HYDROULIC ANALYSIS AND MODELLING OF SMALL HYDRO POWER: A CASE STUDY OF PLANT AT GOGRIPUR, KARNAL

Submitted in the partial fulfillment of the requirement for the award of degree of

MASTER OF TECHNOLOGY IN
RENEWABLE ENERGY TECHNOLOGY

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation, entitled **"Hydroulic Analysis and modelling of Small Hydro Power : A Case Study of Plant at Gogripur, Karnal"** towards the partial fulfillment of the requirements for the award of the degree of Master of Technology with specialization in Renewable Energy Technology, from Delhi Technological University Delhi, is an authentic record of my own work carried out under the supervision of **DR. R.S. MISRA, Professor** and **DR. J.P KESARI, Associate Professor,** Mechanical Engineering Department, Delhi Technological University, Delhi.

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree.

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CERTIFICATE

It is certified that **Satish Kumar Kadian** Roll no.2K14/RET/14, student of M.Tech. Renewable Energy Technology, Delhi Technological University, has submitted the dissertation titled **“Hydroulic Analysis and modelling of Small Hydro Power: A Case Study of Plant at Gogripur, Karnal”** under my guidance towards the partial fulfillment of the requirements for the award of the degree of Master of Technology.

He has studied head and flow analysis of small hydro power plant. His work is found to be satisfactory during the course of the project. His enthusiasm, attitude towards the project is appreciated.

We wish him success in all his endeavors.

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LIST OF NOMENCLATURE

H_{gross} — Gross head (m)

H_{net} — Net head (m)

N — RPM (rpm)

P — Power (kw)

Q — Flow rate (m3/s)

D_2 — Runner diameter (m)

D_1 — Hub diameter (m)

D_m — Mean diameter (m)

u — Tangential velocity (m/s) or peripheral velocity

V_f — Flow velocity (m/s)

V — Absolute velocity (m/s)

V_r — Relative velocity

N_S — Specific speed of turbine (dimensioned parameter)

No — Overall efficiency (dimension less)

$H_{turbine}$ — Head of turbine (m)

D — Outer diameter of runner

D_h — Diameter of the boss

V_r — Relative velocity

α – Guide vane angle

ß – Blade angle

$Suffix_1$ — Inlet

$Suffix_2$ — Outlet

η_h — Hydraulic efficiency

ABSTRACT

Chapter 1 deals with introduction of small hydropower plant with renewable potential and achievement in India as well as hydro-power potential of India. It also deals with major elements of a hydro system i.e. basic element, turbine efficiency, drive system, and control system. Chapter 2 deals with literature review of hydropower projects, there cost effectiveness, life cycle, Performance analysis and study of renewal energy using micro hydro turbine. It shows the detail summary of various research paper in a brief way, including their results. Chapter 3 gives us the Idea about Head and Flow analysis of small hydro power sites. It gives a brief knowledge of condition for Head, Pressure Head of a small hydro power plant. It deals with the determination of Nozzle Velocity by using Bernoulli's equation and Euler's equation and thereafter developed power delivered by flowing fluid to the turbine. In chapter 4 a case study was done on the site of small hydro power plant at Gogripur by visiting the site and various parameters are taken of that plant as a general information having the capacity of 2000 k.w. of small hydro power plant. All the necessary details were taken about the turbine, generator and about power evacuation for this case study. In the last chapter the various results are taken by using EES software program using EES software and different mathematical calculation were done to determine the overall efficiency of the Gogripur small hydro plant, hence various input parameter such as Head, Flow rate, RPM, power, Tangential velocity, Flow, flow velocity, absolute velocity are provided to calculate and to obtain the overall efficiency.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time. Renewable energy offers our planet a chance to reduce carbon emissions, clean the air, and put our civilization on a more sustainable footing. It also offers countries around the world the chance to improve their energy security and spur economic development. Modern biomass encompasses a range of products derived from photosynthesis and is essentially chemical solar energy storage. Renewable energy supplies 18% of the world’s final energy consumption counting traditional biomass, large hydropower, and “new” renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels). Traditional biomass, primarily for cooking and heating, represents about 13% and is growing slowly in some regions as biomass is used more efficiently or replaced by more modern energy forms. Large hydropower represents 3% and is growing modestly, primarily in developing countries. New renewables represents 2.4% and are growing very rapidly in developed countries and in some developing countries. Global renewable energy capacity grew at rates of 15-30% annually for many technologies, including wind power, solar hot water, geothermal heating, and off-grid solar PV Renewable energy markets grew robustly. Among new renewables (excluding large hydropower), wind power was the largest addition to renewable energy capacity. An estimated $120 billion was invested in renewable energy worldwide including new capacity (asset finance and projects) and biofuels refineries.

Renewable energy sources (RES) that use indigenous resources have the potential to provide energy with negligible emissions of air pollutants and greenhouse gases. Renewable energy technologies produce marketable energy by converting natural phenomena or resources into useful energies. The usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. Therefore, an attempt has been made through to review the availability of renewable energy options in India, and provides information about the current status of renewable, future potentials of their uses, major achievements, and current government policies, delivery and outreach in Indian context. It paints a remarkable overall picture of renewable energy resources and position of India on global map in utilizing these resources.

1.1 Renewable Energy Potential and Achievement in India

India's population of more than 1350 million is growing at an annual rate of 1.58%. As fossil fuel energy becomes scarcer, India will face energy shortages significantly due to increase in energy prices and energy insecurity within the next few decades. Increased use of fossil fuels also causes environmental problems both locally and globally. The economy of India, measured in USD exchange-rate terms, is the twelfth largest in the world, with a GDP of around $ 1 trillion which makes it the second fastest big emerging economy, after China, in the world. There is a very high demand for energy, which is currently satisfied mainly by coal, foreign oil and petroleum, which apart from being a non-renewable, and therefore non-permanent solution to the energy crisis, it Is also detrimental to the environment. Thus, it is imperative that India obtains energy security without affecting the booming economy, which would mean that the country must switch from the nonrenewable energy (crude oil and coal) to renewable energy.

For these reasons the development and use of RES & Technologies are becoming vital for sustainable economic development of India. Expert consultation at the Asia Energy Vision 2020, organized under the World Energy Council agreed on energy demand projection in India up to 2020. The Expert Committee on Integrated Energy Policy in its Report (IEPR 2006) has estimated that by 2032. i.e., 25 years from now primary commercial energy requirement in the country would need to go up 4-5 times the current level, electricity generation installed capacity 5.6-7 times the current level and oil requirement by 3-6 times the current level.

Energy is a basic-requirement for economic development and in every sector of Indian economy. It is thus necessary that India quickly look towards new and emerging renewable energy and energy efficient technologies as well as implement energy conservation laws.

Against this background, the country urgently needs to develop a sustainable path of energy development. Promotion of energy conservation and increased use of renewable energy sources are the twin planks of a sustainable energy supply. Fortunately, India is blessed with a variety of renewable energy sources, like biomass, the solar, wind, geothermal and small hydropower and implementing one of the world's largest programs in renewable energy.

India is determined to becoming one of the world's leading clean energy producers. The Government of India has already made several provisions, and established many agencies that will help it to achieve its goal. Renewable energy, excluding large hydro projects already account for 9% of the total installed energy capacity, equivalent to 12,610 MW of energy. In combination with large hydro, the capacity is more than 34%, i.e., 48,643 MW, in a total installed capacity of 144,980 MW.

The country has an estimated renewable energy potential of around 85,000 MW from commercially exploitable sources, i.e., wind, 45,000 MW; small hydro, 15,000 MW and biomass/bioenergy, 25,000 MW. In addition, India has the potential to generate 35 MW per square kilometer using solar photovoltaic and solar thermal energy. Renewable electricity, excluding hydro above 25 MW installed capacity, has contributed 10,243 MW representing 7.7% of total electricity installed capacity. There has been phenomenal progress in wind power and, with an installed capacity of over 8757 MW, India occupies the fifth position globally.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. The renewable energy industry has approximately USD 500 million as turnover, the investment being' about USD 3 billion. Of the estimated potential of 10,00,000 MW from RE only about 69022 MW has been exploited to-date. The Indian Government has been at work, making a comprehensive policy for compulsory use of renewable energy resources through biomass, hydropower, wind, solar and municipal waste in the country, particularly for commercial establishments, as well as Government establishments.

The major contribution to renewable energy investment comes from private sector participation. This is due to the support from the government, which leverages the private investment. The financial allocation for renewable energy sources vis-a-vis total allocation, however, remains in the range of 0.1 % during Tenth Plan period. This is expected to increase during the Eleventh Plan.

The Ministry of New and Renewable Energy has identified renewable energy R&D as an important factor for developing this sector. R&D subsidy is 100% of a project’s cost in government R&D institutions, and 50% in the private sector. The R&D subsidy for the private sector may be enhanced for initial stages of technologies that have longer time-horizons. Renewable sources already contribute to about *5%* of the total power generating capacity in the country. During the last two decades, several renewable energy technologies have been deployed in rural and urban areas. Some of the achievements along with the estimated potential

1.1.1 Biomass

In recent years, the interest in using biomass as an energy source has increased and it represents approximately 14% of world final energy consumption. Estimates have indicated that 15-50% of the world’s primary energy use could come from biomass by the year 2050. Many countries have included the increased use of renewable sources on their political agenda. Biomass is one such resource that could play a substantial role in a more diverse and sustainable energy mix. The energy obtained from biomass is a form of renewable energy and, in principle, utilizing this energy does not add carbon dioxide, a major greenhouse gas, to the atmosphere, in contrast to fossil fuels. As per an estimate, globally photosynthesis produces 220 billion dry tonnes of biomass each year with 1% conversion efficiency. Biomass resources suitable for energy production covers a wide range of materials, from firewood collected in farmlands and natural woods to agricultural and forestry crops grown specifically for energy production purposes. Energy production from food wastes or food processing wastes, especially from waste edible oils, seems to be attractive based on bio-resource sustainability, environmental protection and economic consideration. India is very rich in biomass and has a potential of 16,881 MW (agro-residues and plantations), 5000 MW (bagasse cogeneration) and 2700 MW (energy recovery from waste. Biomass power generation in India is an industry that attracts investments of over Rs. 600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas.

1.1.2 Hydropower

Hydropower is another source of renewable energy that converts the potential energy or kinetic energy of water into mechanical energy in the form of watermills, textile machines, etc., or as electrical energy (i.e., hydroelectricity generation). It refers to the energy produced from water (rainfall flowing into rivers, etc.). Hydropower is the largest renewable energy resource being used for the generation of electricity. Only about 17% of the vast hydel potential of 150,000 MW has been tapped so far. Countries like Norway, Canada, and Brazil have all been utilizing more than 30% of their hydro potential, while on the other hand India and China have lagged far behind. India ranks fifth in terms of exploitable hydro potential in the world. According to CEA (Central Electricity Authority), India is endowed with economically exploitable hydropower potential to the tune of 148,700 MW.

The dominant annual rainfall is located on (the North-Eastern part of India; Arunachal Pradesh, Assam, Nagaland, Manipur and Mizoram, and also on the west coast between Mumbai (Bombay) and Mahe. Primary hydroelectric power plants are located in Bihar, Punjab, Uttaranchal, Karnataka, Uttar Pradesh, Sikkim, Jammu & Kashmir, Gujarat, and Andhra Pradesh. In India, hydropower projects with a station capacity of up to 25 megawatt (MW) fall under the category of small hydropower (SHP). India has an estimated SHP potential of about 15,000 MW, of which about 11% has been tapped so far. The Ministry of New and Renewable Energy (MNRE) supports SHP project development throughout the country. So far, 523 SHP projects with an aggregate installed capacity of 1705 MW have been installed. Besides these 205 SHP projects with an aggregate capacity of 479 MW are under implementation. With a capacity addition, on an average, of 100 MW per year and gradual decrease in gestation periods and capital costs, the SHP sector is becoming increasingly competitive with other alternatives.

1.1.3 Wind energy

Winds are generated by complex mechanisms involving the rotation of the earth, heat energy from the sun, the cooling effects of the oceans and polar ice caps, temperature gradients between land and sea and the physical effects of mountains and other obstacles. Wind is a widely distributed energy resource. Wind energy is being developed in the industrialized world for environmental reasons and it has attractions in the developing world as it can be installed quickly in areas where electricity is urgently needed. In many instances it may be a cost-effective solution if fossil fuel sources are not readily available. In addition there are many applications for wind energy in remote regions, worldwide, either for supplementing diesel power (which tends to be expensive) or for supplying farms, homes and other installations on an individual basis.

The availability of wind varies for different regions. Wind resources can be exploited mainly in areas where wind power density is at least 400 W/m^2 at 30 m above the ground. The Wind Resource Assessment Program is being implemented by C-WET (Centre for Wind Energy Technology) in coordination with state nodal agencies. An annual mean wind power density greater than 200 W/m^2 (watts per square meter) at 50-m height has been recorded at 211 wind monitoring stations, covering 13 states and union territories, namely Andaman and Nicobar Islands, Andhra Pradesh, Gujarat, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttaranchal, and West Bengal. India's wind power potential has been assessed at 45,000 MW. Wind Power Program in India was initiated towards the end of the Sixth Plan, in 1983-1984. The program aims at survey and assessment of wind resources, setting up demonstration projects, and provision of incentives to make wind electricity competitive.

India is surpassed only by Germany as one of the world's fastest growing markets for wind energy. By the mid-1990s, the subcontinent was installing more wind generating capacity than North America, Denmark, Britain, and the Netherland. The ten machines near Okha in the province of Gujarat were some of the first wind turbines installed in India. These 15-m vestas wind turbines overlook the Arabian Sea. Different types of Wind Power Generators used in India for off grip Power generation, i.e., water-pumping windmills, aero-generators a small wind electric generator having a capacity of up to 30 kW) and wind-solar hybrid systems.

1.1.4 Solar energy

Solar energy is the most abundant permanent energy resource on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean, etc.) forms. Solar energy, experienced by us as heat and light, can be used through two routes: the thermal route uses the heat for water heating, cooking, drying, water purification, power generation, and other applications; the photovoltaic route converts the light in solar energy into electricity, which can then be used for a number of purposes such as lighting, pumping, communications, and power supply in un electrified areas.

