Module 2: DIESEL ENGINE POWER SYSTEM, HYDRO ELECTRIC ENERGY

Structure

Objectives

After studying this unit, student should be able to

- Know about layout diesel engine power plant,
- Understand about cooling and lubricationsystem in diesel engine plant
- Know about intake and exhaust system in diesel engine power plant

2.1 Introduction

We know that, all types of automobiles including tractors, trucks and buses use internalcombustionengines. These internal combustion engines can also be used for power generationwherethesupplyofcoalandwateris not available in abundantquantity.Theseplantsaresuitableforsmalland medium out puts and can be used as stand by plants to hydro electric power plantsandthermalpower plants. These can also be used to meet peak load demand in some powerplants andcan be used to supply the seasonal electric loads.Low capacity plants uses petrolengines and are meant primarily for emergency service. A large capacity plant uses diesel enginesforpowergeneration. The capacity of these plants ranges from 2 to 50MW and are used asstandbysetsin hospitals, cinemas, telephone exchanges, radio stationsetc. It is one of themosteconomicmeans of generating electricity in a small scale where cheap fuels are not available andloadfactorsareconsiderablyhigh.

Ina steam plant, one or more diesel generating units may be installed to serve as stand by ortosupplypeak loads of small duration. As stand bys, these units may provide for the totalresidentialload of the power plant. In thermal plant, the diesel generators suppl y power forauxiliaries in case of failure of main working units. In industrial plant where the steam is used forprocesswork, fliesel engines supplies power during seasons when steam for process work is notrequired.

2.2 Advantages and disadvantages of diesel Power Plants;

Advantages

1. Verysimplein designandeasyto install
2. The plant can be located very near to the load centre.
3. The overall capital cost per unit of installed capacity is lesser than thermal or hydelplant.
4. Theplantrequireslesseroperatingandsupervisingstaff.
5. Fuel handlingis easierandno ashdisposalproblem.
6. The cooling waterrequirementis less.
7. It canbequickly installedandcommissionedandcanbeput on loadquickly.
8. It canmeetsuddenchangesin theloadwithoutmuchdifficulty.

Disadvantages

1. The size of the unit is limited and very large capacity plants are not possible.

2. The operating cost is high.

3. Lubricating cost and maintenance costs are high.

4. The plant cost per KW is comparatively more.

5. Noise*from* the exhaust is a seriousproblem.

6. The life of theplant is limitedto 2 to 5 yearswhencomparedto thermalplants

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Applications of diesel Power Plants

1. It can be used as peak load *or* stand by unit *for* hydel plants.

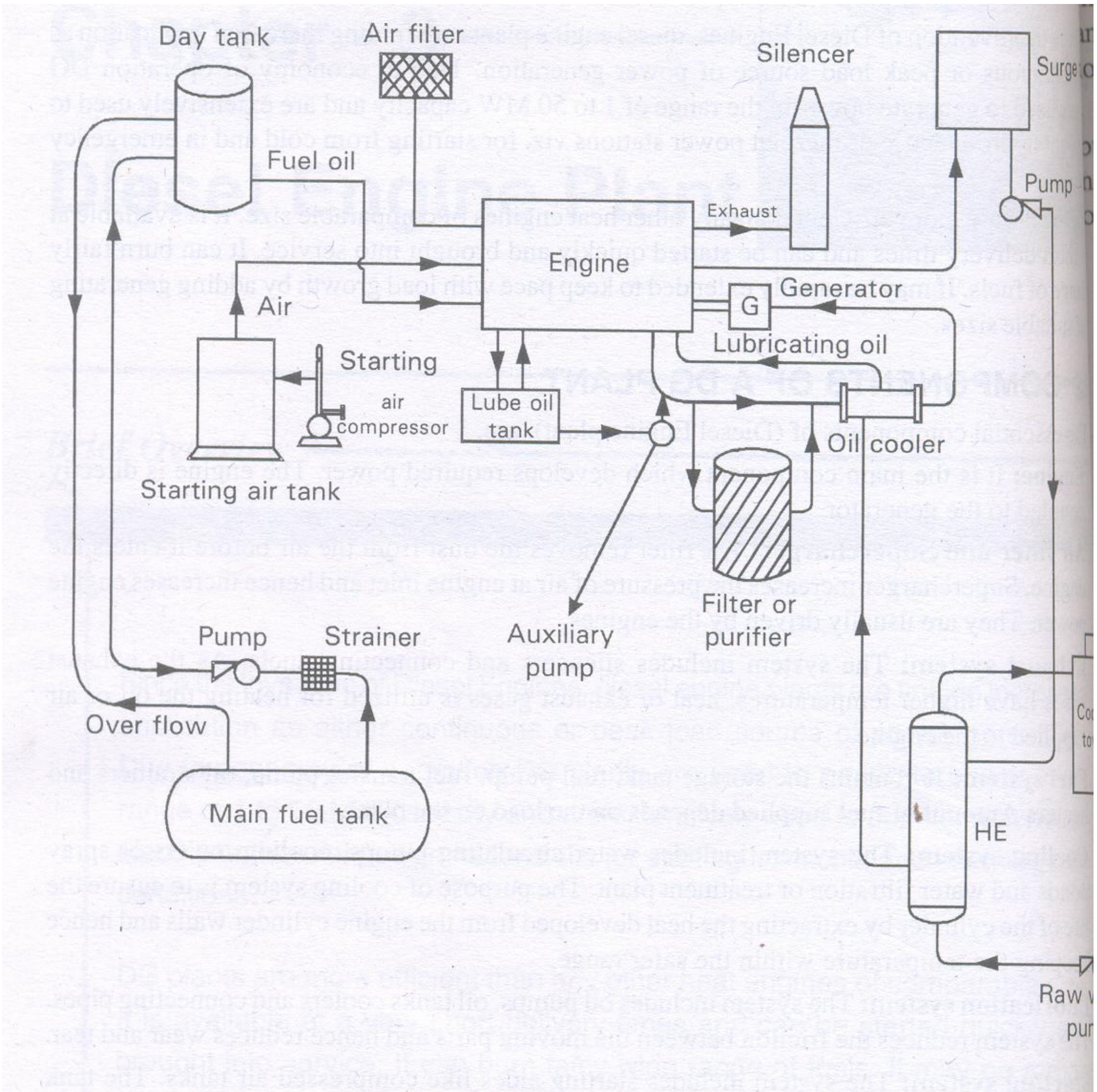
2. It can be used as mobile plants *for* temperory *or* emergency purposes (for large civillengineering works etc..)

3. Thesecanbeusedin emergencycaseswherepowerinterruptionwould result in financialloss *or* danger, in key industrial processes, tunnel lighting and operating rooms of hospitals,

4. It can be used as a Nursery station. The plant supplies power to a small town in absenceof main grid and can be moved to another area which needs power in a small scale whenthe maingridis availableisknown as "Nurserystation".

5. It can alsobe used as startingstation.The plantruns the auxiliaries*for* starting the largethermal plants.

2.3 Layout of a diesel power plant



2.4 Engine Intake system

A large diesel engine requires 0.076 to 0.114 m3/ min of airperkW of power developed, the air intake system supplies required quantity of air for combustion. The system consists ofapipe line which connects source of fresh air and engine manifold. Filters are reprovided toremove dust from the air, otherwise dust particles may cause wear and tear of the engine. Thesefilters may be of dry type (made up of cloth, felt, glass, wool etc.,) or oil bath type. ElectrostaticPrecipitator filters can also be used. In oil bath type of filters the air is swept over or throughabath of oil, so that the dust particles are gets coated. The intake ducts are made up of light weightsteel. Some times, a silencer may be used between the engine and intake since the noise maybetransmitted back to the outside air via the air intake system. In the air intake system, pressure lossshould be minimum. If pressure loss is high, it reduces engine capacity and increases specific fuelConsumption.There fore in total,the functionsof air intakesystemare:

i) Toclean the air suppliedto theengine

ii) Tosilencethe intakeair.

iii) Tosupplyair for supercharging.

