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ENERGY CONSERVATION THROUGH OPTIMAL SELECTION OF IRRIGATION PUMPS

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Abstract- **This paper presents a prominent energy conservation opportunity and solution in irrigation system. Pumps installed in agricultural fields are generally oversized and lead to uneconomic operations. Energy conservation in such cases is achieved through optimally selecting pumps. The proposed sizing method for pumps, considers irrigation water need, hydraulic head and pump operating hours. By considering the velocity of water flow as 1.5m/s for PVC pipes, optimum size of irrigation pump is attained. The proposed methodology is validated by a critical survey at agricultural field in the Malaprabha riverbed, Karnataka. The detailed walkthrough survey of 50 farmers is conducted and size of land, crops grown, pipe network, elevation and installed pump capacity are noted. Based on crop water requirements of individual farmers, optimum sizes of pumps are assessed. The results revealed that, in a span of 2.5 km of riverbed, approximately 60% of excessive installations were observed. Further, energy conserved, cost savings and reduction in CO_2 emissions are obtained and analyzed. Thus, it is concluded that proposed method will provide a reliable solution for energy conservation in agricultural sector.**

Index Terms- **Energy conservation,Total differetial head, Optimum pump sizing, Cost savings and Reduction in CO_2 emission.**

I. INTRODUCTION

Agriculture is the backbone of Indian economy. It contributes a major part in GDP of the country. Approximately 36%of the agriculture lands are having irrigation facility and rest relies on the rainfall. Electric irrigation pumps currently account for over 20% of the load on the grid. This created difficulty in load management and lead to load shedding. On other hand, to serve required crop water within available time, farmers install excessive pump capacities. This will cascade the excessive demand on the electric grid. This issue can be resolved by identifying the excessive installations and re-sizing them optimally. The optimized irrigation load will reduce burden on grid and reduce the CO_2 emissions.

Many publications discussed the issues associated with design of irrigation pumps. However, the attempt towards energy conservation opportunity is not been successful. Dr.Jangamshetti had proposed a new method to select optimum rating of solar powered irrigation pumps. Sizing is carried based on crop water requirement and head offered at the field. Case studies are presented to show successful implementation. The proposed method helps in preventing excessive HP installation thereby saving energy. However, the conservation of energy, cost savings and reduction in CO_2 has not been carried [2]. Dr. Guy Fipps discussed the assessment of hydraulic head and optimal irrigation pump rating. It is shown that for sustained operation, velocity of water in PVC pipes must be 5 foot/sec I.e. 1.52m/s. Further, potential damage to pipe network due to higher velocity is discussed [5]. Mathew Milnes discussed assessment of hydraulic head due to major and minor losses. Significant causes and assessment of minor losses are discussed. Inference about improper sizing is made.

The current scenario in Indian agricultural lands has a great deal of energy saving chances. In this regard, a new method for sizing irrigation pumps based on water need and land structure is proposed. Further, checked for validation by conducting a survey of agriculture lands at Malaprabha riverbed, Karnataka.

II.METHODLOGY

Proposed methodology includes two parts. Assessment of optimal size for irrigation pumps and other is calculation of energy conservation, cost savings and reduction that could be achieved in CO_2 emissions.

