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DEVISE AND EXPLORATION OF MICRO HYDRO ENERGY STORAGE SYSTEMS

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Abstract: *Hydropower isn't only a renewable and sustainable energy source, but its flexibility and storage capacity also make it possible to enhance grid stability and to support the deployment of other intermittent renewable energy sources like wind and solar energy. As a result, renewed interests in micro hydro energy storage plants (MHES) and an enormous demand for the rehabilitation of old small hydropower plants are emerging globally. As regards MHES, advances in turbine design are required to extend plant performance and adaptability and new strategies for optimizing storage capacity and for maximizing plant profitability within the regulated energy market need to be developed. In small hydropower systems, Pumps as Turbines (PaT) represent a cheap alternative to plain turbines are often predicted before their installation.*

This paper traces a summary of the micro pumped-hydro energy storage within the light of sustainable development. A design procedure is carried to seek out the quantity of reservoir required, selection criteria for turbo machinery needed for the project. During this paper the potential and feasibility of Pump as Turbine (PAT) is discussed .An design procedure is administered for calculating the simplest Efficiency Points (BEP) is administered. A model design is administered using the planning procedure mentioned during this paper and Computational Fluid Analysis (CFD) of impellor is completed through Ansys.

Index Terms - Micro-Hydro Energy Storage (MHES), Pump as Turbine (PAT), Renewable Energy, Computational Fluid Analysis

INTRODUCTION

The antagonistic impacts of comprehensively changing climatic conditions because of human role in the common ecosystem of the existence cycle have driven individuals to limit such exercises which are driving the planet towards devastation. Individuals from various different backgrounds have understood the results of utilizing petroleum products and are creating and using spotless and inexhaustible wellsprings of vitality.. These sources of energy include wind, solar photovoltaic's, geothermal, hydroelectricity, bio fuels, biomass, wave, tidal, and so on. Wind and solar resources have become popular due to their technological maturity and commercial acceptance. As can be seen from the literature, the global expansion and investment of these resources is increasing year by year. More high costs, reliance on fossil fuels, and environmental considerations have been a powerful driver to increase the exploitation of renewable energy efficiency over the past decades.

Adding to this, there is shortage of electricity supply and other forms of modern energy in most of the developing countries. Lack of capacity to exploit natural resources into modern forms of energy as well as limitations in industrial application of the generated energy may explain the reasons for the shortage of energy supply. In most of the developing countries, shortage of electricity is worse in rural communities who are often marginalised from grid-based electricity supply due to economic and technical reasons. Currently, the requirement for inclusive national economic growth and development has heightened the importance of rural electrification. Rural electrification is achieved through grid extension (on-grid), mini-grid and isolated individual home power systems.

According to United Nations Development Program (UNDP), 1.4 billion people still remain without access to electricity [1]. a large dam with high capital cost is required to produce sufficient power supply. Low head smaller scale hydropower stations present an appealing and proficient route for power age in country, remote and bumpy regions as a result of the addition in the degree of ozone depleting substance discharges and fuel costs in these locales and they have gotten progressively mainstream for application at little waterways. Smaller scale hydropower plans can be utilized to create enough electrical force for home, homestead, and manor or for little town. They can likewise be utilized in mechanical end-utilizes like agro-handling, textile materials manufacture, frozen yogurt creation, cooling, and drying. The principle preferences of low head miniaturized scale power framework are that it is unsurprising if enough water gracefully is accessible and has positive natural effects. Hence, the framework has become the principle enthusiasm for future hydro-advancements

PUMP CHARACTERISTIC CURVES

The pump characteristics curves bends [30, 31] are regularly characterized as 'the graphical portrayal of a particular pump's conduct and execution under various working conditions'. The working properties of a pump are set up by the geometry and measurements of the pump's impeller and casing. Curves relating all out head, productivity, force, and net positive attractions head required (NPSHR) to release limit (Q) are used to clarify the working properties (attributes) of a pump [31].

Classification of Pump Characteristic Curves

Pump characteristics curves can be classified into four groups:

1. Main characteristic curves
2. Operating characteristic curves.
3. Constant efficiency curves
4. Constant head and constant discharge curves

Main Characteristic Curves

The pump is typically designed to run at an equivalent speed because the driving unit (i.e., prime mover), which is usually an electrical motor of the AC induction type. When the electrical power isn't available, the pump could also be driven by a diesel, or could also be coupled to the tractor engine. In such conditions, it's important to comprehend the exhibition of a pump at various rates, which might be best observed from the most trademark bends of a pump

So In order to get the most characteristics curve of a pump, it is worked at various velocities. For each speed, the pump release (Q) is shifted by methods for a conveyance valve and for the different estimations of Q, the comparing estimations of manometric head (Hm), shaft power (SP) and generally speaking effectiveness (ho) are estimated or calculated. Thereafter, Hm versus Q; SP versus Q, and ho versus Q bends for different

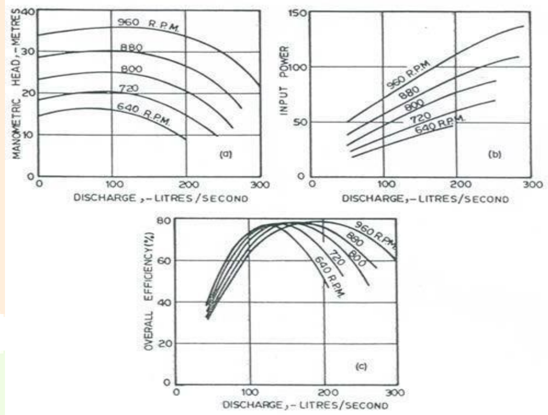


Figure: Main characteristics curve of a centrifugal pump.

Velocities are plotted which speak to the most qualities of a pump. Obviously, these bends are valuable in demonstrating the presentation of a pump at various paces. Most characteristics of a pump

Operating Characteristic Curves

During activity of a pump, the pump must run continually with the speed of the central player; this steady speed is commonly the arranging speed. The arrangement of fundamental attributes bends which relates to the arranging speed is normally used in pump activity, and henceforth such bends are alluded to as the working qualities curves. A run of the mill set of such attributes of a pump is appeared in Fig , which comprises of 4 bends at a proceeding with speed viz.,head versus release (Hm versus Q) bend, effectiveness versus release (ho versus Q) bend, power versus release (BP or SP versus Q) bend, and net positive pull head required versus release (NPSHR versus Q) bend. From these trademark bends, it's conceivable to work out whether the pump will deal with the necessary amount of fluid against the predetermined head and what will occur if the top is expanded or decreased. Additionally, these trademark bends outline what size engine will be required to work the pump at the predefined conditions and whether the engine will be over-burden under the other working conditions. A short depiction of those bends is given beneath.