2.5 Engine exhaust system

Engine exhaust system including ducts, mufflers, water heaters, silencers etc.,

The exhaust system is used to convey the exhaust gases to the atmosphere out side thebuilding.It alsoconsistsof a silencerto reducethenoiselevel.Amufflerprovidedin theexhaustpipe reduce the pressure in the exhaust line and reduce the noise.Some times, a device maybeused in the path of exhaust gases to recover heat of exhaustgases.Theexhaustpipecomingout of buildingshouldhaveoneor two flexibletubingsectionsinorder to isolate the systemfrom vibrationby taking the effect of vibration.Its length shouldbeshorterand should have minimumnumber of bends. Every engine should be provided withanindependentexhaustsystem.

The points to be consideredin the design of exhaustsystem are;

1. Thenoiselevel shouldbeminimum.
2. Thesystemshoulddischargetheexhausfsufficientlyabovethegroundlevel.
3. The duct should take up effect of expansionand contraction due to temperaturevariation.
4. As back prssureimposedon the enginereducesenginepower, it shouldbekept minimum
5. Theflexibletubing sectionsareto be used in the exhaustpipe in orderto isolatethesystemfromvibration.

2.6 ***Fuel System***

The fuel system includes fuel storage tanks, fuel transfer pumps, strainers, heaters andconnectingpipes. The trucks, rail road tank cars, or barge and tankers are used to deliver thefueloilto the plant site.Then, fuel oil is delivered to main storage tanks through unloading facility.Thenthe transfer pumps are used to deliver fuel oil to smaller service storage tanks (day tanks).Forthemainflow, piping arrangementis made with necessary heaters,by - passes, shut offs,drainlines,reliefvalves,strainers,filters,flowmeters,andtemperatureindicators.Theminimumsto ragecapacityof maintance should satisfy at least a month'srequirementofoil.Butin order to availthe advantageof price fluctuationsof the fuel, it is essential to provide storage or few months requirement.The capacity of the daily consumption tank should be atleasthe8 hoursrequirementof the plant.Usuallythesetanks arelocatedabovetheenginelevelsothat theoil mayflow to the enginesundergravity.

Thefueloil supplysystemhasto satisfycertainrequirements for it'ssatisfactoryworking;

1. Provisionshouldbe madeforcleaningandchangingover of linesduringemergency.
2. Tight pipejoints shouldbe usedin allsuctionlines.
3. The oil flushing is done through the piping between filter and engine before beingplaced in service.
4. High grade filters are to be used to hold water, dirt, metallic chips and other foreignmatter.

2.7 Cooling System

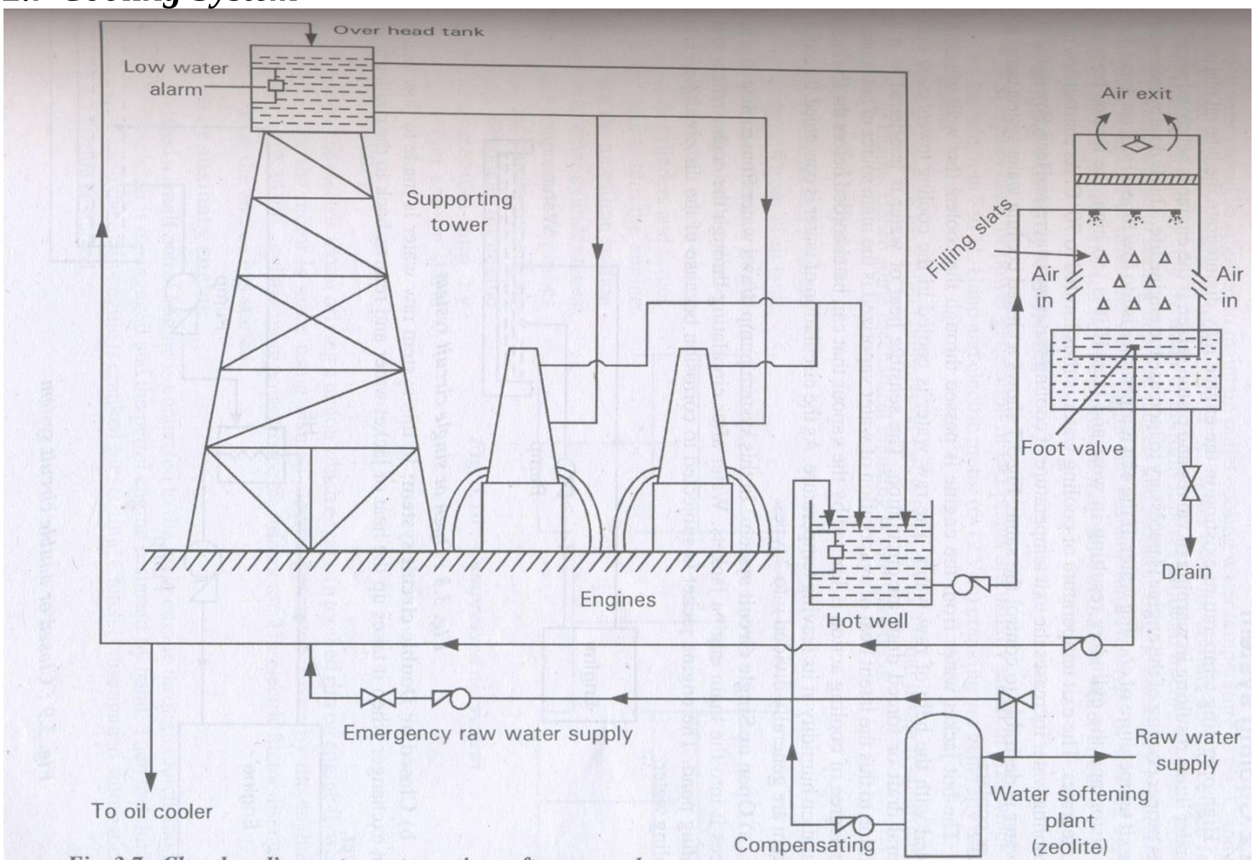


Fig. 3.7 : Closed cooling water system using soft water coolers

Thecoolingsystemin a dieselplantincludescoolantpumps, coolingtowersor sprayponds,waterfiltrationplantandpipes.The purposeof cooling systemis to provideproper circulationof cooling water all around. Theenginestokeepthetemperatureat reasonablylowerlevel.Iftheengineis not cooledproperly,thehigh temperatureexistingin theengines (cylinder and piston are exposed to hightemperatureof theorderof 1000to 15000C) woulddisintegratethefilm oflubricating oil, causeswarpingofvalves, piston etc., The overheatingof engine would cause damage to the piston, piston rings,head andcytinder liners. A pump circulates water through cylinder and headjackets to carryaway the heat. Some heat is also taken away by the lubricating oil. Same water should be usedagain and again and hence a method of cooling the cooling water is required. This is achieved bypassingwater through radiators, evaporative coolers, cooling towers, spray ponds etc., nearly25%to35% of total heat of the fuel is removed by the cooling system.The heattakenawayby Oilandradiation heat lost accounts to 3% to 5% of total heat supplied.

3.8 Cooling system for diesel engine

The cooling system in a diesel plant includes coolant pumps,coolingtowers or spray ponds, water filtration plant and connecting pipes. The function of coolingsystem is to provide proper circulation of cooling water all around the engines to keep thetemperatureat safe level. Under cooling raises engine temperature, decreases engine performance and its life. Excessive cooling makes the combustion poor and affects the fuel economy. It increasesviscosity of oil due to low temperature and hence increases power loss due to friction. Basical there are two methods of cooling,

i. Air cooling

ii. Liquid cooling

Air cooling: In thismethod,engine cylinderis directlyexposed to atmosphericairwhich carries the heatfrom the cylinder. The cylinder is finned, particularly heavily nearthe exhaust.Theuse of fins over engine cylinder provides additional heattransfer surfaces, there by increasesrate'WaterorLiquidcooling: In thismethod, thecylinderwallsandheadsaresurroundedwith cooling water jackets. The water while circulating through jackets, take the heat from cylinderwalls by convection and conduction. The heated water itself is cooled by circulating it throughaircooledradiatorsystem. In stationary diesel engine plants the watercooling systemsare used and areas follows;

i) Open or single circuit system

Water is pumped from cooling pond to the mainenginejackets.Aftercirculation,wateris returnedto thecoolingpondby sprayingthrough nozzles.Thedissolved gassesin the cooling water may corrode thecylinderjackets.

ii) Closed or double circuit cooling system

Double circuit cooling system

In this system, heatxchangeris used inbetweenengineand coolingpond.The waterfromthe pondispumpedthrough the heat exchanger,whereit takes the heat fromjacket waterand isreturnedtothecoolingpond. The cooled water is again pumped back to the engine side.Thismethodeliminatesinternaljacket corrosion.

