THE INNOVATION & RENOVATION IN DESIGN O & M OF PUMPING SYSTEM FOR ENERGY CONSERVATION & RELIABILITY IN OPERATION

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The confederation of Indian industries (CII) surveyed water pumping system in many villages & found that there is considerable loss of energy (electrical) due to wrong design, operation & maintenance of pumping system.

During my more than five decades experiences in this line (1961-2016) I have noticed some blunders/ mistakes made by water works engineers due to which 25-30% energy is wasted.

I have pointed these mistakes for rectification by W.W. Engineers during design stage (Innovation) & during O & M stage (renovation).

These 16 points are explained by way of practical examples so that urgent necessity of rectification/replacement is realized by the W.W.Engineers.

1 (A) ENERGY SAVING BY INSTALLATION OF TRANSFORMER HAVING LESSER LOAD & NO LOAD LOSSES.

There are two types of energy losses in any transformer:-

a) **NO LOAD LOSSES -** which are continued even if there is no load on the transformer. These losses are from 0.2 to 0.5% of the rated power of transformer.

b) **LOAD LOSSES: -** These losses depend on the % of the load & duration (total working hours) of the load. Loading is generally considered 40% of full load and duration depends on usage of transformer. These losses vary from 0.7 to 2.1 % of rated power of transformer.

Transformers manufactured bywell-known reputed companies are always having less loss in comparison to the losses in locally manufactured transformers. Reasonable load no losses parameters are prescribed by G.O.I in manual published C.B.I.P (Central board of irrigation & power). However now a day's manufactures have innovated in the design & designed transformer having considerable less losses than CBIP manual losses.

Purchaser should get information from the 4-5 reputed manufacturer such as kirlosker, , SimensesSchinder ,ABB, etc& fix base No load & Load losses without any minus tolerance & mention in tender documents & levy Penalty if losses are noticed more than that or may reject the transformers.

The procedure of levy of penalty should be clearly mentioned in the tender documents as mentioned below

a) Service life of transformer : 25 year (n)

b) Discounting rate : 6%

c) Cost of loss/kw (p)

d) Net present value of loss for n year : Ft

Ft = E p

(1 +r) n

NO LOAD LOSSES / YEAR : 24 hour/day x 365 days in year x Rs. 5.5 kw rate per Kwhr

: Rs- 48,180/Year /Kw

LOAD LOSSES /YEAR : 24 x 365 x (.4) ^2 x5.5 = Rs: - 7708.80/year/kw

To Calculate N.P.V (Net present Value) at 6% discount rate

25 years - multiplying factor will be 13.54

: - N.P.V of No load losses will be Rs. - 48180 x 13.54 = Rs. 6, 52,357/- Say Rs 6.5 lacs/kw

& N.P.V of load losses will be Rs. - 7708.80 x 13.54 = Rs. - 104377 Say Rs 1.00 lacs/kw

CAPITALIZED COST OF TRANSFORMER

Purchase cost + 650000 x No Load losses in Kw + 100000 x load losses in KW

In case working hours are less than mentioned above load losses may be calculated accordingly.

However no load losses well remain same because it is not affected by loading factor.

Note: Billions of rupees can be saved by selecting energy-efficient transformer. Now a day's Bureau of Energy Efficiency (BEE) has started STAR-RATING of small sized transformer in that transformer of 5 star rating should be preferred for public services for bigger sizes, getting info from 4 to 5 reputed manufactures is advisable.

1(B) ENERGY SAVING BY PARALLEL OPERATIONS OF TRANSFORMERS

Generally we purchase two transformers of the required capacity and call it one working and one stand by (1W + 1S).

Case I: In some locations it is noticed that full load is taken by one transformer & another transformer is kept on No-load but charged.From the energy conservation point of view this system is not correct.

Case II: Load should be shared in between both transformers.