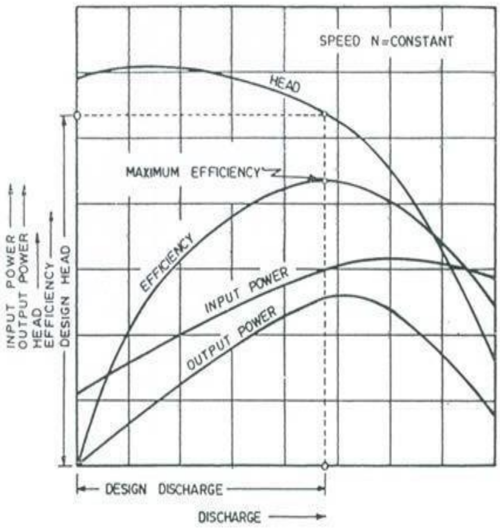


Figure: Operating characteristic curves of a centrifugal pump

Head versus Discharge Curve

The head-release bend (H-Q bend) relates the top delivered by a pump to the amount of water pumped per unit time (i.e., release of the pump). For the most part, the top delivered by a pump consistently diminishes in light of the fact that the release of the pump increments. The estimations of the top and in this manner the release like the most extreme proficiency are alluded to as the arranging head or typical head and the structure release or ordinary release of a pump..

The type of the H-Q bend differs with the exact speed. Run of the mill H-Q bends for different explicit velocities and impeller structures are appeared in Fig. For outspread stream impellers, head diminishes just somewhat then drops quickly as discharge (Q) increments from zero. Incline changes along H-Q bends for the blended and pivotal stream impellers aren't as sensational as those for spiral stream impellers. Spiral stream impellers working on the level part of their H-Q bends function admirably in circumstances where head must remain basically steady as Q vacillates (e.g., as in set- move frameworks where the measure of working laterals differs during the water system season). In circumstances where a similarly consistent Q is wanted and H is anticipated to vary (e.g., water sources kind of a well, little stream, or little supply), the impellers with higher explicit velocities will most likely play out the least difficult.

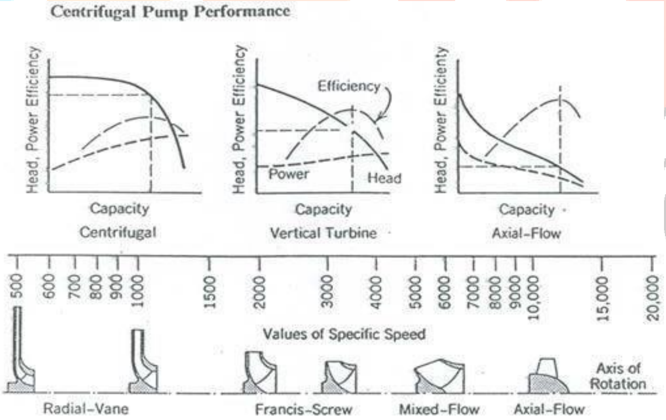


Figure: Head-discharge curves as a function of specific speed and impeller design

Moreover, the top generated by the pump when discharge is zero (i.e., when the pump is working against a closed valve) is named shutoff head. For pumps with steadily declining H-Q curves, the shutoff head is that the maximum head and must be known to style piping on the discharge-side of the pump. In such situations, discharge-side piping must be ready to withstand the shutoff head when the discharge valve is closed. Note that the efficiency of a pump is zero at the shutoff head, since energy is employed to show the pump.

Efficiency versus Discharge Curve

The theoretical pump efficiency may be a function of specific speed, impeller design, and pump discharge as shown in Fig. This figure indicates that the larger capacity pumps are often expected to possess the very best efficiency. the general efficiency (ho) is additionally associated with the kinds of materials utilized in construction, the finish on castings, the standard of machining, and therefore the type and quality of bearings used. for example, impellers with extremely smooth surfaces tend to be more efficient than rougher surfaced impellers.

Furthermore, it should be noted that the efficiency versus discharge curve is typically for a selected number of stages. If a special number of stages are needed for a specific situation, efficiencies must be adjusted upward or downward counting on the amount of stages. Manufacturers usually provide information for creating these adjustments.

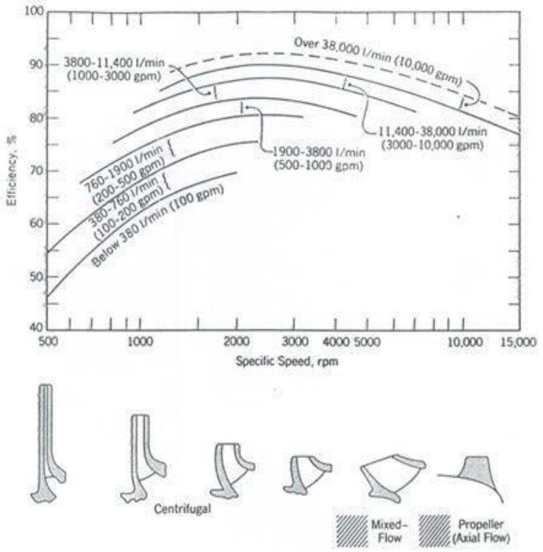


Figure: Variation of theoretical pump efficiencies with specific speed, impeller design and discharge

Power versus Discharge Curve

The brake power (BP) or shaft power (SP) versus release/limit (Q) bend for a pump is gotten from its H-Q and ho-Q bends. The state of the BP-Q bend relies upon the pump's particular speed and impeller structure, this shows for spiral stream impellers, BP by and large increments from a nonzero incentive to a pinnacle at that point diminishes somewhat as Q increments from zero. For blended stream impellers, BP increments step by step from a nonzero esteem as Q increments. In any case, for hub stream impellers, BP is most extreme when Q is zero and it consistently diminishes as Q increments from zero. Subsequently, when hub stream pumps are begun, the release side valve (or release valve) ought to be cordial the climate in order to lessen the beginning up load interestingly, the release side valve ought to be shut when outspread stream and blended stream pumps are begun

NPSHR versus Discharge Curve

The fourth trademark work ordinarily distributed by pump produces is that the net positive attractions head required (NPSHR) versus pump release (Q) bend as appeared in Fig. it's clear from this figure for a commonplace spiral stream pump, NPSHR step by step increments in light of the fact that the pump release increments.

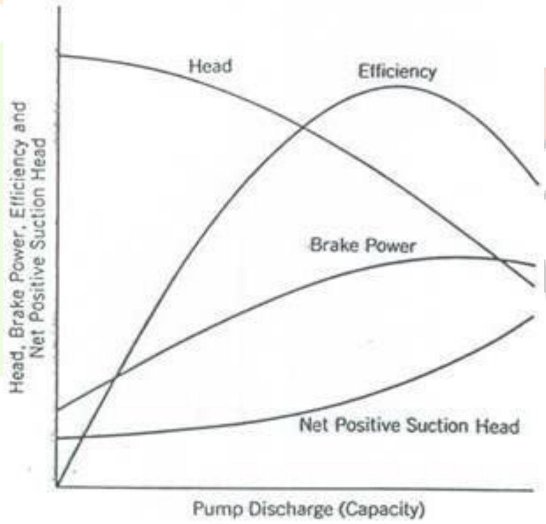


Figure: NPSHR versus discharge curve

Constant Efficiency Curves

The consistent productivity bends or Muschel bends help decide the scope of pump activity for a particular proficiency. As appeared in figure, the consistent or iso- productivity bends could likewise be acquired from H_m versus Q and h_o versus Q bends of primary trademark bends. in order to plot the iso-effectiveness bends, flat lines speaking to steady efficiencies are drawn on the ho versus Q bends. The focuses at which these lines cut the productivity bends at different rates are moved to the relating Hm versus Q bends. The focuses like an equal effectiveness are then joined by smooth bends, which speak to the iso-proficiency bends or Muschel bends. From these bends, the street of most extreme effectiveness is regularly gotten.

