LEARNING OBJECTIVES

For

HYDRO-ELECTRIC

POWER PLANT OPERATIONS

(2700)
HYDRO-ELECTRIC POWER
PLANT OPERATIONS

TABLE OF CONTENT

2701: The Hydro-Electric Role in the Power System ................................................................. 3
2702: Hydro Power Stations ...................................................................................................... 4
2703: Water Management ......................................................................................................... 5
2704: Hydro Turbines ................................................................................................................ 6
2705: Turbine Monitoring & Control ......................................................................................... 7
2706: The Hydro Generator ...................................................................................................... 8
2707: Generator Monitoring & Control .................................................................................... 8
2708: Hydro Plant Auxiliaries ................................................................................................. 8
2709: Operating Electrical Equipment ....................................................................................... 8
2710: Hydro Plant Operation & Maintenance ............................................................................ 8
2701: The Hydro-Electric Role in the Power System

The objective of this videotape, the first in the Hydro-Electric Power Series, is to give hydro power plant operators and technicians an understanding of the role of hydro-electric power in the overall power system. The characteristics of different types of hydro plants are briefly discussed in relation to their effect on power system operation. An overview of the power system is presented plus a review of the tasks and responsibilities of the power dispatcher and power system operators.

Upon completion of this module and accompanying workbook exercises, the participant should have an overall understanding:

- The characteristics of different types of hydro-electric plant:
  1. low head, run-of-the river plant,
  2. intermediate head with storage reservoir,
  3. High head plant,
  4. pumped storage.
- Advantage of interties to neighboring power systems.
- The power generation mix.
- Characteristics of different types of power generation including fossil, combustion turbines, and nuclear.
- Advantages of hydro power generation.
- The purpose of the transmission system, i.e. to deliver bulk power from the
- Advantages of the integrated power system generating stations to distribution systems.
- The purpose of the distribution system, i.e. to deliver power to all of the individual consumers at the appropriate voltage.
- Comparison of overhead transmission with underground cable.
- Specific applications where transmission by high voltage DC is advantageous.
- Review of equipment installed in typical switching stations, transformer stations, and substations.
- The daily load curve and seasonal load curve.
- The need to have sufficient generating capacity on line at all times of the day to equal the daily load forecast, plus an allowance for fluctuation, plus an allowance for spinning reserve.
- Economic load dispatch.
- Constraints on economic loading.
- Prevention of system overload (low frequency).
- The application of the AGC system to control frequency and interchange.
- Methods of controlling voltage at different points in the system.
- The hydro generator as a synchronous condenser.
- Power system security.
2702: Hydro Power Stations

The purpose of this videotape is to introduce the major components of a typical hydro electric power station. A brief overview of each item of equipment is presented noting that detailed study will be shown in subsequent videotapes in the series.

Basic hydraulic principles are also presented as an aid to better understanding of hydro plant operation.

Upon completion of this module and associated workbook, the participant should have an understanding of the following concepts:

- Factors affecting the power output of a water wheel or hydro turbine, i.e. Q x H x efficiency.
- The function of dams and spillways.
- Location of the powerhouse.
- Environmental concerns in design and operation of hydro schemes.
- The function of major items of equipment including:
  1. intake structure and head works,
  2. penstocks, surge tanks, and turbine shut-off valve,
  3. impulse and reaction turbines,
  4. turbine control system,
  5. the rotating element consisting of turbine runner coupled to the generator rotor,
  6. thrust bearings, guide bearings, and associated lubricating systems,
  7. the generator’s exciter, excitation panels, and voltage regulator,
  8. the generator stator, cooling radiators, and bus discharge duct,
  9. generator step-up transformer, breaker and associated controls,
 10. the plant main control room and local control panels.
11. auxiliary transformers and auxiliary bus,
12. pumps and piping for auxiliary systems, including compressed air, dewatering, and fire protection.
- Example calculations of hydro power output for different conditions, i.e. flow and head.
- The measurement of pressure in American and metric units.
- The effect of head and specific gravity on pressure.
- The distinction between force and pressure.
- The incompressibility of fluids, principle of the hydraulic jack.
- The relationship between potential head, velocity head and pressure head.
- Formation of vacuum due to high velocity flow.
- The need for venting of vessels and piping systems.
2703: Water Management

The objective for this videotape is to present and discuss all of the functions involving the use and control of water in a hydro-electric scheme. The importance of hydrological records is discussed in relation to hydro power plant planning and operation, and reservoir control. After completion of this video and associated workbook, the participant should be able to understand the following concepts and apply them in day-to-day activities.