A. FLOWCHART

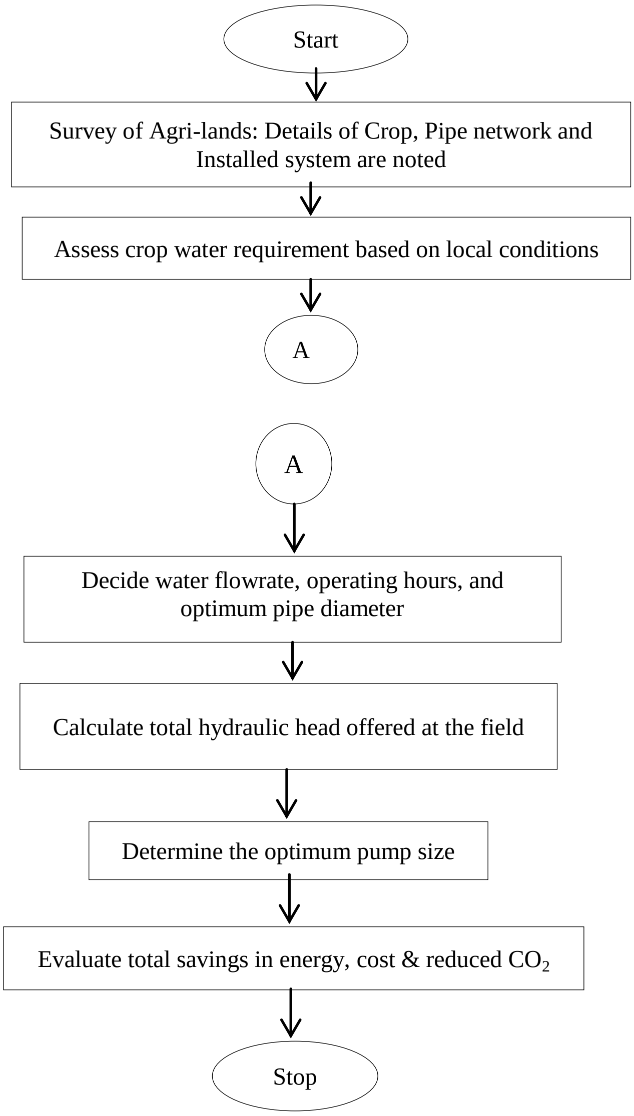

Fig.1: Flowchart of Methodology

The flowchart shown in figure.1 presents the methodology adapted in the present work. A detailed walkthrough survey of 50 cases of farmers is conducted at Malprabha riverbed. The details of field such as land area, crops grown, operating period and pipe network are noted. Crop water requirement [8] is calculated using Blaney-Criddle Method. Pipe diameter is selected depending on the time of operation. For a particular pipe diameter if time of pump operation is less than6 hours or lies in 6-9 hours then corresponding diameter is selected. Dynamic head (H_d) & static head (H_s)at the field are assessed. Total Differential Head (H) is assessed. Further, optimal pump rating is assessed.

B. ASSESSMENT OF OPTIMAL PUMP SIZE

Flow rate is the amount of water discharged per second at velocity V in a cross sectional area A [1]. It is given by equation (1).

$$Q = V \times A \qquad (1)$$

Where,
V is velocity of water in m/s
A is area of the pipe in m^2

For sustained operation, velocity of water in PVC pipe is limited to 5 feet/sec i.e. 1.524 m/s [5]. This is carried to minimize water hammer effect and wear &tear of the pipe. Considering the velocity limit, flow rate for various pipe diameters are assessed using equation (1) and presented in table 1.

Table. I: Allowable flow rate in different pipe sizes to keep velocity of water less than 1.524m/s [5]

Pipe Diameter (mm)	Flow rate (LPS)	Flow rate (LPM)	Flow rate (LPH)
40	1.91	114.9	6895
50	3	179.56	10773
65	5.05	303.46	18207
80	7.66	459.68	27581
100	11.9	718.26	43095
125	18.7	1128.2	67336
150	26.93	1616	96965

Time of operation is significant as it indicates whether required water is discharged in specified time. It is mainly dependent on the pipe diameter and is given by equation (2).

$$\text{Time of operation}(T_p) = \frac{Total\ water\ required}{LPH\ of\ a\ given\ diameter} \qquad (2)$$

Total Differential Head (TDH) is calculated [7] using following equations presented in table 2.

Table. II: Head lost due to various field parameters

Head lost due to friction	$h_f = \frac{4flV^2}{2gd}$
Head lost due to expansion	$h_e = \frac{(V_{be} - V_{ae})^2}{2g}$
Head lost due to contraction	$h_c = \frac{KV_{ac}^2}{2g}$

Head lost due to 90°	$h_b = 0.45\frac{V^2}{g}$
Head lost due to 45°	$h_b = 0.25\frac{V^2}{g}$
Head lost due to fittings: Foot Valve	$h_{fi} = 0.75\frac{V^2}{g}$
Dynamic Head(H_d)	$h_f + h_e + h_c + h_b + h_{fi}$
Static Head(H_s)	Suction& Discharge Head +Elevation Head
Total Differential Head(H)	Dynamic Head+Static Head

Pump rating mainly depends on discharge rate and the total head to overcome. It is observed that an increase in diameter increases pump rating as more water is to be pumped. Reduction in diameter will reduce the pump rating approximately as less water is being pumped. The pump capacity is assessed by the given equation (2).

$$Pump\ rating = \frac{\rho g Q H}{\eta} \quad (2)$$

Where,
ρ is density of water in KG/m^3
g is the acceleration due to gravity in m/s^2
Q is the discharge rate in m^3/s
H is the total head developed on the pump in meters
η is the efficiency of the pump

Efficiency Considerations
Through comparison and observation using a standard pump performance sheet, the following steps are followed while choosing efficiency of pump.

- The pump rating is calculated assuming the pump is working at Best Efficiency Point (BEP) 70%.
- A cross verification is done between diameter selected, pump rating obtained and pump rating in performance sheet.
- If the calculated head lies in BEP blocks as compared with a standard centrifugal surface pump chart then the power rating obtained is considered to be accurate. Further if the calculated head is outside the BEP blocks then efficiency is considered to be 60%.
- If the head to overcome is almost near to the shut off head, then all the calculations are repeated with a lower diameter pipe. This is done as the pump will not be able to delivery water at the said head.