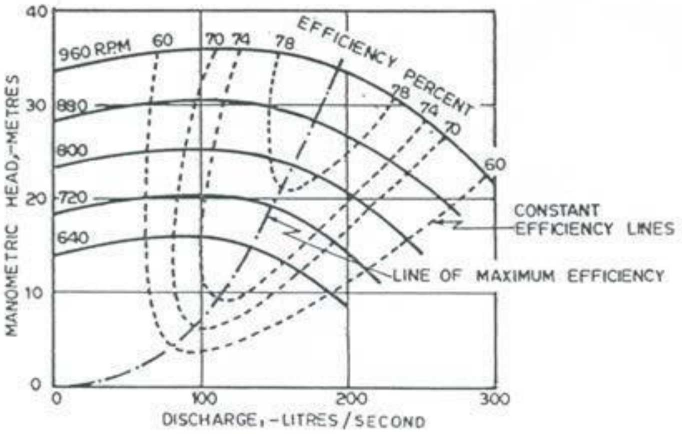


Figure: Constant efficiency curves of a centrifugal

Constant Head and Constant Discharge Curves

It is quite possible that a pump could also be required to deliver water at a particular height, wherein head (H) is fixed. If for a few reason, the pump speed (N) varies, the discharge of the pump also will be affected. so as to predetermine the performance of the pump under such conditions, it's necessary to draw a continuing head curve by plotting Q versus N .The constant head curve are often wont to determine the speeds required to discharge varying amounts of water at a continuing pressure head. Similarly, to work out the speeds required to discharge a particular quantity of water at different heads or to seek out variation of head with N, it's convenient to draw constant discharge curves by plotting H versus N. The constant head curves and the constant discharge curves are also useful for determining the performance of a variable speed pump having constantly varying speed.

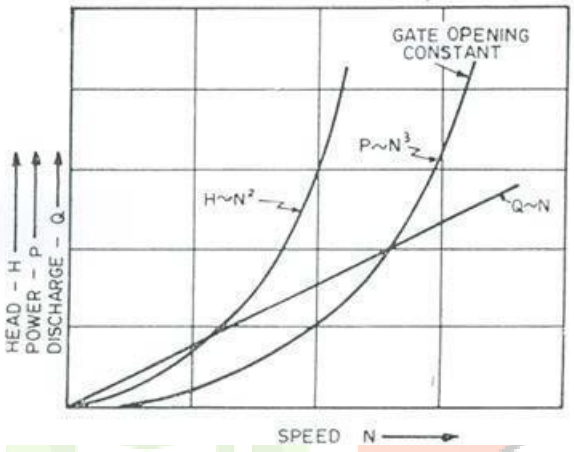


Figure : Q versus N, Hm versus N, and P versus N curves of a centrifugal

METHODOLOGY

DESIGN PROCEDURE FOR MHES

The basic steps to be carried out while designing MHES is mentioned below,

1
- Determination of Head (H)
- Determination of Flow rate (Q)

2
- Determination of Upper and Lower Reservoir

3
- Selection of Turbo machinery
- Calculation of Best performance Points.

4
- Selection of PAT Installation Configuration

DETERMINATION OF DESIGN PARAMETERS:

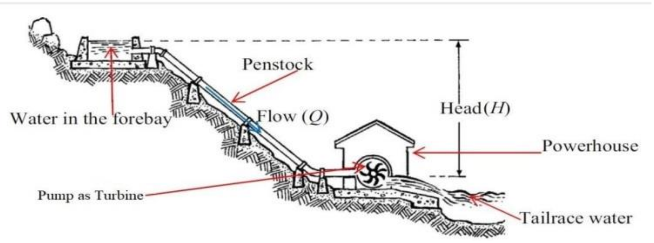


Figure: Basic layout of Hydro Energy Storage

Determination of head (H)

The available (H) head on the hydropower plant is equal to the difference in water levels between water in fore bay and tailrace water (refer to Fig. 1). Its measured value depends on the topography of the site and on the location of the powerhouse in relation to the position of the fore bay. For MHES system of run-of river type, the requirement to avoid flooding of the generating equipment by locating the power-house above the flood level dictates the location of the powerhouse. Determination of head and location of powerhouse is an important exercise in the construction of MHES plants. Usually, head on the estimated is estimated using topographical maps and then confirmed through direct measurements on the site. Methods for measuring head on the site include use of water-filled tube, spirit-level and altimeters instruments.

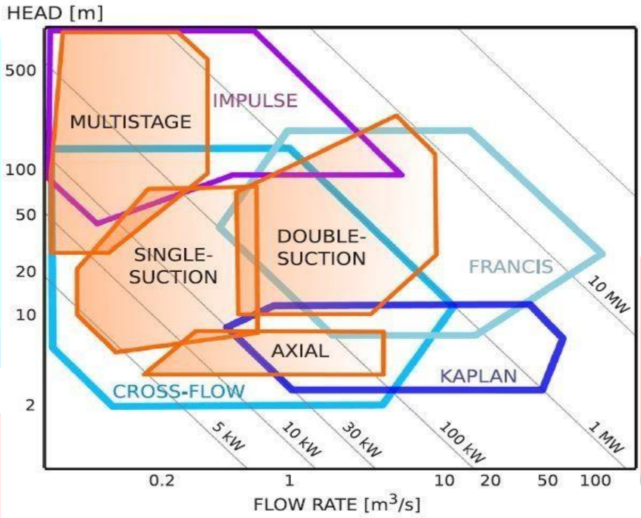


Figure: Types of hydraulic turbines and PaT (multistage, single suction, double suction and axial type) in their application area Q-H for micro-hydropower.

Determination of flow rate (Q)

The flow (Q) is the volume of water passing through the turbine per unit time for power generation. The flow depends on the hydrology of the catchment area, which is influenced by rainfall pattern, temperature and other metrological factors. Flow can be estimated from hydrological records but for the sake of system design, the estimated flow should be confirmed through direct measurement. In practice, the following methods are used to measure flow in a river: using a bucket, float, weir and salt dilution.

Determination of design flow is one of the challenging tasks in the design of a MHES plant. Most of the MHES projects are run-of river type, as already stated. In this case, the design flow can be based on generation of firm power from the site. The design flow can also be based on minimizing unit generating cost. the design flow is obtained by taking into account the annual flow pattern of the river, which can be obtained from its flow duration curve (FDC). The FDC shows the percentage of how many days in a year a particular flow is exceeded. For an isolated MHES system where the goal is to produce power almost throughout the year (firm power), a flow which is available 345 days in a year (that is 95% of the year), practically known as Q^{95} of FDC (or firm flow), is selected as a design flow.

Design Procedure for the Calculation Of Volume Of Reservoirs

The design of the upper and reservoirs is dependent on a number of factors.

