

# A INVESTIGATION ON THE PERFORMANCE OF WATER PUMPING STATION ON ADOPTION OF THROTTLING FOR FLOW CONTROL IN WATER WORKS OF JABALPUR MUNICIPAL CORPORATION

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## ABSTRACT

This paper gives a review of proper and improper use of pump and explains how the operating point of the pump depend on system parameters and hence results in obtaining the best efficiency point and possible energy savings. This paper gives a review of the concept of specific energy consumption for a pumping system, the cost of pumping as a function of static head, friction head, voltage, current, power factor and calculated efficiency

The Ramnagra water project has been constructed and put in operation in 2011, in order to supply water from jack well to WTP. Due to deficit in water in the water treatment plant side in the Jabalpur Water Supply Administration (JWSA), we have suggested a reasonable solution in which about 3300 m<sup>3</sup>/hr of water will be transferred from jack well to WTP water services more efficiently. In the area under study, pumps were operated using throttling process to match up with the demand of the WTP however, creating many hydraulic problems and high annual energy consumption. When these existing pumps were throttled, the pump efficiency found to be very poor i.e. 24% and the annual power consumption of these pump under test amounts to over 4786847.99 kWh with a corresponding annual operating cost of 1.81crores.

Considering the optimal operation and characteristic curves of pump without throttling, study reveals satisfactory outcome. With protection of pump life and increased pump efficiency, this work would help other pumping stations and also for similar operating practices adopted in other parts of Indian Urban Local Bodies

**Keywords :** pumping station, water demand, throttle control valve, energy efficiency, energy savings

## 1 INTRODUCTION

**E**NERGY is very scarce commodity particularly in developing and underdeveloped countries.

Cost of energy is spirally increasing day-by-day. Generally pumping installations consume huge amount of energy wherein proportion of energy cost can be as high as 40 to 70% of overall cost of operation and maintenance of water works. Need for conservation of energy, therefore cannot be over emphasized. All possible steps need to be identified and adopted to conserve energy and reduce energy cost so that water tariff can be kept as low as possible and gap between high cost of production of water and price affordable by consumers can be reduced. Conservation of energy is also important and necessary in national interest as the nation is energy deficit due to which problems of low voltage, load shedding and premature failures of equipments are encountered. Some adverse scenarios in energy aspects as follows are quite common in pumping.

**Installations:** Energy consumption is higher than optimum value due to reduction in efficiency of pumps, Operating point of the pump is away from best efficiency point (b.e.p.), Energy is wasted due to increase in head loss in pumping system e.g. clogging of strainer, encrustation in column pipes, and encrus-

tation in pumping main, Selection of uneconomical diameter of sluice valve, butterfly valve, reflux valve, column Pipe, drop pipe etc. in pumping installations, Energy wastage due to operation of electrical equipments at low voltage and/or low power factor[1].

Water is a precious natural resource and management of water is a challenging task in developing countries. Increase in population is causing an ever increasing demand on water supply system. Water resources are limited and this requires better management of water resources and supply. The supply of water is not able to meet the demand due to several reasons like pump using throttling, high amount of leakage, poor maintenance of the system etc. An urban water distribution pipe network of a mega city consists of huge capacity of pumps, pipes, valves, reservoirs and tanks. It is a challenging task for the water supply board to operate the system to deliver drinking water of required quantity and quality. Indian cities have intermittent water supply and demand is not met by supply and there is considerable amount of gap between demand and supply. To minimize this gap people are depending on other sources of water like groundwater, rainwater harvesting, treating and reusing waste water generated etc. In

the present study Ramnagra raw water pumping station Jabalpur [2].

This study is to propose to improve the overall energy efficiency of the Greater Jabalpur Municipal Corporation, thus leading to sustainable energy and cost reductions, in water supply segment, which is one in energy consuming segments namely Water pumping system And pump using throttling so larger amount of power waste and more loss account to pump loss[3].