3Evaporativecooling: In this method, a large swface of the hot water is exposed to an airflowt,herebyhumidifies the air and cool the remaining water.This can be done by providingcooling towers,evaporativewatersetc., Thecoolingactionis samein allof them.Theatmosphereisamixtureof air and water vapour in proportion and is described by humidity. Proper latentheatofevaporation must be supplied for vapourization of water. The source of heat may beinternaelnergy of the liquid water from which the vapour is being produced. During the process Ofhumidification,some off the warm water goes off inJOthe atmosphere and make up water of2.5%ofwater flow must be added to the system.

Atmospherictowers are long and having narrow structures with considerable height. Theaxis(vertical)of the tower is normal to the prevailing wind and are built to utilize horizontal windmovementsF.rom the top of the towers, waterfalls through the air currents a'ndevaporativelycooled.Thesetowers are not used in diesel power plants.For effective cooling, tower should be sufficientlyhigh. The cooling water is collected and pumped from the bottom of the tower andsuppliedto the engine for cooling.Afanis provided in mechanicaldraughctoolingtower.The use of fanreducesthe height of tower. Dependingonlocation, the fan used could be aforceddraught type or Induced draught type.The faIling water meets the air which is flowing in the oppositedirection..

An evaporative cooler is one inwhichthe cooler is constructed fromsteelincluding a heat exchanger forcoolingthe water. This type is notsuitablefor diesel plants.Theevaporative cooling is also known as steam or vapour cooling in which the coolingwatertemperaturereaches to a temperature of 100°C.The cooling of water can be done withminimumof waterby usinghigh latentheatof vapourization.Thecoolantis alwaysin theliquidstate,but the steam formed is flashed off in a separate vessel. The fresh water so formed is,returnedback for cooling. This system is used many industrial engines.Spray eliminators

Radiator in place of cooling towers, cooling ponds and spray ponds are used. But these are inefficientfor bigger power plants.

Lubrication for the diesel engine: As discussed, the roleof lubricationsystemis moreimportantin dieselpowerplant thananyother plantbecause of veryhigh pressuresand small clearancesin these engines.

The lubrication system influences theenginelife, efficiencyandthe extentto whichtheengineisput incontinuousservice.

In a dieselengine, thefollowing gare themainpartswhichrequirelubrication,

1. Pistonandcylinders.

2. Crankshaftandconnectingrod bearings.

3. Gearsandothermechanismused forpower transmission.

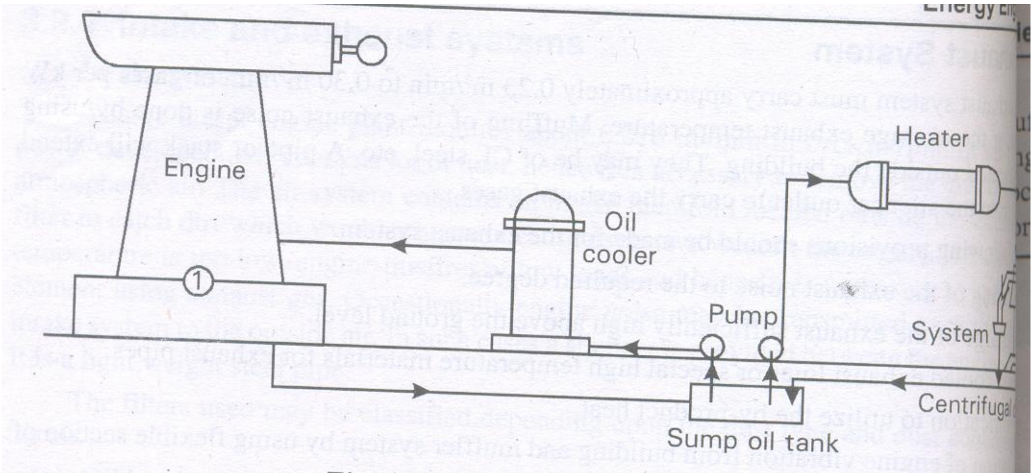
4. Integralinjectionor scavengingaircompressors.

Lubrication may beclassifiedinto

1. Full pressurelubricationsimilarto thatusedin automobileengines.

2. Mechanical force-feeds lubricationandgravitylubricationfromanover headtank.In pressurelubricationsystem,anoilpumpisusedto deliver the lubricantunderpressuretovariousparts of the enginethrougha duct systemandto the crankshaft and wristpin bearingsbydrilledpassagesintheshaftandrods.Forlubricationofcylinderwalls,oilmistslungoutwardfrom the connectingrod bearingsor splashlubricationmethod is used. Mechanical force-feedlubricationis usedto effect the lubricationof cylindersof large and slowspeed engines.The crankcase serves the purpose of oil sump from where the oil may be withdrawn by apump.Thelubricating oil, duringitscirculationthroughthelubricationcycleaccumulatesimpuritiessuch as carbonparticles, waterandmetal scrapandis cleanedby settling,centrifuging,filteringor chemical reclaiming. Mechanical filters such as cloth bags, wool felt pads, paper discsandcartridges of porous material are used for cleaning the oil. In centrifugal cleaning, first screenfilters are used to clean the oil and then the oil is passed through high speed centrifuges forultimatecleaning. The oil shouldbe heated, before it enters to the centrifugal cleaner.The oilconsumption is in the range of 2.27xl 0-6to 4.1Ox10-6m3per kW hour. In chemical reclaimingmethoadf, terfiltering, a combination of heat and activated clay are used. In settling method,impuritieasre made to settle down by allowing the hot oil to enter in to a large tank. Clean oil isthenusedfromthe top of the tank.Thelubricatingoil gets heated due to friction between rubbing surfaces and should be cooledbeforerecirculation. The lubricating oil absorbs about 2.5% of the heat of the fuel. The hotlubricatin oil may be cooled with the help of cooling water used for engine cooling. The lubricating oilconsumptionis about 1% of fuel consumption (3 litres per 1000 kWhr generated at full loadconditions).

2.8 Lubrication system



Thelubricationsystem includes oil pumps, oil tanks, filters, coolers, purifiers and connecting, thepurpose of lubrication system is to reduce the friction and wear of the rubbing

Lubricating oil is used to

1. Lubricate the moving parts

2. Remove heat from cylinder and bearings '-

3. Carryawaysolid matter from rubbing moving parts.

4. Absorbthe shock between bearings and other parts and consequently reduce noise.Pumpsare used to deliver the oil to the engine and the oil is recirculated under pressure.

Thelubricationsystem has to effect the lubrication of following engine parts.

1. Maincrank shaft bearings

u. Big-endbearing

iii. Smallend or gudgeon pin bearings

iv. Cylinderwalls and piston rings

v. Tuninggears.

vi. Carnshaft and its bearings

vii.Valvemechanism

Viii.Valveguides, valve tappets and rocker arms.

3.9 Lubricating system (continuous centrifuging system)

The lubricating oil in use is subject to changes in operating temperature and results information of sludge and varnish. Therefore, it is necessary to use the oil with engine cleaningproperties. In order to improve the oil characteristics, additives such as anti oxidants, detergents,corrosion inhibitors are added with straight mineral oils.Anti oxidants are used to prevent chemical reactionwith oxygen and due to heating. The addition of detergents keep the engine clean bycontrollinglacquer and preventing the deposition of carbon, soot, dirt and combustion productsonpistonand rings. Aprotective filw is formed on engine parts due to the addition of corrosion inhibitorsand this film protects the engine parts from corrosion acids, which is due to presence ofsulphur in the fuel.