Upon completion of this videotape and accompanying workbook exercises, the participant should be familiar with:

- Requirements for siting a hydro-electric power plant.
- Water flow in the catchment area (water shed, drainage basin).
- Elevation (available head) at potential sites.
- Study of hydrological data:
  1. daily average flows,
  2. monthly average flows,
  3. annual average flows,
  4. flash flood flows,
  5. cyclical variations, i.e. 12 year drought pattern.
- The relationship between generator size, seasonal variation in flow, and capacity factor.
- Application of the duration curve in sizing hydro plant generators.
- Construction of dams.
- Features of different types of dam:
  1. the gravity dam,
  2. the embankment dam (earthfill, rockfill),
  3. the concrete arch type dam,
  4. the concrete buttress type dam.
- Forces trying to destroy the dam.
- Monitoring dam performance, i.e. leakage, stability.
- Function and location of spillways.
- Spillway capacity.
- Spillway construction.
- The uncontrolled overflow spillway.
- Spillway gates.
- Skimmer gates.
- Forebay construction.
- The intake structure including trash racks, stop logs, intake gates and air vents.
- The function of bubblers in cold climates.
- Water conveyances, canals, flumes.
- Cascade arrangement of power plants.
- Reservoir control parameters.
- Aids to water management (water dispatch):
  1. reservoir storage curve,
  2. anticipated inflows for the coming weeks and months,
  3. anticipated generation and outflows,
  4. predicted reservoir draw down curve.
2704: Hydro Turbines

The objective of this videotape is to present and discuss the structural and functional features of different types of hydro turbines. Certain operational considerations are also presented such as cavitation, tailrace elevation, surge, run away speed, etc.

After completion of this videotape and associated workbook exercises, the participant should be able to understand and apply the following concepts:

- Impulse and reaction type turbines.
- The Pelton wheel, vertical and horizontal.
- Single and multiple nozzle arrangements.
- Needle valve control and deflectors.
- Turbine shut-off valves.
- Propeller type turbines, vertical and horizontal.
- Fixed and variable pitch blades (Kaplan).
- Function of the draft tube.
- Wicket gates, shear pins, lubrication.
- Turbine guide bearing.
- Francis type turbine, vertical and horizontal.
- Hydraulic thrust, head cover leakage.
- Tube type turbines.
- Bulb type turbines.
- Deriaz type turbines.
- Comparative turbine efficiencies.
- Turbine generator overspeed due to load rejection.
- Pressure surges due to load variation (and rejection).
- The function of surge vessels.
- Cavitation - causes and effects.
- The influence of tailrace elevation.
The objective of this module is to present and discuss types of equipment used to monitor and control the operation of the hydro turbine. Typical examples of mechanical hydraulic and electro hydraulic actuators are demonstrated plus monitoring and protection devices.

Upon completion of this videotape and associated workbook, the participant should be able to understand and apply the following concepts:

- The need for turbine controls, monitoring systems, alarm and annunciators, and protection devices.
- Methods for controlling the flow of water through the turbine.
- The effect of control action before the generator is synchronized, and after the generator is synchronized.
- Operation of the mechanical hydraulic actuator for control of wicket gates.
- Force amplification through the servo mechanism. The need for reset action to stabilize actuator operation.
- Operation of the hydraulic oil system, including pressurized oil tank, oil pumps, and compressors.
- Automatic governor operations using the "flyball" type governor head.
- The purpose of the PMG, "Permanent Magnet Generator".
- The function of the governor speeder set point control, i.e. speed or load adjustment.
- Response of the turbine governor to frequency (speed) changes.
- The function of the speed droop characteristic, i.e. sharing of load changes between generators in parallel.
- The effect of changes in speed droop setting.
- The function of the gate limiter.
- The use of the gate limiter for manual control during start-up or power output control.
- The function of reset signal damping, i.e. the dash pot in older machines.
- Requirements for monitoring turbine conditions, i.e. critical measuring points.
- The implications of high bearing temperatures, excessive vibration, and shaft misalignment.
- Abnormal turbine conditions which necessitate shutdown of the unit, i.e. overspeed.
- The turbine generator trip (shut-down) circuit.
- Types of overspeed trip devices.
- Operation of the electro hydraulic actuator and governor system.
- Operation of the electronic SSG (Speed Signal Generator) in place of the PMG.
- The nature of digital control systems versus analog.
- Pre-programming turbine operations through microprocessor control.
- Using the SCADA system for remote operation from the energy control centre.
- Monitoring and control of the turbine through the operator CRT interface in the powerhouse.
2706: The Hydro Generator

The objective of this videotape is to present and discuss the major constructional features of the hydro generator. A review of AC generation fundamentals is also included, as this is considered necessary for complete understanding.

Upon completion of this module and associated workbook, the participant should be able to understand and apply the following concepts:

- Constructional features of the vertical generator.
- Function of the stator frame, stator iron core, and core laminations.
- Stator windings and stator conductor arrangements.
- Constructional features of the rotor.
- Rotor poles, excitation current, and slip rings.
- Thrust bearing arrangements, using tilting or spring-loaded pads.
- Generator guide bearings.
- Lube oil cooling.
- High-pressure oil jacking system.
- Protecting bearings against stray eddy currents, i.e. bearing insulation and shaft grounding.
- The function and operation of the braking system.
- Sources of heat loss in the generator.
- Generator air-cooling system.
- Stator conductor cooling water system.
- Generator terminal equipment, i.e. generator terminals, isolated phase bus, PT's and CTs.
- Constructional features of the horizontal generator.
- Review of AC generation fundamentals.
- Production of the voltage sine wave due to the rotating magnetic field.
- RMS values of voltage and current.
- The relationship between frequency, speed of rotation, and number of poles.
- Three phase windings and connections.
- Neutral grounding through resistance and/or grounding transformer.
- Voltage relationships for the Wye connection.
- Types of excitation systems:
  1. static excitation,
  2. brushless exciter,
  3. externally driven exciter,
  4. the traditional shaft mounted main and pilot exciter.
- Control of excitation.
- The conditions required for synchronizing the generator to the power system.
2707: Generator Monitoring & Control

The objective of this module is to present and discuss supervision of the hydro generator including control, monitoring, and protection. Included is a review of the significance of active and reactive power output from the generator.

After completion of this module, the participant should be able to understand and apply the following:

- Control of active (megawatt) and reactive (megavar) power output form the generator.
- The significance of megawatt, megavar, megavolt amps, and powerfactor.
- Governor control of power output.
- AVR control of excitation with consequent control over terminal voltage and reactive power output.
- The significance of load angle (power angle) in determining the power outputs of generators, which are synchronized together on the same system.
- The limits of generator operation as indicated by the generator capability curve.
- The arrangement of the traditional operators' control panel for the hydro generator, including indicating instruments, recorders, alarms and annunciators.
- Calculation of generator MVA output from indicating instruments such as terminal voltage, and stator current.
- The function of energy integrating meters, i.e. MWH and MVARH.
- Sensing points for monitoring the physical condition of the generator.
- Operation of alarms and annunciators.
- Digital control systems; the operator CRT interface.
- Monitoring and control of remote plants through the SCADA system.
- Information printouts, trends, log.
- Information transfer to the energy control centre and other company departments.
- The need for generator protection; the nature of generator internal faults.
- The application of protective relays, and resultant tripping action.
2708: Hydro Plant Auxiliaries

The objective of this videotape is to present and discuss the function and typical layout of the various auxiliary systems which are needed to support operation of the hydro turbine generator. Also demonstrated are the main features of auxiliary equipment that form the common elements of auxiliary systems.

