EE 0403 POWER SYSTEM OPERATION AND CONTROL

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SYALLABUS

1. INTRODUCTION

Necessity for voltage and frequency regulation of power system - P-f and Q-V control loops – recent trends in real time control of power system – Introduction to load dispatching, load forecasting, unit commitment, load shedding and islanding.

2. FREQUENCY CONTROL

Plant and system level control – mathematical model of speed governing system – speed load characteristics – regulation of two generators in parallel – concept of control area – LFC control of a single area system – static and dynamic response of uncontrolled and controlled system - LFC of two area system – static and dynamic response of uncontrolled system – tie line with frequency bias control of two area system.

3. VOLTAGE CONTROL

Type of excitation system – Characteristics of excitation system – block diagram of excitation system - static and dynamic analysis. Methods of voltage control: OLTC, synchronous condenser, SVC, shunt capacitor – Power system level voltage control using tap changing transformer (simple problems).

4. ECONOMIC DISPATCH AND UNIT COMMITMENT

Incremental cost curve – co-ordination equation without loss – solution by Lamda iteration method – co-ordination equation with loss – solution of co-ordination equation using B_{mn} coefficients (no derivation) – base point and participating factors. Unit commitment (UC) problem – constraints in UC – Solution methods – Priority list method (Numerical problems) – Economic dispatch controller added to load frequency control.

5. COMPUTER CONTROL OF POWER SYSTEM

Energy control center – various levels – national, regional and state level – SCADA system – computer configuration – function – monitoring, data acquisition and controls – EMS system – System operating states: Normal, alert, emergency, restorative – control strategies.

TEXT BOOKS

1. **Olle.I.Elgerd, *Electric energy system theory – An introduction,* Tata Mc Graw Hill publishing Company, New Delhi, 2003.**
2. **Allen J. Wood, Bruce F. Woolenberg, *Power generation operation and control*, John Wiley and sons, 2003.**

REFERENCE BOOKS

1. **Kundur P.,*Power system stability and control,* McGraw Hill Publishing Company, 1994.**
2. **Mahalanabis A. K., Kothari D.P. and Ahson S.I., *Computer aided power system analysis and control,* Tata Mc Graw Hill Publishing Company, New Delhi, 1999.**
3. **Nagrath I.J. and Kothari D.P., *Power system engineering*, Tata Mc Graw Hill Publishing Company, New Delhi, 1994.**

Chapter 1

INTRODUCTION TO POWER SYSTEM OPERATION AND CONTROL

1. INTRODUCTION

Power systems are large and complex electrical networks. In any power system, generations are located at few selected points and loads are distributed throughout the network. The system load keeps changing from time to time.

Properly designed power system should have the following characteristics:

1. It must supply power, wherever the customer demands.

2. It must supply power to the customers at all time.

3. It must be able to supply the ever changing load demand.

4. The power supplied should be of good quality.

5. The power supplied should be economical.

6. It must satisfy necessary safety requirements.

The delivered power must meet certain minimum requirements with regards to the quality of the supply. The following determine the quality of the power supply.

i) **The system frequency must be kept around the specified 50 Hz with a variation of ± 0.05 Hz.**

ii) **The magnitude of bus voltages are maintained within narrow prescribed limits around the normal value. Generally voltage variation should be limited to $\pm 5\%$.**

Voltage and frequency controls are necessary for the effective operation of power systems.

Frequency fluctuations are detrimental to electrical appliances. The following are a few reasons why we should keep strict limits on frequency deviations.

* **Three phase a.c. motors run at speeds that are directly proportional to the frequency. Variation of system frequency will affect the motor performance.**
* **The blades of steam and water turbines are designed to operate at a particular speed. Frequency variations will cause change in speed. This will result in excessive vibration and cause damage to the turbine blades.**
* **Frequency error may produce havoc in the digital storage and retrieval process.**

Both over voltage and under voltage are detrimental to electrical appliances.

Electric motors will tend to run on over speed when they are fed with higher voltages. Over voltage may cause insulation failure, vibration and mechanical damage.

For a specified power rating, when the supply voltage is less, the current drawn is more and it will give rise to heating problems.

Therefore it is essential to keep the system frequency constant and the voltage variation within the tolerance.

3. P.f and Q-V CONTROL LOOPS

In order to perform voltage and frequency control, a basic generator will have two control loops namely:

Automatic voltage regulator loop

Automatic load frequency loop.