## 2 STUDY AREA

Jabalpur is the third largest city in the State of Madhya Pradesh. The city is blessed with perennial water source and good rainfall and yet the water availability is unsatisfactory. Jabalpur supplies around 250 MLD of treated water covering over 9.5 lacks population, besides it withdraws 20 MLD of ground water through tube wells and hand pumps. The actual situation is much less with estimated per capita availability of around 80 lpcd. Further, the city gets only 2 to 3 hours of water supply in a day with little reliability. Assessment of the city water supply system highlights non-availability of most of the information on operational aspects. Absence of data on leakages, poor efficiency of pumps and motor and the reliability of the available basic data on the availability of water supply & motor performance has been the major concern in arriving at water balance & motor audit. Non-revenue water in Jabalpur city is estimated between 37 % to 44 %. The water supply problem in the city of Jabalpur is attributed more to the lack of infrastructure and current management practices rather than lack of water availability. Moreover of this supply system of water is being affected by low input power that is because of using old machinery and connections with old transformers in water pumping station. And also study what will have to effect on motor & pump performance due to throttling.

The elevation difference between the raw water pumping plant at Ramnagra and the treatment reservoirs is about 2420 m and distance between them is about 2.42 km. Hence water is pumped to the treatment reservoirs through single stages of pumping which has a large pumping station in each stage. Water is pumped from jack well to WTP plant. The raw water is supplied 40 MLD to WTP with different capacities, and most of them receive water for 12 hours of the day. From these treated water have supplied to consumers on alternate days with shifts between different areas. Pipe diameters from source to all areas are ranging from 1350 mm. All the data used in this study are collected from Jabalpur Water Supply.

In Ramnagra pumping station Discharging capacity 220 MLD water is using from Narmada River naturally flow in suction tank. The elevation difference between the water pumping station to the water treatment plant. The total length of pipe 2420m. The treated water is supplied to 120 MLD to city storage tank with different capacities, and most of them receive water for 12 hours of the day. From these water is supplied to consumers on alternate days

with shifts between different areas . Pipe diameter is 1350 mm. All the data used in this study are collected from Jabalpur Water Supply.

## 3 OBJECTIVE OF PRESENT WORK

In water pumping sector, most of the pump sets operate at poor efficiency. There are many other parameters such as use throttling, irregular maintenance, poor supply voltage use of non-standard pumps, improper pump sizing etc. which could affect the efficiency of the pump sets. The broad objective of this work is to study on the performance of water pumping station on adoption of throttling for flow control in water works of Jabalpur Municipal Corporation and also impact of this external parameter on overall average operating efficiency and to existing. The energy saving potential.

A Study was conducted with the following Objectives:

1. To find energy saving potential in Ramnagra Tilwara raw water pumping station Jabalpur M.P.
2. To investigate motor and pump water supply operations and adopt suitable measures for satisfactory operation.

## 4 SCOPE OF WORK

### 4.1 Plant Machinery under Study

Ramnagra pumping station get water from Narmada River and 40 MLD water is pumped to filtration plant for treatment. 120 MLD of water is pumped and filtered in these plants for distribution to the citizens in the nearby locality. In line with the objectives dissertation provides an overview of existing facilities and current operating system like electrical distribution system, metering system and subsidy, electricity availability, seasonal as well as historical water level variation pattern and capacity of the pumping station in MLD and water sheds available in the Jabalpur municipal corporation. The detailed energy consumption /survey is undertaken to collect detailed information (about all pumping station) such as detailed about pumps (number, type, make, age & rating) water requirement/consumption.

Study provides overview of energy and water consumption pattern in different season and energy audit (performance evolution) for all pump sets is carried out by measuring the suction and discharge head power input and water flow to evaluate operating efficiency of all pump sets .based on audit study and efficiency index for the existing pumping system is prepared.

