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Computer Aided Power System Studies

Objective of CAE — Purpose and need — Basic power system studies — List of studies — Main aspect of studies — Preparation — Software programs — Simulation of power system — Network planning system — Means of power system studies.

53.1. COMPUTER AIDED ENGINEERING (CAE) FOR POWER SYSTEM STUDIES

To ensure *high availability* and *operational reliability* of electrical power networks, their *steady-state* and *dynamic behaviour* must be known in detail. Highly advanced computer programs are used which allow a wide range of alternative configurations and operating conditions to be realistically simulated in a short time and at a lower cost. The data provided by Computer Aided Engineering (CAE) studies is essential to meet the growing needs of power system studies and the equipment.

Today's power system engineer needs high-performance personal computers and CAE environments at his disposal for planning, engineering, documentation (such as single-line diagrams) and cost-effectiveness.

The earlier experience and data in the development and application of power system engineering packages is also useful. The main topics covered in CAE studies include :

- Load-flow calculation
- Stability investigations
- Harmonic frequency analysis
- Short-circuit studies
- Transient analysis
- Reliability planning.

With various highly advanced tools, at his disposal, today's power systems planning engineer can quickly identify and solve even complex problems. Thus, operational disturbances can be reduced to a minimum and system failures, such as blackouts, prevented.

53.2. PURPOSE AND NEED OF SYSTEM STUDIES

The purpose of system studies is to assist in evaluation of present and future system performance, reliability etc. Such evaluation is essential for design, expansion, planning and operation of power systems.

Following objectives of both technical and economical aspects are fulfilled by Computer Aided Engineering (CAE) :

- Formulation of objectives :
  - What is to be achieved ?
  - What are the objectives ?
- State evaluation and sensitivity analysis :
  - How was the problem handled till now ?
  - What influence do certain parameters have ?
- Looking for alternative sources :
  - To improve or extended the present system ?
  - A new concept and/or replacement of certain components.

53.3. BASIC POWER SYSTEM STUDIES*

A wide variety of power systems engineering problems are solved by means of CAE. Some typical examples are given here. The ultimate goal is to have the application programs and know-how necessary to solve every power system problem which could arise during planning or operation. The same specialized engineering support is also available from specialised companies and research institutions.

Quasi-steady-state load-flow calculation. The quasi-steady state load-flow calculation is one of the most common, but also most important calculations performed when analyzing and planning power systems. Tasks the power system engineer performs with the help of load-flow simulation, for example, typically concerns reactive-power compensation and voltage-level control.

Transient stability studies. To secure reliable and economic operation it must be known how the power system will react to disturbances and system failures. The transient stability problems a traditional. The stability limits for the system are to be determined for various conditions. In many cases the stability of a power system can be considerably improved by installing static shunt compensators or series capacitors, etc. Programs have been developed to simulate the power system behaviour, and to solve stability or reactive power balance problems.

Analysis of electromagnetic transients. A detailed analysis of the transient phenomena due to switching or other causes, either internal or external, is often essential for insulation co-ordination studies. Only an in-depth knowledge of the very fast processes involved, reproduced by high frequency models which cover the travelling-wave range, allow suitable precautionary measures to be taken for the overvoltages occurring.

Reliability planning. The series reliability of a modern power supply system is of vital importance, and as such has to be taken into consideration during the *project engineering*. Reliability Analysis are therefore essential to system planning. Alternative designs have to be compared and that design selected which best conforms requirements while still complying with economic constraints. The aim is to achieve 99.99% *availability*.

Project Studies. These include feasibility studies for new projects, design calculations for various subsystems, main circuit parameters, control criteria etc.

Before finalising the design specifications of new transmission projects,

- Load flow
- Load shedding
- Harmonic filtering
- Insulation coordination
- Reactive power balance
- Transient overvoltages
- Economic feasibility
- Reliability

Expanding and upgrading large supply system for Industries

When system studies have to be carried out for expansion of large supply networks to industries, the following aspects may have to be considered :

- Evaluation of short circuit levels
- Projection system coordination
- Steady-state stability
- Load-frequency and load shedding
- Starting of motors
- Motor Stability
- Extension planning
- Component and system reliability
- Simulation of special operating events and disturbances.