The total annual solar radiation falling on the earth is more than 7500 times the world's total annual primary energy consumption of 450 EJ. The annual solar radiation reaching the earth's surface,' approximately 3,400,000 EJ, is an order of magnitude greater than all the estimated (discovered and undiscovered) non-renewable energy resources, including fossil fuels and nuclear. However, 80% of the present worldwide energy use is based on fossil fuels. Most parts of India receive 4-7 kWh of solar radiation per square meter per day with 250-300 sunny days in a year. The highest annual radiation energy is received in Western Rajasthan while the North-Eastern region of the country receives the lowest annual radiation-India has a good level of solar radiation, receiving the solar energy equivalent of more than 5000 trillion kWh/yr. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m^2, with the hours of sunshine ranging from 2300 to 3200 per year. A solar map of India is given below:-

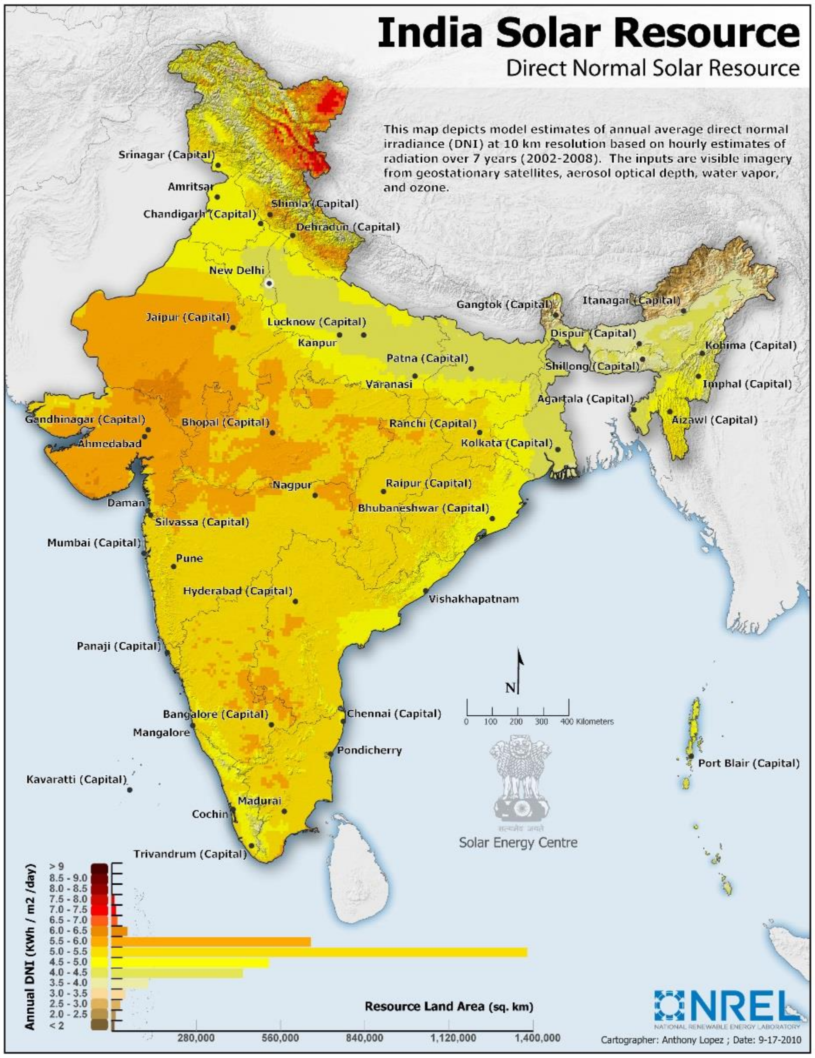


Figure 1.1: A solar map of India

The MNRE, working in conjunction with the Indian Renewable Energy Development Agency (IREDA) to promote the utilization of all forms of solar power as well as to increase the share of renewable energy in the Indian market. This promotion is being achieved through R&D, demonstration projects, government subsidy programs, and also private sector projects.

Solar thermal and solar photovoltaic technologies are both encompassed by the Solar Energy Program that is being implemented by the Ministry (regarded as one of the largest in the world) to utilize India's estimated solar power potential of 20 and 35 MW/km^2 solar thermal. India's overall potential for solar water heating systems has been estimated to be 140 million m^2 of collector area.

1.1.5 Geothermal energy

Geothermal is energy generated from heat stored in the earth, or the collection of absorbed heat derived from underground. Immense amounts of thermal energy are generated and stored in the Earth's core, mantle and crust. Geothermal energy is at present contributing about 10,000 MW over the world and India's small resources can augment the above percentage. Studies carried out by the geological survey of India have observed existence of about 340 hot springs in the hot country. These are distributed in seven geothermal provinces. The provinces, although found along the west coast in Gujarat and Rajasthan and along a west south west-east-northeast line running from the west coast to the western border of Bangladesh (known as SONATA), are most prolific in a 1500 km stretch of the Himalayas. The resource is little used at the moment but the Government has an ambitious plan to more than double the current total installed generating capacity.

1.1.6 Other renewable energy technologies

Solar thermal technologies, particularly solar water heating system, solar cookers and solar generation systems are the most commercialized technologies among renewable energy technologies in India. Policies are set to provide further impetus to dissemination of solar technologies.

Biogas represents an alternative source of energy, derived mainly from organic wastes. In India, the use of biogas derived from animal waste, primarily cow dung, has been promoted for over three decades now. Biogas is a clean fuel produced through anaerobic digestion of a variety of organic wastes: animal, agricultural, domestic, and industrial. Biogas is the only technology that has put cooking in rural areas on technological ladder and has made cooking a pleasure with associated social and environmental benefits including zero indoor pollution. India's National Project on Biogas development (NPBD) has been one of the well organized and systematic program to provide logistic and institutional support for that has been under implementation since early 1980s. India Biogas program is one of the most successful program if we compare with other such program implemented in Rural India. Till December 2004, under the National Biogas Program, over 3.7 million biogas plants in the capacity ofl-6 m^3 had been installed. The ultimate goal of this program is to set up biogas plants in around 12 million households that have enough cattle to maintain a regular supply of dung.

Biofuel program in the country is at nascent stage. The policy measures currently in place include an excise tax reduction for E-5, the obligation to blend all petrol with 5% ethanol in certain regions since January 2003 and government regulation of the ethanol selling price on the basis of ethanol production costs. Subsequently the percentage of ethanol mixture in petrol is planned to be increase to 10%. A new biofuel policy for the country is under construction.

Hydrogen energy is also at early stage of development. Ministry of New and Renewable Energy also funded research projects on different aspects of hydrogen energy technology development. India is the member of the International Partnership on Hydrogen economy (IPHE) set up in Washington, DC in November 2003. Future challenges to India includes lowering cost of hydrogen substantially and improve production rates from different methods, development of compact and inexpensive storage capacity, establishment of hydrogen network and development of hydrogen fuelled 1C engine and efficiency improvement of different type of fuel cell systems. The road map envisages taking up of research, development and demonstration activities in various sectors of hydrogen energy technologies and visualized goals of one million hydrogen-fuelled vehicles and 1000 MW aggregate hydrogen based power generation capacity to be set up in the country by 2020.

1.1.7 Major achievements

India's major achievements on renewable energy development can be summarized as follows:

- Over 4200 M W grid power from wind, small hydro, biomass and solar energy.
- 3600 remote villages/hamlets, including those in Sunderbans, Bastar, Ladakh and the North East electrified through solar energy.
- Largest solar-steam cooking system for 15,000 persons/day set up at Tirupati Tirumala Devasthanam.
- 7 lakh square meter collector area solar water heating systems installed.
- 3.5 million biogas plants installed for cooking and lighting applications.
- 35 million improved wood stoves in rural homes.
- Integrated Rural Energy Program implemented in 860 blocks.
- 30 MW capacity Solar Photovoltaic products exported to various developed and developing countries.
- 280 Energy Parks set-up in educational institutions for demonstration of renewable energy systems and devices.
- Rs. 25,000 million direct subsidy given so far to beneficiaries/ users of renewable energy systems and devices, including subsidy for grid connected renewable power projects.
- Rs. 32,000 million loan provided so far by Indian Renewable Energy Development Agency Limited for 1600 renewable energy projects.
- Centre for Wind Energy Technology set up as a scientific and industrial research organization for wind resource assessment, equipment certification and R&D at Chennai in Tamil Nadu.
- Solar Energy Centre set up for development of solar energy systems and devices at Gurgram in Haryana.
- International Solar Alliance headquarter formed at Gurgram in Haryana.

1.2 Hydropower Potential of India

India is endowed with rich hydroelectric power potential that is estimated at 84,000 MW at 60% load factor corresponding to an installed capacity of about 150,000 MW. India ranks fifth in the world in terms of exploitable hydropower potential. The first hydropower power plant in India is a run-of-river plant in Darjeeling district in West Bengal with an installed capacity of 130 KW and was commissioned in the year 1897. The first major hydro plant in India was the

Shivanasamudram project of the Cauveri in Karnataka. It was a 4.5 MW plant commissioned in 1902. Since then, there has been considerable progress and the current installed capacity is 45,403 MW which is nearly 26% of the assessed potential. In the beginning of year 2018, the total installed capacity of electrical energy from all sources was 3,43,778 MW. A map is given below to show major hydroelectric plants in India.

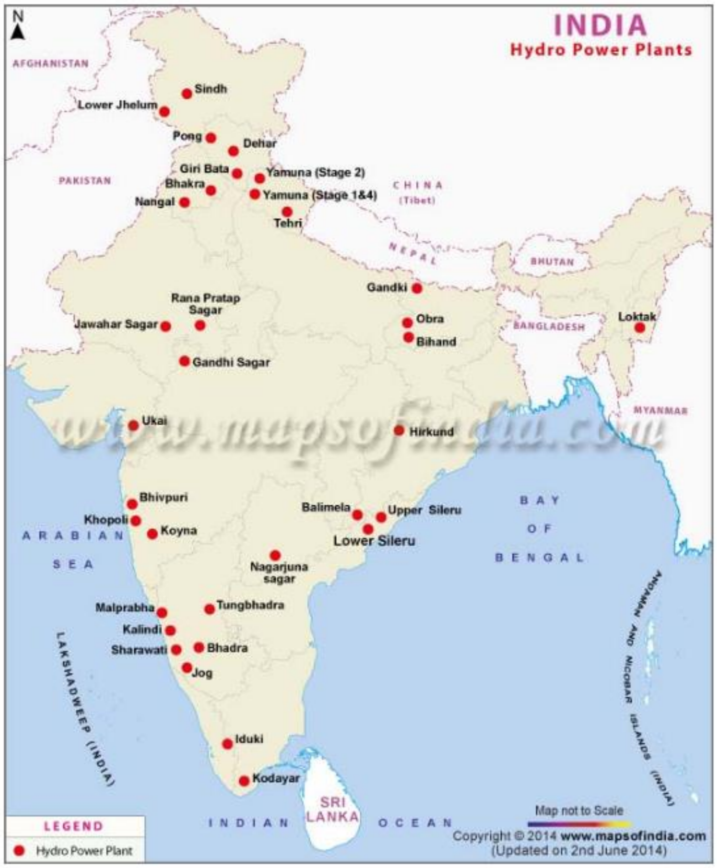


Figure 1.2: A map of major hydraulic electric plants in India

Since the beginning of the 21st century, there is renewed interest in the development of small hydropower projects (SHP), primarily from its environmental benign aspects and ability to produce power in remote areas. SHPs have been identified as an important tool for the economic development of isolated and remote mountainous areas. Further, SHPs are not only economically viable but also have the advantage of short gestation period, SHPs in India have substantive private investment. About 4,485 MW of installed capacity exists in the SHP sector spread over about various projects. Facilities for the manufacture of practically all the components of all the types SHPs are available in the country.

Many high-quality turbine and pump testing laboratories do exist in both public and private sectors. International standard turbine laboratories exist at the Central Water Power Research Station, Pune, and at some educational and research institutes in the country, for use in verification of designs, generation of design data and validation of designs through high-level CFD analysis. Facilities and capabilities are available in country for CFD analysis of various components of both large and small hydro projects.

1.2.1 Hydropower Development

Hydropower is the most energy efficient power generator. Currently, hydropower is capable of converting 90% of the available energy into electricity. This can be compared to the most efficient fossil fuel plants, which are only 60% efficient. The principal advantages of using hydropower are its large renewable domestic resource base, the absence of polluting emissions during operation, its capability in some cases to respond quickly to utility load demands, and its very low operating costs. Hydroelectric projects also include beneficial effects such as recreation in reservoirs or in the water below dams.

Hydropower is renewable because it draws its essential energy from the sun that drives the hydrological cycle, which in turn provides a continuous renewable supply of water. Since water is not altered as it goes through the turbines, it can be used to produce more electricity or be used in other sources.

Considering the electric industry that exists today, hydropower has a distinct advantage over fossil fueled generator plants: it is clean, green and renewable. Hydropower does not contribute to local air pollution. Other energy generators are an important source of air, water, and soil pollution and greenhouse gases, and provide fewer opportunities for economic spin-offs.

Hydro developments are subject to extremely demanding environmental standards. Before a project can be developed, it must go through a rigorous process that examines the impact the project would have on the environment and on local communities. Water flow, water quality, water shed, management, fish passage, habitat protection, as well as the welfare and lifestyle of the local communities are taken into consideration.

In comparing hydropower to other energy generators, the other generators take less time to design, obtain approval, build and recover investment. However, they have higher operating costs and typically shorter operating lives (about 25 years).

A hydropower plant has a high capital cost but maintenance costs are only minimal when looking at some other sources of energy production. The plant life can be extended economically by relatively cheap maintenance and the periodic replacement of equipment (replacement of turbine runners, rewinding generators, etc). Typically a hydro plant in service for 40 - 50 years can have its operating life doubled.

Comparing the cost of electricity with the initial investment of a hydropower system, the payback period is short. Theoretically, a hydro plant should be able to produce electricity for a fixed amount during the life span of the unit. The operating costs should not change because there is no associated price to the water. Unlike in fossil fuel plants, the price of natural gas, coal, etc. fluctuates depending on what the market is doing.