“The energy efficient pump sets that cannot replace but only avoid throttling the existing pump for the same discharge has been decided based on field studies after evaluating the existing pump set performance and operating efficiency”

The energy saving potential that can be achieved by eliminate throttling existing pumps with that of pump set operating at best efficiency point for the actual side condition is quantified

based on analysis of the measurement.

## 4.2 Pump Study

In raw water pumping station detailed study for each and every pump set is carried out. The objective of detailed study is to determine. The existing pump set efficiency, which mainly involves measurement of flow, head, losses and power, piping type, diameter, length and pump set input power. Flow measurement is made by Ultrasonic flow meter. Digital type meters were used to make Head and Power measurement only. Every minute data logging of flow, head and power is made for minimum period of one hour [3]. Wherever, the flow measurement is not possible with ultrasonic flow meter, the next best method for flow measurement (mechanical) is adopted [3]. In additional information like name plate details of existing pump and Recommendations are made to improve the overall efficiency of pumping System. Analyze the design parameters and actual operational parameters with a view to identify losses. Based on this study, it is suggested best combination(s) of pump sets to be operated for each site [3].

## 5 A SYSTEM APPROACH

There are several reasons for reviewing the system elements in reverse sequence. First, the greatest efficiency improvement opportunities are found in situations where the fluid system is doing more work (e.g., delivering a higher flow rate or head) than is needed to support the ultimate purpose of the system. Another important reason is that energy savings identified at the end of the energy transfer path are multiplied at the power line (the distribution point) because of the inefficiencies in the intermediate elements (e.g., pump, motor).

There are methods for estimating efficiencies for the individual components (such as the pump) in the field; the systems approach, however, encourages looking at overall efficiency or effectiveness.

Couplings are important from a reliability standpoint but are inconsequential from an energy efficiency perspective.

Because pumping systems consist of many of these interrelated components, understanding how the entire system operates and its purpose is important in optimizing overall system performance. A favorable adjustment to one component may result in another component in the system operating less efficiently, with a net loss in system efficiency and higher energy consumption. Thus, any effort toward reducing energy consumption should take into consideration the unique interrelationships of the system Components [4].

## 6 METHODOLOGY

### 6.1 Power and Efficiency Relationships

Some fundamental power and efficiency relationships may be defined for the principal active components in motor driven pumping systems, in reverse sequence from the

pumped fluid to the electrical power supply [4].

Useful hydraulic power developed by a pump is proportional to the product of the volumetric flow rate, head, and fluid specific weight.

$$H_p = Q \text{ (m}^3\text{/s)} \times (h_d - h_s \text{ in m)} \times \rho \text{ (kg/m}^3\text{)} \times g \text{ (m/s}^2\text{)} / 1000. \quad (1)$$

Pump efficiency is defined as the pump's fluid power divided by the input shaft power.

$$\text{Pump efficiency } (\eta \text{ pump}) = \text{Pump shaft power} / \text{Electrical input power}. \quad (2)$$

Shaft input mechanical power is the product of the rotational speed and torque

$$\text{Pump shaft power } P_s = \text{Hydraulic power } h_p / \text{Pump efficiency } \eta \text{ pumped}. \quad (3)$$

The majority of electric motors used to drive pumps in industrial service is 3-phase, alternating current, Induction motors. For a balanced 3-phase condition, the motor input power is

$$P = \sqrt{3} V I \cos\theta. \quad (4)$$

Combining and rearranging terms, pump efficiency can then be expressed as

$$\text{Pump Efficiency} = \text{Output Power} / \text{Input Power}. \quad (5)$$

The relationships defined by Eqs. 1-5 are generally applied to individual components, or in the case of the wire-to-water efficiency, the pump and motor combination [4].

The head and flow rate terms are based on hydraulic measurements performed in the immediate vicinity of the pump. The same relationships can also be applied to the system so that efficiencies include some or all of the system components [4].

### 6.2 System Requirement

All pumping system share certain characteristics, one of which which is the nature of fluid flow. To produce fluid flow through a pipe or valve, a pressure differential must be created across the component [4].