- The layout of reservoirs depends on the topography of the project site and the presence of streams and rivers.
- Due to the rapid change in water levels in both the upper and lower reservoirs during reservoir filling and emptying (during pumping and turbine operation) the stability of the reservoir slopes can be greatly impacted; consequently, lining of the reservoir may be required. Seepage losses in the reservoir foundations are also a concern, lining of the reservoir. This is of particular concern for a closed- system pumped storage hydropower project where conservation of water is important.
- The sizing of the upper and lower reservoirs depends on the size of the installed units, the operating head, the site characteristics, and the number of hours that operation of the turbines is required. A typical plant is sized to operate between 4 and 20 hours depending on local energy needs.
- A simplified equation for determining the storage required in the system, can be estimated using the following equation [9].

$$S = \underline{976\,(C)\,t_s} \qquad (3.1)$$

H.Eg

Where,
S = Storage (mm^3)
C = Plant capacity (MW)
t_s= Storage requirement in hours of equivalent full-load generation (hours)
H = Average gross head (feet)
E_g= generation efficiency, including head losses (%)

The calculated storages are 40% lower than the planned design upper reservoir storage volumes from comparing existing reservoir models. This would suggest that the USACE equation consistently underestimates the required storage volume, so additional design considerations.

The power used or generated at each time step depends on a number of factors. These factors include:

- Excess energy available on the power grid.
- Peak energy required by the power grid.
- Volume of water available in the upper reservoir.
- Space available in the upper reservoir.
- Volume of water available in the lower reservoir.
- Space available in the lower reservoir.
- Efficiency of pump/turbine units during both pumping and generating mode.
- Capacity of pump/turbine units
- Type of pump/turbine units (e.g., single speed versus adjustable speed)
- Head loss in waterway.
- Total head available.

3.2.1Consider Pumping mode

When excess energy is available on the power grid and the system is able to pump water to the upper reservoir, this is referred to as pumping mode. In pumping mode the model considers a number of factors to establish whether water will be pumped to the upper reservoir at each time step. There are three main limiting factors that dictate whether energy is available, and if so, what quantity of energy is available for pumping.

The limiting factors include:

1) Available Excess Energy - Excess energy available on the power grid for pumping.
2) Water Available in Lower Reservoir - The quantity of water available in the lower reservoir
3) Volume Available in Upper Reservoir - What is the volume available in the upper reservoir. At each time step water can only be pumped if there is space available in the upper reservoir.

For each time step, of one hour, the pumping mode limiting factors were converted to units of cfs, to allow for better comparison at each time step. For energy, E is used and for power, P is used.

1. The Available Excess Energy was calculated using the following power equations:

$$Epump=Ppump*t \qquad (3.2)$$

$$Ppump=(\gamma \,.\, Q \,.\, H)\,/\eta \qquad (3.3)$$

$$Q = \frac{Ppump\ .\eta}{\gamma\ .H} \qquad (3.4)$$

(3.4)

Where,
γ = Specific weight of the fluid [lb/ft^3;N/m^3]
η = Pumping efficiency

For example, consider a situation where power available for pumping is 1,000 MW, pumping efficiency is 98%, and net head is 1,452.3 feet. Using equation, the available excess energy limiting factor is,
225.7mm^3/s

2. Water Available in Lower Reservoir : It can be calculated with , the volume of water available (V) in the lower reservoir is converted into units f cfs using the following equation where t is time as:

$$V = Qf \quad (3.5)$$

Solving for Q provides the following,

$$Q = \frac{V}{t} \quad (3.6)$$

For example, consider a situation where the water available is 1,000 acre-feet and the time period is 1 hour (1 time step). Using equation, the equivalent flow is 342.63mm^3/s

3. Volume Available in Upper Reservoir: The minimum Q value is used in the power equation, equation 1, to calculate the energy used to pump water to the upper reservoir.

For example: Consider a situation where the flow available is 3,986 cfs, the pumping efficiency is 98%, the net head is 1,452.3 feet, and the time period is 1 hour using equation 1 is 550/s

Therefore, the energy used to pump water to the upper reservoir is known equation 9 is used to calculate the volume of water pumped to the upper reservoir.

For example, consider a situation where flow available is 3,986 cfs and the time period is 1 hour. Using equation 9, the volume of water pumped to the upper reservoir is 405815mm^3

SELECTION OF SUITABLE PUMP FOR THE OPERATION AS TURBINE (PAT)

- This is the most important step in the designing of MHES project. Pump is mainly selected based on the head (H_p) and flow rate (Q_p) from available pump manufactures catalogue.
- Based on the model selected, essential design parameters are drawn out from the model for predicting the performance of pump working as turbine.

Constraints for the prediction of Pump working as turbine mode (PAT)

- Pump manufacturers do not usually offer performance curves of their pumps operating under turbine mode. A large number of theoretical and experimental studies can be found in the literature for the prediction of PAT performance.
- These prediction models show low reliability, accuracy and robustness since they usually have been developed based on a limited number of samples. As result, each model is usually accurate only with respect to the set of considered pumps.

Based on the literature review model having minimum error percentage considering the fact of reliability and can be applicable to all pumps, Stefanizzi is selected.

SELECTION OF SUITABLE CONFIGURATION

Various PAT configuration are available some of them are illustrated below

1. Model having two pumps

No. of pumps = 2
Motor No. = 1
Generator No = 1

2. The two unit system

No. of pumps = 1
Motor (also generator) = 1

1. Model having two pumps

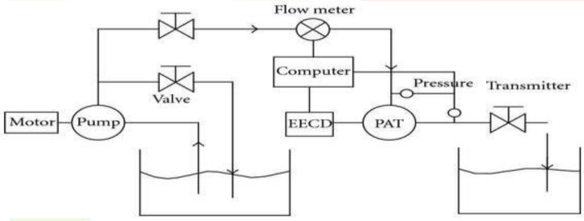


Figure: Configuration of model having two pumps

- In this type of model two separate pumps are there in the configuration.
- One of the pump is used as PAT which is coupled generator module and other is normally used as pump which is used for the supply of water to PATs for power generation.
- In this type of system necessity of upper reservoir not required because as their separate pump for the supply of water to PAT.
- Separate motor and generator module is required; therefore construction cost will be higher.
- Installation of this type of arrangement is easy, but to extra piping structure, valves which may lead to the increase in overall cost.

2. The two unit system.

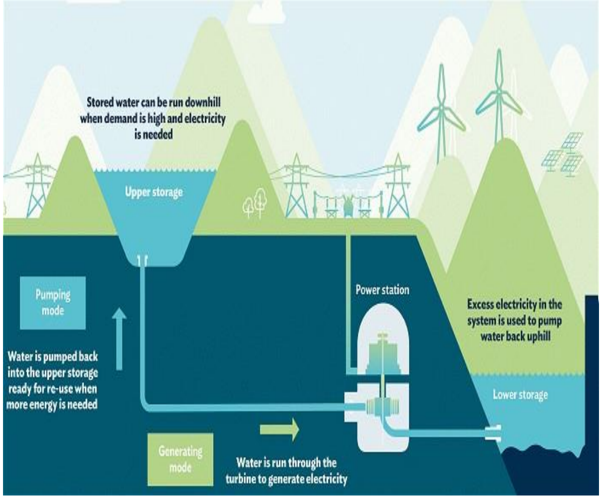


Figure: Configuration of two unit system

- In this type of system only one pump is used.
- In Pumping mode, the pump normally works as pump that transfers water from lower reservoir to the upper reservoir. In generating mode, it works as turbine which receives water from upper reservoir generates electricity, and transfers water to the lower reservoir.
- In this system the only single motor is used, that would work as generator in generation mode and motor in pumping mode. This is achieved by the coupling of Variable Frequency Driver (VFD) module to the motor.

