VTU eNotes On

Power System Operation and Control

Electrical And Electronics Engineering

POWER SYSTEM OPERATION AND CONTROL

CONTROL CENTRE OPERATION OF POWER SYSTEMS

Syllabus :

Introduction to SCADA, control centre, digital computer configuration, automatic generation control, area control error, operation without central computers, expression for tie-line flow and frequency deviation, parallel operation of generators, area lumped dynamic model.

General

Electrical Technology was founded on the remarkable discovery by Faraday that a changing magnetic flux creates an electric field. Out of that discovery, grew the largest and most complex engineering achievement of man : the electric power system. Indeed, life without electricity is now unimaginable. Electric power systems form the basic infrastructure of a country. Even as we read this, electrical energy is being produced at rates in excess of hundreds of giga-watts (1 GW = 1,000,000,000 W). Giant rotors spinning at speeds up to 3000 rotations per minute bring us the energy stored in the potential energy of water, or in fossil fuels. Yet we notice electricity only when the lights go out!

While the basic features of the electrical power system have remained practically unchanged in the past century, but there are some significant milestones in the evolution of electrical power systems.

Topics to be studied

- Introduction to SCADA
- Control Centre
- Digital Computer Configuration
- Automatic Generation Control
- Area Control Error
- Operation Without Central Computers
- Expression for Tie Line Flow
- Parallel Operation of Generators
- Area Lumped Dynamic Model

1.0 Introduction

Electrical energy is an essential ingredient for the industrial and all round development of any country. It is generated centrally in bulk and transmitted economically over long distances.

Electrical energy is conserved at every step in the process of Generation, Transmission, Distribution and utilization of electrical energy. The electrical utility industry is probably the largest and most complex industry in the world and hence very complex and challenging problems to be handled by power engineering particularly, in designing future power system to deliver increasing amounts of electrical energy. This calls for perfect understanding, analysis and decision making of the system. This power system operation and its control play a very important task in the world of Electrical Power Engineering.

Power Quality

Power quality is characterized by –

a. Stable AC voltages at near nominal values and at near rated frequency subject to acceptable minor variations, free from annoying voltage flicker, voltage sags and frequency fluctuations.
b. Near sinusoidal current and voltage wave forms free from higher order harmonics

All electrical equipments are rated to operate at near rated voltage and rated frequency.

Effects of Poor Power Quality

- Maloperation of control devices, relays etc.
- Extra losses in capacitors, transformers and rotating machines
- Fast ageing of equipments
- Loss of production due to service interruptions
- Electro-magnetic interference due to transients
- power fluctuation not tolerated by power electronic parts

Major causes of Poor Power Quality

- Nonlinear Loads
- Adjustable speed drives
- Traction Drives
- Start of large motor loads
- Arc furnaces
- Intermittent load transients
- Lightning
- Switching Operations
- Fault Occurrences

Steps to address Power Quality issues

- Detailed field measurements
- Monitor electrical parameters at various places to assess the operating conditions in terms of power quality.
- Detailed studies using a computer model. The accuracy of computer model is first built to the degree where the observed simulation values matches with those of the field measurement values. This provides us with a reliable computer model using which we workout remedial measures.

- For the purpose of the analysis we may use load flow studies, dynamic simulations, EMTP simulations, harmonic analysis depending on the objectives of the studies.
- We also evaluate the effectiveness of harmonic filters through the computer model built, paying due attention to any reactive power compensation that these filters may provide at fundamental frequency for normal system operating conditions.
- The equipment ratings will also be addressed to account for harmonic current flows and consequent overheating.

Power Quality Solutions :

Poor power quality in the form of harmonic distortion or low power factor increases stress on a facility's electrical system. Over time this increased electrical stress will shorten the life expectancy of electrical equipment. In addition to system degradation, poor power quality can cause nuisance tripping and unplanned shutdowns within electrical system.

In an increasingly automated electrical world, it is important for a facility to evaluate power quality. Harmonic distortion, low power factor, and the presence of other transients can cause severe damage to electrical system equipment. PSE provides system analysis and evaluation of power quality issues and makes recommendations for system design solutions

1.1 Structure of Power Systems

Generating Stations, transmission lines and the distribution systems are the main components of an electric power system. Generating stations and distribution systems are connected through transmission lines, which also connect one power system (grid, area) to another. A distribution system connects all the loads in a particular area to the transmission lines.

For economical technical reasons, individual power systems are organized in the form of electrically connected areas or regional grids.

As power systems increased in size, so did the number of lines, substations, transformers, switchgear etc. Their operation and interactions became more complex and hence it is necessary to monitor this information simultaneously for the total system at a focal point called as **Energy Control Centre.** The fundamental design feature is increase in system reliability and economic feasibility.