The greater pressure differential, the greater the rate of flow. For a given system, a curve can be drawn to show the pressure differential required at any given flow rate. This is called the system curve. Figure 1 shows an example of a system curve where the pressure (head) is a function of flow [4].

System curves are made up of two fundamental components: the static head and the frictional head. Fig. 2 shows a system curve and illustrates the static and frictional head comprising the total head. Static head is predominant in systems where

the fluid changes elevation, such as cooling towers. Frictional head is associated with piping and piping components (e.g., valves, fittings), rather than gravity, such as in closed loop cooling systems. Most systems have a combination of static and frictional head [4].

is the intersection of the pump and system curves and represents the equilibrium flow point where the pressure drop through the system equals the pressure added to the fluid by the pump [4].

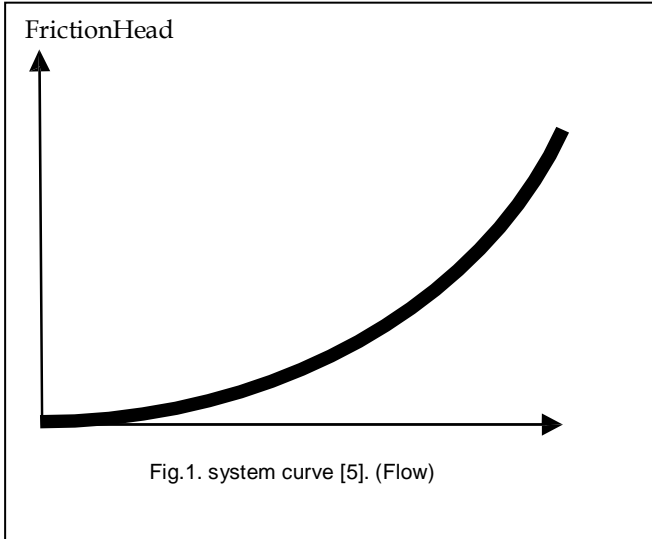


Fig. 1. system curve [5]. (Flow)

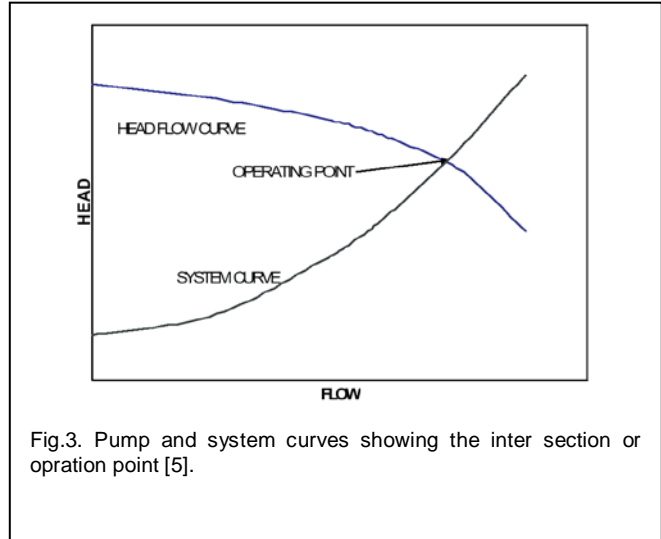


Fig. 3. Pump and system curves showing the intersection or operating point [5].

Similarly, performance curves showing the relationship between head and flow rate can be drawn for pumps. A typical curve for a centrifugal pump is shown in Fig. 3. Starting at some head (pressure) at zero flow, the curve shows a slight decreasing pressure as the flow initially increases and a steeper decline with further increases in flow [4].