1.2.2 Current Scenario of Hydropower

India is the seventh largest producer of hydroelectric power. The present installed capacity as on 30Apirl 2018 is 45,293 MW which is 13.5% of total electricity generation in India. The public sector has a predominant share of 93% in this sector. National Hydroelectric Power Corporation (NHPC), Northeast Electric Power Company (NEEPCO), Satluj Jal Vidyut Nigam (SJVNL), THDC, NTPC-Hydro are a few public sector companies engaged in development of Hydroelectric Power in India. India has the resources available but lacks infrastructural development to harness it.

Bhakra Beas Management Board (BBMB), an illustrative state owned enterprise in north India, has an installed capacity of 2.9 GW and generates 12,000-14,000 million units per year. The cost of generation of energy after four decades of operation is about 27 paise (0.40¢ US) per kWh.[citation needed] BBMB is a major source of peaking power and black start to the northern grid in India. Large reservoirs provide operational flexibility. BBMB reservoirs annually supply water for irrigation to 12.5 million acres (51,000 km2; 19,500 sq mi) of agricultural land of partner states, enabling northern India in its green revolution.

1.3 Environmental Impact:

a) Land Use:

The size of the reservoir created by a hydroelectric project can vary widely, depending largely on the size of the hydroelectric generators and the topography of the land. Hydroelectric plants in flat areas tend to require much more land than those in hilly areas or canyons where deeper reservoirs can hold more volume of water in a smaller space. At one extreme, the large Balbina hydroelectric plant, which was built in a flat area of Brazil, flooded 2,360 square kilometers—an area the size of Delaware—and it only provides 250 MW of power generating capacity (equal to more than 2,000 acres per MW) . In contrast, a small 10 MW run-of-the-rive plant in a hilly location can use as little 2.5 acres (equal to a quarter of an acre per MW) .

Flooding land for a hydroelectric reservoir has an extreme environmental impact: it destroys forest, wildlife habitat, agricultural land, and scenic lands. In many instances, such as the Three Gorges Dam in China, entire communities have also had to be relocated to make way for reservoirs.

b) Wildlife Impacts:

Dammed reservoirs are used for multiple purposes, such as agricultural irrigation, flood control, and recreation, so not all wildlife impacts associated with dams can be directly attributed to hydroelectric power. However, hydroelectric facilities can still have a major impact on aquatic ecosystems. For example, though there are a variety of methods to minimize the impact (including fish ladders and in-take screens), fish and other organisms can be injured and killed by turbine blades.

Apart from direct contact, there can also be wildlife impacts both within the dammed reservoirs and downstream from the facility. Reservoir water is usually more stagnant than normal river water. As a result, the reservoir will have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds can crowd out other river animal and plant-life, and they must be controlled through manual harvesting or by introducing fish that eat these plants. In addition, water is lost through evaporation in dammed reservoirs at a much higher rate than in flowing rivers.

In addition, if too much water is stored behind the reservoir, segments of the river downstream from the reservoir can dry out. Thus, most hydroelectric operators are required to release a minimum amount of water at certain times of year. If not released appropriately, water levels downstream will drop and animal and plant life can be harmed. In addition, reservoir water is typically low in dissolved oxygen and colder than normal river water. When this water is released, it could have negative impacts on downstream plants and animals. To mitigate these impacts, aerating turbines can be installed to increase dissolved oxygen and multi-level water intakes can help ensure that water released from the reservoir comes from all levels of the reservoir, rather than just the bottom (which is the coldest and has the lowest dissolved oxygen).

c) Life-cycle Global Warming Emissions:

Global warming emissions are produced during the installation and dismantling of hydroelectric power plants, but recent research suggests that emissions during a facility’s operation can also be significant. Such emissions vary greatly depending on the size of the reservoir and the nature of the land that was flooded by the reservoir.

Small run-of-the-river plants emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour. Life-cycle emissions from large-scale hydroelectric plants built in semi-arid regions are also modest: approximately 0.06 pounds of carbon dioxide equivalent per kilowatt-hour. However, estimates for life-cycle global warming emissions from hydroelectric plants built in tropical areas or temperate peat lands are much higher. After the area is flooded, the vegetation and soil in these areas decomposes and releases both carbon dioxide and methane. The exact amount of emissions depends greatly on site-specific characteristics. However, current estimates suggest that life-cycle emissions can be over 0.5 pounds of carbon dioxide equivalent per kilowatt-hour.

To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

d) Problem with Hydro-Power Plant:

There are few problems with hydropower. The first hydropower plants installed did not take into consideration environmental effects. Now, much effort is made to insure that there are minimal environmental and social biggest drawback to hydropower is the high initial cost but this cost can be recovered quickly due to low operating and maintenance costs. In the past hydro sites were easier to develop because environmental requests were less stringent and there was less public opposition. New locations for hydro sites are more difficult to develop because of environmental concerns. Micro hydro is generally easier to develop because these can be implemented with minimal change to the water flow or surrounding areas.

CHAPTER - 2

LITERATURE REVIEW

Saurabh Sangal[23]: Hydro power projects involve various considerations at different levels of project implementation. To harness the potential, new turbines have been developed and commercially available. For the cost effective and efficient project we need to study the optimal selection of hydro turbine .The objective of this paper is to review the selection of hydro turbine for hydroelectric project.

The turbine selection is the first phase of the project which will look at developing the network technology requirements. This paper can be a guideline for the developers in selection of hydro turbine for available operating conditions.

Sachin Mishra[22] : Small hydro is one of the cost-effective and environmentally benign energy technologies to be considered for rural electrification in less developed countries. The installation cost of the small hydropower project is mainly divided into two parts – Civil works and electromechanical equipment. One of the most important element on the recovery of a small hydro-power plant is the electromechanical equipment (turbine alternator). The cost of the equipment means a high percentage of the total budget of the plant.

An analysis of cost of electro-mechanical equipment for small hydropower has been made and a co-relation is developed to determine the cost of electro-mechanical equipment. This can be useful for the prediction of cost of electro-mechanical equipment for the new sites. This co-relation gives the cost estimation with in ± 10% accuracy. By using developed co-relation it has been found that the cost of the electro-mechanical equipment decreases with increase in the head. This is because the size of the electromechanical equipment reduces with increase in the head. That is for high head small hydropower the cost of electro-mechanical equipment will be less as compared to the small head SHPs for the same capacity.

Jessica Hanafi[11] : To assess the life cycle of a mini hydro power plant in Simalungun, Indonesia. Life cycle inventory data were collected and impacts were assessed using SimaPro software. A sensitivity analysis comparing two methods, CML-IA and TRACI 2.1 were conducted.

Based on the life cycle assessment performed on the mini hydro power plant in North Sumatera, it is found that the construction phase contributes to the environmental impact to the whole life cycle of the hydropower plant. Within the construction phase, the rapid pipeline construction stage is the major source of environmental impact.

The topography of the site has required a long pipeline (536 m), almost doubled the distance from the water head (256m). The site consists of terrains, which are prone to terrestrial changes. One example is from the sudden soil erosions that changes the terrain.

Thus, environmental impact associated with the rapid pipeline is mainly caused by its design, installation location and material.

Generally, the optimum penstock is as short, straight and steep as practical and has a continuous downward gradient. The penstock used in this plant was installed above the ground.

Although there are some impacts resulted from the construction of mini hydro power plant, in the long run, the run-of-river hydro power plant has virtually no hazardous components. Its benefit of producing electricity for the nearby village is far greater than the environmental impact.

K.H. Motwani[13] : The main hindrance in implementing hydropower schemes is high initial cost of conventional hydro turbines. The cost of these plants can be brought down by using centrifugal pump in turbine mode in context of various advantages associated with die pumps viz. low initial and maintenance cost, ready availability, simple construction etc. However, die efficiency of pump as turbine (PAT) is lower than that of conventional hydro turbines. For commercial justification of PAT technology, a cost analysis of 3 kW capacity pico hydropower plant was carried out by considering PAT and Francis turbine as a prime mover. The hydro turbine test rig was developed by installing PAT and its performance characteristics were plotted.

A 3 kW capacity pico hydro test rig was developed by installing the PAT and maximum overall efficiency of PAT was found to be around 60 percent which is lower than that of Francis turbine, which is around 80 percent. However in pico hydro range, the cost of Francis turbine may be 6 to 8 times more than that of the centrifugal pump. For economical justification of PAT, annual life cycle cost analysis was carried out as a case study by considering both the options. Based on the analysis, the ratio of ALCC and the cost of electricity generated per unit between Francis turbine and PAT were found to be6.8 and 5.07 respectively, which has justified the use of PAT in place of Francis turbine for the considered case under study.

Pimnapat Iemsomboo[20] : The performance analysis and study of hybrid renewable energy using micro hydro turbine and photovoltaic system in the case study area: Bunnasopit School, Nan province, Thailand. The main problem of die implementation of such system in this rural area is the voltage instability of the grid distribution system. Electrical Power consumption, hydrology and metrology data are necessary for the designing and analyzing for such hybrid system. The data was corrected all over a year in order to analyze the performance of electrical generating system using Homer program. The simulation results were used for the breakeven point analyzing by engineering economics.

The design a PV-Hydro turbine Hybrid System for Bunnasopit school by calculate and to use program Homer for to exam Simulation study to work and optimized by die software program before install real system. Found that the system design can be able to supply energy to the load continually design size.

Miguel M. Uamussep[16] : The objective of this investigation research is to analyze the Chua Micro-Hydropower Plant exploration in Manica district in Mozambique and to examine the possibility of increasing energy production. The current total installed power generation capacity in Mozambique is about 939 MW. Hydropower contributes 561 MW, making a contribution of 61%, oil contributes 27%, and natural gas 12% of the total electric grid generation in Mozambique.

The presence of electricity will be a major drive towards contributing to economic and social sustainability of the village. The power availability will change the livelihood of the villagers, resulting into creation of jobs such as small business enterprises. This will add some income to the village community.

This study were carried out with aim of capacity optimization study of Chua mini hydropower plant at Chua River in Manica Mozambique where a hydropower was used for milling corn other cereals.

Alesh Darb[5] : The performance of hydropower plants is significantly influenced by the durability and service life of installed technical equipment, which in the case of small hydropower plants is often simple and inexpensive. The study presents the results of durability analysis based on the analysis of defects and failures of two turbines (Francis, cross flow Banki) installed on the bypass of the bottom outlets of the Sance Dam in the Czech Republic. Firstly, the durability of the equipment and the main types of turbine shutdowns are defined. Empirical probability distribution curves for time to failure are plotted for both turbine sets based on available records of incidents and reasons for individual shutdowns from 20 years of operation. The analysis shows the average periods between shutdowns and period length probabilities between shutdowns for each turbine set.

Durability analysis was carried out for two turbine sets located at the Sance HPP using operation records. Unfortunately, practically no records exist for the Francis turbine during its first 19 years of operation. The following decade also provides only poor information about the performance of both turbine sets. The analysis therefore provides relevant results only for the period of the last 17 years of operation. However, the contribution of the presented method is that it can act as a guide in the durability analysis of any HPP.

The results of the durability analysis show there are quite short periods between forced shutdowns, which in general is not a favorable state of affairs for the HPP owner. Shutdowns for significant reasons that call for the exchange of parts of equipment may occur practically every year. Probability analysis indicates that common forced shutdowns can be expected with relatively high probability (70 - 80%) within about 100 days of a previous repair, though one may even happen much sooner. The quite short intervals between shutdowns for significant reasons indicate the low durability of both turbines.

S.U. Patel[21] : Many turbines are available but among them cross flow water turbine becomes popular as having advantages over using u us in small head and small water flow rate, simple structure and manufacturing method for power generation in hydro power plants. The objective of paper is to review the implementation of cross flow water turbine in Micro hydro power plants (MHP) for power generation.

Hydropower is a clean source of energy. It does not consume but only uses the water, and after use the water is available for other purposes (although on a lower horizontal level). Cross flow water turbine is used in micro hydro power plant in case of low head and flow rate. This paper gives. a complete study of cross flow turbine and necessary fulfill requirement for using in micro hydro power plant. It will helps for selection of turbines to developers to implement CFWT in MHP plants.

2.1 Literature Review Summary

For the cost effective and efficient project we need to study the optimal selection of hydro turbine .The objective of this paper is to review the selection of hydro turbine for hydroelectric project[23]. An analysis of cost of electro-mechanical equipment for small hydropower has been made and a co-relation is developed to determine the cost of electro-mechanical equipment[22].**:** To assess the life cycle of a mini hydro power plant in Simalungun, Indonesia. Life cycle inventory data were collected and impacts were assessed using SimaProsoftware[11]. A 3 kW capacity pico hydro test rig was developed by installing the PAT and maximum overall efficiency of PAT was found to be around 60 percent which is lower than that of Francis turbine, which is around 80 percent[13].The data was corrected all over a year in order to analyze the performance of electrical generating system using Homer program. The simulation results were used for the breakeven point analyzing by engineering economics[20]. The power availability will change the livelihood of the villagers, resulting into creation of jobs such as small business enterprises. This will add some income to the village community[16].Durability analysis was carried out for two turbine sets located at the Sance HPP using operation records. Unfortunately, practically no records exist for the Francis turbine during its first 19 years of operation. The results of the durability analysis show there are quite short periods between forced shutdowns, which in general is not a favorable state of affairs for the HPP owner [5]. A complete study of cross flow turbine and necessary fulfill requirement for using in micro hydro power plant. It will helps for selection of turbines to developers to implement CFWT in MHP plants[21].

2.2 Research Gaps:

Hydropower has traditionally been considered environmentally friendly because it represents a clean and renewable energy source. The term renewable refers to the hydrologic cycle that circulates water back to our rivers, streams, and lakes each year. At hydroelectric projects, this water is used as fuel to generate electricity. In contrast, fossil fuels like coal, natural gas, or oil must be extracted from the earth and burned to produce electricity. The term clean is also used because production of electricity with hydropower does not pollute the air, contribute to acid rain or ozone depletion because of carbon dioxide emissions, or (like nuclear power) leave highly toxic waste that is difficult to dispose off. As there are number of small hydro power plant in India but also we have a large number of canals so had a flow analysis of these small hydro power plant is very important. So that electricity can be provided to the villages uninterruptedly hence Gogripur 2MW small hydro power plant which is situated at Karnal is chosen to carry out head and flow analysis on this plant. Therefore we can finally find out the overall efficiency of this plant also power load factor of the recent years can be calculated.