In this micro hydro energy storage, this configuration model is selected due to the requirements of smaller number of equipment's, and relative low cost as compared to the first model.

COMPUTATIONAL FLUID ANALYSIS (CFD) WAS CARRIED OUT ON IMPELLOR.

CFD analysis was carried out on impellor to study the flow pattern. In this case, analysis is carried on ANSYS .The main Ansys tools used are described below

- Vista CPD
- Blade Gen
- Ansys CFX

The procedure carried out for this is mentioned below,

1
- Entering of basic parameters on Ansys Bladegen
- The value of Head(H) and Flow rate (Q) and Rpm (N) is entered

2
- Calculation of Meridional Contour is carried out

3
- Meshing of the impellor is carried out

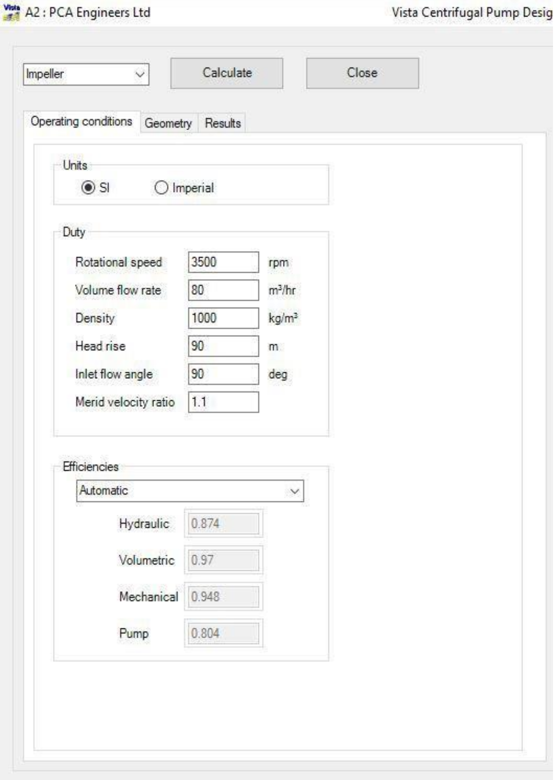
4
- Meshed model transfered to Ansys CFX for analysis

5
- Final Results are analysed

Entering of parameters

Parameters obtained earlier was inputted into Ansys Blade Gen

Head (H) = 90m
Flow rate (Q) = 80m^3/hr
Rotational speed (N) = 3500rpm



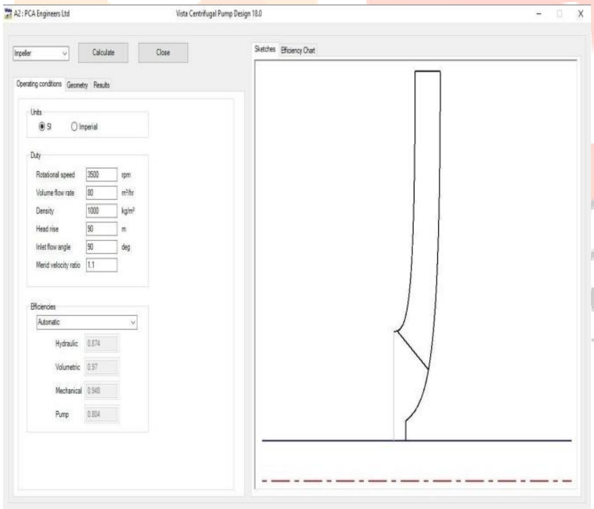
Units
● SI ○ Imperial

Duty
Rotational speed 3500 rpm
Volume flow rate 80 m³/hr
Density 1000 kg/m³
Head rise 90 m
Inlet flow angle 90 deg
Merid velocity ratio 1.1

Efficiencies
Automatic
Hydraulic 0.874
Volumetric 0.97
Mechanical 0.948
Pump 0.804

Figure: Panel showing entered values of basic parameters

Creation of Meridional contour

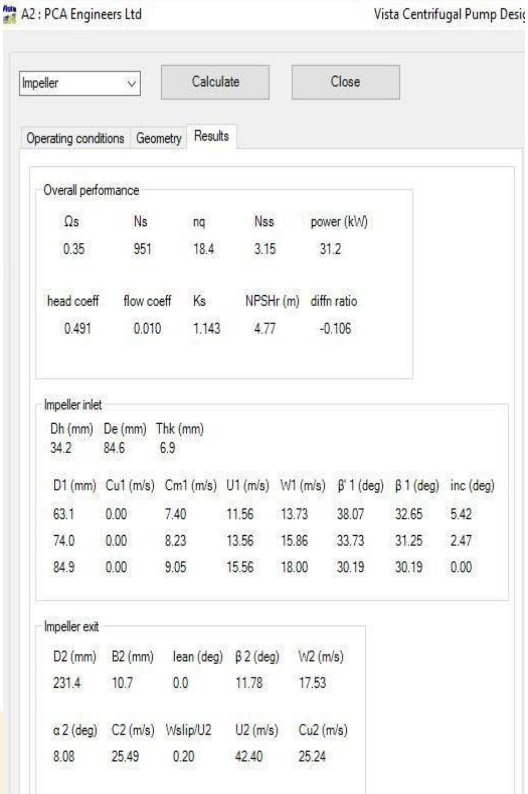


Units
● SI ○ Imperial

Duty
Rotational speed 3500 rpm
Volume flow rate 80 m³/hr
Density 1000 kg/m³
Head rise 90 m
Inlet flow angle 90 deg
Merid velocity ratio 1.1

Efficiencies
Automatic
Hydraulic 0.874
Volumetric 0.97
Mechanical 0.948
Pump 0.804