### 6.3 Hazen William Equations

The base form of the Hazen William Equation is as follows [6].

$$V = 1.318CR^{0.63}S^{0.54}$$

V = velocity (ft/sec)

C = Hazen Williams friction coefficient

R = hydraulic radius (feet)

S = head loss (feet/foot)

The conventional form of the equation has been rearranged as follows [13]

$$H_f = (L) 10.5(Q/C)^{1.85}(D)^{4.87}$$

H<sub>f</sub> = head loss due to friction (feet/feet)

L = Force main length (ft)

Q = flow (gpm)

D = pipe diameter (in)

### 6.4 Minor Losses

As discussed earlier, when water flows through a straight pipe there are energy losses due to the internal friction of the fluid, as well as the friction between the water and the pipe wall. Additional energy losses are encountered as the fluid passes through bends, constrictions, valves, etc. These are referred to as minor losses. The two typical methods of calculating minor losses are K value estimates, and the equivalent length. In this example, the K value estimate method is used which assigns coefficients to various fittings and valves. The following values can be used to estimate minor losses. These values should be verified against specific manufacturers' recommendations [6]. To calculate the head loss due to minor losses, the following equation can be used

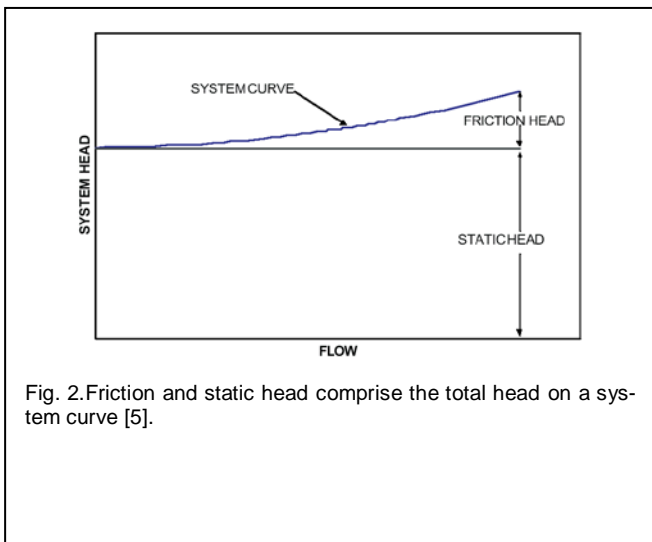


Fig. 2. Friction and static head comprise the total head on a system curve [5].

A fundamental concept for analyzing fluid pumping systems is the operating point, which is the combination of pressure and flow at which a given system and pump operate. The operating point is determined by plotting the system and pump curves, as in Fig. 3. For centrifugal pumps, the operating point

$$h_m = \sum K \frac{v^2}{2g}$$

$h_m$  = Minor head loss(m)

$K$  =  $k$  coefficient (dimension less)

$$\text{Velocity of fluid pipe} = \frac{\text{flow(m}^3\text{/hr)}}{\text{cross sectional area of pipe(m}^2\text{)}}$$

### 6.5 Total Dynamic Head

The total dynamic head (TDH) of a submersible lift station is essentially the total energy loss experienced by the fluid between the pump and the outlet of the station. Another way to think of TDH is the head the pump must overcome to move the fluid to its destination [6].

The TDH which the pump must overcome is the summation of the elevation head, head loss due to friction, and the minor head losses [6]

$$TDH = \Delta H + h_f + h_m$$

TDH=Total Dynamic Head (m)

$\Delta H$ =Static head (m)

$$TDH = \Delta H + (L) 10.5(Q/C)^{1.85}(D)^{4.87} + \sum K \frac{v^2}{2g}$$

The above equation demonstrates that the only variable which is not constant in a submersible lift station system is the flow. By calculating multiple TDH values based on incrementing flow values, and plotting these on a graph of TDH (m) vs. flow (m<sup>3</sup>/hr) [6].

## 7 PROBLEM DISCUSSED UNDER THE PROPOSED WORK

In Ramnagra raw water pumping station The pump sets used are generally very inefficient with operating efficiency level of nearly 24% is common because these pumps have used throttling .these pump sets are more Afton over sized i.e. for lower head higher capacity of pump sets are installed so as to suck water from increasingly declining depths and also with stand voltage fluctuation. The major pumps sets are operated beyond the range of best operating point in high mainly due to throttling, improper selection of pump use of high-friction loss in pipe and lack proper maintain.