2.3 Research Problem:

Here the head and flow analysis is quantified us to improve the overall efficiency of small hydropower plant so that improvements can be done further. The small hydro power plant not consider the head and flow analysis so the work need to be done here.

2.4 Research Objective:

Here the study to be done on Gogripur 2MW small hydro power plant situated at Karnal. Analysis is to be carried out on head and flow of small hydro power plant by using EES software programme thus various input parameters are used to calculate other required parameters and finally to calculate the overall efficiency of the Gogripur small hydro power plant. The various objectives as follows:

(i) To study renewable energy potential in general and hydro power potential in particular in India.
(ii) To study various classifications of small hydro power plants and Impulse Turbine.
(iii) To present detail information about Gogripur Micro hydropower plant.
(iv) To analysis various parameter regarding modelling of small power plant.
(v) To present various results and conclusions of above power plant.

CHAPTER–3

MODELLING OF HYDRO POWER PLANT

3.1 Determination of Head of Micro Hydro-Power

In a potential micro hydropower site, head is the vertical distance of waterfall. When evaluating a potential site, head is usually measured in feet, meters, or units of pressure. Head also is a function of the characteristics of the channel or pipe through which it flows; you can use your site's head calculation along with its flow calculation to determine the site's potential power output.

Most micro hydropower sites are categorized as low or high head. The higher the head the better the output, less water is needed to produce a given amount of power and we can use smaller, less expensive equipments. Low head refers to a change in elevation of less than 3 meters. A vertical drop of less than 0.6 meters will probably make a small-scale hydroelectric system unfeasible. However, for extremely small power generation amounts, a flowing stream with as little as 0.33 meters of water can support a submersible turbine. This type of turbine was originally used to power scientific instruments towed behind oil exploration ships. When determining head, you need to consider both gross head and net head. Gross head is the vertical distance between the top of the penstock that conveys the water under pressure to the point where the water discharges from the turbine. Net head equals gross head minus losses due to friction and turbulence in the piping.

3.2 Condition for Head analysis

Experiment on micro – hydropower plant site have shown that the Kaplan turbine will give as high efficiency as any form of turbine under head as low as 2-4 meters but its construction does not admit of handling sufficient water to develop any considerable amount of power under low head within a reasonable limit of cost. It is not, therefore recommended for heads of less than 4 meters where a comparatively small amount of power is required. High head and low flow rate with increased pressure give desirable power output and could be employed when sitting large scale SHPP while low head and high flow rate with decreased pressure give a lower power output and can be employed when sitting a small scale SHPP.

3.3 Pressure Head

Hydro power is obtained from the potential and kinetic energy of water flowing from a height. The energy contained in the water is converted into electricity by using a turbine coupled to a generator. The hydro power potential of a site is dependent on the discharge.

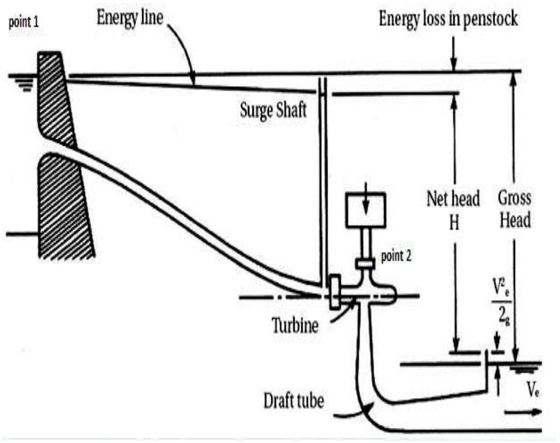


Fig. 3.1 : Components of SHPP unit

A hydro power resource can be measured according to the amount of available power or energy per unit time. The power of a given situation is a function of head and the rate of flow as shown in Fig.3.1. The energy in a SHPP starts out as potential energy by virtue of its height above the power house. Water under pressure in the penstock is able to do work when released, so there is energy associated with the pressure as well. The transformation of energy is from potential to pressure to kinetic energy. The power in the hydro power system strongly depends on the net head and the flow-rate of water. SHPP sites are characterized as high head or low head. The higher the head the better the power output because one would need less water to produce a given amount of power. This would mean that smaller and less expensive material could be used. A vertical drop of less than 0.6m will probably make a small hydroelectric system unfeasible. This means that head less than 0.6m would produce less power and it would not be economical.

Net head is the gross head minus the head losses that occur when water flows from the intake to the turbines through canals and penstock. Water loses energy (head loss) as it flows through a pipe, fundamentally due to:

Friction against the wall

The friction against the pipe wall depends on the wall material roughness and the velocity gradient. The friction in the pipe walls can be reduced by increasing the pipe diameter. However, increasing the diameter increases the cost, so a compromise should be reached between the cost and diameter.

Flow turbulence

Water flowing through a pipe system with bends, sudden contractions and enlargement of pipes, racks, valves and other accessories experiences in addition to the friction loss, a loss due to inner viscosity. This loss depends on the velocity and is expressed by an experimental K multiplied with the kinetic energy. Water flow in a pipe bend experiences an increase of pressure along the outer wall and a decrease of pressure along the inner wall. This pressure imbalance causes a secondary current. Both move together (the longitudinal flow and the secondary current), produce a spiral flow at a length and is dissipated by viscous friction. The head loss produced depends on the radius of the bend and the diameter of the pipe. The loss of head produced by water flowing through an open valve depends on the type of the valve.

Thus, H which is the head can be gotten by using the Bernoulli's equation to analyze the fluid flow from point 1 to point 2 as in fig.3.1. Kelly. J.R used the Euler's equation to obtain Bernoulli's equation by integrating along a streamline for steady, incompressible, frictionless flow which gives to Eq. 3.1.

$$H = \frac{p}{pg} + \frac{v^2}{2g} + z \qquad (3.1)$$

Where; $\frac{p}{pg}$ = the head due to local static pressure, $\frac{v^2}{2g}$ = the head due to local dynamic pressure, Z = the elevation head, H = the head for the flow.

From Eq.3.1;

$$H = \frac{p}{pg} + \frac{vr^2}{2g} + z_{\mathbf{1}} = \frac{pn}{pg} + \frac{vn^2}{2g} + z_{\boldsymbol{n}} \qquad (3.2)$$

At the surface of the river bed, the fluid moves very slowly compared to the flow along the pipe. We say that $u_r = 0$, Also the pressure is atmospheric pressure, $p_r = p_n$ = Patomspheric. $Z_r - Z_n$ is the elevation of the river bed and the turbine.

$$Z_r = \frac{vn^2}{2g} + Z_n \qquad (3.3)$$

$$Z_r - Z_n - H_f = \frac{vn^2}{2g} \qquad (3.4)$$

3.4. Determination of Nozzle Velocity: V_n

The velocity is the velocity of fluid particle at the water source surface fig.3.1. The velocity is the velocity of the water jet at the nozzle. The pressure head at point 1 and 2 is equal to zero.

From Eq. 4, $Z_r - Z_n - H_f = \frac{vn^2}{2g}$; $v_n \left(\frac{M}{S}\right) = \sqrt{2xg\ (Z(m) - Z_m - H_f}$ (3.5)

Where; V_n is the same as $V_1 H_f$ is equal to f L/d_{pipe} × $\frac{vn^2}{2g}$. therefore the flow rate entering the turbine from the nozzle is expressed as Q = AV.

$$Q = V \times A = V \times \frac{\pi d^2}{4} \qquad (3.6)$$

The flow rate entering the turbine is influenced by the static head, pipe diameter and nozzle diameter; increase in any of these values or decrease will definitely affect the flow rate.

3.5 Derivation of Power Output

Power delivered by flowing fluid to the turbine is given in as P = ρgQH. Where H is the available head and Q is the flow rate from the nozzle where ρ is the water density and is the water jet velocity. Either one of these expressions gives a theoretical power available from water jet.

Power at turbine wheel:

$$\text{Power}[\,P] = \rho g Q H \qquad (3.7)$$

3.6 Terminology Used

(i) tangential velocity [u] = $\frac{\pi \times D_M \times N}{60}$

(ii) flow rate [Q] = $\frac{\pi\left(D_2^2 - D_1^1\right)}{4} \times vf$

(iii) absolute velocity [v] = $\sqrt{2g \;\; H_{net}}$

(iv) Flow Ratio = $\frac{v(\,f\,)}{v}$

(v) Speed ratio = $\frac{u}{v}$

(vi) specific speed of time [Ns] = $\frac{N \times \sqrt{P}}{H^{5/4}}$

(vii) Overall efficiency [N$_0$] = $\frac{H_{turbine}}{H_{net}}$

(viii) Power = $\rho g Q H_{turbine}$

3.7 Analysis

Analysis procedure for axial flow turbine was done. Let for Kalpan turbine suffixes 1 and 2 denote inlet and outlet conditions respectively. Thus, for example D_1 represents the inlet location at the tip of the runner. (Since for a Kaplan turbine, $D_1 = D = D_2$, in the diameter of the runner of a Kaplan propeller turbine is consistently referred to as D_1). The flow in axial through the blades.

Area of flow $A = \frac{\pi}{4}\,(D_1^2 - D_h^2)\;\; K_1$ where K_1 is the net area factor after deducting for the area occupied by the blades in the cross section. For preliminary studies, it is usual to take $K_1 = 1.0$.

$$\text{Area of flow } A = \frac{\pi}{4}\,(D_1^2 - D_h^2) \tag{3.8}$$

$$\text{Discharge } Q = \frac{\pi}{4}\,(D_1^2 - D_h^2)\,V_{f1} \tag{3.9}$$

$V_{f1} = V_{f2}$ = Velocity of flow which is taken as constant in the entire inlet-outlet space, i.e. all along the inlet radius as well as all along the outlet radius.

Let u_1 = Peripheral velocity an inlet at any radius r, and u_2 = Peripheral velocity at the outlet at the same ra2dius r. Then

$$u_1 = u_2 = u = \frac{2\pi r N}{60} \tag{3.10}$$

The flow is assumed to leave the runner axially without any whirl component. Thus, at the outlet $\alpha_2 = 90°$ and $V_2 = V_{f2}$, as used in the case of a Francis turbine.

It is assumed that the flow entering the whirl chamber from the guide vanes creates a free vortex in the whirl and runner chambers where the velocity is inversely proportional to the radius. Thus, if $r_h = (D_h/2)$ is the radial distance of the hub from the axis, $r_t = (D_1/2)$ is the radial distance of the blade tip and r_m is the radial distance of the midpoint of the blade then

$$(V_{u1})_t\, r_t = (V_{u1})_m\, r_m = (V_{u1})_h\, r_h = \text{Constant} \tag{3.11}$$

In this $(V_{u1})_x$ is the velocity of whirl at the given radius x on the inlet side of the blade.

The Euler equation is applicable given in Euler head H_e as

$$H_e\ \frac{V_{u1}u_1 - V_{u2}u_2}{g} = \frac{V_{u1}u_1}{g} = \qquad (\therefore\ V_{u1} = 0) \tag{3.12}$$

Further, the hydraulic efficiency $\eta_h = \frac{H_e}{H} = \frac{V_{u1}u_1}{gH}$ [where H = Net head] (3.12a)

Values of α_1, β_1 at inlet and β_2 at outlet change all along the blade length. The velocity triangle at the inlet at any radial location on the blade is an acute-angled triangle. The outlet velocity triangle is a right-angled triangle. Both are constructed in the same way as done in connection with the Francis turbine. The nature of variation of the flow angles of the velocity triangle viz. α_1, $\beta_1$at inlet and β_2 at outlet could be described in a general as below:

(i) Angle β_1 is maximum at the blade tip and decreases along the radius to a minimum at the hub.

(ii) Angle α_1 is minimum at the blade up and increases along the radius to a maximum at the hub.

(iii) Angle β_2 is maximum at the blade tip and decreases along the radius to a minimum at the hub. Generally, β_2 is larger β_1 than at all radial locations.

Mean radius $r_m = \frac{(D_1 + D_h)}{2}$ is used sometimes as a representative location for estimation of values of hydraulic efficiency, specific speed, power and overall efficiency of the turbine.

CHAPTER – 4

SMALL HYDRO POWER PLANT AT GOGRIPUR

4.1 Classification of Hydro-Power Plant:

The central electricity authority (CEA) and the ministry of new and renewable energy (MNRE) have classified SHPs depending on capacity range and available head. The classification are as follows:

a) Based on capacity(MNRE Report 2005)

Category	Unit Size
Micro	Up to 100 kW
Mini	101-1000 kW
Small	1-25 MW

b) Depending on head

Ultra low head	Below 3 metre
Low head	Above 3 metres and upto 40 metre
Medium/High head	Above 40 metre

4.2 Classification of Turbine

Water turbines are classified based on the action of flowing water on turbine blades, the existing head and the quantity of water available, the direction of water flow on water turbine blades, and the name of the inventor. Water turbines are divided into two parts reaction and impulse turbine with further sub divisions as low, medium, high head turbines. Small hydro is characterized with low head and nominal water flow.Net head available to the turbine leads to the selection of the type of turbine, and the rate of water flow determines the capacity of the turbine. Various types of turbine are:

Reaction turbines

The essential features of medium and low head turbines shall be covered by enumerating the details of Francis turbine. Francis turbine blades are joined to two rims and are specially shaped to ensure maximum extraction of energy from water. The major parts of a Francis turbine system are penstock pipe from high water level to scroll casing. Scroll casing provided around turbine welded with pen stock on upper side and draft tube on lower side. Guide vanes installed on pivots to control water entering the runner.

Axial Flow Turbines

Axial flow reaction turbines are suitable for low heads and, therefore need a large quantity of water. These are sub-divided into three types

(i) Propeller type: Propeller turbines are with fixed blades and adjustable guide vane Turbine discharge and generator output can be only controlled over a limited range

(ii) Semi Kaplan: Turbines with adjustable runner blades and fixed guide vanes are called semi-Kaplan. This design offers high efficiencies at several operating points.