Figure: Meridional plot obtained



Overall perfomance

Ωs	Ns	nq	Nss	power (kW)
0.35	951	18.4	3.15	31.2

head coeff	flow coeff	Ks	NPSHr (m)	diffn ratio
0.491	0.010	1.143	4.77	-0.106

Impeller inlet

Dh (mm)	De (mm)	Thk (mm)
34.2	84.6	6.9

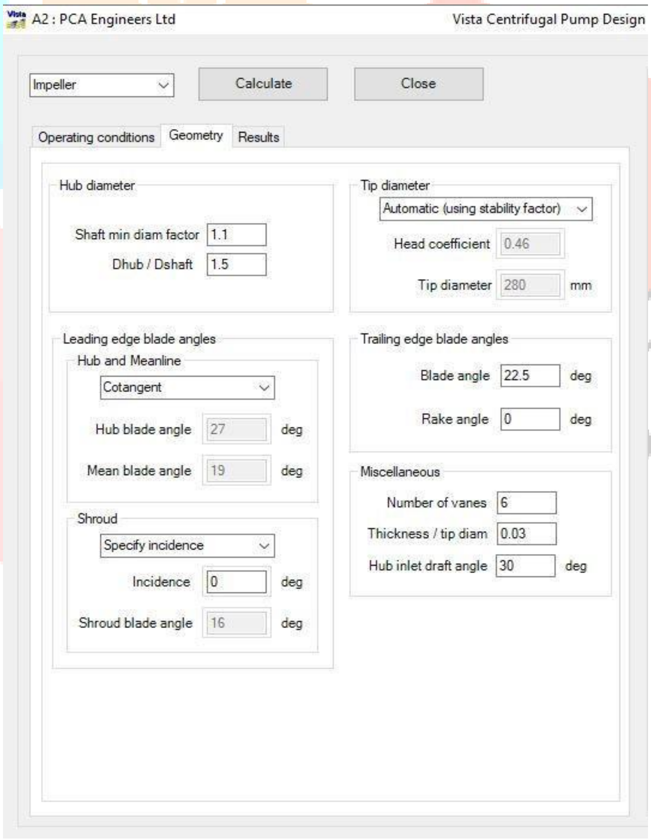
D1 (mm)	Cu1 (m/s)	Cm1 (m/s)	U1 (m/s)	W1 (m/s)	β' 1 (deg)	β 1 (deg)	inc (deg)
63.1	0.00	7.40	11.56	13.73	38.07	32.65	5.42
74.0	0.00	8.23	13.56	15.86	33.73	31.25	2.47
84.9	0.00	9.05	15.56	18.00	30.19	30.19	0.00

Impeller exit

D2 (mm)	B2 (mm)	lean (deg)	β 2 (deg)	W2 (m/s)
231.4	10.7	0.0	11.78	17.53

α 2 (deg)	C2 (m/s)	Wslip/U2	U2 (m/s)	Cu2 (m/s)
8.08	25.49	0.20	42.40	25.24

Figure: Calculated Values of impellor



Hub diameter
Shaft min diam factor 1.1
Dhub / Dshaft 1.5

Tip diameter
Automatic (using stability factor)
Head coefficient 0.46
Tip diameter 280 mm

Leading edge blade angles
Hub and Meanline
Cotangent
Hub blade angle 27 deg
Mean blade angle 19 deg

Shroud
Specify incidence
Incidence 0 deg
Shroud blade angle 16 deg

Trailing edge blade angles
Blade angle 22.5 deg
Rake angle 0 deg

Miscellaneous
Number of vanes 6
Thickness / tip diam 0.03
Hub inlet draft angle 30 deg