Experience in India has established that the electric energy required to deliver a given quantity of water can be substantially reduced simply by replaced/avoiding throttling the inefficient pump set with more efficient, right sized pump set and installing a low friction loss and piping.

The energy efficiency of existing pumping system. It has been aimed to analyses methods of possible improvement to enhance energy efficiency or reduce consumption during the energy audit study detailed information about all pumps (number, type, make age and rating) water requirement/consumption and underground water level in different season, power supply pattern and economic condition etc. has been called and analyzed in respect of nearly 3 number of pump sets

## 7.1 Calculation For: Present Raw Water Pumping Station

Detailed field study for each and every pump set is carried out the objective of detailed study is to determine the existing pump efficiency and hydraulic power when these existing pump operate throttling .which mainly involves length and pump set input power.

The most of the pump installed across the studied feeders are of submersible type. The suction head varies seasonally. The seasonal variation is more severe than the annual water level depletion. According to the pump manufacture the pump are installed 30 m and varies water level show below table. The discharge pipe length is of more concern. Former increases the discharge pipe as per there requirement without considering the effect on the pump efficiency .the pipe should be adequate size and material so as to reduce the friction loss to the accepted level. And below show all the calculation to find out total head by taking field data.

### 7.1.1 Calculation of Head Losses: With Throttling

TABLE 1  
MAXIMUM AND MINIMUM WATER LEVEL

1	Min. water level	356	m
2	Max. water level	377	m
3	Pump House floor level	383	m
4	Discharging level	384	m

$m$  = meter

There are three numbers of existing pumping mains of dia 1350 mm.

It is interconnect these three pumping mains through common delivery manifold so as to reduce friction losses

TABLE 2  
GENERAL INTRODUCTION OF RAW WATER PUMPING MAIN

1	Diameters of pipe	1350	mm
2	Lengths of all pumping mains	2420	m
3	Quantity of water to be pumped in a day	40	MLD
4	Pumping hours	12.12	Hrs
5	Total discharge	3300	m <sup>3</sup> /s
6	No. of pumps	3	working

$Mm$ = mili meter,  $m$  = meter,  $MLD$ = million liter/ day,  $m^3/sec$ = discharge,  $hrs$ = hour.

For calculation of frictional losses old Hazen-Williams formula with value of "C" AS 140 is considered for existing pumping mains

**TABLE 3**  
**CALCULATION HEAD AND HEAD LOSSES**

1	Frictional losses (h <sub>f</sub> )	0.50 m	(a)
2	Minor losses due to band, valve(h <sub>m</sub> )	0.50 m	(b)
3	Static head	17.0 m	(c)
4	Suction head	12.0 m	(d)

$$\begin{aligned} \text{Total design head (a) + (b) + (c) + (d)} &= 30 \text{ m} \\ \text{Design head} &= 30 \text{ m} \end{aligned}$$

### 7.1.2 Calculation of Pump Output Power and Efficiency

Out of the total studied 3 pumps studied most of the pump having efficiency 24%. pump with efficiency below also been found 30%. The poor efficiency of pump due to throttling, poor maintenance, improper selection of pump, extremely lower water depth with operating condition 12 m suction head, and high supply voltage is 3.5 KV loading to lower output 269 KW and power consumption with throttling is to higher 4786847.99 kWh/Annual.