(iii) Kaplan turbine: Named after the Austrian engineer, V.Kaplan who designed it with adjustable runner blades and guide vanes. Runner blades and guide vanes are regulated to variable flow rates. It offers good efficiency even at partial load.

Tube Turbine

Tube turbines are horizontal or slant mounted units with propellers runners.

A tube turbine may be fixed propeller type, semi-Kaplan type or fully adjustable type. The generator is located outside the water passage; driven by a shaft. The performance range of a tube turbine with movable blade runner fixed guide vanes is good. It operates efficiently between the head range of 2 to 15 meter especially where the discharge is heavy compared to the head. As the stream flow approaching the runner is axially symmetrical, a higher specific speed can be used with reduction turbine and generator size. Tube-turbines are available in the range from 5 kW to 700 kW for heads up to 20 meters. A tube turbine can also be used as a pump. The requirements of civil works in a powerhouse are reduced as the height and the width required are 60% of the dimensions needed for a conventional turbine and generator.

Bulb Turbine

Bulb turbines are horizontal units that have propeller runners directly connected to the generator. The generator is enclosed in a watertight bulb shaped enclosure. The bulb unit is placed horizontally, completely submerged in the water passage. Turbines are available with fixed or adjustable runner blades. The performance characteristics are similar to the vertical adjustable propeller turbine .Bulb units operate efficiently between the head range of 1.25 m to 25 m with a discharge of 3 cumecs to 70cumecs. Being compact in design, the powerhouse floor space and the height for the bulb turbine installations are minimized. Other advantages over a Kaplan unit as no spiral case friction loss are minimum due to straight draft tube. Less civil works construction and less affected by cavitations and higher specific speed. Bulb units can be used as reversible pump turbine units. This function cannot be performed by conventional units.

Straflo Turbine

A straflo turbine is one where the generator rotor is mounted at the periphery of the turbine runner thereby providing minimum obstruction to the flow. This turbine was developed by Esches Wyss Ltd of Zurich, Switzerland and given the name straflo. The performance characteristic of Straflo turbine is similar to that of the Bulb unit. The Straflo design is attractive because of simplicity and compactness. Other advantages as no driving shaft, a higher output generator can be accommodated as the same is mounted on the outer periphery, a larger inherent inertia ensures better stability compared to bulb turbines of the same capacity. The Straflo unit is suitable for the head range of 2 m-50 m and water flow of 3-20 cumecs. Capacities range from 100 Kw to 1900 Kw.

4.2.1 Impulse Turbines

An impulse turbine consists of a wheel or runner, with a number of buckets around its periphery High velocity water, issuing from one or two nozzles, impinges on the buckets causing the wheel to rotate. The pressure of water before the nozzle causes the energy to be converted into kinetic form that is imparted to the wheel. The turbine is set above the tail water level: water leaving the buckets falls into a pit below the runner and escapes by the tail race. The head between the tail race and the nozzle is ineffective for producing power.

Various types of impulse turbine are:

1. Pelton turbine(For High Speed)

2. Turgo Impulse Turbine (For Medium Head)
3. Ossberger cross flow turbine (For Low Head)

Pelton Turbine

Pelton Turbine is installed with a horizontal shaft. Buckets are shaped like two spoons place side by side with a knife edge between them. A jet striking the knife edge gets divided into two equal parts and water is diverted through 180 degree by the bucket thus transferring energy to the turbine wheel. Control of turbine is maintained by hydraulically operated needle nozzles in each jet. In addition a jet deflector is provided for emergency shutdown. The deflector diverts the water jet from the bucket to the wall of the pit liner. Pelton turbine is suitable for high heads in the range of 60 meter to 700 meters with an output capacity of 50 to 10000 Kw.

Turgo Impulse Turbine

It is a free jet impulse turbine where the water jet impinges on the runner cup at one side and is discharged at the other end into the tail race. The turgo runner is cast in one piece suitable for horizontal shaft as single or multijet configuration. The turgo impulse turbine is ideal for heads in the range of 32 m to 210 m. The specific speed of this turbine is almost equivalent to that of six jet pelton turbines.The jet in turgo turbine strikes three buckets simultaneously which increases the speed whereas in pelton turbines the jets strikes only one bucket at a time. Being a free jet turbine there is no cavitations damage to turgo runner. Governing the turgo impulse turbine with a long penstock is impossible without making a provision for such tank valve.

Ossberger Crossflow Turbine

The cross flow turbine is another form of impulse wheel that can be used in low head applications. It was designed by Ossasbergerfalirik co. of Germany. The turbine carries the horizontal shaft, the runner in rotar form has a number of blades and the length of blades can be changed matching with the output. The blades are curved only in the radial direction, hence no axial thrust is experienced which feature obviates the need of a thrust bearing. Water enters through a rectangular jet into a cylindrical runner and passes from periphery towards the centre, then after crossing the open centre it moves outwards. As the water passes physically crosses the runner, hence the name given is cross flow. For obtaining higher efficiency at part load, the turbine guide vane is split into two valve sections, one covering two third and the other balance one third of the runner. At maximum flow condition both sections are open. At moderate rates, the two third section is open and at reduced flow rates only one third section of the guide vane is open. The expected peak efficiency of the cross flow turbine is 85%. The allowable head range is from 1m to 200 m for flow of 0.03 to 9 cumecs.

4.3 Definition of Head and Flow

Water Power is the combination of Head and Flow. Consider a typical hydro system. Water is diverted from a stream into a pipeline, where it is carried downhill and through the turbine (Flow). The vertical drop (Head) creates pressure at the bottom end of the pipeline. The pressurized water emerging from the end of the pipe creates the force that that drives the turbine. More Flow, or more Head, produces more power.

- **Head:** Head is water Pressure, which is created by the difference in elevation between the water intake and the turbine. Head can be expressed as vertical distance (feet or meters), or as pressure, such as pounds per square inch (psi).

- **Net Head:** Net is the pressure available at the turbine when water is flowing, which will always be less than the pressure when the water is turned off.

- **Flow:** Flow is water Quantity, and is expressed as "volume per second or minute" such as gallons per minute (gpm), cubic feet per second (cfs) or liters per second (lps). Both Head and Flow must be present to produce water power.

- **Design Flow:** Design Flow is maximum flow or which your hydro system is designed. It will be less than the maximum flow of the stream (especially during rainy season), and is often a balance between power output and cost.

4.3.1 Major Elements of a Hydro System

A hydro system is a series of interconnected components: water flows in one end and electricity comes out the other. This section provides a high-level overview of these components, from the water source to voltage and frequency controls.

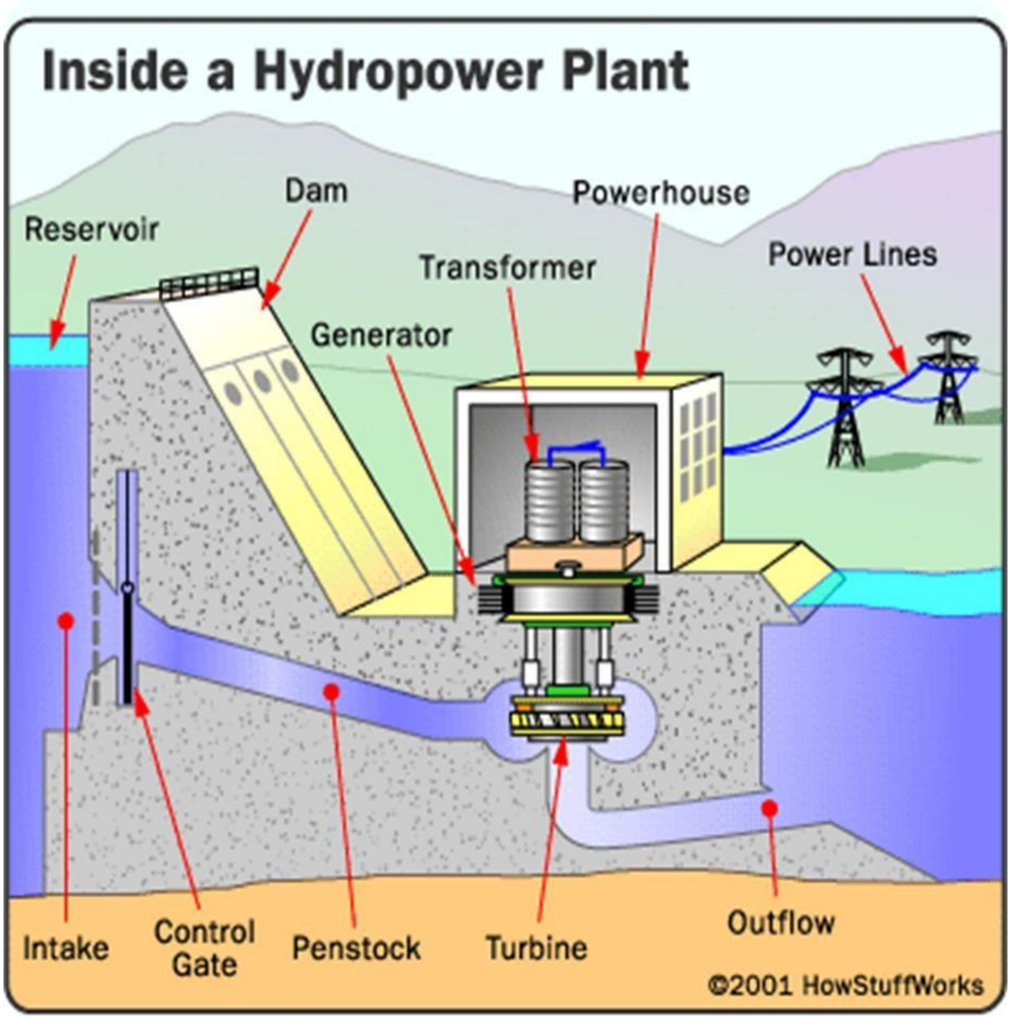


Figure 4.1: Basic Elements of Hydro power Plant

i) Water Diversion (Intake)

The intake is typically the highest point of your hydro system, where water is diverted from the stream into the pipeline that feeds your turbine. In many cases a small dam is used to divert the water. (In most large hydro projects, the dam also creates the HEAD necessary to drive the turbine.)

ii) **Pipeline (Penstock)**

The pipeline, sometimes called the penstock, is responsible for not only moving water to turbine, but is also the enclosure that creates Head pressure with increasing vertical drop. In effect, the pipeline focuses all the water power at the bottom of the pipe where the turbine will connect. In contrast, an open stream dissipates the energy as it travels down the hill.

Pipeline diameter, length and routing all effect efficiency and there are guidelines for matching the size of your pipeline to the Design Flow of the system. A small-diameter pipeline can considerably reduce your available horsepower, even though it can carry all available water. Larger diameter pipeline create less friction as the water travels through.

iii) Powerhouse

The powerhouse is simple a building that houses your turbine, generator and controls. Proper design significantly affects system efficiency, however, especially with regard to how the water enters and exits turbine.

4.3.2 Turbine and Efficiency

a) Turbine

The turbine is the heart of the hydro system, where water power is converted into the rotational force that drives the generator. There are many different types of turbines, and proper selection requires considerable expertise. A Pelton design, for example work best with the high Head. A Cross flow design works better with low Head but high flow. Likewise, other turbine types such as Francis, Turgo and Kaplan, each have optimum applications.

b) Major Types of Turbine:-

- Reaction Turbine run fully immersed in water and are typically used in low-Head (pressure) system with high Flow. Examples include Francis, Propeller and Kaplan.

- Impulse turbines operate in air, driven by one or more high-velocity jets of water. Impulse turbines are typically used high-Head systems and use nozzles to produce the high-velocity jets. Examples include Pelton and Turgo.

- Cross flow turbine is although technically classified as an Impulse turbine because it is not entirely immersed in water; it is used in low-Head, high-Flow systems. The water passes through a large, rectangular opening to drive the turbine blades, in contrast to these all, high-pressure jets used for Pelton and Turgo turbines.

c) Turbine Efficiency

Each turbine type can be designed to meet vastly requirements and minor differences in specifications impact power transfer efficiency.

The turbine system is designed around Net Head and Design Flow. Net Head is the pressure available to the turbine when water is flowing and Design Flow is the maximum amount of Flow the hydro system is designed to accommodate. These criteria not only influence which type of turbine to use, but are critical to the design of the entire turbine system.

The turbine runs most efficiently when it turns exactly fast enough to consume all the energy of the water. In turn, the water must enter the turbine at a specific velocity (typically measured in feet or meters per second) to maximize efficiency at this RPM.

This velocity is determined by Head pressure.

4.3.3 Optimizing Water Velocity

Since power is a combination of Head and Flow, it’s easy to see how a large orifice that moves more water (Flow) at the same velocity could generate more electricity. Conversely, as Flow drops off in the dry season, the orifice must be made smaller to maintain the same optimum velocity for efficient power transfer. But as the disparity between actual and optimum water velocity grows, less of the energy from the water is transferred to the turbine. The correct orifice ensures the system is operating at its most efficient level.

4.3.4 Drive System

The drive system couples the turbine to the generator. At one end, it allows the turbine to spin at its optimum RPM. At the other, it drives the generator at the RPM that produces correct voltage and frequency. The most efficient and reliable drive system is a direct, 1:1 coupling between the turbine and generator. These types of drive systems can use either gears, or pulley and belts, all of which introduce additional efficiency losses into the system.

4.3.5 Generator

The generator converts the rotational power from the turbine shaft into electrical power. Efficiency is important at this stage too, but most modern, well-built generators deliver good efficiency. There can be big differences in the type of power generated, however. DC (Direct Current) generators can be used with very small systems, but typically are augmented with batteries and inverters for converting the power into the AC (Alternating Current) power required by most appliances.

4.3.6 System Control

- **Governors and Controls**

  Governors and other controls help ensure that the generator constantly spins at its correct speed. The most common types of governors for small hydro systems accomplish this by managing the load on the generator.

- **Electronic Load Governors**

  An electronic load governor works by automatically adjusting the load so the generator always turns at exactly the right speed. In effect, it is always slowing the generator down just enough to produce correct voltage and frequency. Electronic load governors constantly monitor voltage or frequency, adding or subtracting electrical loads as necessary to compensate for human usage.

