GEC223: FLUID MECHANICS

MODULE 4: HYDROPOWER SYSTEMS

DEPARTMENT OF CIVIL ENGINEERING, LANDMARK UNIVERSITY, KWARA STATE, NIGERIA

Course Objectives/Goals

1. Teach students the basic concepts and theories governing fluid in motion and at rest.
2. Teach students frictional effects and losses in pipe and duct flow.
3. Make students understand the practical uses of dimensional analysis in hydraulic engineering.
4. Familiarize students with principles of construction and operation of selected hydraulic machinery
5. Make students appreciate the use of hydropower systems, governing equations and operations.

HYDROPOWER SYTEMS

Hydropower is the power generated by utilizing the hydraulic energy of water. The world's exploitable hydropower potential is approximately 2724MKW. The present installed capacity is approximately 200MKW which is about 9% of exploitable hydropower potential. It has the advantages of operational flexibility and spectacular operational flexibility.

Hydropower system utilizes hydraulic turbines which converts hydraulic energy of water into mechanical energy. This is made possible by a change in moment of momentum between turbine entrance and exit producing a torque on the turbine runner causing it to rotate. As the turbine runner rotates, the turbine main shaft rotates. Likewise, since the generator shaft is coupled to the turbine main shaft, the generator shaft rotates which ensures the rotation of the generator, which produces electrical power.

ADVANTAGES OF HYDROPOWER PLANTS

1. Large untapped potential at abundant sites.
2. Cheapest among new renewable sources of energy.
3. Highly reliable
4. Maintenance and operation charges are very low.
5. Running cost of the plant is low.
6. Plant efficiency does not change with age.
7. High efficiency between 85% - 95%.

8. Less supervising staff is required.
9. Less pollution.
10. Long project life between 100-125 years
11. Capability of multiple uses such as irrigation and flood control.
12. Machines used in hydro-electric plants are more robust and run at low speeds between 300-400r.p.m.
13. No fuel charges
14. Minimum transmission and distribution losses.

DISADVANTAGES OF HYDROPOWER PLANTS

1. Initial cost of the plant is very high.
2. Long gestation period between project initiation and implementation.
3. Require long transmission lines which generate some losses.
4. Highly dependent on quantity of available water.

MAJOR OBSTACLES TO UTILIZATION OF HYDROPOWER RESOURCES

1. Large investments
2. Long gestation period
3. Increased cost of power transmission

LOCATION OF HYDROPOWER PLANTS

1. Rivers
2. Canals and river falls
3. Seas/ocean

FACTORS TO CONSIDER IN LOCATION OF HYDROPOWER PLANTS

1. Site data assessment
2. Hydropower design and engineering
3. Economic feasibility analysis and finance services
4. Procurement of land and site development
5. Civil and electrical works associated with hydropower systems
6. Complete infrastructure for development of hydropower system
7. Establishment of sub-stations
8. Operation and maintenance

COMPONENTS OF HYDROPOWER SYSTEM AND THEIR AVERAGE LIVES

S/N	COMPONENT	AVERAGE LIFE
1	Reservoirs	70-80
2	Dams (i) Earthen, concrete (ii)Loose rock	 150 60
3	Waterways (i) Canals, tunnels (ii) Penstocks (a) Steel (b) Concrete	 50-100 40-50 25-50
4	Power house and equipment (i) Building (ii) Generators (iii) Transformers (iv) Turbines (hydraulic) (v) Pumps	 35-50 25 30 5 20-25

HYDROPLANT CONTROLS

1. Hydraulic controls
2. Machine controls-starting and stopping
3. Machine controls-loading and frequency
4. Voltage control of generator and system
5. Machine protection

COST CONSIDERATIONS FOR HYDROPOWER PLANT

1. Cost of land
2. Cost of highway required for the construction work
3. Cost of construction
4. Cost of engineering supervision of project
5. Cost of building
6. Cost of equipment
7. Cost of equipment used for power transmission

CLASSIFICATION OF HYDROPOWER PLANTS

A. Based on storage characteristics
    1. Run-of river plants
    2. Storage/reservoir plants
    3. Pumped-storage plants
    4. Tidal plants
B. Based on load characteristics
    1. Base-load plant
    2. Peak-load plant
C. Based on head
    1. Low-head plants
    2. Medium-head plants
    3. High-head plants
D. Based on plant capacity
    1. Micro-capacity plants
    2. Medium-capacity plants
    3. High-capacity plants
    4. Super-capacity plants

E. Base on type of fall
    1. Concentrated fall plant
    2. Divided fall plant

A. STORAGE CLASSIFICATION

(1)RUN-OF-RIVER PLANTS

These are located on perennial rivers with adequate water discharges all seasons. It makes use of pondage created upstream using weirs to store water which are utilized during off-peak hours.

(2) STORAGE PLANTS

These are constructed on non-perennial rivers. They utilize large reservoirs which are created by dams constructed the river. The reservoir carries over storage from rainy season to dry season.

(3) PUMPED-STORAGE PLANTS: The water used in generating electrical power is pumped back. They generate power only during peak-load period. Pumps are run with secondary power available from some other plants in the system. They provide additional capacity to meet peak demand.

(4) TIDAL PLANTS

They utilize high tides at sea for generation of power. They are used where tidal range is high e.g. at La Rance power plant in France where tidal range is approximately 1m.

B. LOAD CLASSIFICATION

1. BASE-LOAD PLANTS-Takes care of base load of the power system
2. PEAK-LOAD PLANT- Takes care of peak load of the power system

C. HEAD CLASSIFICATION

1. LOWER-HEAD PLANT- Operating head between 0-30m e.g. run-of-river plant and Kaplan turbines usually used.
2. MEDIUM-HEAD PLANT- Operating head between 30-250m. e.g. Francis turbine, which could either be low-range of medium head or high-range of medium-head.
3. HIGH-HEAD PLANT-Operating head greater than 250. The power plant is located at the toe of the dam. Storage plants are usually used. Examples include pelton turbines, axial flow and mixed-flow turbines.

D. PLANT-CAPACITY CLASSIFICATION

1. Micro-capacity plants-Capacity <5MW
2. Medium-capacity plants- Capacity between 5MW-100MW
3. High-capacity plants- Capacity between 101MW-1000MW
4. Super-capacity plants- Capacity >1000MW

E. FALL CLASSIFICATION

1. Concentrated-fall plant- Power house located close to dam or weir to utilize entire head created.
2. Divided-fall plants- Located at considerable distance from the dam or weir on the downstream utilizing steep fall available in the ground surface.

GENERAL ARRANGEMENTS OF A HYDROPOWER PLANT

1. DAM OR WEIR: Dam is constructed across a river to create storage on its upstream for storage plants. Weir is constructed across a river to raise the water level.
2. INTAKES: Constructed to draw water stored in the reservoir. It has control gates and trash racks.
3. CONVEYANCE SYSTEM: Carries water from the reservoir to the power house. It may include canals, pipes, penstocks or tunnels.
4. FOREBAYS: This enlarged body of water just upstream of intake. It is also a pond formed upstream of penstocks. It is required only when conveyance system has channel flow.
5. SURGE TANK: It is used to reduce the water hammer effect at the upstream of the power house due to the use of very high pressure conduit called penstock.
6. POWER HOUSE: A building for housing the equipment required for power generation such as turbines and generators.
7. TAIL RACE: This is a channel in which water after passing through the turbines is discharged.