#### With Throttling

Static Head – 17.0 m

Suction Head – 12.0 m

Friction Head – 0.50 m

Minor Loss – 0.50 m

Total head – 30 m

$$Q = 3300 \text{ m}^3 / \text{hr} = 0.917 \text{ m}^3 / \text{sec}$$

$$\text{Hydraulic Power} = Q (\text{m}^3 / \text{s}) \times \text{Total head } h_d - h_s (\text{m}) \times \rho (\text{Kg/m}^3) \times g (\text{m} / \text{s}^2) / 1000$$

$$\text{Hydraulic Power} = 0.917 \times 30 \times 1000 \times 9.81 / 1000$$

$$\text{Hydraulic Power} = 269.58 \text{ KW}$$

Calculation of Input Power & Efficiency with Throttling

$$\text{Total Energy required} = 1082 \text{ KW}$$

$$P = \sqrt{3} V I \cos \phi$$

$$P = \sqrt{3} \times 3.5 \times 85 \times 0.7$$

$$P = 360.689 \text{ KW (Each pump)}$$

$$\text{Total Energy consumed} = 360.689 \times 3 = 1082.067 \text{ KW}$$

$$\text{Efficiency with throttling} = \text{Output Power} / \text{Input Power}$$

$$269.58 / 1082 \times 100 = 24 \%$$

$$\text{Efficiency of the pump with throttling} = 24 \%$$

### 7.2 Measured Power Consumption of Present Operating Water Pump

In existing pumping system. We have measured power consumption of present operating condition whereas these existing pumps have used throttling. In this condition pump efficiency to archive very poor 24% because these existing pumps have not operated best efficiency point and discharged of each pump with throttling 3300 m<sup>3</sup>/hr and to meet 40 MLD per day requirement from jack well to WTP. So these existing pumps are operated 12 hr/day to meet 40 MLD and in this

condition these existing pumps are drawn more power and effected billing side .by taking all the fixed and variable cost per unit cost for the pumping station is 3.80(Rs/ kWh) .as per calculation given below. Total unit of annual consumption is 4786847.99 kWh/ annual

40 MLD Per day Requirement.

Q= 3300 m<sup>3</sup>/ hr (Total discharge). 3- Pumps

Operating hrs of three pump = 12.12 hrs/day.

$$Q = 3.3 \text{ ml/hr} \times 12.12 \text{ hr}$$

$$Q = 39.996 (40 \text{ MLD})$$

Total energy required in KW

$$\text{Total Energy required} = 1082 \text{ kW}$$

$$P = \sqrt{3} V I \cos \phi$$

$$P = \sqrt{3} \times 3.5 \times 85 \times 0.7$$

$$P = 360.689 \text{ KW (Each pump)}$$

$$\text{Total Energy consumed} = 360.689 \times 3 = 1082.067 \text{ KW}$$

$$\text{Annual power consumed} = 1082.067 \text{ kW} \times 12.12 \text{ hr} \times 365 \text{ day}$$

$$\text{Annual power consumed} = 4786847.99 \text{ kWh/Annual}$$

$$\text{Power cost (Rs/ kWh)} = 3.80$$

$$\text{Annual cost (Rs)} = 3.80 \times 4786847.99$$

$$\text{Annual cost (Rs)} = 18190022.36/-$$

## 8 SUGGESTION AND RECOMMENDATION

During investigation it is observed that if these existing pumps are operate without throttling so pump efficiency archiving higher and pump will operate best efficiency and energy point without effected head and discharge. In the new operating condition it has been observed that single existing pump operates without throttling, then pump efficiency will increases with same discharge, head, and transfer to 40 MLD water from jack well to WTP. Pumps operate without throttling so huge amount of energy saving without effect head and discharge.

## 9 CONCLUSION

In the area under study it was concluded that because of throttling the operating point of the pump moves to the left of the pump characteristics and the efficiency of the pump at the new operational point will always be lower than at the optimal operational point. This means that the internal losses of the pump increase at the cost of extra energy loss, when throttling the control valve, extra friction losses are deliberately generated within the system and extra friction loss also means extra loss of energy. When these existing pumps were throttled, the pump efficiency found to be very poor i.e. 24% and the annual power consumption of these pump under test amounts to over 4786847.99 kWh with a corresponding annual operating cost of 1.81crores. On observing the above figures it is recommended that frequent actions are required to improve the efficiency of the operating pumps which involves least investments

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