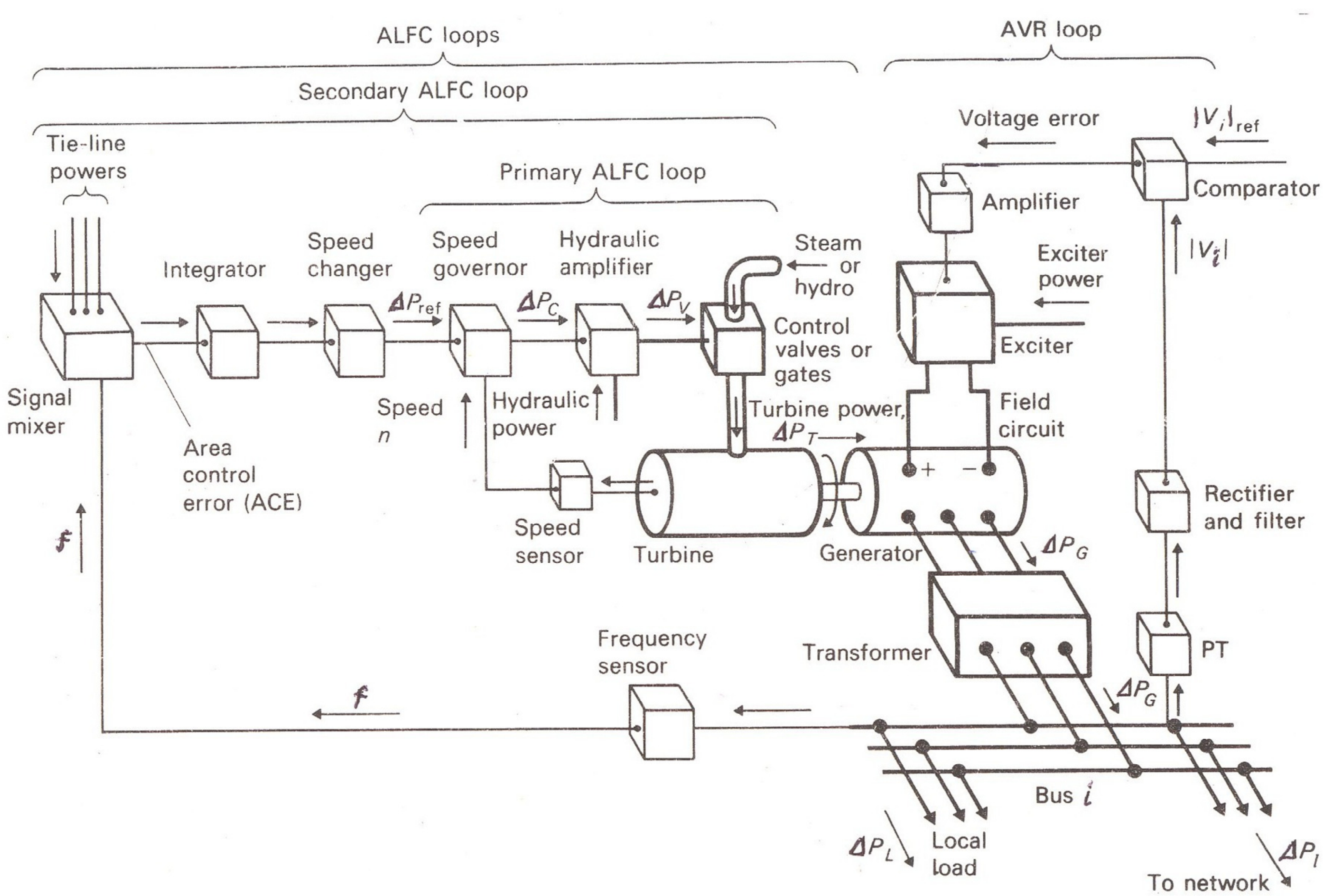
The *automatic voltage regulator* (AVR) loop controls the magnitude of terminal voltage, |V|. Terminal voltage is continuously sensed, rectified and smoothed. The strength of this dc signal, being proportional to |V|, is compared with a dc reference $|V|_{ref}$. The resulting "error voltage" after amplification and signal shaping, serves as input to the exciter, which applies the required voltage to the generator field winding, so the generator terminal voltage |V| reaches the value $|V|_{ref}$.

The *automatic load frequency control* (ALFC) loop regulates the real power output of the generator and its frequency (speed).

This loop is not a single one as in the case of AVR. A relatively <u>fast</u> *primary loop* responds to a frequency (speed) changes via the speed governor and the steam (or hydro) flow is regulated with the aim of matching the real power generation to relatively fast load fluctuations. By "fast" we mean changes that takes place in one to several seconds. Thus, aiming to maintain a megawatt balance, this primary loop performs a course speed or frequency control.

A <u>slower</u> *secondary loop* maintains the fine adjustment of the frequency, and also maintains proper real power interchange with other pool members. This loop is insensitive to rapid load and frequency changes, but focuses drift-like changes which take place over periods of minutes.

Fig. 1 shows the two control loops, AVR loop and ALFC loop.