- **Load Management Systems**

  A load management system is an enhanced version of the electronic load governor, offering not only the ability to regulate power usage, but also the option for you to choose and prioritize how power is used. In addition to the ballast loads described above, it can directly control a wide variety of devices via relays. Small load adjustments work just like the electronic governor; the variable electronic switch regulates power to the ballast loads. When there is enough excess power, however, the load management system will control other devices in a certain priority.

- **Emergency System Shutdown**

  An emergency shutdown system is an option that protects the system from over speed, which may damage the generator. For example, if a tree falls over a power line, it may cause either a dead short (an extremely high load on the generator) or an open line (zero load) which would cause generator runaway. (A dead short may also cause runaway if it trips a breaker.) Any of these conditions are both dangerous and expensive, so an emergency shutdown system is a wise investment.

4.4 Utility Grid Interface Controls

Utility Grid connections are becoming more commonplace, but proper controls are essential for proper operation and – above all – safety. The grid interconnects very large, public utility power generation systems. It allows hundreds of megawatts of power to move around the country as regional supply and demand change. It provides automatic controls and switchgear, so that a failure in one location can be bypassed with minimal impact to consumers.

It is possible to interconnect a small hydro system with the utility grid. Grid connection would allow drawing power from the grid during peak usage times when your hydro system can’t keep up, and feed excess power back into the grid when your usage is low. This significant synchronization and safeguards must be in place.

Grid interconnection controls do both. They will monitor the grid and ensure your system is generating compatible voltage, frequency, and phase. They will also instantly disconnect from the grid if major fluctuations occur on either end.

4.5 Location Introduction

Gogripur is a village situated in Karnal district of Haryana. It is along the left bank of WYC canal about 3 km from Karnal town. The small Hydro power plant was set up in Gogripur by Haryana Renewable Energy Development Agency (HREDA) through P&R Gogripur Hydro Power Private Ltd. The small hydro power plant has 2 turbines both are operational. The small hydro power plant has the capacity of 2000 KW (2 MW) where each unit have 1000 KW capacity. The main purpose of the plant is to generate electrical energy through sustainable means by exploiting the potential energy of the flowing water for power generation. It leads to a cleaner environment through lower greenhouse gas emissions and other pollutants and greater security of the nation through lower fuel consumption, fossil fuel conservation for other activities. As it generates electricity through sustainable means, it will not cause any negative impact on the environment and there by contribute to climate change mitigation efforts. The total gross generation potential is 11913.60MWhbased on 75% dependable year. The generated power is supply to the grid by connecting it with HAREDA transmission lines.

Figure 4.2: Inside View of plant

Figure 4.3: Outside view of plant

4.6. General Information of Plant:

1. Name of Power Station: **Small Hydro Power Plant, Gogripur, Karnal**
2. Owner of Power Station: **HREDA**
3. Private Entity Involved: **P&R Gogripur Hydro Power Pvt. Ltd.**
4. Location:
   - Nearest town with distance: **Karnal**
   - District : **Karnal**
   - State : **Haryana**
5. Source of water : **WYC (Western Yamuna Canal)**
6. Type of Power Station : **Irrigation Canal type**
7. Number of generating units : **2 units of 1000 Kw each**
8. Maximum and Minimum head :
   - Maximum head : **3.74 m**
   - Minimum head : **2.75 m**
9. Commissioning date (for each unit) : **10 September, 2010**

4.7 Generating Units

4.7.1 Turbine

- Type : **Semi kaplan**
- Shaft : **Vertical**
- Rated discharge : **68.3 m^3/s**
- Rated output : **1000 kW each unit**
- Rated speed : **110 rpm**
- Number of generating units : **2**

4.7.2 Generator

- Type (Synchronous / induction) : **Synchronous**
- Rated speed : **110 rpm**
- Overload : **10%**
- Frequency : **50 Hz**

- Generation Voltage : **66.5 kva**
- Power factor : **0.8**

4.7.3 Power Evacuation:

- Transmission voltage (grid) : **33 kV**
- Transmission line : **11 kV**

CHAPTER – 5

RESULTS, CONCLUSIONS AND FUTURE RECOMMENDATION

In this section, results of unit generation and power load factor (PLF) under total hours were discussed monthwise and yearwise from 2010 to 2018 through tables and figures. Thus by using EES software program using EES software and by using different mathematical equations to determine the overall efficiency of the Gogripur small hydro power plants. Hence input parameters such as tangential velocity, flow rate, absolute velocity flow ratio, speed ratio, specific speed of turbine, and head of turbine are calculated to obtain the overall efficiency.

5.1 Results and Discussions

From year 2010 to 2018, a table of the occurrence of the export 1, export 2, export, unit generation, total hours and PLF under total hours, is constructed as in yearwise tables. The export1 (A) is noted in column3.The export 2(B) is recorded in column 4. The difference between column4 and column3 gives the export value in column 5.The unit generation is calculated and noted in column 6.The data of total hours is noted in column 7 and finally PLF under total hours (in%) is calculated in column8 . Thus the unit generation and PLF under total hours is shown by bar graph (unit generation v/s month) and by curve (PLF under total hours v/s month) respectively.

Therefore, all the tables, bar graphs and curves are discussed yearwise from 2010 to 2018 and results of unit generation and PLF under total hours are also calculated yearwise. The following are tables, unit generation bar graphs and PLF under total hours curves as shown below:

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2010 to Dec. 2010

TABLE 5.1: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	0	0	0	0	744	0
2	Feb.	0	0	0	0	672	0
3	March	0	0	0	0	744	0
4	April	0	0	0	0	720	0
5	May	0	0	0	0	744	0
6	June	0	0	0	0	720	0
7	July	0	0	0	0	744	0
8	August	0	0	0	0	744	0
9	September	0	10573	10573	422920	720	29.36944444
10	October	10573	21444	10871	434840	744	29.22311828
11	November	21444	36324	14880	595200	720	41.33333333
12	December	36324	55549	19225	769000	744	51.68010753
TOTAL		**68341**	**123890**	**55549**	**2221960**	**8760**	**37.9015009**

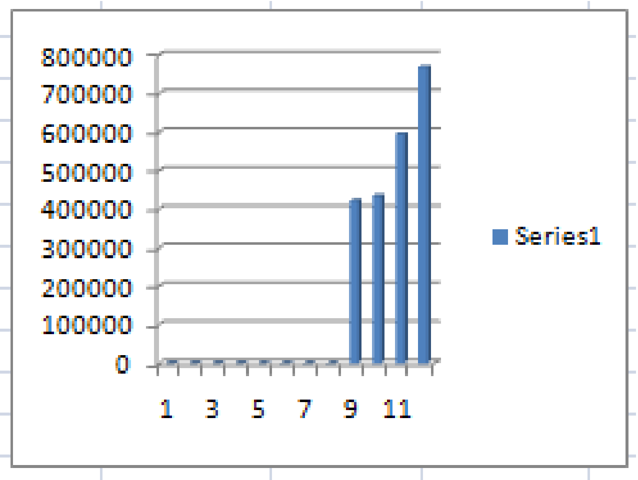


Figure 5.1: Unit Generation Bar Graph

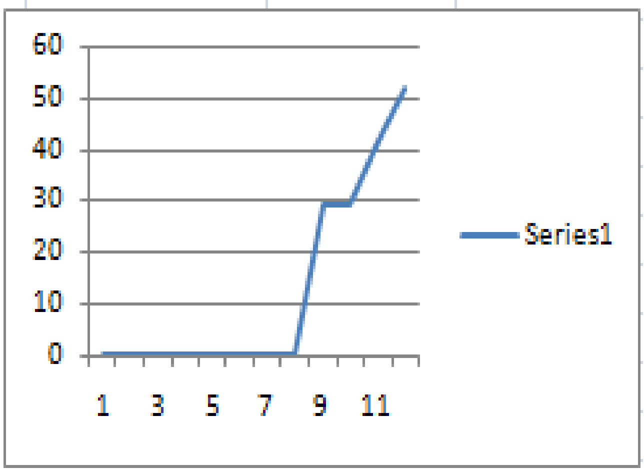


Figure 5.2: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2011 to Dec. 2011

TABLE 5.2: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	55549	71433	15884	635360	744	42.69892473
2	Feb.	71433	88737	17304	692160	672	51.5
3	March	88737	112090	23353	934120	744	62.77688172
4	April	112090	130855	18765	750600	720	52.125
5	May	130855	133701	2846	113840	744	7.650537634
6	June	133701	148588	14887	595480	720	41.35277778
7	July	148588	153493	4905	196200	744	13.18548387
8	August	153493	159177	5684	227360	744	15.27956989
9	September	159177	169295	10118	404720	720	28.10555556
10	October	169295	172481	3186	127440	744	8.564516129
11	November	172481	183332	10851	434040	720	30.14166667
12	December	183332	199973	16641	665640	744	44.73387097
TOTAL		**1578731**	**1723155**	**144424**	**5776960**	**8760**	**33.17623208**

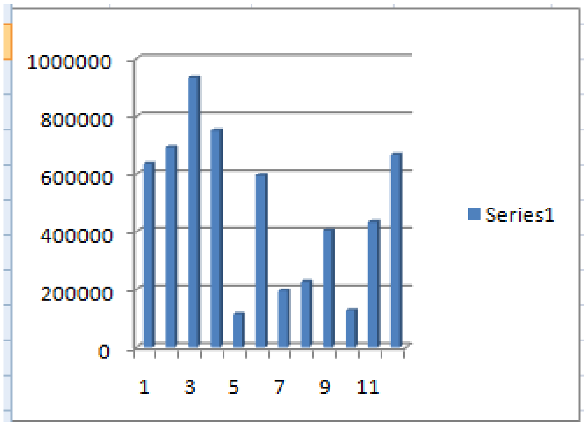


Figure 5.3: Unit Generation Bar Graph

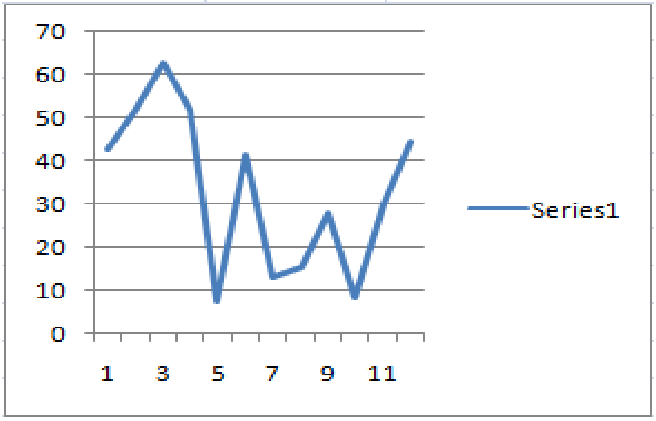


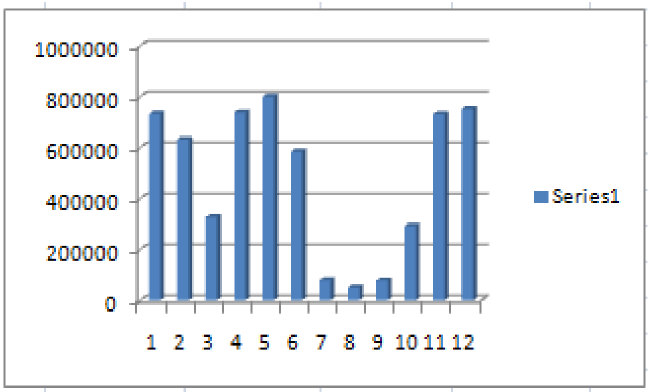
Figure 5.4: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2012 to Dec. 2012

TABLE 5.3: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	199973	218312	18339	733560	744	49.2983871
2	Feb.	218312	234105	15793	631720	696	45.38218391
3	March	234105	242284	8179	327160	744	21.98655914
4	April	242284	260739	18455	738200	720	51.26388889
5	May	260739	280740	20001	800040	744	53.76612903
6	June	280740	295333	14593	583720	720	40.53611111
7	July	295333	297309	1976	79040	744	5.311827957
8	August	297309	298574	1265	50600	744	3.400537634
9	September	298574	300543	1969	78760	720	5.469444444
10	October	300543	307840	7297	291880	744	19.6155914
11	November	307840	326129	18289	731560	720	50.80277778
12	December	326129	344946	18817	752680	744	50.58333333
TOTAL		**3261881**	**3406854**	**144973**	**5798920**		**33.11806431**



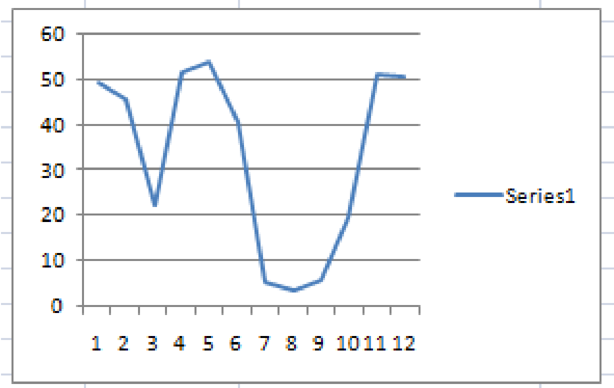


Figure 5.5: Unit Generation Bar Graph

Figure 5.6: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2013 to Dec. 2013

TABLE 5.4: PLF TABLE

SR. NO.	**Month**	**Export 1**	**Export 2**	**Export**	**Unit Generation**	**Total Hrs.**	**PLF Under Total Hrs. (in %)**
		(A)	**(B)**	**(C=B-A)**	**(D=C*40)**	**(I)**	**[(K=D*100)/I*2000)]**
1	Jan.	344946	363670	18724	748960	744	50.33333333
2	Feb.	363670	374694	11024	440960	672	32.80952381
3	March	374694	388311	13617	544680	744	36.60483871
4	April	388311	401141	12830	513200	720	35.63888889
5	May	401141	412234	11093	443720	744	29.81989247
6	June	412234	422499	10265	410600	720	28.51388889
7	July	422499	423578	1079	43160	744	2.900537634
8	August	423578	429191	5613	224520	744	15.08870968
9	September	429191	432571	3380	135200	720	9.388888889
10	October	432571	435612	3041	121640	744	8.174731183
11	November	435612	441497	5885	235400	720	16.34722222
12	December	441497	455156	13659	546360	744	36.71774194
TOTAL		**4869944**	**4980154**	**110210**	**4408400**		**25.1948498**