Major Concerns of Power System Design and Operation

- **Quality :** Continuous at desired frequency and voltage level
- **Reliability :** Minimum failure rate of components and systems
- **Security :** Robustness - normal state even after disturbances
- **Stability :** Maintain synchronism under disturbances
- **Economy :** Minimize Capital, running and maintenance Costs

1.2 Need for Power System Management

- Demand for Power Increasing every day
  - No of transmission line, Sub-stations, Transformers, switchgear etc.,
- Operation and Interaction is more and more complex
- Essential to monitor simultaneously for the total system at a focal point – ENERGY LOAD CENTRE

Components of power system operation and control

- Information gathering and processing
- Decision and control
- System integration

Energy Load Centre

The function of energy load centre is to control the function of coordinating the response in both normal and emergency conditions. Digital Computers are very effectively used for the purpose. Their function is to process the data, detect abnormalities, alarm the human operator by lights, buzzers, screens etc., depending on the severity of the problem.

Control Centre of a Power System

- Human Machine Interface – equipped with
- CRT presentations
- Keyboards – change parameters
- Special function keyboards- alter transformer taps, switch line capacitors etc.,
- Light-Pen cursor – open or close circuit breakers
- Alarm lights, alarms, dedicated telephone communications with generating stations and transmission substations, neighboring power utilities

Control Features – Control Centre

- System Commands – Mode of control
- Units – base / peak load
- AGC – Automatic Generation Control
- Data Entry
- Alarms – To find source of alarm and necessary action
- Plant/Substation selection
- Special Functions - To send/retrieve data etc.,
- Readout control – Output to CRT/printers etc.,
- CPU control – Selection for the computer

Functions of Control Centre

- Short, Medium and Long-term Load Forecasting
- System Planning
- Unit Commitment and maintenance Scheduling
- Security Monitoring
- State Estimation
- Economic Dispatch
- Load Frequency Control

1.3 SCADA – Supervisory Control and Data Acquisition

One of key processes of SCADA is the ability to monitor an entire system in real time. This is facilitated by data acquisitions including meter reading, checking statuses of sensors, etc that are communicated at regular intervals depending on the system.

A well planned and implemented SCADA system not only helps utilities deliver power reliably and safely to their customers but it also helps to lower the costs and achieve higher customer satisfaction and retention.

SCADA – Why do we need it?

- If we did not have SCADA, we would have very inefficient use of human resources and this would cost us (Rs,Rs,Rs)
- In today's restructured environment SCADA is critical in handling the volume of data needed in a timely fashion
- Service restoration would involve travel time and would be significantly higher
- It is essential to maintain reliability

SCADA - Architecture

- Basic elements are sensors which measure the desired quantities
- Current Transformers CTs – measure currents and Potential Transformers PTs- measure voltages.

- Today there is a whole new breed of Intelligent electronic devices (IEDs)
- This data is fed to a remote terminal unit (RTU)
- The master computer or unit resides at the control center EMS

SCADA - Process

- Master unit scan RTUs for reports, if reports exist, RTU sends back the data and the master computer places it in memory
- In some new substation architectures there could be significant local processing of data which could then be sent to the control center.
- The data is then displayed on CRTs and printed

SCADA - Logging

- The SCADA provides a complete log of the system
- The log could be provided for the entire system or part of the system
- Type of information provided
  - Time of event
  - Circuit breaker status
  - Current measurements, voltage measurements, calculated flows, energy, etc.
  - Line and equipment ratings

SCADA as a System

There are many parts of a working SCADA system. A SCADA system usually includes signal hardware (input and output), controllers, networks, user interface (HMI), communications equipment and software. All together, the term SCADA refers to the entire central system. The central system usually monitors data from various sensors that are either in close proximity or off site (sometimes miles away).

For the most part, the brains of a SCADA system are performed by the Remote Terminal Units (sometimes referred to as the RTU). The Remote Terminal Units consists of a programmable logic converter. The RTU are usually set to specific requirements, however, most RTU allow human intervention, for instance, in a factory setting, the RTU might control the setting of a conveyer belt, and the speed can be changed or overridden at any time by human intervention. In addition, any changes or errors are usually automatically logged for and/or displayed. Most often, a SCADA system will monitor and make slight changes to function optimally; SCADA systems are considered closed loop systems and run with relatively little human intervention.

SCADA can be seen as a system with many data elements called points. Usually each point is a monitor or sensor. Usually points can be either hard or soft. A hard data point can be an actual monitor; a soft point can be seen as an application or software calculation. Data elements from hard and soft points are usually always recorded and logged to create a time stamp or history

User Interface – Human Machine Interface (HMI)

A SCADA system includes a user interface, usually called Human Machine Interface (HMI). The HMI of a SCADA system is where data is processed and presented to be viewed and monitored by a human operator. This interface usually includes controls where the individual can interface with the SCADA system.

HMI's are an easy way to standardize the facilitation of monitoring multiple RTU's or PLC's (programmable logic controllers). Usually RTU's or PLC's will run a pre programmed process, but monitoring each of them individually can be difficult, usually because they are spread out over the system. Because RTU's and PLC's historically had no standardized method to display or present data to an operator, the SCADA system communicates with PLC's throughout the system network and processes information that is easily disseminated by the HMI.

HMI's can also be linked to a database, which can use data gathered from PLC's or RTU's to provide graphs on trends, logistic info, schematics for a specific sensor or