The AVR and ALFC loops are not fully non-interacting. Little cross coupling does exist between AVR and ALFC loops. AVR loop affects the magnitude of the generator emf E. As the internal emf determines the magnitude of the real power, it is clear that changes in the AVR loop will be felt in the ALFC loop. However, the AVR loop is much faster than the ALFC loop and hence AVR dynamics may settle before they can make themselves felt in the slower load-frequency control channel.

Chapter 2 and Chapter 3 will deal with LOAD FREQUENCY CONTROL (LFC) and AUTOMATIC VOLTAGE REGULATOR respectively.

4. ECONOMIC DISPATCHING

Once it is possible to ensure electric power supply with constant frequency and voltage, next we may be interested to operate the power system in a most economic manner.

The main aim of economic dispatch problem is to minimize the total cost of generating real power at various stations while satisfying the load and losses in the transmission links.

There are certain engineering constraints that are to be satisfied while finding the optimal solution. The problem become completed when the power system has different types of generations such as thermal, hydro, nuclear, wind, solar etc. Optimal Power Flow method, which makes use of optimizing technique, is used to determine the optimal status of power system for a given load condition.

5. UNIT COMMITMENT

The other challenging problem is Unit Commitment (UC).

The system load changes in cyclic manner. It is not advisable to keep all the units available all the time. When system load decreases, it is better to shut down one or more units and when the system load increases at a latter time, units are to be brought in.

Unit commitment problem is finding the shut down and commissioning rule so that the total cost of generation over a period of time, say one day, is minimum.

A simple but sub-optimal approach to the UC problem is to impose priority ordering, wherein the most efficient unit is loaded first to be followed by the less efficient units in order as the load increase. Several practical constraints will make the UC problem more complicated.

Economic dispatch and Unit commitment problem are discussed in Chapter 4

6. LOAD FORECASTING

If the load coming on the system is known in advance, then we can schedule how to operate various units. But customers used to switch on or switch off the load as per their requirements. Hence it becomes necessary to forecast the system load.

Load forecasting is done by analyzing the past load data. Certain load forecasting techniques are available to find the system loads at different points of time, as well as peak load, based on the records of past data.

Short term forecasting is carried out to find load for a day while long term forecasting aims to get load for a month or a year.

There is a continuing need to improve the methodology for forecasting power demand more accurately.

7. LOAD SHEDDING

When the total load is more than the total generation capacity, then load shedding has to be resorted. This has to be done to save the electric grid from collapsing.

If it is a regular power shortage, load shedding can be done in a planned manner. There are situation wherein because of unexpected fault in generators or in transmission lines, deficiency may be created all at a sudden and the operators will have no time for decision making. To save the system on such cases we need to implement *automated load shedding*.

8. ISLANDING

Islanding is the functioning of a section of power system separating from the original power system. This may happen due to major fault, resulting a portion of network disconnected and start functioning of its own if possible. The whole system will go to restorative mode after which normal status will be restored slowly.

9. RECENT TREANDS IN REAL TIME CONTROL OF POWER SYSTEM

Power systems are operated by system operators from the area control centers. The main goal of the system operator is to maintain the system in a normal secure state as the operating conditions vary during the daily operation.

Accomplishing this goal requires:

i) **continuous monitoring of the system conditions**

ii) **identification of the operating state and**

iii) **determination of the necessary preventive action in the case of state found to be insecure.**

This sequence of operation is referred as the security analysis of the system.

The first step of security analysis is to monitor the current state of the system.

This involves acquisition of measurements from all parts of the system.

The measurement may be both of analog and digital type.

Substations are equipped with devices called Remote Terminal Unit (RTU) which collect various types of measurements from the field and are responsible for transmitting them to the control center.

More recently, the so-called Intelligent Electronic Device (IED) are replacing or complementing the existing RTUs.

Once the data are collected, they are processed in order to determine the system state.

It is possible to have a mixture of these devices (RTUs and IEDs) connected to a Local Area Network (LAN) along with Supervisory Control And Data Acquisition (SCADA) front end computer, which supports the communication of the collected measurements to the host computer at the control center.

The SCADA host computer at the control center receives measurements from all the monitored substations' SCADA systems via one of many possible types of communication links such as fiber optic, satellite, microwave, etc.

Fig.2 shows the configuration of EMS / SCADA system for a typical power system.

