - Electrical power 4 - Accelerating power
-1 - Induction motor	32 - ST 2 33 - ST 3 41 - SCRX 42 - SCRXIL		5 - Deviation of terminal voltage
	51 - 55 User - Defined	231 - 235 User - Defined	321 - 325 User - Defined

3.2.6 Load Representations, Network Model and Their Interface with Machine Models

The simulation of various load models in TSSP is accomplished as has been explained in Chapter 2. In order to maintain the accuracy at an acceptable level without making the computations excessive, a mechanism is designed to calculate new operating point by the fast decoupled load flow program only at instant when the configuration of the network changes. The network represented by lumped parameters is described by algebraic equations. The interface between network and machine models is accomplished by utilizing the iterative procedure of subtransient and transient saliency [14].

3.2.7 User-Defined Modules

If the module of a power component or a controller is not available in TSSP, it is required to derive its transfer function. A block diagram can be built with integrators according to the transfer function. Then the block diagram can be programmed into a module. The name of the module is the name of the component, (for instance, AVR), plus the identifying number corresponding to it as given in Table 3.1. A dummy variable is required to identify the machine on which the component is installed. Other parameters for the module are passed through the input data file *mach.inp*. Detailed programming procedure is given in [3].

3.3 Data Files and Program Structure

Three input data files are created by copying and modifying the sample data files provided in TSSP. Each data file consists of a number of blocks of data. In each block, data items are entered as a record in free format with a comma between items. A slash (/) signifies the end of a record. Preceding each block, there are comments and definitions specifying what data are to be entered and how. Any length of comments can be added into the files as long as a (!) precedes each comment line.

Data file *pqlf.inp* contains all the information required to perform a load flow study. Provision has been made to allow the use of different system base MVA, per unit or nominal unit system. Data file *ntwk.inp* contains fault information, sequence network parameters and branch incidence of the zero sequence network. Data file *mach.inp* contains parameters for machine, excitation system (AVR), speed governor and turbine system (AGC) and power system stabilizer (PSS) in four blocks. Each controller is identified in the corresponding block by its machine number. If a controller is absent from a machine, a record 888/ is entered to signify this fact.

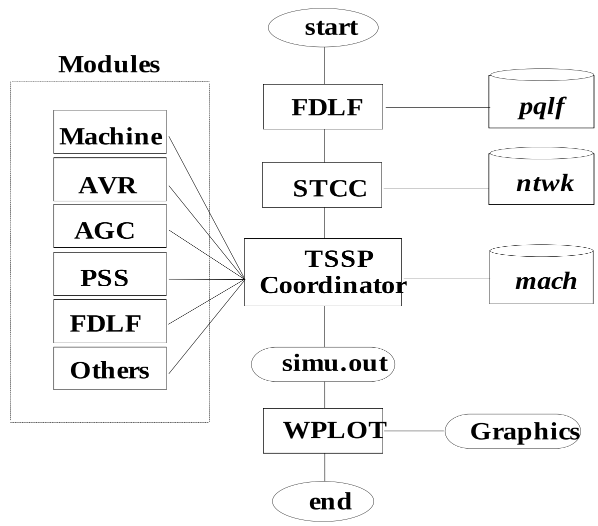

Figure 3.1: Overall structure of the TSSP.

The overall structure of the package is shown in Figure 3.1. To initialize TSSP, the fast decoupled load flow (FDLF) is run first. Then, the short circuit calculation (STCC) program is executed. The results of the two runs are passed onto TSSP coordinator internally. Finally, the TSSP is run. The end result of a simulation is stored in the file *simu.out*. A data sorting and plotting program (WPLOT) can be employed to plot a maximum of five curves on one screen and up to fifteen variables can be sorted out at a time. The sorted data is stored in a file specified by the user and can be further utilized by other applications.

3.4 Summary

This chapter has presented a transient stability simulation package (TSSP) implemented on an IBM PC in FORTRAN language. The structure, database and modeling aspect of the package are described.

The package consists of four parts: a fast decoupled load flow program (FDLF), a short circuit calculation program (STCC), the transient simulation main body (TSSP) including a coordinator, and a plotting program (WPLOT). Three data files are required for a complete stability study. A minimum of 410K conventional memory is required for a system of 100 buses and a CGA, EGA or VGA graphics card to run the WPLOT program.

A power component or a controller is simulated by its written module. Modules for commonly used power components and controllers are available in TSSP. User-defined modules can also be incorporated into the package. TSSP was used to perform the stability studies reported in subsequent chapters.