C. RESULTS OF USING OPTIMAL PUMP CAPACITY

Energy consumed by installed pump in the entire crop cycle is given by equation (3).

$$E_{ic} = P_{ic} \times 745 \times T_{ip} \times f_i \times A_i \quad (3)$$

Where,
E_{ic} energy consumed by installed capacity in Watt-hours
P_{ic} is installed capacity in HP
T_{ip} is the time of operation of the installed pump in hours
f_i is the frequency of irrigation
A_i is area irrigated in hectares

$$f_i = \frac{C_d}{g_i} \quad (4)$$

Where,
C_d is the crop cycle duration in days
g_i is the number of day's gap between irrigation

Energy consumed by assessed pump in crop cycle duration C_d is given by equation (5),

$$E_{ac} = P_{ac} \times T_{ap} \times C_d \quad (5)$$

Where,
P_{ac} is the assessed pump capacity in Watts
E_{ac} is energy consumed by assessed pump in Watt-hours
T_{ap} the time of operation of the assessed pump in hours

Energy conserved in crop cycle (E_c) is the total energy saved when optimal sized pump is used for irrigation against installed pump in the entire crop cycle. It is given by equation (6).

$$E_c = \frac{E_{ic} - E_{ac}}{1000} \quad (6)$$

Where E_c is Energy conserved (KWh) for all hectares in crop cycle duration C_d.

Energy conserved per day (E_{cpd}) is the average energy consumed per day given by equation (7).

$$E_{cpd} = \frac{E_c}{C_d} \quad (7)$$

Cost savings are the savings on generation side as energy conserved is the energy prevented from generation. It is the product of units of energy conserved and cost of 1Kwh energy generation. Cost savings on generation side for entire crop cycle, per day and per year are given by equations (8), (9) and (10) respectively.

$$Cost\ saved\ in\ crop\ cycle = E_c \times Cost\ per\ kWh \quad (8)$$
$$Cost\ saved\ per\ day = E_{cpd} \times Cost\ per\ kWh \quad (9)$$
$$Cost\ saved\ in\ year = Cost\ saved\ per\ day \times 365 \quad (10)$$

The cost of power generation for coal fired power plant is 1.9Rs/KWh [10].The cost of power consumption for agriculture is 5.08Rs/KWh. The cost of power consumption for domestic purpose is 2.77Rs/KWh.

CO_2 emissions from coal powered generators are highest, as it involves burning of coal. CO_2 emission reduced is the product of units of energy conserved and amount of CO_2 emitted for 1Kwh energy generation. Amount of CO_2 gas emission reduced for entire crop cycle and per day are calculated. In a coal fired power plant, CO_2 emitted for 1KWh is 909 grams [9]. CO_2 reduced for crop cycle, per day and per year are given by equations (11), (12) and (13) respectively.

$$CO_2\ emission\ reduced\ in\ crop\ cycle\ = E_C \times 0.909 \quad (11)$$
$$CO_2\ emission\ reduced\ per\ day = E_{cpd} \times 0.909 \quad (12)$$
$$CO_2\ emission\ reduced\ per\ year = E_{cpd} \times 0.909 \times 365 \quad (13)$$

III. RESULTS AND DISCUSSIONS

Optimal pump sizing requires the assessment of flow rate, head loss and efficiency. Optimal pump sizing is explained using results of an individual case from survey.

A. Case Study

A case study of a farmer is performed whose field parameters are presented in table 3.

Table. III: Details of Farmer's Field

Farmers Name	Shivanna Shettar
Area(Hectares)	2
Crop Grown	Sun Flower
Installed Capacity	10 HP
Pipe Length	520 meters
90^o	1
45^o	2
Fittings	Foot Valve

Crop Water Requirement

Water required for 2 hectares of sunflower is assessed using Blaney-Criddle method, which is 71,000 liters/day.

Assessment of Head

Nominal pipe diameter & time of operation are assessed using equation (4), (5) & (6) and table 1.

Nominal diameter pipe diameter = 65mm

Time of operation =4 hours

Discharge Rate= $0.00493m^3/s$

Table. IV: Head lost due to various field parameters

Head lost due to friction	16.40mts
Head lost due to 90^o	0.10mts
Head lost due to 45^o	0.11mts
Head lost due to fittings: Foot Valve	0.17mts
Suction and Discharge Head	2mts
Total Differential Head	**18.79mts**
Assessed Pump Rating	**2 HP**

Results obtained from analysis of Shivanna Shettar case is presented in table V.