Studies of this kind and performed to determine weak points in the power system and to obtain detailed recommendations for possible system improvement. The final goal is always to raise the reliability and availability of the power supply.

Likewise there are several areas of applications of CAE. Table 53.1 gives a list with remarks.

* *Courtesy* : ABB, Sweden.

Table 53.1. System Studies Associated with Transmission Planning

Type of study	*Remarks*
1. Load flow studies	To determine bus voltage magnitude and phase angles, Real Power and Reactive Power through lines for steady condition, for various buses.
2. Stability studies under various states of control	To determine the transient stability limits for various conditions.
3. System Dynamic Studies	To determine system behaviours under dynamic condition considering generation, transmission and load characteristic.
4. Switching overvoltage studies	To determine switching over voltages under various switching conditions for EHV, HV, MV.
5. Lightning performance studies.	To determine effect of lightning on shield wire, conductor, tower etc.
6. METIFOR optimisation studies.	Metrologically Integrated Forecasting based on hourly weather observations and lightning outage rate.
7. Voltage Level Studies.	Carried out before introducing new voltage level for expansion, new lines.
8. Reactive Power Studies.	Carried out on the basis of load flow studies and voltage regulation requirements.
9. Short-circuit studies.	Carried out for determining short-circuit currents at various points for equipment specifications, protection settings.
10. Studies of abnormal operations and protection planning and relay co-ordination.	Based on network phenomena analysis equipments withstand levels and protection system capabilities.
11. Reliability studies and security studies.	Aim at keeping the system and normal state of operation, demands are met, no apparatus is overloaded.

53.4. PREPARATION FOR SYSTEM STUDIES

The background required for system studies includes : familiarity with fundamentals. Thevenin's equivalent circuit, phasor representation, Fourier series, symmetrical components, etc.

Equivalent circuits of the system are prepared with assumptions acceptable in the particular study. Basic system data is collected before proceeding with the preparation of the program or simulation.

System modelling is an essential requirement in the power system studies. The system to be analysed is represented by its equivalent model. Modelling involves choosing swing bus and infinite bus, nodes, and branches (line and transformers), balanced three phase network, single line diagram impedance diagram etc.

After these preparations, the computer program or simulation on Network Analyser is arranged. Computer programming involves programming language and associated computation method. The type and capabilities of the computer to be used should be considered before preparing the programs.

53.5. SOFTWARE PROGRAMMES ON POWER SYSTEM ENGINEERING*

The summary of key software tools which are available to the power system engineers is given below. All the programs are routinely updated and upgraded so that they are always up-to-date. The listed programs are used in various electric utilities, consulting engineers and industrial companies, and also some of them by universities for educational purposes.

Simulation of Power System (SPS) and Network Planning System (NPS) are generally the mainframe packages for investigating load flows, short circuits, dynamic stability and harmonic propagation. The programs are used for solving problems in large to very large utility networks

* *Courtesy* : ABB, Sweden.

with complex HVDC transmission and static VAr compensators as well as in the small or medium-size power networks installed in industrial plants.

The programs features enhanced data management and facilities for graphics, *e.g.* Single-line networks containing the computed results and can be run on main frame computers or workstations (IBM, VAX, APOLLO, etc).

The majority of the programs are written in FORTRAN and can be customized for special tasks. Program modules for different analysis functions can be combined as required or run as independent programs.

Table 53.2. Main Aspects of Power System Planning and Calculation

Power system operation	*Reactive load compensation and voltage control*	*Evaluation of special phenomena and disturbances*	*Determination of system component stresses*	*System planning and dimensioning*	*Insulation coordination and transient overvoltages*
Calculation of load and short circuit currents	Use of shunt reactors, capacitors and static phase shifters	Analysis of harmonic and flicker problems	Circuit-breakers Transformers	Reliability planning and coordination	Calculation of internal and external over voltage
Load forecast and unit commitment	Control of generators and transformers	Interference in telephone and other transmission systems	Electrical machines	Earthing problems	
Evaluation of losses and their minimization	Determination of load-frequency over-voltages.	Effect of voltage fluctuation on operation of electrical machines	Lines and cables Compensators Surge arresters	Planning and coordination of protection systems Installation layout.	Analysis of switching operations
Investigation of dynamic stability problems	Use of capacitive series compensation for improved stability and increase in transmission capability	Resonance problems	Insulators	Extension planning Evaluation of alternative concepts	Insulation coordination Use of surge arresters
Evaluation of system behaviour during and after disturbances		Switching operations in power systems			

Courtesy : ABB, Sweden.