Filters and centrifuges

Filtersand centrifugesareused to arrest dirt, metallicchips or other foreign substancesinthefuel.Filtersmay be of drytypeand madeup of cloth, felt, glass,filterpaper,somecellulosematerialwooletc.,or oil bath type. In the later type, the oil is sweptover or through an oilbathfilter, whichretainsthe oil coated dust particles. The clean fuel oil provides trouble free operation of theengine.Theuseof bulk storagetanksremovesmostof thesuspendedimpurities, waterdirtetcted from theoil, if it is light andallowedto standin thestoragetankfor sometime.This methodis too effective,if heavieroilsareusedorif thetemperatureof oils isbelow10°C.Hencecleaningdoneby filteration andcentrifugingwhentheoilistransferredfrom bulk storagetankstothetanks.Filteringmeanspassingtheoil throughfilterswhicharemostlyof absorbenttypeandretain the oil contaminants and allow clean oil to pass through. The filterscanbecleaned andreused and replacement ofcartidge is not very frequent. In other type of filters, ie., inoilimpingement type, a frame filled with crimped wire or metal shaving is used. A special oilcoated, so that when the air passing through the frame, is broken up in to a number of smallfilamentsandthesefilamentsmakescontact withtheoil.Thepropertyof oil is to seizeandholdanydustparticlescarriedbytheair.Thesefiltersrequireperiodiccleaningbyremoving,waterand re oiling. Some times, engine noise may be transmitted back to the out side air through theairintakesystem.In suchcases,a silencerisprovidedbetweentheengineandintake.Atypicalfilterandsilencerinstallationfor a dieselengine.

Acentrifugeis adevicein which thesuspended impurities in the oil are removedby givingarapidwhirling motion.Thisprocessis known as"centrifuging". This processremovesimpurities by separating heavierparticlesfrom light cleanoil. Theviscosityof oil isthefactorwhichinfluencet thedegreeof cleanlinessandit canbeimprovedby heatingtheoil. But whentheoil is heatedtohigh temperature, thecontaminant water may go in to the solution with oil andhenceavoidsseperation.Soin orderto obtaingood results, the oil temperature in the range of 15°Cto 38°Cis considered to be optimum. The centrifuge requires periodic servicing to ensure cleanliness ofoil after centrifuging.

2.9 Starting System

Thestartingsystem includes storage battery, self starter, and compressed air supply etc., theautomobileenginesare generally started by cranking. But in power plants, large capacity enginesareusedandarestartedby, i) Using compressed air ii) By using an auxiliary engine iii) By usingelectricmotors or self starters.

Governing System

Thepurpose of this system is to regulate the engine speed constant irrespecti ve of load on theplant.usually, this is done by varying the supply of fuel to the engine according to load.

Enginesfor power generation

Internal combustion engines are used for power generation, where the supply of coal andwateris not available in abundant quantity. An internal combustion engine is one in whichcombustionoffueltake place inside a cylinder. Areciprocating piston inside a cylinder developspower. Aconnectingrod connects piston to the crank shaft and converts reciprocating motion ofpistonintotherotarymotion of the crank shaft.

Petrol enginesareusedin low capacity plantsandareprimarily intendedfor emergency service. Diesel engines are suitable for large capacity plants and theseengines are mainly usedfor'power generation. The capacity of diesel plants ranges from 2 to 50MW and are used as standby units in hospitals, cinema halls, telephone exchanges, radio stations, etc., It is one of themosteconomic means of generating electricity in a small scale where cheap fuels are not availableandload factors are considerably high. ;

The diesel plants are more efficient than any other heat engines of comparable size. It iseas~to start and can bum wide variety of fuels. The advantages of diesel engine over petrol engineare

1. At partloadand full load,the specificfuelconsumptionis low.
2. For samecylinderdimensions,highcompressionratio yieldsmorepower
3. Longeroperatinglife. ,
4. Reducedfire hazardsl
5. The vibrationand balancingproblemsarenot severe at mediumspeed operation. In an internal combustion engine, the following steps are followed in the production ofpower.

1. Air/ Airfuelmixtureisdrawninto thecylinderthroughvalves/ portswhichisrefeITredas suction.
2. Compressionof air/airfuelmixtureduringtheupwardmovementof piston.
3. Combustionby fuelinjectionintothehighlycompressedairorbyproducingaspark in thecompressedair fuelmixturewhichinitiatesthecombustion.
4. Expansionof combustiongaseswhichthrustthe piston to performpower stroke.
5. Exhaustof burnt gasesfromtheenginecylinder.

Thedieselengines are moresuitablefor smalland mediumoutputpowerplants due tothereasons as Methods of starting the diesel engine

In powerplants, large capacityenginesare used and are startedby the following devices.

1) By compressed air.

2) By anauxiliaryengine(petrolengine)

3) By electricmotors.

*Compressedair system:*Largestationarydieselengines are startedwith compressedair.In thissystemcompressed air at a pressureof about 17bar is suppliedfrom an air tank or bottleto theengineinletvalvethroughthedistributororAtroughinletmanifoldTwoormorecompressedair storage tanks are provided.Asmallcompressoris installed for supplyof compressed airtothestoragetanks.Duringstartingofamulticylinderengine,compressedairisadmittedto oneormorecylindersand forces the pistonto movedownward which in turn rotatestJ1eengine shaft. Theinjectionor fuel pumps are inoperative while the speed is gained under air power.ThisPowerstheenginemuchthe same as steamworksin a steamengine.The air is turnedoff andoilInjectioinsstartedandtheenginegainsthemomentumandby supplyingfuel,theenginewillstartruning.

Byan auxiliary engine: In this method, a small petrol engine is mounted close to theMainengineandis connectedto it throughclutchandgear arrangements.Firstly theclutchis toBedisengagedand petrol engine can be easily started by manual operations. When it has warmedup,theclutch is to be gradually engaged to transmit power to the main engine i.e., the mainengineis cranked for starting. The clutch of auxiliary engine automatically dis engages after themainenginehasstarted.Thecapacityof auxiliaryengineisjust sufficienttoovercomethefriction ofthemainengine.

By electric motors or self starters: Electric motors or self starters are employed for smallgasoline and diesel engines. The engine consists of an electric motor which is used forstartingpurpose. Astorage battery of 12 to 36 volts is used to supply power to an electric motorwhichdrivesa pinion which engages a toothed rim on engine fly wheel. A small electric generator,drivenbyenginemay also'be used to drive the motor.The motor is engaged continuouslyforabout30 seconds only, after which it is required to cool off for a minute and then re engaged.

Thisistobe continued till the engine starts up. After the engine has started, the electricmotorAutomaticallydisengages. This method is more simple and effective than other method.

Methodof starting or starting procedure

Beforestarting the engine, it is necessary to go through all precautions supplied by manufacturers.

Theprocess of starting the engine is different for various engines. Some common steps are Aslistedhere;

1. Before starting the engine, it is necessary to'check air pressure and any possible air Leakagein theairsystem.In case of electricmotorstarting,thebatteryconditionshouldbe checkedregularly.
2. It is necessaryto checkfuel system,lubricatingsystemandcooling watersystem.
3. Theengineis crankedafter ensuringno loadonthe engine and decompressiondevice is use
4. By running the engine at slow speed, the workingof fuel pump is to be checked.The Inspectionis to be made for fuel andoil pressures,lubricatingoil systemetc.,