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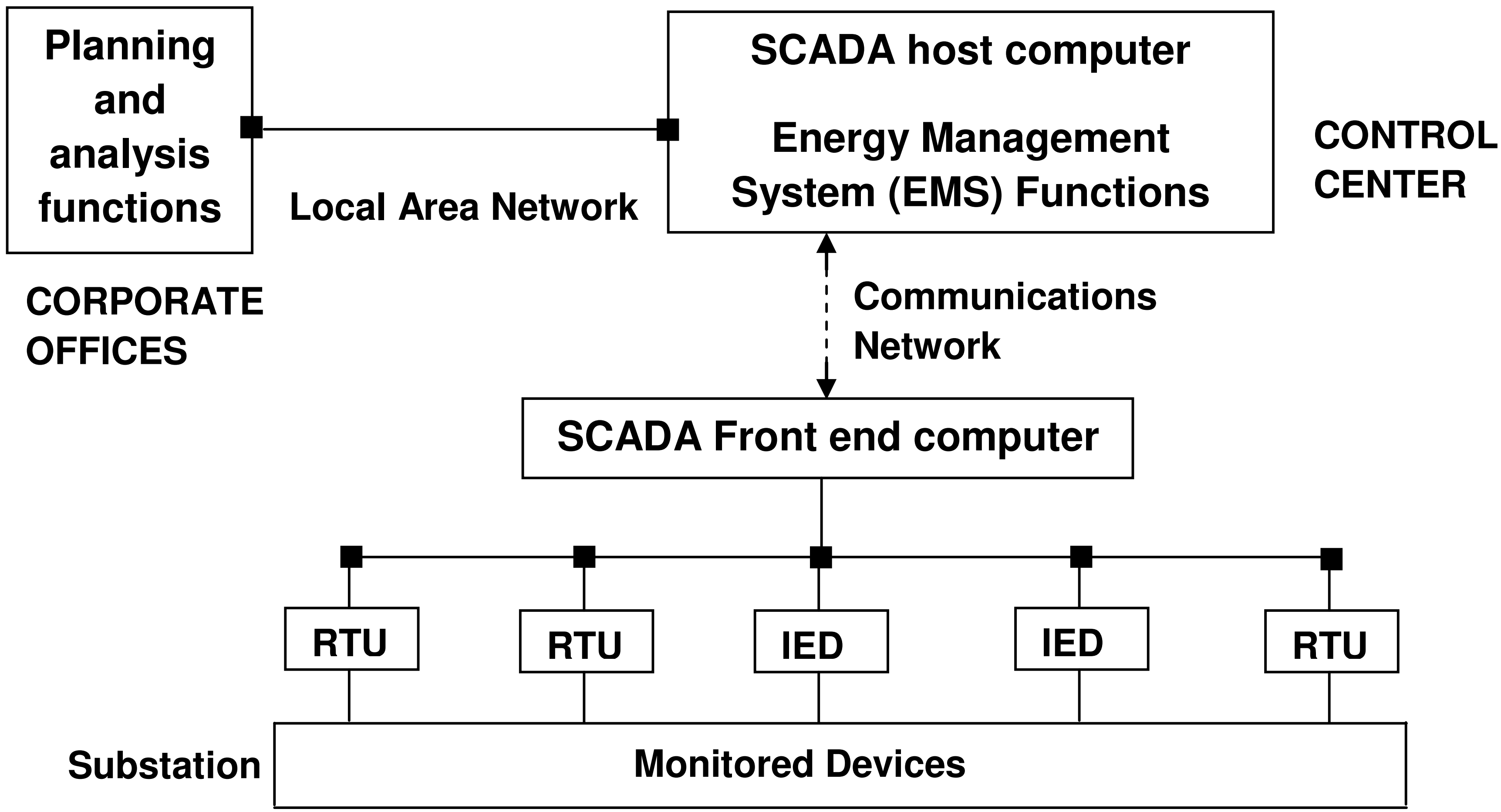

Fig. 2 EMS / SCADA system configuration

Measurements received at the control center will include line power flows, bus voltage and line current magnitudes, generator outputs, loads, circuit breaker and switch status information, transformer tap positions and switchable capacitor bank values.

These raw data and measurements are processed by State Estimator (SE) in order to filter the measurement noise and detect gross errors. State estimator solution will provide reliable estimate of the system state based on the available measurements and on the assumed system model.

This will then be passed on to all the Energy Management System (EMS) application functions such as the contingency analysis, automatic generation control, automatic load frequency control, economic load dispatching, load forecasting and optimal power flow, etc.

The same information will also be available via a LAN connection to the corporate offices where other planning and analysis functions can be executed off-line.

Questions on “Introduction to Power System operation and control”

1. What are the requirements of a good power system?
2. What do you mean by good quality of power supply?
3. Frequency fluctuations are detrimental to electrical appliances. Justify this.
4. What are the effects of over voltage and under voltage?
5. Name the two control loops in a generator and briefly describe them.
6. What is economic dispatching?
7. What is Unit Commitment problem?
8. What is load forecasting?
9. When load shedding is resorted?
9. What do you understand by Islanding?
10. With necessary block diagram, explain what do you understand by “Real Time Control of Power System”.