The main functions of the SPPS and/or NPS systems are :

- Load flow
- Optimal load flow
- Dynamic stability
- Load flow graphics
- Short-circuit graphics
- Harmonic frequency analysis
- Machine transients and subsynchronous resonance (SSR)
- Steady-state short-circuit calculations in accordance with IEC 909 or using the superposition method.
- Steady-state stability and eigen value analysis.

SPS and/or NPS *allow power systems planning* personnel to benefit from the following enhanced facilities.

— Automatic voltage regulators and turbine governor systems.
— Implementation of control systems by means of a dedicated macro language.
— Investigation of symmetrical or unsymmetrical network conditions, such as simultaneous occurrence of faults at different locations.
— Phasewise-controlled static VAr compensators.
— Different machine models.
— Transformers with automatic load tap changers.
— Different relay representations.

53.6. TOOLS FOR POWER SYSTEM STUDIES

For planning, designing and analysing power systems, various means are used. These are called the tools for analysis. Important tools, available today include the following :

1. DC Calculating Board
2. AC Calculating Board (Network Analyzer)
3. HVDC Simulator (Ref. Ch. 47)
4. Transient Network Analyser (TNA)
5. Special High Frequency Models.
6. Digital Computer (Sec. 24.5)

Transient Network Analyser (TNA0 is used for Transient analysis and simulation of AC Networks. Due to non-linearit and varying machine characteristics, some problems of AC systems cannot be solved by digital computer. TNA is a useful tool in which the AC Network can be closely represented.

The response of AC Networks to fast switching transients, lightning transients etc. is simulated on special *high frequency models.*

Problems on HVDC systems are analysed on *HVDC simulator.*

SUMMARY

Power system studies are generally aid to control room engineer, planning engineer, design engineer. The power system studies are carried out by means of Transient Network Analyser (TNA), HVDC Simulator, Digital Computer. The Network is represented by an equivalent physical or mathematical model. The studies include (1) steady state studies (2) Transient studies and also (1) Static studies (2) Real time studies.

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Power System Reliability Studies

Reliability — Quantitative Evaluation — Terms and Definitions — Rliability Indexes — Procedure of Evaluation — Service interruptions — Failure Mode and Effect Analysis FMEA — Types of Failures — Availability — Schedules Outage — Forced Outage — Summary

54.1. INTRODUCTION

The term 'reliability' is closely associated with *'outages', interruptions', 'failure', 'availability'* etc. and the reliability is closely associated with switchgear, protection and control. Absolute 100% reliability and availability of generating systems, transmission systems and distribution systems cannot be guaranteed. However, a very high level (99.99%) is aimed at and is being achieved in developed countries. High reliability (more than 99.8%) is possible with

— Availability of generation, transmission and distribution systems.
— Reserve capacity (margin) between installed capacities and expected maximum load.
— Design and quality aspects,
— Operation and Maintenance aspects.

An important aspect of power system studies involves *quantitative evaluation* or reliability, availability, security etc.

1. As required by the load.
2. To be supplied by the supply company ; proposed generating/transmission/distribution system.

Quantitative evaluation calls for precise definitions of terms, reliability indices, computer programs etc. the studies are based on set theory probability theory, combination analysis etc.

For quantitative evaluation, the *reliability performance* of constituent 'components' of the system should be known.

Alternative designs and alternative choice of components is considered while evaluating the service reliability. The choice of the following is based on the studies of reliability.

— Service reliability and cost of alternative components.
— Service reliability and cost of alternative system configuration.
— Maintenance requirements of components and subsystems.
— Operating practices and policy.
— Switching and protective schemes.

54.2. TERMS AND DEFINITIONS*

1. **Adequacy.** To have sufficient margin between generating capacity and maximum load.

2. **Availability.** A term which applies either to the performance of individual components or to a system. Availability is the long-term average fraction of time that a component or system is in service satisfactorily performing its intended function. An alternative and equivalent definition for availability is the steady-state probability, that a component or system is in service.

* *Courtesy* : IEEE.