Example:	Transformer capacity	: 1600 KVA
	Load	: 1100 KVA
	Say No-load losses	: 1600 KVA-1.8 KW
	Say Load losses	: 1100 KVA-13.50 KW
	Energy cost @	: Rs 5.5/KWH

Case I: Total cost of energy losses for two transformers /annum

= (1.8*2 + 13.5) * 24 hrs *365 days * Rs 5.5 = Rs 8, 23,787/-

Case II: Both transformers on part load (50% load on each transformer)

Load losses at 50% load = (1/2) ^2 of full load losses = (1/4)*13.5 KW = 3.375 KW

Therefore total cost of energy losses per annum

= (1.8+3.375) * 2 * 24 hrs * 365 days * Rs 5.5 = Rs 4, 98,663/-

Saving in energy losses in case II is followed

= Rs 823878-498663 = Rs 325215/annum says Rs 3.25 lacs/year

IMAGINE ENERGY SAVING IS THOUSANDS OF TRANSFORMERS INSTALLED IN THE COUNTRY

2 ENERGY SAVING BY VOLTAGE STABILIZING UP TO RATED VOLTAGE.

If the motor is operated at low voltage, the current drawn increases, resulting in increased copper losses & consequent energy losses.

Example: Motor KW : 1000 KW,

Rated voltage V1 : 100%

Low voltage (now) V2 : 90% rated voltage

I^2 *R losses of 1000 KW motor = 30 KW at rated voltage V1

Since I1 * V1 = I2 * V2

I2/I1 = V1/V2 = 100%/90% = 1.11

There for I^2*R losses at 90% voltage will be (1.11)^2 * 30 KW = 37 KW

Increase in I^2*R losses due to low voltage = 37-30 = 7 KW

Annual extra energy cost due to the low voltage = 7 * 24 hrs *365 days * Rs 5.5/unit = Rs 337260/annum

It is therefore beneficial to convert operating voltage to rated by any of the following methods.

1. Installing on-load tap changer (OLTC) on transformer above1000 KVA
2. Selecting suitable tap on off load tap-changer
3. Installing automatic voltage stabilizers

IMAGINE ENERGY SAVING IS THOUSANDS OF TRANSFORMERS.

3 ENERGY SAVING BY INSTALLING ENERGY EFFICIENT PUMP SETS

Now a day's very energy efficient pump sets (pumps + motors) are available in the market.

The only precaution required for selecting of pragmatic parameters for overall efficiency (without minus tolerance) is getting information about pump & motor efficiency from very reputed companies & FIX REQUIRED EFFICIENCY (WITHOUT MINUS TOLERANCE) AS LAND MARK & INVITE TENDERS ON THAT BASIS. Manufactures should produce type test certificate from NABL approved labs regarding efficiencies. No energy loading beyond guaranteed efficiency as it encourages bidder for manipulating efficiency during testing.

Example: One pump sets having following technical parameters

Q= 860 m^3/hr, H = 45 meters, Overall efficiency = 85 %&89 %

Sr.	Particulars	Overall efficiency-85 %	Overall efficiency-89 %
1	Water kw = (Q*H)/(367.2)	105.392 wkw	105.392 wkw
2	Motor input kw = wkw/?o	105.392/0.85 = 123.99 kw	105.392/0.89 = 118.418 kw
3	Kw saving /Hr due to higher efficiency= 123.99-118.418 = 5.572 kw/hr		
4	Annual saving = 5.572 *20 hr/day * 300 days/year * Rs 5.5/unit = Rs 183876 say Rs 1.8 lacs for 4% better efficiency		

IMAGINE WASTE OF ENERGY WHERE THOUSANDS OF PUMPS ARE RUNNING AT 10 TO 15% LESS OVERALL EFFICIENCY.

IN EVERY PUMP HOUSE BENCH MARK EFFICIENCY FOR EACH PUMP SHOULD BE MENTIONED ON THE BOARD. THIS WILL BE AN EYE-OPENOR FOR VISITING/INSPECTING OFFICERS.