Table. V: Results obtained Energy Conservation

Energy Consumption	
Energy consumed by installed capacity	1532.0 kWh
Energy consumed by assessed capacity	715.2 kWh
Energy Conservation	
Energy conserved in crop cycle	816.8 kWh
Energy conserved per day	6.8 kWh
Cost Savings	
Cost saved in crop cycle	1551.92 Rs
Cost saved per day	12.93 Rs
CO_2 emissions reduced	
CO_2 emissions reduced in crop cycle	742.47 Kg
CO_2 emissions reduced per day	6.18 Kg

3.2 COMPARISON OF SURVEY AND ASSESSED DATA

The proposed method was used for the surveyed cases of the agriculture lands [6]. Analysis of the results presents the optimal pump capacity for irrigation field and indicates the possible energy conservation opportunities. Comparison of installed pump capacity and assessed pump capacity for 10 cases is shown in figure 2. Further, analysis of 10 cases suggests reduction in pump rating of approximately 187 HP. This results in reduction of load on the grid and cost of pump to farmers.

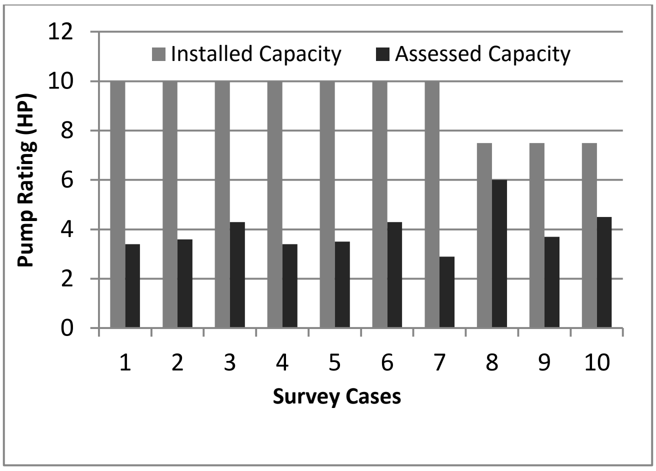

Fig.2: Installed Pump Capacities vs. Assessed Pump Capacities

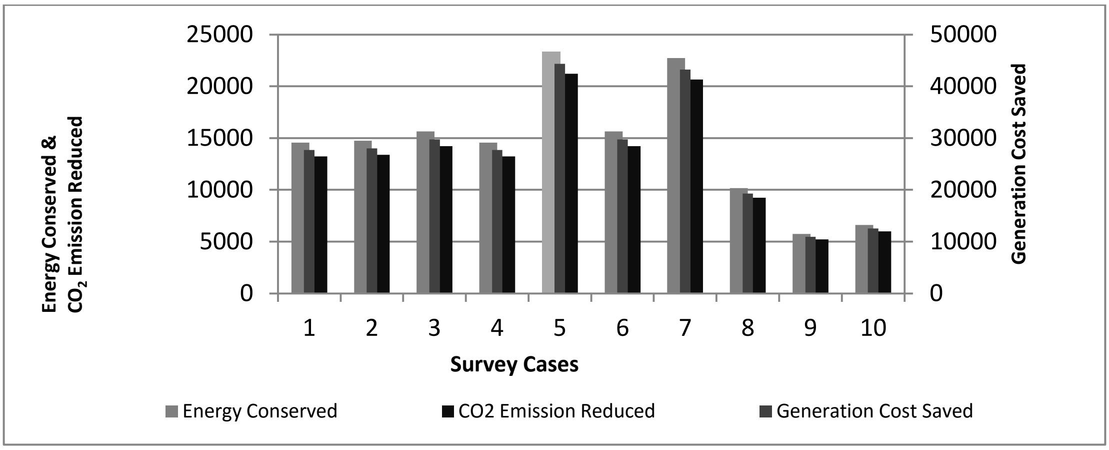

Fig.3: Energy Conserved, Generation Cost Saved and CO_2 Emission Reduced

Optimal pump sizing of the pump results in the energy conservation. Energy conserved varies in individual cases depending on the assessed pump capacity, irrigated area and time of operation. Energy conservation results in reduced power generation, cost savings in generation and reduced emission of waste gases. A reduction in power generation results in reduced fuel usage. CO_2 gas is the main effluents of coal plant and it is a major cause for global warming. A chart representing Energy conserved, Generation cost saved and CO_2emission reduced is shown in figure 3.

IV. CONCLUSION

Energy conservation opportunity in irrigation systems and solution is presented in the paper. Methodology for optimally sizing the pumps based on water need and local hydraulic conditions was proposed. Survey was conducted for 50 agriculture lands at Malaprabha riverbed and optimal sizing of pumps was carried for each case. The newly proposed sizes for each case indicated the excessive installations by farmers. Further, energy conserved and cost savings are analyzed. It was concluded that, energy saving opportunity in irrigation systems is a significant option and reduces the CO_2emissions.

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