After completion of this videotape and associated workbook, the participant should be able to understand and apply the following:

- The function and application of different types of valves, including the gate valve, the globe valve, the control valve, the butterfly valve, the spherical ball valve, bypass valves, check valves, and the pressure relief valve.
- The operation of vents and drains on piping systems and equipment.
- The effect of water hammer.
- The function and application of centrifugal pumps, both horizontal and vertical.
- The function and application of positive displacement pumps, including the reciprocating pump, the screw type pump, and the gear pump.
- The function and application of compressors, including compressor cooling and water extraction from compressed air.
- Strainers and filters.
- The importance of correct lubrication on all types of equipment.
- Typical raw water and service water systems.
- Features of cooling water systems.
- Dewatering and drainage systems.
- The supply of high-pressure water for fire protection systems, including sprinkler deluge systems.
- Other fire protection systems, i.e. CO₂ or Halon.
- Compressed air systems, including service air, instrument air, high-pressure governor accumulator air, and blowdown air for synchronous generator operation.
- Oil storage and cleaning systems.
- Ventilation systems for the powerhouse.
2709: Operating Electrical Equipment

The objective of this videotape is to examine, from the operational point of view, the various items of electrical equipment that are commonly installed in the hydro-electric power plant. The video looks at switchyard equipment, station service supply, DC power supply, and uninterruptible AC power supply. Safety of personnel and equipment is also discussed.

Upon completion of this videotape and associated workbook, the participant should be able to understand and apply the following concepts:

- Reading one-line diagrams and schematics.
- Generator circuit breaker arrangements
  1. at generator voltage,
  2. on the high voltage side of the directly connected generator step-up transformer.
- Features of transformers including:
  1. terminal connections,
  2. grounding,
  3. cooling arrangements,
  4. transformer protection devices,
  5. the significance of transformer gassing,
  6. nitrogen sealing.
- The function and characteristics of switchyard equipment including:
  1. disconnects,
  2. grounding disconnects,
  3. lightning arresters,
  4. potential transformers - PTs.
- The application of high voltage cables.
- The function of circuit breakers including arc extinction by oil, air blast, SF6, vacuum, and blowout coils.
- The function of the switchyard bus.
- Bus arrangements.
- Station service supply.
- Black start capability.
- Plant auxiliary power board layout.
- Auxiliary power for remote locations, i.e. spillway and control structures.
- Circuit breakers and motor contractors for operation of plant auxiliaries.
- The characteristics of breakers and contractors on loss of power supply, i.e. to remain closed or to open.
- The application of DC power for emergency lighting, emergency equipment, control, alarm and protection circuits.
- DC power supply sources.
- Critical AC circuits, including communications, computer equipment, protection and control circuits.
- The provision of uninterruptible AC for critical circuits.
- The importance of equipment safety and personal safety in connection with high voltage electrical equipment.
- The application of operating procedures to avoid equipment damage due to faulty operation.
- The application of clearance procedures to ensure personnel safety when performing maintenance.
- The responsibility of each individual to ensure his own personal safety when working around electrical equipment in the plant.
2710: Hydro Plant Operation & Maintenance

The objective of this videotape is to review and demonstrate the general responsibilities and tasks performed by operations and maintenance personnel in a typical hydro plant. It thus brings together many of the items discussed in earlier videos. Included is a brief overview of environmental requirements affecting the operation of the plant.

After completion of this videotape and associated workbook, the participant should be able to understand and apply the following:

- Operating personnel for different types of plant.
- General responsibilities of the operator.
- Safety of equipment and personnel.
- Clearance procedures.
- Equipment status (availability).
- Routine inspection of operating equipment.
- Logging and reporting; Conditions, incidents, defects.
- The importance of good housekeeping.
- Operating routines i.e. start-up, shutdown, synchronous condenser operation, dewatering, etc.
- Factors that impose limits on operation.
- Operation of intakes and control structures.
- Ecological factors.
- Fish ladders and lifts, effects of variation in water level, dissolved oxygen content.
- The importance of long range maintenance planning.
- Breakdown maintenance, running maintenance, preventive maintenance, predictive maintenance.
- Equipment inspection programs, daily, monthly, annual and overhaul.
- Maintenance job procedures (work guides).
- Maintenance records.
- Condition monitoring.