4 ENERGY SAVING BY USING ONE/TWO SIZE HIGHER CABLES IN PUMP HOUSE

Cable sizing depends on the following 4 requirements

1. Current drown during running (rated current on full load)
2. Voltage drop not more than 3% in the cable length
3. Derating factor due to installation type
4. Current carrying capacity during short circuit

It is noticed that in many case cable size is calculated on the basis of upper two factors and roughly cable size is calculated as follows

Full load current of motor= 1.4 *HP

Current carrying capacity = 1.4 times full load current

= 1.96 SAY 2 TIMES HP

This is non-technical design. If other two factors are also considered cable size will be 1 or 2 size higher than that with safety of installation & energy saving will be as given below:

Example: 1000 KVA transformer, 11 Kv/0.433 Kv, Delta-Star, short circuit current level 250 MVA

Full load current of transformer = (1000)/ (v3*11) = 52.49 A

De rating factor of environment & laying condition:

Buried cable with ground temperature of 30° C = K1 = 0.93

Solid type (very dry) = K2 = 0.86

Cable configuration (two cables with spacing of 0.12 m) = K3 = 0.85

Effective derating factor = K = K1*K2*K3 = 0.69

So, current carrying capacity of cable required = (52.46)/ (0.69)= 76.07 A

The size of the cable that will safely carry 76.07 A is three core, 25 mm^2 XLPE with current carrying capacity of 120 A.

BUT CONSIDERING SHORT CIRCUIT CURRENT WITH STAND CAPACITY THIS SIZE IS NOT SUITABLE.

Short circuit current at the HT terminal of the transformer = (25000)/ (v3*11) = 13.122 KA

Suitable size will be 150 mm^2 as current carrying capacity of 150 mm^2 XLPE cable is 14.1 KA

SIMILARLY ENERGY SAVING IN MOTOR CABLING DUE TO HIGHER SIZE & LESS D.C. RESISTANCE WILL BE AS FOLLOWS:

Sr. No.	Description	Generally used size	One size higher cable	2 size higher cable
1	Motor rating KW	15 KW	15 KW	15 KW
2	Full load current	28 A	28 A	28 A
3	Operating load	22 A	22 A	22 A
4	Cable size 3C*AL	10 mm^2	16 mm^2	25 mm^2
5	Length of cable	0.3 KM	0.3 KM	0.3 KM
6	**D.C. RESISTANCE OF CABLE**	0.92 ohms	0.57 ohms	0.36 ohms
7	I^2*R losses	(22^2)*0.92=445.3W	(22^2)*0.57=275.8W	(22^2)*0.36=174.2W
8	Energy saving/Hr	-	445-275.8=170 W	445-174 = 271 W
9	Energy saving/24 Hr	-	4.08 kwhr units	6.48 kwhr units
10`	Energy saving/300 days		1224 units	1994 units
11	Cost of energy saving/Rs 5.5/unit		Rs 6732	Rs 10692
12	Cost of cable	Rs 12000	Rs 15000	Rs 18000
13	Difference on cost		Rs 3000/-	Rs 6000/-
14	Payback periodmonth		(3000/6732)*12=5.35	(6000/10692)*12=6.73

5 ENERGY SAVING BY RUNNING PUMP AT THE VICINITY OF DESIGN POINT (I.E. DUTY POINTS COINCIDING WITH DESIGN POINT)

The pump efficiency curve of centrifugal pumps is parabolic. Max efficiency is at designed Q & H, which is apex point of the efficiency curve.

The efficiency decreases when pumps are operated on left or right side of the apex (design point).

In best design pump sets pump efficiency is nearby flat in the resign of +/- 5% of flow rate we should manage to run our pumps in this flat efficiency region only. While selecting pump sets efficiency curve should be studied properly.