HYDRO-ELECTRIC ENERGY

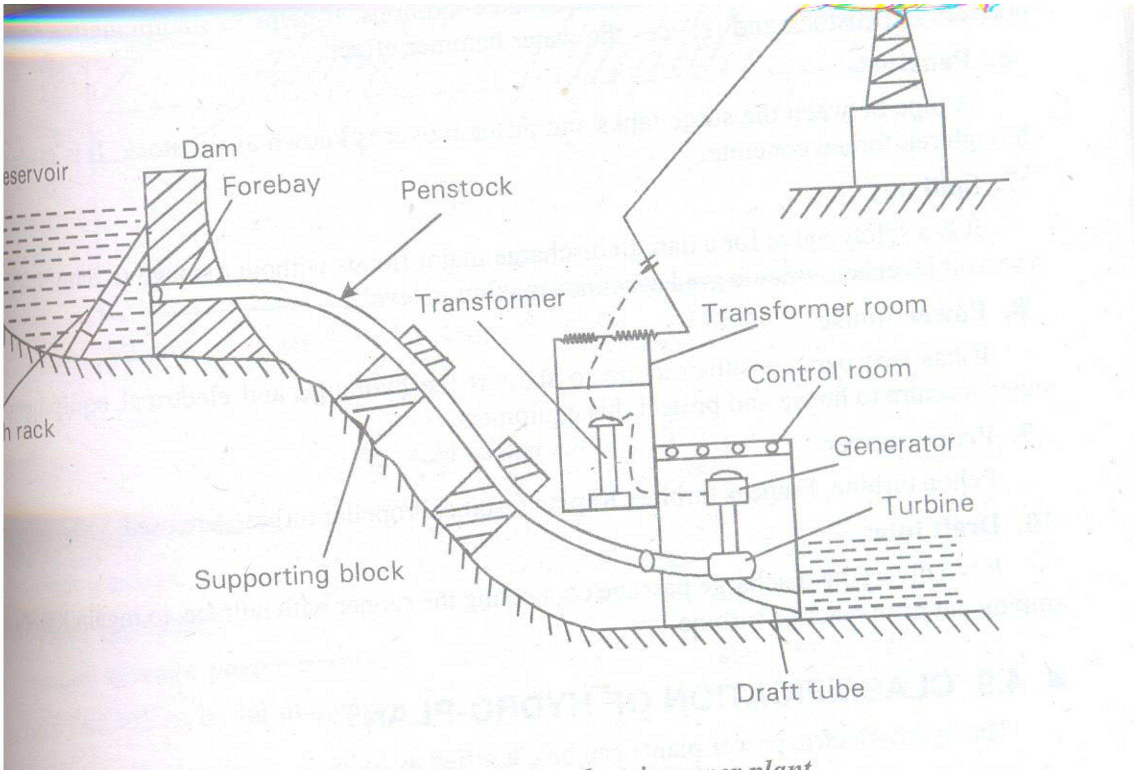
2.10 Introduction to hydro power

Wateris the cheapest source of power. In the earlier days, it was used to run the waterwheels generate electric power. The power generation by hydro electric plant is nothing butthe utilization of the part of hydrological cycle. These plants utilize the energy of water to drive theturbinewhich intum run the electric generators. In 1882, the first hydro-electric station wasstarted inAmerica.In India, these plants contributenearly half of the total power requirementandplaysaveryimportantrole in the developmentof country.In India, a hydro electricpower stationwasinitiatedwith run of river schemenear Darjeling and the first major hydro electricplant wasdevelopednear Mysore in 1902(SivaSamudram of 4.5 MWcapacity)Thepotential energy of

rain falling on earth's surface, relative to the ocean is converted in toMechanicalenergy by using suitable prime movers i.e., hydraulic turbines. In hydro powergenerationth, e kinetic or potential energy of water may be used. The kinetic energy of water is itsenergyin motion and is a function of mass and velocity. The potential energy is nothing but thedifferenceof water level between two points i.e., head. In both the cases, water should be
available continuously and in ample quantity. The past history of the place oflocation of the plantmustbe known to estimate minimum and maximum quantity of water which is available forpowergeneration. The water from natural lakes and reservoirs at high altitudes may be used orstoragereservoirs may be constructed to store the water during peak periods and utilise thesameduring off peak periods. The dams constructed across the flowing stream serves thispurpose.A significant amount of rain fal goes in the form of direct evaporation and a major
portionof rail fal seeps in to the soil to form the under ground storage. The remaining smallportionof rainfal is utilised for power generation.

Hydro or water power is a con ventional renewable source of energy. This energy source isclean,pollution free and environmental friendly. The hydro projects controls floods in the rivers,storesthe water for irrigation and for drinking purpose. The capital cost of the plant is high. Astheplants are situated in hilly areas, away from the load centre, the erection and transmissioncostsare also high. Hence, the cost of power generation is also high in comparision with steam,oilor gas plants. But inspite of these factors, a number of advantages favours the use of hydro projects.

2.11 Main Elements of hydro electric power plant



Arrangement of hydro-electric power plant

The hydroelectricpowerplantessentiallyconsistsof hydraulicstructures,powerplantetc.In the plant, hydraulicstructuremeansdams, Spillways,head work,diversion works,forebaysor surge tanks, penstocksand conduits.The essential elementsof waterpower plant are

i) Catchmentarea

ii) Reservoir

iii) Dam

iv) Spillways

v) Conduits

vi) Surgetanks

vii) Prime movers

viii) Drafttubes

ix) Power houseandequipments.

Catchment area: The catchment areaisthewhole area behind the dam which is builtacrossariverat a suitable place.

Reservoir: Itisthe basic requirementofahydro-electricpower plant and the ofwhich is to collect and store wholeofthewateravailablefrom the catchmentareabehind the dam.The stored water is usedlonmtl1tuerbines to produce electric powerimdulisyieldsuniform power out put through outtheyear.Areservoir may be natural typesuchaslakeor artificial one which is built byerectingdam across the river. Water held inupstreamreselvoiris called storage and waterbehindthedam,at the plant is called pondage.

Dam:The dam is the most importanteJemenotf the water power plant. It is aban'ierbuiltacrossthe riverto increasetheheightofwaterlevel behind it (to increase thereservoircapacity) and creates the necessaryheadtobeutilized in the water turbines.Economy and safety are the basicrequirements of the dam. The dam should resist water pressure and should be stable under conditions.In hydro - electric plants, several types of dams are used such as concrete or stonemasonry,earth and and/or rock fill and timber. Timber and steel are used for dams of height 6mto12monly.Earth dams are constructed upto about 100m.)he foundation must provide stabilityUnderdifferent forces and has to support the weight. It must be impervious to prevent seepage ofWaterunder the dam.

Forebay: It acts as a sort of regulating reservoirtemporarily store the water when the load on the plant isreduced and there is with drawl of water from it whenloadis increased. The river water is diverted away fromthemain stream. The enlarged portion at the end of canal forms the forebay.

Trashrack: It is provided on the way of waterfrom the dam or from the fore bay to prevent the entry ofdebris which might damage the wicket gates and turbinerunners or may choke up the nozzles of the impulse turbine.Manual or mechanical cleaning may be done to remove

Spill ways: It is a safety device for the dam, discharges the surplus water from the storagereservoir in to the river on the down stream side of the dam. It is arranged in the dam ornearthedam or on the periphery of the reservoir basin. This should provide structural stability tothedarnunder all conditions of floods. There are several designs of spill ways such as simple spillway,sidechannel spillway,saddlespillwaysiphonspillway,solidgravityspillway,chuteor troughspill way, emergency spill way etc.

Conduits: Inlet water way or head race is the passage of water from dam to the turbinesand tail race (outer water way) is the passage of water from the wheels. The inlet waterwayconsists of tunnels, canals, flumes, fore bays, penstocks and surge tanks. The tunnels aremadebycuttingthemountains where topography prevents the use of canalorpipeline.Headworkincludes, gates valves and trash rack etc.. The conduit may be open (canals and flumes)orclosed one (tunnels, pipe lines and penstocks).

Pen stock: A penstock is a closed pressure pipe (supplying water under pressure)
made of reinforced concrete or steel, used to supply water to the turbines. It is a pipe of shorterlength used to connect turbine and main water way. The penstocks are used where the slopeistoo great for a canal, especially where the land pitches steeply to the power house. As the working pressure or head of water increases, the thickness required in the penstock also increases,
Apenstock of larger diameter, gives lesser frictional loss. The flow of water through the penstockdecides the diameter, and the product of discharge and head gives the horse power whichthepenstock can carry. It indicates strength of the penstock. In the location of a penstock, economicalshortest route is always desired. It is desirable to locate the penstock always sloping towardsthepower house, but the extent of slope may be varied to suit the topography. In order to provideadequate water seal under all conditions, especially at low water, at the dam or fore bay.Theintake of penstock should be at a lower level. Generally penstocks are not covered, becauseexposed pipes are cheaper and maintenance and repair becomes very easy. Covered penstocksare used in the places where there is achance of sliding of snow, rock andearth etc. In the penstock, velocity of water ranges from 2 to 6 mlsec.lf thewater velocity increases, size of thepenstock required decreases andconsequently it's cost also reduces,butfrictional lossesincreases.Thelifeof the penstock may be increased byusing a protectivecorrosionresistantcoating on the steel penstock.penstocks may be burried orsupported on the piers and craddles.