Figure: Geometry of the impellor

Meshing of the impellor model

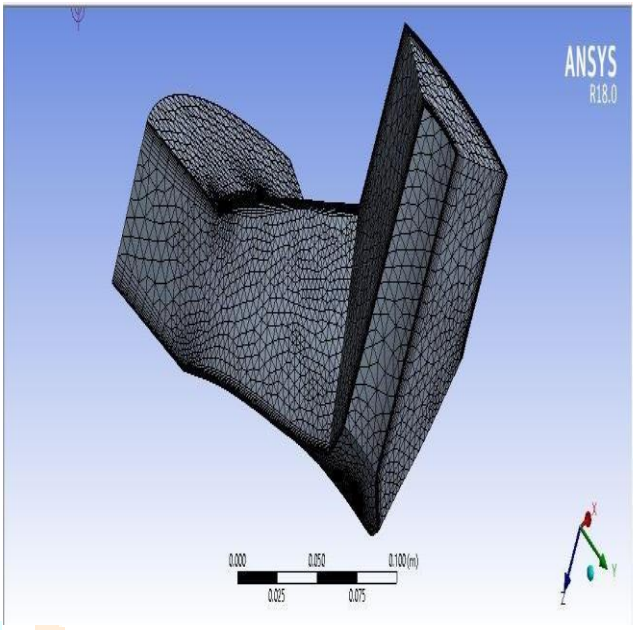


Figure: Side view of one section of meshed impellor

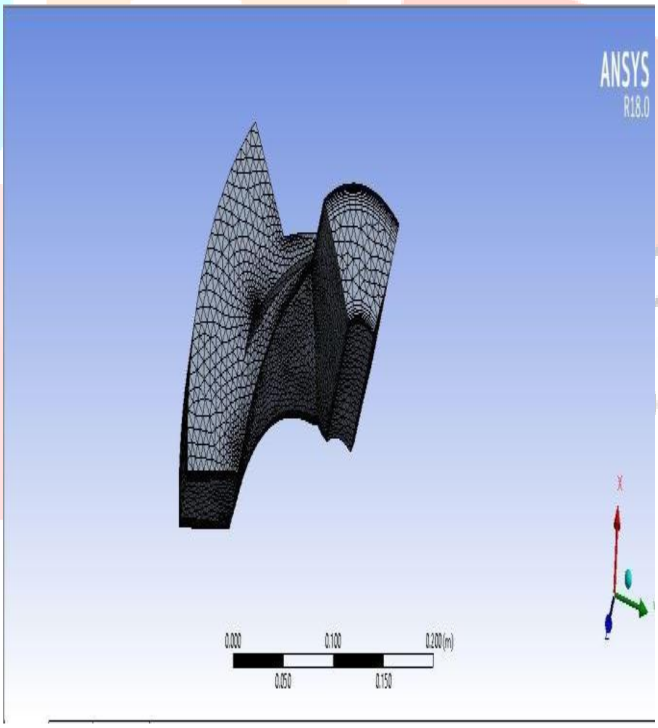


Figure: Top View of the meshed model

Result of analysis of the Impellor

1. Velocity Distribution of Blade

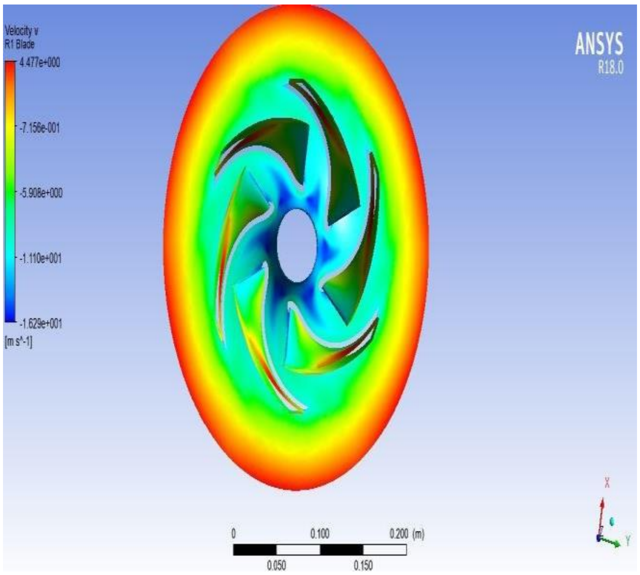


Figure: Top View of the Blade velocity distribution

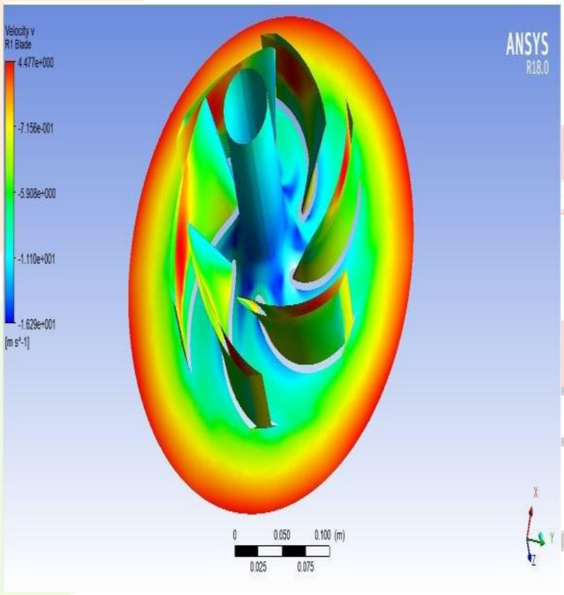


Figure: Isometric View of the Blade velocity distribution

2. Velocity distribution of shroud

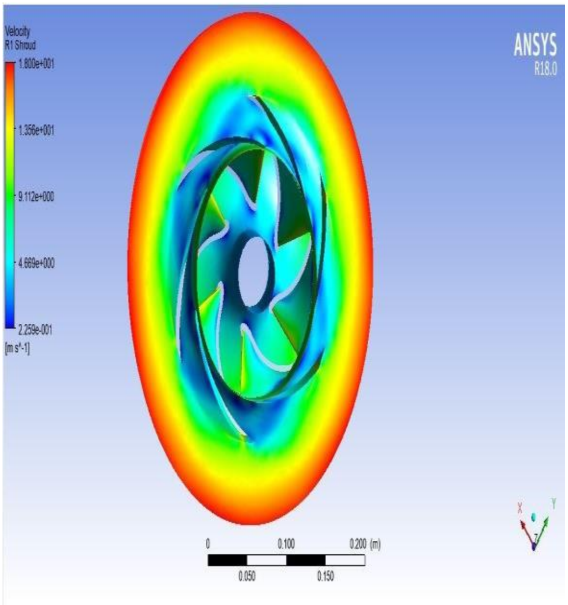


Figure: Top view of velocity distribution of shroud

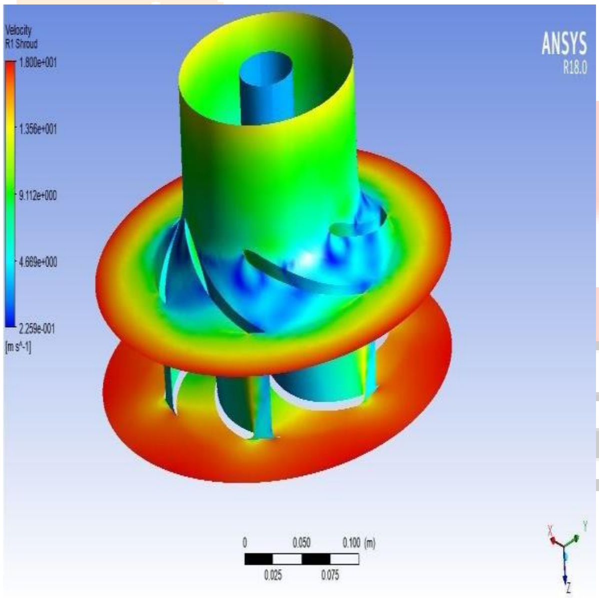


Figure: Side view of velocity distribution of shroud

3. Pressure distribution of blades

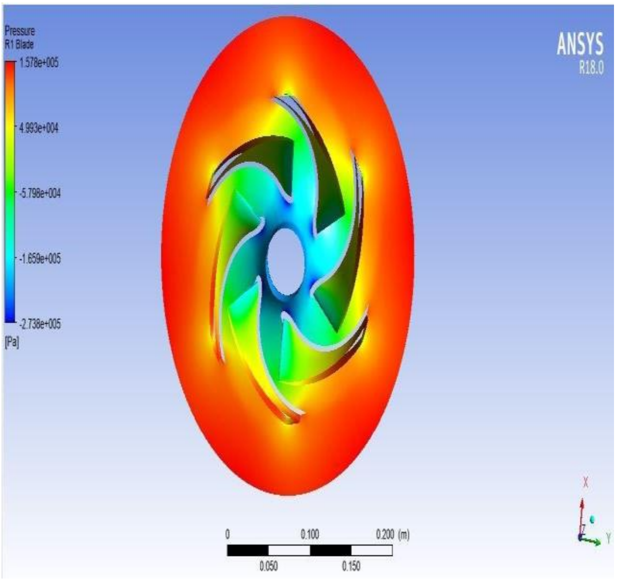


Figure: Top view of pressure distribution of blades

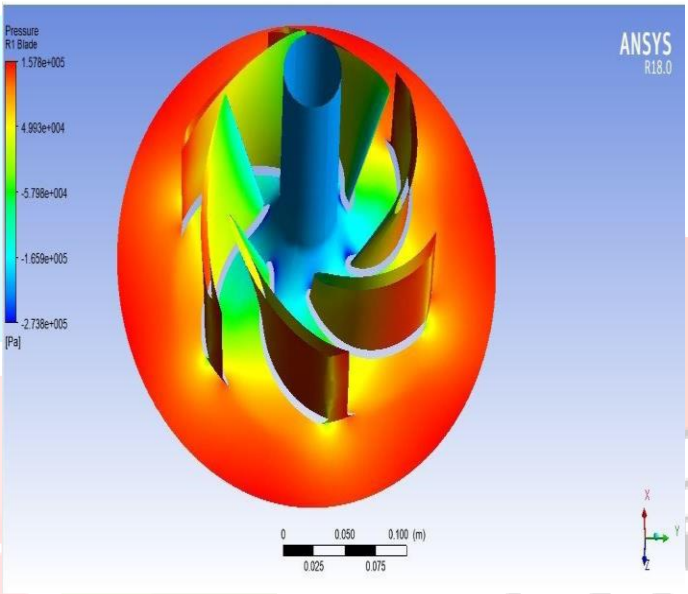


Figure: Side view of pressure distribution of blades

4. Pressure distribution in shroud

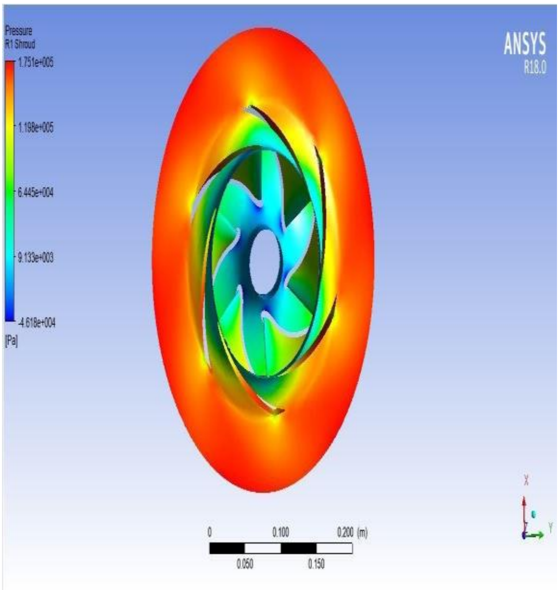


Figure: Top view of pressure distribution of shroud

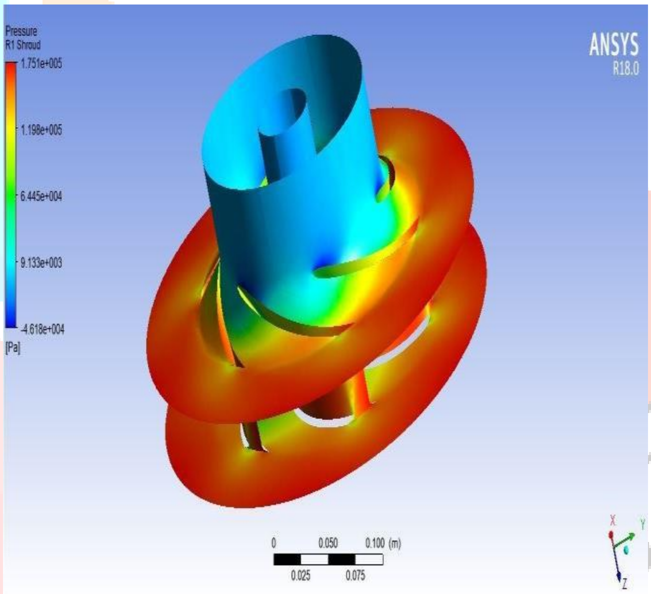


Figure: Top view of pressure distribution of shroud

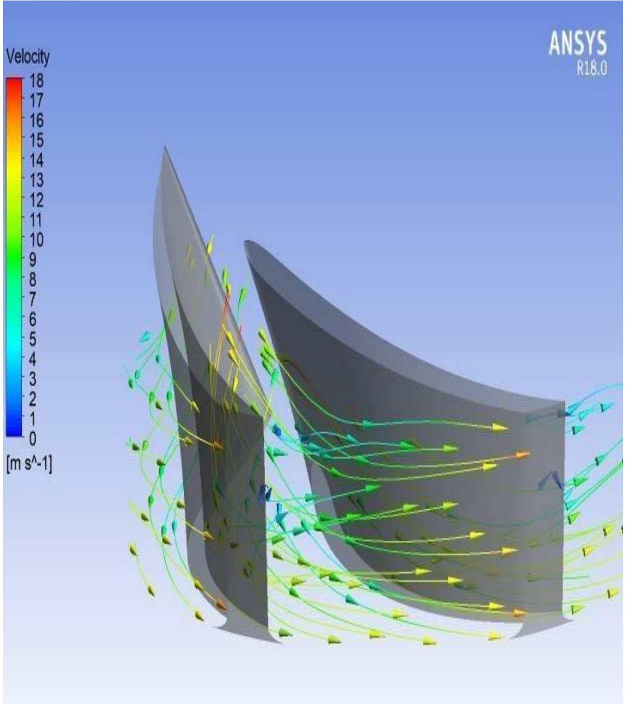


Figure: Velocity flow pattern through impellor blades

5. Inside view of steps carried out in Ansys

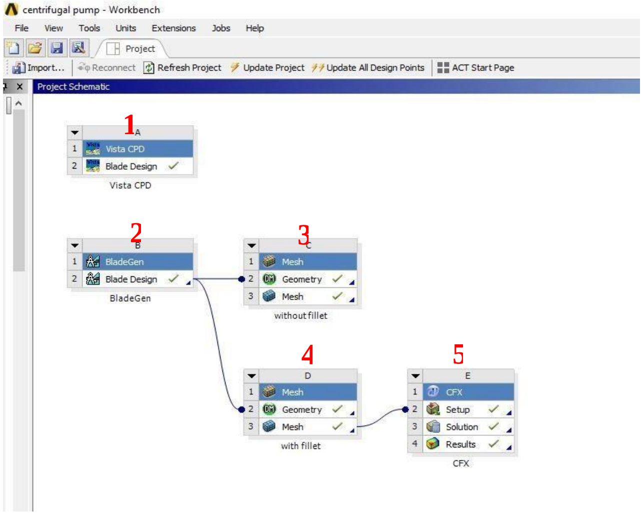


Figure: Ansys analysis procedure

CONCLUSION

In this thesis a detailed study on the scope of Micro Hydro Energy Storage (MHES) is carried out. This proposed design is to serve remote rural, agricultural fields were it is difficult to access any other kind of energy sources. Generally, this type of projects produces power up to 500kW. In this thesis a model design procedure of Micro Hydro Energy Storage is carried out.

- In this thesis a detailed design procedure for calculating volume of reservoir for both upper and lower reservoir based on the factors like peak energy required, excess energy in grid, volume of water needed in upper and lower reservoirs in both pumping and generating mode is considered for estimating a rough volume requirement for reservoirs.
- In this thesis a detailed study on the turbo machinery feasibility and constraints it faces during the building Micro Hydro Energy Storage (MHES) is carried out. After examining various turbo machinery's, selecting centrifugal pump as turbine (PATs) is most suitable and feasible for this kind of projects producing output power up to 500kW and payback period below 2 years.