In pump, power consumption is inversely proportionate to the efficiency considering Q, H & motor efficiency same. So if pump efficiency is 10% less than optimal, motor input power will be proportionately higher. Motor input power = (Q*H)/ (367.2*np*nm)

6 OVER DESIGNING THE PUMP SET FOR HEAD-PARAMETERS

It is found that in more than 70% cases the total head designed for the pump set is on higher side due to the "FEAR-OF FAILURE". Pump designer is always fearing whether water will reach the farthest end of the supply or not?

The higher than required head is waste of energy proportionate to the % of higher head as other parameters remains the same.

Motor input power = (Q *H)/(367.2*no)

Moreover higher head than required, damages pipe lines and also increases leakage of water.

After installation if head is found more than the required these actions should be taken:

a. Trim the impeller diameter as required but up to 20%

b. Change the impeller

c. Change the pump itself

7 BIGGER SIZE PUMP SETS ARE BETTER IN EFFICIENCY, OPERATION & MAINTENANCE & PRICE THAN MULTIPLE SMALL PUMP SETS

Pumps & motors of bigger sizes have following advantages:

a. More efficient than multiple small size

   Pump of 900 m^3/hr will have 92% efficiency whereas pump of 450 m^3/hr will have 88% efficiency. It means 4% less & so at least 4% more power consumption. (Other parameters remain the same)

b. Operation of one bigger size pump will be easier than 2 to 4 small size pumps.

c. Maintenance of one bigger size pump will be easier & quicker than 2 to 4 small size pumps.

d. Cost of one bigger size pump set will be less than 2 to 4 small size pumps sets.

e. Parallel operation of multiple small pumps is always problematic & non-economical.

For the flexibility in flow rate and or head (pressure) it is better to control by running hours or by V.F.Ds (variable frequency drivers)

8 ENERGY SAVING BY KEEPING AN EAGLE-EYE ON ESR-FILLING TIME

Every pumping station is almost having E.S.R. (Elevated Service Reservoir) or overhead tank and capacity mentioned on it in ....lakhs liters in red link.

It will be an eye-opener for the operator and inspecting engineer if ESR filling ideal time with the installed pump sets in mentioned along with in hours say 5 hours, 8 hours or so for filling the tank.

If tank filing time increase by more than 10% time it reveals that pump sets have become in efficient or there is heavy leakage in between pump header & ESR.

Remedial actions can be taken as this information.

9 PRESSURE GAUGE ON DELIVERY SIDE IS WARNING ABOUT HEALTH OF PUMP SETS

Pressure gauge on delivery lines/headers is very important instrument to reveal the following information.

a. Whether pressure in the pipe line is less or more than required

b. Whether pressure is decreased considerably than duty during installation. Pressure decreases may be due to the leakage or the theft of water.

Operator/inspecting engineer should invariably check this gauge regularly & keep it in good running condition. Pressure gauge should be glycerin-filled type & design pressure should be marked in red ink on the dial of the gauge.

10 ENERGY SAVING BY TIMELY DISCARDING IN EFFICIENT PUMPING MACHINERY

The government's policy regarding discarding/condemnation of old in efficient machinery is not clear and not based on pragmatic back ground.

Government has fixed life for pumping machinery as mentioned below: (O & M manual CPHEEO jan 2015 page no.385)

1. Submersible Pumps: 4-7 year
2. Centrifugal Pumps : 15-20 Years
3. Vertical Turbine Pumps : About 15 year

Now a day's technology up gradation is so fast that any well-designed machinery becomes downgraded in energy -efficiency, reliability & ease of operation & maintenance.