2.12 **Classification of Hydro Plant**

The hydro electricpowerplants are classified according to Head of water available

a) Low head Plants:

These power plants are also known as canal power plants. In these plants, the water headavailable is less than 30 metres. The necessary water head is created by constructingadamacross the river and the water is diverted in to a canal which allows the water to flowinloaforebay, from wherethewateris madeto flowthroughturbines.Thenthewaterisdischargeidnto the river through a tail race. The power house is located near the dam itself and doesnotrequiresurgetank.Thisplantuses verticalshaftFrancisturbineor Kaplan turbine.

(b): Medium Head Plants:

In these plants, the operating head of water ranges from 30m to 100 metres. The forebay isprovided at the beginning of penstock, serves as water reservoir and conveys water to theturbines through penstocks. Open canals are used to carry the water from main reservoir to theforebay which it self acts as a surge tank. Forebay also stores the rejected water when the loadon the turbine decreases. Francis turbines are used in these type of plants.factor is less than one. Therefore, forsatisfactory working of the plant, it is tobe designedfor averageloadandthistypeisknownasbaseloadplant.Asmallplant known as peak loadplant peak load plant is usedto satisfytheloadwhichiscorningabove the mean load.

c) High head plants

Whenthe available water head for power generation exceeds 100 metre, the plant is knownAshighheadplant.During rainy season,usually the water is stored in lakes or high mountains. Fromthereservoirs, water is passed through tunnels which distribute the water to penstockThroughwhichthe wateris conveyedto the turbines.Asurgetank is attachedto the penstock toReducethe water hammer effect on the penstock. Waterflow is regulated by head gates at thetunnelintake, butterfly valves at the entry to the penstocks and gate valves at the turbines. Theseplantsareusuallyprovidedwithpeltonturbinesforpowergeneration.

d) Peak load plants

These plants are mainly intended to supply power during peak loads. Somepeakplants, deliver power during average and also peak load as and when it is there.Runofplants with pondage and pumped storageplants are used as peak load plants.In thefirstit uses a largepond which provides extensive seasonal storage.These work onrelativelhyIt.heads and load factor is considerably low.

According to quantity of water available for power generation

(a) : Run otTriver plant without pondage

This type of plant has no control over the river flow.The plant does not store waterand usethe water as it comes. During low load and high flood conditions, water will be wasted by over thedam spill ways.During dry seasons,the low flow of water reducesthe plantcapacl~.These plants are usually used to supply peak load. The non-uniformity of supply makes itsutili~ veryless in comparisionwith othertypeof plants.

(b) : Run of river plant with pondage

In theplant,additionof apond increasestheusefulnessof the run off riverplant.The wateris stored behind a daIrl and this increases the stream capacity for a short period. The conditionsat the tail race should be such that the water level in the tail race should not be increased duringfloodsas it decreasesthe effectiveheadof theplant.This plant can be used as base loador peakload plant. This plant is more reliable and its generating capacity is not fully dependent on the waterflowrates available.

(c): Storage type plants

This type of plant stores the water during rainy season in the reservoir and it is releasedduring dry season.The reservoir incorporatedis of a sufficiently large size to allowcarryoverstorage from the wet season to dry season. The power generation in dry seasons will notbe affected.

According to nature of load

The load on the power plant varies depending on seasons and every hour in a day. Consideraloadcurve as shown in figure 4.9 for an industrial town. The peak load is the plant capacity tosatisfythe demand. If the plant is designed for peak load capacity, then the working of the plantnot economical as most of the time the plant is working under low load conditions and the loadaffectplantcanbeusedasbaseload plant aswell aspeak load plant aswater is availablewithcontralsrequiredMostof thehydro-electricplantsinIndiaanaswellasin theworldareGeneraylltheseplantsareusedto supply thepeakloadfor the baseloadpower plantsandTosupply thesuddenpeakloadfor ashduration ie., afew hoursor few daysin ayear.Theseareusedintheplaceswherethewaterisnot availablein sufficient quantity for powergeneration.

Inthisplant,apenstockconnectsthe headwater pond andtail water pond. The generating Pumping plantis locatedonthelower sideasshown.Thebaseloadplant,generatessome surpluselectricenergyduring off peakhours.This energyis beingusedto pumpthewaterfromtailwaterpondto theheadwaterpondandthisenergywillbe storedthere.Duringpeakloadtime,this energy will be released by allowing waterto flow from head water pondthrough
theturbineof the pumped storage plant.

Pumpedstorage plant is a special type of hydroelectric plant works in combination withplantsto improvetheoverallefficiencyof thecombinedsystem.Theplantusesverylittle
Rateforitsoperationandhence decreases the operatingcost of the thermal plant.

2.13 Storage and pondage

Storage means, collection of water in the upstream reservoirs to increase the capacitystream over an extended period of several months. The water is stored in a reservoir forcontinuous generation of power through out the year and the power generation is not affected by thevariationin the rainfall during the year. The excess water is stored in the reservoir during rainy seasonan and it is released during run off (dry) periods. Storage plants may work satisfactorilly asbaseload Sand peak load plants. Maximum storage should be provided with economic expenditure.Thereare two types of storage.

i) The storage of water is provided for one year only (considering losses also),sothatthere is no carry over water for the next season.

ii) The water is stored, so as to be useful even during the worst dry periods.

Pondage means, collection of water behind a dam at the plant and increases the streamcapacity for a short period, ie., for a week. The generating capacity of the plant is less dependenton the flow rates of water available and the plant with pondage is more reliable than that withoutpondage.Arunof riverplantwithoutpondageuseswaterjust as it comes,withoutstoring.Thereis no controlon flow of waterso that wateris wastedduringhigh floods or low loads.Theplantcapacity is reduced during low run off period. The capacity of pondage should be such that,itshould take care of hour to hour fluctuations in load on the plant through out the period.

2.14 Hydrology

Hydrology is the science that deals with the depletion and relplenishment of water resourceson and beneath the surface of earth. It is the natural science in which rain fall and run off canbeanalysed and studied and occurence and availablity of water can be studied. It also deals withal formsof wateri.e., solid,liquidand vapour.Thestudyofhydrologyprovidesinformationabouttransportationof waterfromoneplace to onother,andfromoneform to another.The scienceofhydrologyis very importantin the design of irrigationstructures,planning and constructionofbridges and flood control works etc.

Hydrologic cycle

We know that, the cloulds are formed due to evaporation of water from plants, rivers andoceans and the evaporated water is carried with air in the form of vapour. In the atmosphere, thevapour falls in the form of water or snow depending on atmospheric temperature, when these arecooled below the dew point temperature. This evaporation (water lost in atmosphere as vapour)and precipitation (vapour condensed back in the form of rain, snow, hail, dew, sleet or frost)continues for ever and there by maintains a balance between these two. This is known as"Hydrologic cycle".

The Hydro logical cycle involves various processes such as transfer of moisture from thesea to the land and back to the sea again. The hydro logic equation is expressed asevaporation

P = R+E

P = Precipitation

R = Runoff

E = Evaporation

Precipitation (Rain fall); It includes all the water that falls from atmosphere to the earth surfacei.e.,vapourcondensed in the fonn of rain, snow, hail, dew, sleet, or frost. It consists of i) Liquid

precipitation (rain fall) and ii) Solid precipitation (snow, hail etc).

Runoffand surface run off: The portion of rain fall or precipitation, flows through the catchment areaonthesurfaceof theearthisknownas runoff.or dischargeorstreamflow.It includesalltheWaterflowingin the streamchannelatanygivensection.Theramainingportionof the rainfallis directlyevaporated by the sun, taken by the vegetation and growing crops and some percolates intotheground. Run off occurs when the rate of precipitation exceeds the rate at which water infiltratesin to the soil. The factors which in influence the rate and volume of runoff are duration,intensityand distribution of rain fall.

The surface run off means the water that reaches the stream channel without first percolatingdownto the water table (WT).

Evaporation: The change of phase of water from liquid to vapour state is called evaporation

Transpiration: *It* is the process by which the plant releases water to the atmosphere.

Run off can be measured daily, monthly seasonally or annually by using the following methods

i) Fromrain fall records

ii) Byusingempiricalequations

iii) By using runoff curvesandtablesand

iv) Dischargeobservationmethod.