- Design procedure for impellor and volute design is carried out. A Computational Fluid Dynamics (CFD) Analysis is carried on pump impellor with ANSYS Blade Gen to find out the flow analysis like velocity and pressure distribution on impellor. Initial parameters like Head (H) =90m and flow rate (Q) =80m^3/hr with 3500rpm are entered into the ANSYS Blade Gen Tool. It automatically generates Meridional contour of impellor blade needed. Specific Speed (Nss) 3.15 was obtained which shows that centrifugal falls in axial flow category. The impellor inlet diameter (D_h) 34.2mm and impellor outlet diameter (D_2) 231.4mm was needed that is obtained from Ansys Blade Gen calculation. The width of impellor blades (B_2) needed would be 10.2mm.The blade trailing edge angle is 22^05. The number of vanes needed for impellor is 6.From calculation the amount of power needed for pump to run in pump mode is 31.2kW.A meshed impellor was generated in Ansys Turbo Grid with considering one impellor vane. Finally after meshing results obtained for impellor flow distribution with considering pressure and velocity on different domain of impellor like on blades and shroud.

FUTURE SCOPE

An extensive study of Micro Hydro Energy Storage (MHES) systems is conducted, focusing on the turbo machinery operation and maintenance, using of pump as turbine, pros and cons, environmental aspects, and economics .Thus the Micro Hydro Energy Storage (MHES) thus would produce enough power for power requirement of same pump used in pumping and generating mode. The power generated can be further be increased by coupling MHES with other renewable sources of energy like solar, wind there by increasing the reliability of the project. Advances in turbine design are required to enhance plant performance and flexibility and new strategies for optimizing storage capacity and for maximizing plant profitability in the deregulated energy market. The Micro Hydro Energy Storage is not only a renewable and sustainable energy source, but its flexibility and storage capacity also make it possible to improve grid stability and to support the deployment of other intermittent renewable energy sources such as wind and solar.

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