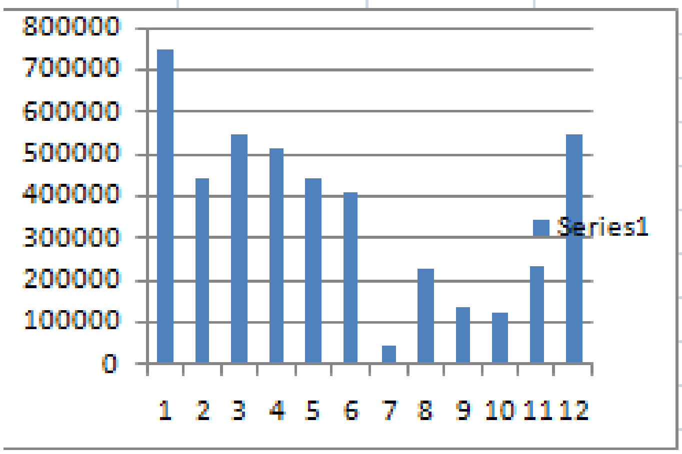


Figure 5.7: Unit Generation Bar Graph

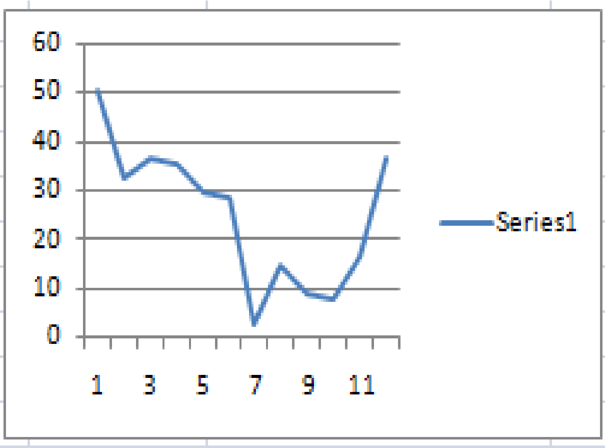


Figure 5.8: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2014 to Dec. 2014

TABLE 5.5: PLF TABLE

SR. NO.	**Month**	**Export 1**	**Export 2**	**Export**	**Unit Generation**	**Total Hrs.**	**PLF Under Total Hrs. (in %)**
		(A)	**(B)**	**(C=B-A)**	**(D=C*40)**	**(I)**	**[(K=D*100)/I*2000)]**
1	Jan.	455156	473823	18667	746680	744	50.18010753
2	Feb.	473823	490940	17117	684680	672	50.94345238
3	March	490940	507707	16767	670680	744	45.07258065
4	April	507707	521010	13303	532120	720	36.95277778
5	May	521010	535284	14274	570960	744	38.37096774
6	June	535284	547497	12213	488520	720	33.925
7	July	547497	552529	5032	201280	744	13.52688172
8	August	552529	553774	1245	49800	744	3.346774194
9	September	553774	561035	7261	290440	720	20.16944444
10	October	561035	574556	13521	540840	744	36.34677419
11	November	574556	593781	19225	769000	720	53.40277778
12	December	593781	612847	19066	762640	744	51.25268817
TOTAL		**6367092**	**6524783**	**157691**	**6307640**		**36.12418555**

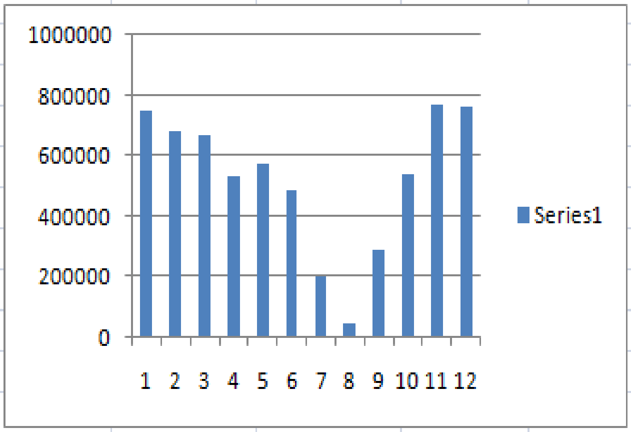


Figure 5.9: Unit Generation Bar Graph

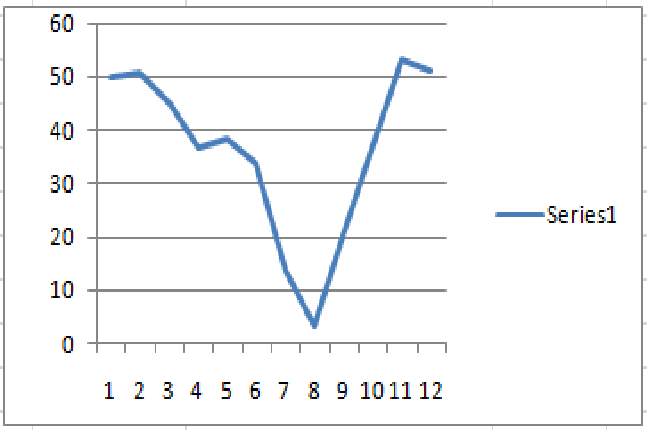


Figure 5.10: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2015 to Dec. 2015

TABLE 5.6: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	612847	633683	20836	833440	744	56.01075269
2	Feb.	633683	651832	18149	725960	672	54.01488095
3	March	651832	662382	10550	422000	744	28.36021505
4	April	662382	667374	4992	199680	720	13.86666667
5	May	667374	671026	3652	146080	744	9.817204301
6	June	671026	680855	9829	393160	720	27.30277778
7	July	680855	686380	5525	221000	744	14.85215054
8	August	686380	687473	1093	43720	744	2.938172043
9	September	687473	694903	7430	297200	720	20.63888889
10	October	694903	707704	12801	512040	744	34.41129032
11	November	707704	722556	14852	594080	720	41.25555556
12	December	722556	741175	18619	744760	744	50.05107527
TOTAL		**8079015**	**8207343**	**128328**	**5133120**		**29.45996917**

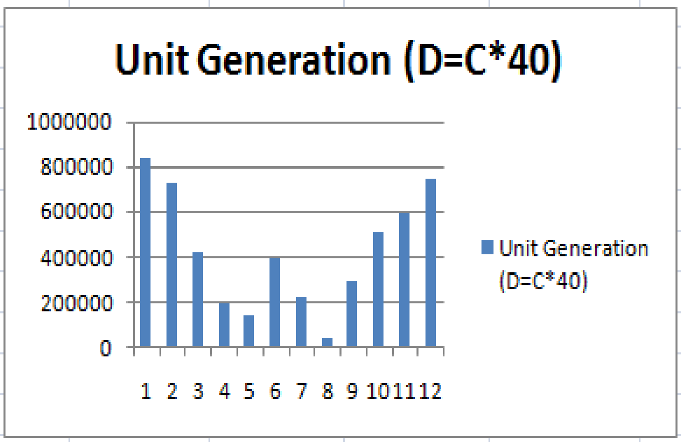


Figure 5.11: Unit Generation Bar Graph

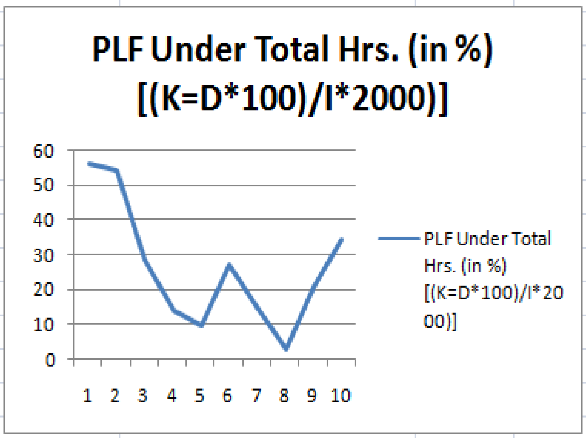


Figure 5.12: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2016 to Dec. 2016

TABLE 5.7: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	741175	759766	18591	743640	744	49.97580645
2	Feb.	759766	778398	18632	745280	672	55.45238095
3	March	778398	798645	20247	809880	744	54.42741935
4	April	798645	817344	18699	747960	720	51.94166667
5	May	817344	835086	17742	709680	744	47.69354839
6	June	835086	849926	14840	593600	720	41.22222222
7	July	849926	855654	5728	229120	744	15.39784946
8	August	855657	856581	924	36960	744	2.483870968
9	September	856581	858193	1612	64480	720	4.477777778
10	October	858193	871432	13239	529560	744	35.58870968
11	November	871432	884819	13387	535480	720	37.18611111
12	December	884819	902168	17349	693960	744	46.63709677
TOTAL		**9907022**	**10068012**	**160990**	**6439600**		**36.87370498**

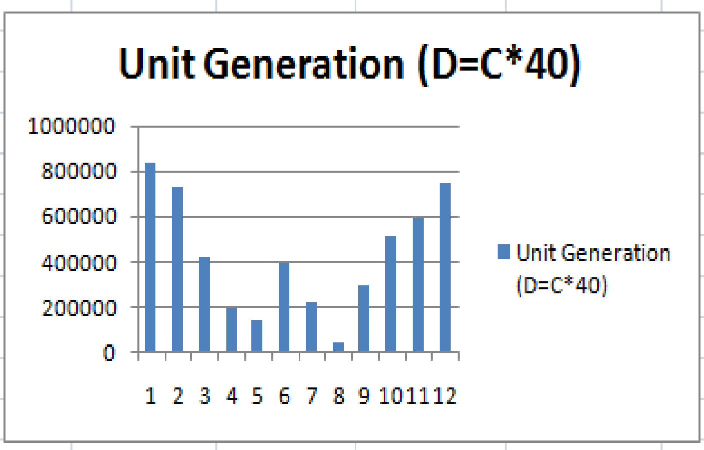


Figure 5.13: Unit Generation Bar Graph

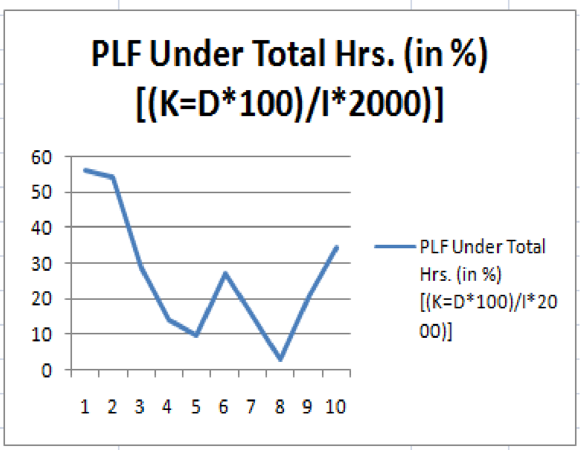


Figure 5.14: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2017 to Dec. 2017

TABLE 5.8: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	902168	921739	19571	782840	744	52.61021505
2	Feb.	921739	941512	19773	790920	672	58.84821429
3	March	941512	964505	22993	919720	744	61.80913978
4	April	964505	973772	9267	370680	720	25.74166667
5	May	973772	983446	9674	386960	720	26.87222222
6	June	983446	995591	12145	485800	720	33.73611111
7	July	995591	997465	1874	74960	744	5.037634409
8	August	997465	997465	0	0	744	0
9	September	997465	1001062	3597	143880	720	9.991666667
10	October	1001062	1014132	13070	522800	744	35.1344086
11	November	1014132	1032506	18374	734960	720	51.03888889
12	December	1032506	1051364	18858	754320	744	50.69354839
TOTAL		**11725363**	**11874559**	**149196**	**5967840**		**34.29280967**

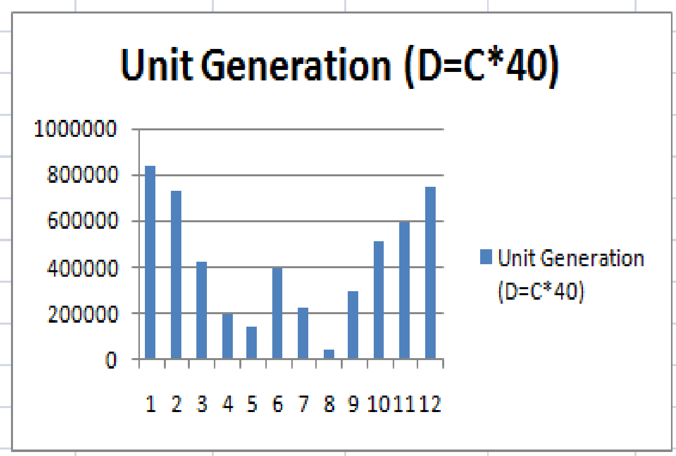


Figure 5.15: Unit Generation Bar Graph

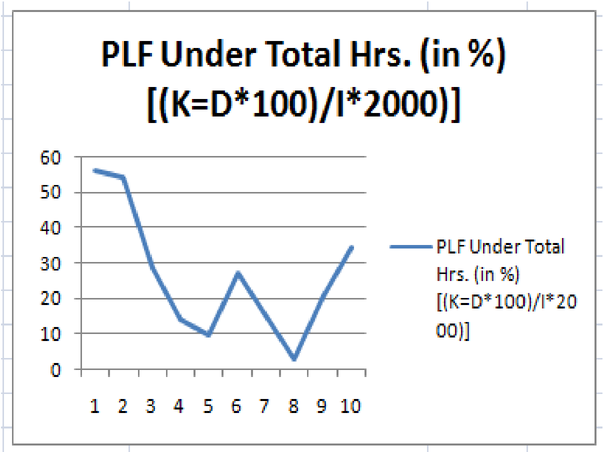


Figure 5.16: PLF Curve

Gogripur Hydro Power Project Plant

Load Factor from Jan. 2018 to Dec. 2018

TABLE 5.9: PLF TABLE

SR. NO.	Month	Export 1	Export 2	Export	Unit Generation	Total Hrs.	PLF Under Total Hrs. (in %)
		(A)	(B)	(C=B-A)	(D=C*40)	(I)	[(K=D*100)/I*2000)]
1	Jan.	1051364	1070776	19412	776480	744	52.1827957
2	Feb.	1070772	1088542	17770	710800	672	52.88690476
3	March	1088542	1107716	19174	766960	744	51.54301075
4	April	1107716	1117040	9324	372960	720	25.9
5	May	1117040					
6	June						
7	July						
8	August						
9	September						
10	October						
11	November						
12	December						
TOTAL		**5435434**	**4384074**	**65680**	**2627200**		**45.6281778**