2.15 Hydrograph

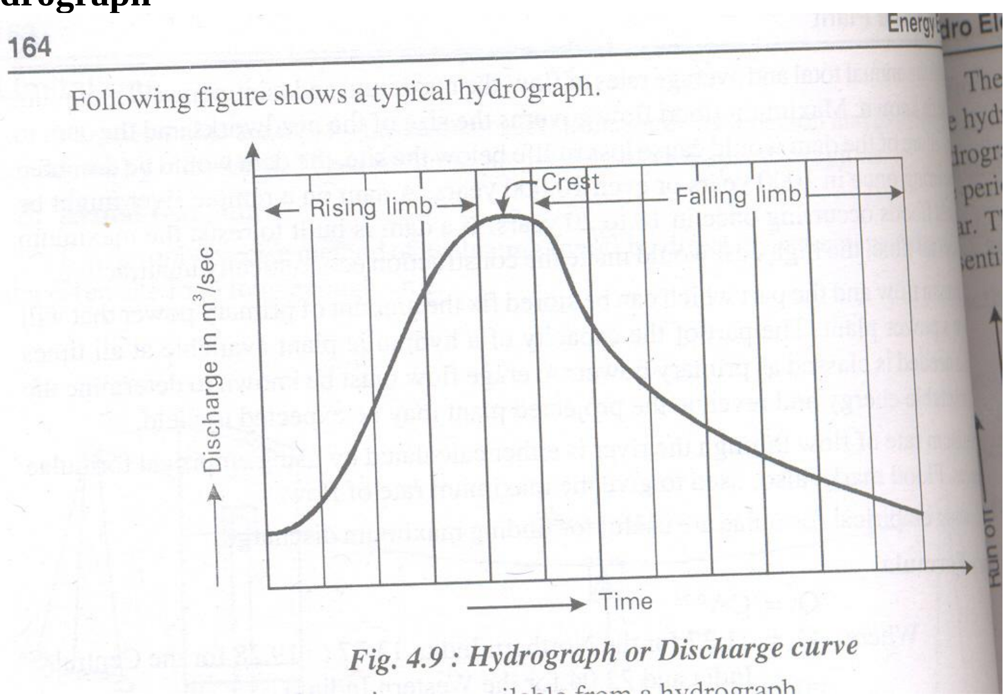


Fig. 4.9 : Hydrograph or Discharge curve

A hydrograph is a graphical representationshowing discharge (run off)offlowing water withrespect to time for a specified time. It indicatesvariation of flow or discharge with time. Ahydrographmay be plotted for hours, days,weeksor several months. It is plotted with flow as theordinate (inm3/sec)andtimeintervalas abscissas(in hours, days etc). Besides the variation of flow,indicatedbyahydrograph~italsoindicatesthepoweravailablefrom the stream at different times of theday, week or year. A hydrograph also indicatesextremeconditionsof flow and helps in analyzing theeffectof storage onflow.The characteristicsofthe catchment andprecipitationoverit, will effectthe nature of hydrograph of stream of river. Flodflow of the rivers can also be assessed and hencefora givenstorm,anticipatedhydrographofthegivenriver could be drawn.

A hydrograph is used to determine

1. Flow rate atanyinstantduring thedurationperiod.
2. Asareaunderhydrographgivesvolumeofwaterin a particularduration,thetotalvolumeof flow duringthat periodcan be determined.
3. The meanannualrun offor meanrunoff for each monthof the year.
4. Themaximumandminimumrunoff for theyearandforeachmonth.
5. Flooddurationandfrequencyandmaximumrate of runoff duringthe floods.

The peakflow shows only a momentaryvalue.There fore it is required to analysethefullHydrographofflowandtheconceptof unithydrographhasbeenintroduced.ie.,Thetwoidenticalstormsproduces same hydrographsfor the run off. Usually identical stormsrarely occursandgenerallyrainfallvariesin duration.Hencefor thebasin,a typicalhydrograhis tobe constructedwhichcouldbe used as a unitof measurementof run off.A unit hydrographis onewhichrepresentsunit run off resultedfrom an intenserain fallofUnitdurationandspecificarealdistribution.

2.16 Flow duration curve

Curveshowstherelationbetweenflows,plottedastheordinateandlengthsthey are available and plotted on abscissa. This curve represent the run offtime in the another form and is obtained from a hydrograph. The flow duration between flow available during a period and the fraction of time. If the potential flow is plotted on the ordinate, then the curve is known as "Power durationuseful to analyse development of water power. The flow duration curve gives at the site, and may be used to find maximum and mirlimum flow conditions.drawn by using hydrograph from the available run off data and it is required to time during which certain flows are available. This information is obtained eitheror from hydro graph and is tabulated. Then the flow duration curve can be00% time on the x axis and run off on Y axis. Durationcurveisthegraphicalrepresentationofitsflowarrangedin thedescending meanmonthlydischargeata siteis asshown.Drawthehydrographcurve by takingtime in monthson abcissa ordinate.Fromthisdrawflowdurationcurvebyfindinglengthsoftime

Uses offlowduration curve

i) Usefidfor comparisionbetweenstreams

iI) Usefidforprelimiruuystudies

ill)It evaluateslowlevelflows.

iv) It helps inplanningand design of water resourceprojects.

v) It helpsin designingdrainagesystemsandin floodcontrolstudies.

Disadvantages of flow duration curve

i) It does not present the flows in natural sequenceof occurence

ii)Thecurvewillnotgiveanyideawhetherthelowestflowsoccuredinconsecutiveperiods or were scatteredthrough out the consideredperiod.

2.17 Mass curve

In a hydrostationthe capacityof the reservoiris computedbyusing a plotknownas "masscurve".This plot givesthe storage requirement that is needed to produce a certain dependable

flowfrom fluctuating dischargeof a river bya reservoir.Amass curve is defined as a graph ofcummulativevolumesof waterthatcan be storedfromstreamflowagainsttime indays,weeksormonths. The integral curve of the hydrograph leads to mass curve and this expresses the areaunder hydrograph from one time to another. In the mass curve atany point, the curve slope represents the change of volume perchange of time or the flow rate at that moment. Hence, when theflow of the river is large, the curve is steep and when the flow issmall, it gives flat curve. By storage for the same mass flow, theplant generating capacity can be increased by modifying the waterflow as per plant requirements.

Advantages

1. Thepeak load capacityof the plant is increasedat comparatively lowcapital cost.
2. Theoperatingefficiencyishigh
3. Theplant ispartlyindependentof streamflowconditions.
4. Theplant loadfactor is improved.

5. Loadon thehydroelectricplantremainsuniform.

6. There is an overallgain in thepumped storageplant as theenergy available duringpeakload durationis higherthan thatof duringoffpeakload duration.

2.18 Surge tanks

A surge tank is an additional storage reservoir fitted to the penstock, asnear aspossibleto the turbine. Usually surge tanks are provided in high head or medi urn headplantswhenthere is a considerable distance between the water source and turbine, necessitating alongpenstock. It reduces the distance between free water surface and turbine and hence Reducethe effectof waterhammeronpenstock of turbine.Therefore the surge tank furnishesthefollowing functions.

1) Itstoresthe water during load rejection by the turbine and provides additional water during Additionalload on the turbine.

2) Duringsudden changes in the conditions of water flow, it relieves the waterhammer pressureswithin the penstock. Thus it regulates the water flow to relieve water hammer pressures and to improve the performance of the machines by providing better speed regulation.

3) It reduces the distance between free watersmface of the reservoirandturbineandoflll'Reservoirhencereduce theeffect of waterhammer

During goveming of the turbine, when load on turbine decreases, the govemerc\oseslltgates of the turbine partly to adjust water flow rate in order to maintain constantspeedoft~1runner.Underthis condition, watermovingto theturbinehasto movebackwardandisstoredmthe surgetank.In absenceof surgetank,thisbackwardmovementof watermayresultin sudOOtpressure rise in the penstock resulting in water hammer phenomenon. The strengthofthepl~~to be increased, other wise penstock may burst.

Waterhammer: It is defined as the change in pressure rapidly aboveor below normIalpressure caused by sudden changes in the rate of water flow through the pipe accordingtodemandof turbine.It occurs at all the points in the penstockbetween forebayor surgetankandturbines.During turbine goveming, the gates (valves) supplying water to the turbines aresuddenl)closed when the load on turbine decreases. This sudden retardation of the flow in the penstockresults in sudden pressure rise. its fluctuations in the penstocK dunng reduction of load on turbme ISknown as Water hammer When the load on theturbine increases,itneedmorewaterandhenceturbinegatessuddenlyopenscausingrushofwaterthroughpipe.This createsa vacuumin thepipe carryingwater.

Types of surge tanks: At the top, the surge tanks may be opened or closed. In case of open type, it should be lower than the level of water in the reservoir. The various types of surgetanks are

(a) Simple surge tank: Asimple surge tank is a plaincylindrical tank connected by a veltical branch of pipe to thepenstock.In thistype, ifoverflow is allowed,it eliminatesliseofpressurein thepipe,butoverflowsurgetankisuneconomical.surge tanks arebuilt in large size, sothateven during full loadconditiononturbine,water cannotoverflow.Usuallysurgetankis locatedongroundsurface,abovethepenstockline.Thistypeof tank is more expensive and uneconomical due to its largesize and hencerarely used whencompared to other types.The effective water surface inclinedat an angle '8' to the horizontal. This reduces size ofthe tank requiredi.e..incase of Inclinedsurgetanks, height of surge tank canbe reduced for the samediameteror diameterofthetank can be reducedforthe sameheight.Butthis typeismorecostlierthanothertypesdueto difficultyinconstructionandisalso rarelyused unlessthetopographicalconditionsareinfavour.

(c) Expansion chamber and gallary type surge tank

Expansiontimberlower gallery-Expansion chamber surge tank

This type of tank consists of an expansion tank at the top and expansion at thebottom to limit the extreme surges. The expansion chamber absorbs rising surger, and lowergallary reserve the water for starting the turbine or to meet increasing load on the turbine. Theupper one must be above the maximum reservoir level and lower one must be below the loweststeadyrunning level inthe surge tank.

(d) Restricted orifice or throttled surge tanks

The simple surge tanks are not suitable for medium and large head plants. There fore somemodifications are incorporated in the restricted orifice surge tank.

In this type, a restricted orifice is provided between the conduit and the tank. AconsiderableAn10unt of fiiction loss is created when the water flows in and out of the tank through the orifice.

During low load conditions of the turbine, the surplus water passes through the restricted orificeand immediatly a retarding head, equal to the loss due to restricted orifice, is built up in theconduit. The size of the restricted head can be designed for any desired retarding and acceleratingheads. If the area of restricted orifice is equal to or greater than conduit area, the tank is said tobe a simple tank and retarding head is negligible. If an infinitely small restricted orifice isused.then the retarding head becomes equal to the water hammer in the conduit without The size of the restricted orifice selectedin such a way that the initial retarding headis equal to the rise of water surface in the tank during rejection of full load by the turbine. This typeis moreefficient and economical than simple tank, but the main disadvantage is that the considerableportion of water hammer pressure is directly transmitted to the low pressure conduit and alsoinducessuddenfluctuationsof headonthe turbine.

(e) Differentinl surge tank

This type of surge tank is the compromise between simple and restricted orifice surge tanlIn this type, an internal riser whose area equal to that of conduit is provided in the cylindricalchamber. An outer chamber connects the riser at it's base through ports. When the load changes,the water level in the riser also changes rapidly and produces sudden deceleration or accelerationofthe conduit flow. In the outer chamber, water level moves more slowly and thus lagsbehind that in the riser. In differential surge tank, even though the action is very rapid, it gives reasonablylowpressurerises and surges oflow amplitude.

2.19 Gates

i) Vertical lift gate: cross section ofvertic1e lift gate. On the crest ofthe dam, vertical guides on peirs provides path for sliding motion of steel gates. These steel gatesare used for small power plants. The gate lifting mechanism must be able to over come highfrictional losses developed in the guides due to high hydro static force on the gate. Agate of 5m2area weights 150 tonnes and has to with stand 2000 tonnes of water load.

ii) Radial gate: cross section of a radial or tainter gate. A steel framework supports the gate which is in the form of a segment of a cylinder as shown in figure. Theframe is pivoted on trunnions. The gate is also attacl1ed with hoisting cables and other end ofcables are attached to the winches on the plat form above the gate. A motor drives the winches.for the sliding gate and for the same size of sliding gates, the hoist load is also much less.

iii) RoUinggate: cross section of rolling gate. It consists of cylindricaldrum made of steel. The lower portion of gate is a cylindrical segment and touches ~ spill waycrest. The rolling cylinder rolls on the rack provided, with the help of hoist cable. These arepreferredfor longspans and moderateheight. .

iv)Drum gate: The figure 4.17(d)showscross section of drumgate. It is also suitable for longspans.The gate is a segment of a cylinder which can fit in the recess provided in the top of thespillway.When water entersunder force to the recess,the hollow drum gaterasiesup to theclosedpositionflap gate.The lower edgeoftheflapishingedto theupstreampartofthedamandtheupperedgepositionbychainsorscrewedrodssupportedby an over headbridge. The flood wateris passed overcrest of the sizeopenings.

2.20 Advantages and disadvantages of hydro electric plants

Advantages

1.

2. The operating cost including auxiliaries is considerably low (RS 120perKWat1001load factor).
3. Maintenance and running cost of the plant is low.
4. No nuisance of smoke, exhaust gases, soot etc., and hence the atmosphere is notpoulluted
5. No ash disposal problem.
6. In addition to electric power generation, plants are also used for irrigationandfloodcontrol.
7. These plantsare moreeconomicalthan othertype of plantsas it involvesnofuelcharges.
8. Theplant life is more andplantefficiencydoes not changewithageofplant.
9. No fueltransportationproblem.
10. There are no stand by losses.
11. The plants are located away from developed areas, and hence the cost oflandisnot amajorproblem.
12. Theplant requires less skilledoperators.
13. Theseplantscan meet suddenchangesofload withoutloss of efficiency.

Disadvantages

1. The initialcost of the plantis high,as it includesconstructionofdam

2. The power generation depends only on the quantity of water availablewhichinturndepends Uponrainfall. '

3. These plants are usually locatedawayfrom the load centres anduseslongtransmissionlines.There fore, thecost of transmissionlines andlosses inthemaremore.

4. Planterectiontime is more.

2.21 Question bank

1. What are the applications of Diesel power plant?
2. What are the advantages and disadvantages of aircooling System
3. For a diesel power station briefly describe the Lubrication system
4. Draw the general schematic of Diesel power plant
5. Why cooling of diesel engine is necessary?
6. Sketch and briefly explain the working of Exhaust System
7. Give any four important applications of Lubrication Sysytem
8. List six advantages and Disadvantages of Diesel power plant
9. Draw the general layout of Diesel power plant and Explain the working of different systems
10. With the help of a neat digram explain (i) thermostat cooling and (ii) thermosyphon cooling
11. State the important factors considered while selecting a site for hydo-electric power plant
12. Draw a neat flow sheet diagram of a hydro electric powerplant indicating the essential elements
13. At a particular site the mean dischargeof a river (in millions of m^3) in 12 months from January to December are 30, 25, 20, 0, 10, 50, 80, 100, 110, 65, 45 and 30 respectively. Draw the flow duration curve on a graph sheet. Also estimate the power developedin MW if the available head is 90m and the overall efficiency of generation is87.4%. Assume each month of 30 days.
14. Define hydrograph and unit hydro graph and explain its importance in the design of storage in the hydro electric power plant
15. Explain the working of hydro electric powerplant with the help of a neat sketch
16. With the help of a neat sketch explain pumped storage plant

2.22 Outcomes:

Student should be able to understand the

1. Main Components and working of diesel engine power plant.
2. Basic concepts, working and applications of hydro electric power plant

2.23 Further reading:

1. Non Conventional Energy sources, G D Rai, Khanna Publishers.
2. Non Conventional Resources, B H Khan, TMH – 2007

3.http://www.indiawris.nrsc.gov.in/wrpinfo/index.php?title=Hydro_Electric_ojects_in_Karnataka

4. http://indianpowersector.com/wp-content/uploads/2010/09/diesel-gas-engine-power-plants-in-india1.pdf