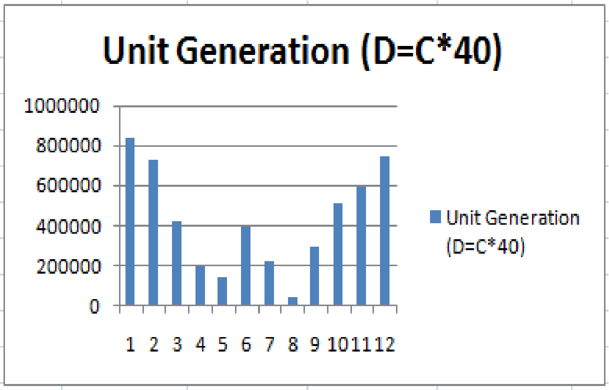


Figure 5.5: Unit Generation Bar Graph

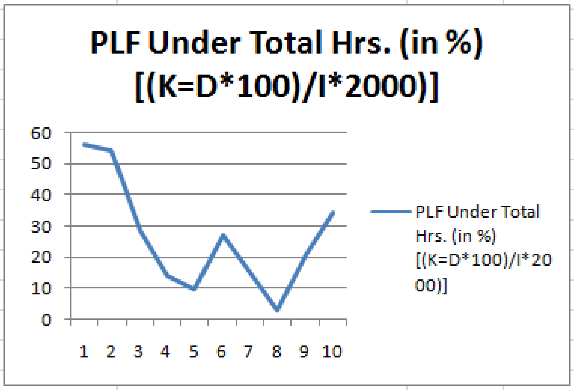


Figure 5.6: PLF Curve

The following curves were obtained by ESS software:

Figure 5.19, shows the flow rate against the net head as, the head increases from 2m to 4m. The volumetric flow rate was decreasing from 95 m3/sec to 47 m3/sec as the volume of water decreases the pressure is increased. This increase in pressure influences the power delivered to wheal by jet of water.

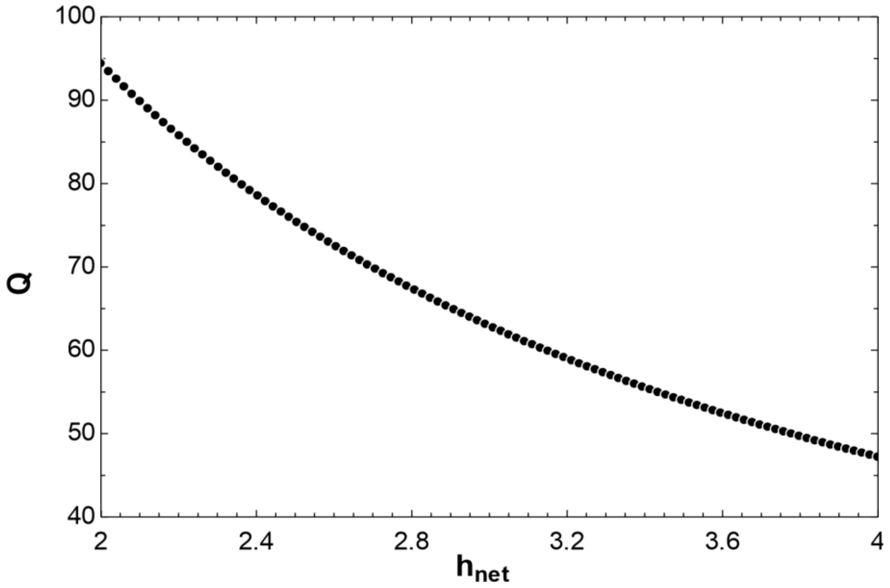


Figure 5.19: Flow rate (m^3/s) versus Net head (m)

Figure 5.20, shows the head of turbine is directly proportional to the net head. Thus head of the turbine was increased with the increase of net head from 2m to 4m and vice versa.

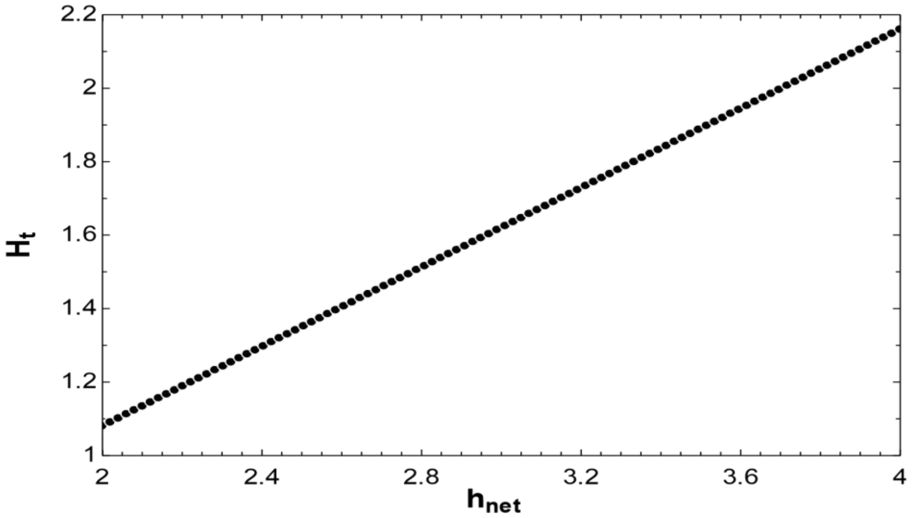


Figure 5.20 : Turbine Head (m) versus Net head (m)

Figure 5.21, shows the overall efficiency of power plant decrease from 0.75% to 0.38% with increased net head from 2m to 4m respectively. Hence, the power load factor of power plant decreases.

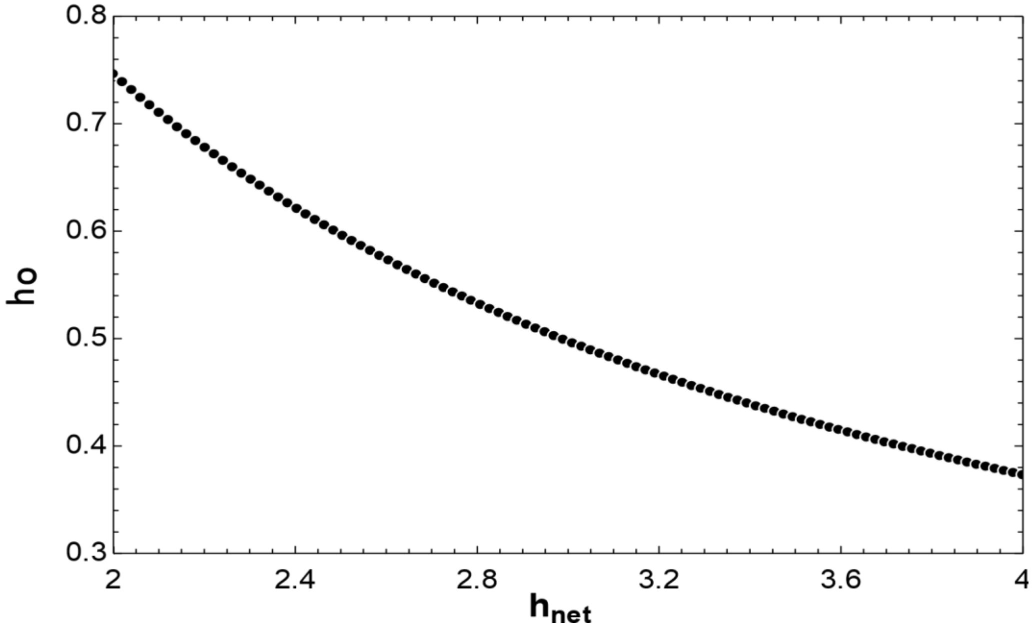
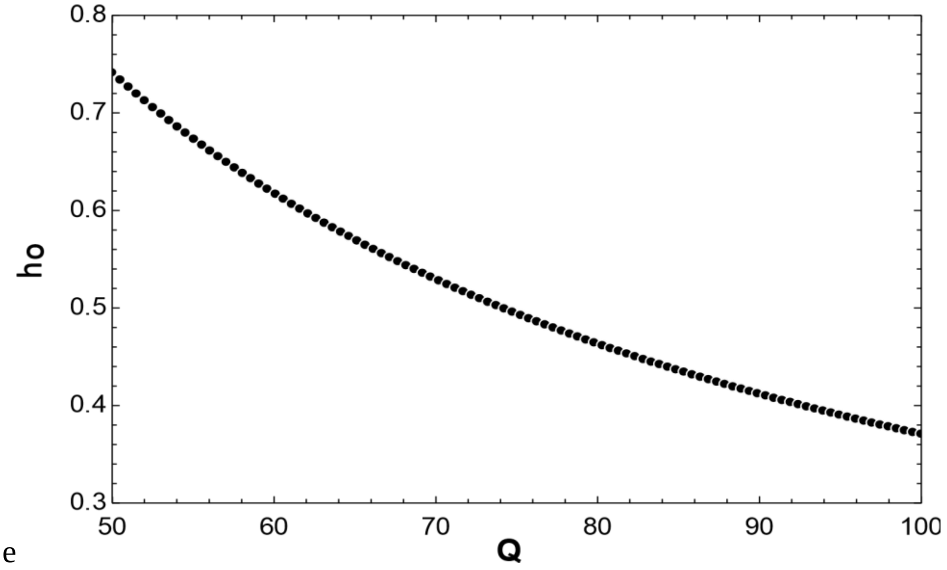


Figure 5.21 : Overall efficiency(%) versus net head (m)

Figure 5.22, shows similarly the overall efficiency of the power plant decreases from 0.75% to 0.38% with the increased flow rate from 50m3/sec to 100 m3/sec. Thus here also the power load factor of the power plant decreases.



e

Figure 5.22 : Overall efficiency (%) versus flow rate (m^3/s)

Figure 5.23, shows as the flow rate increases with decreased elevation, the power delivered to the wheal is decreased as the elevation decreased from 2m to 1.2m by increasing the flow rate from 50m3/sec to 100m3/sec.

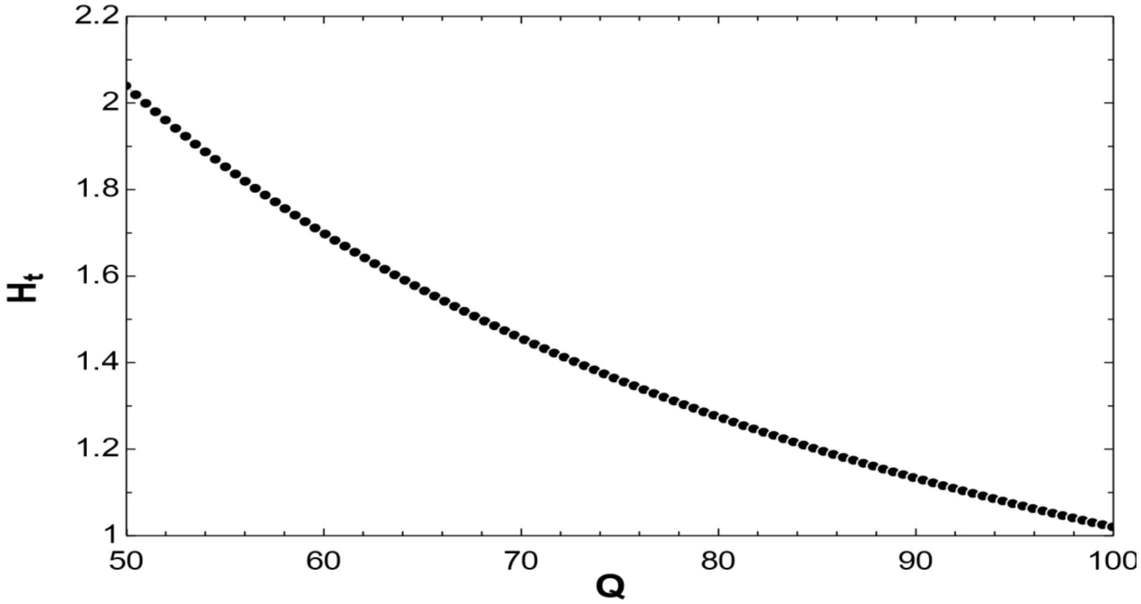


Figure 5.23 : turbine head (m) versus flow rate (m^3/s)

Therefore, after the discussion of all the figure from 5.19 to 5.23 and consider their results outputs and there after carry out various calculation as shown above, we comes to the result that the overall efficiency of the power plant is 54.5% and hence the power load factor is also 54.5%.

5.2. CONCLUSION

The research work investigated by doing head and flow analysis on the 2 MW Gogripur, hydro power plant to calculate the overall efficiency hydro power plant. The analysis was presented by EES computer program. The Kaplan turbine operating on small head and high flow condition generated a overall efficiency higher while that of high head and high flow with decreased pressure will generate lesser overall efficiency and could be applied in sitting a small hydro power plant.

The operating condition for the Kaplan turbine is calculated by considering various input parameters i.e. head, flow rate, RPM, power, tangential velocity, absolute velocity are used to calculate and finally obtain the overall efficiency.

The flow rate decrease from 100 m^3/s to 50 m^3/s with head and also the head is varied from 2m to 4 m with flow rate. Hence, small head and high flow are recommended for power generation of a small hydro power plant that could help to attain required level of overall efficiency of the plant instead of large head and low flow which is applicable for power generation of a large SHPP.

5.3 Future Scope of Work:

As small hydro is one of the cost effective and environmentally begin technologies to be considered for rural electrification is less developed countries. Hence cost of equipment used in hydro power plant is a big concern. So, the cost analysis can be future scope of work for study to develop a correlation to determine the cost based on influencing parameters such as power and head.

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