The practical solution to this problem is to base the discarding/condemnation policy as suggested below:

If the existing machinery has lost more than 10% overall efficiency in comparison to the available overall efficiency in the proposed new energy efficient machinery. OR

The payback period of expenditure on new machinery is less than four years Presently more than 70% pumping machinery is running at 15 to 20% less overall efficiency, it means consuming 15 to 20% more energy than required. How can country as ours afford such huge losses every year. Government in Bureau of Energy Efficiency should formulate policy immediately and also make the registration of pump performance auditors pragmatic i.e. **EXAMINE THEM ONLY FOR THE SUBJECTS NECESSARY TO AUDIT THE PUMP PERFORMANCE.**

11 IMPROVING POWER FACTOR TO 0.98

Generally as per rule of power supply authority, average power factor (PF) of 0.9 or so as to be maintained in electrical installations. If average PF is less than 0.9 or specified limit over the billing period, generally penalty at rate of 0.5% of bill per each 1% (may vary) shortfall in PF is charged. It is, therefore, obligatory to maintain PF to level of 0.9 or specified limit.

Improving PF above the limit is beneficial for conservation of energy. The power factor can be improved to level of 0.97 or 0.98 without adverse effect on motors. Further discussion show that considerable saving in power cost can be achieved if PF is improved.

If PF corrected from 0.90 to 0.98, the annual saving in energy consumption is Rs 226446/- for 1000 KW load and saving in KVA recorded amounts to Rs 1,31.000/-.

Total saving thus, shall be Rs 357446/- per annum. Detailed calculations are as follows:

Initial power factor (Cos ϴ1) = 0.90

Improved power factor (Cos ϴ2) = 0.98

Considering 1000 KW load and 3.3 KV system, the load current and copper losses are:

/0.90	=	(1000)/ (v3*3.3*0.90)	=	194.4 A
/0.98	=	(1000)/ (v3*3.3*0.98)	=	178.5 A

Copper losses (RI^2)0.90 = 30 KW assuming 3% copper losses = (3/100)*1000=30KW

As copper losses a (current)^2

Copper losses (RI^2)0.98 = 30*((178.5/194.4)^2) = 25.3 KW

Thus reduction in copper losses due to improvement of PF is 30-25.3 i.e. 4.7kw

Therefore saving in power cost due to copper losses per annum @ Rs 5.5/per kWh

(A)= (30.0-25.3)*24 hours*365 days*Rs 5.5 = Rs 226446

The KVA recorded at PF 0.9 and 0.98 are,

KVA0.90 = 1000/.90 = 1111 KVA

KVA0.98 = 1000/0.98 = 1020 KVA

Saving due to reduction in recorded KVA demand @ Rs 120/-per KVA per month

(B)= (1111-1020)*12 months*Rs 120 = Rs 1, 31,000 per annum

Total saving in energy cost = (A+B)= Rs 357446/annum

It can be shown that additional capacitors required to improve PF from 0.9 to 0.98 is 283 KVAR from the tables. Approximate cost shall be about Rs 141500/-. Thus by spending the amount once, yearly benefit of Rs 357446/- can be achieved.

Maximum recommended limit for PF correction is 0.98, which allows for margin of 2% below unity. PF above unity is detrimental for induction motors.

For improving PF to 0.98, automatic power factor correction (APFC) with suitable contactors and capacitors banks shall be provided in panel.

12 CHECKING OF PERFORMANCE OF CAPACITOR BANKS FOR ENERGY SAVING

Maintaining of overall system power factor (PF) nearer to unity, through the use of capacitors, has acquired significant importance from two angles viz. cost benefit in the form of rebate in billing offered by the state utilities for PF improvement and also, reduction in losses due to reactive power compensation through capacitors. In order to get maximum benefit out of such investment, it is necessary to monitor performance of capacitors so as to maintain the benefits of energy saving without break. The healthiness of the capacitor bank can be found using very simple measurements and calculations using standard engineering data available for all manufactures of capacitors. A sample is provided here under:

A Capacitor data considered

1.	Capacitor rating	:	100 KVAr
2.	Rated voltage of capacitor Vr	:	440 V
3.	Rated current of capacitors Ir	:	131.2 Amp at 409.5 V

B Capacitor parameters measured at site

1.	Voltage at capacitor terminal Vm	:	409.5 V
2.	Current at capacitor terminal Im	:	96.9 Amp at 409.5 V

C Determination of capacitor current corresponding to rated current at operating voltage of 409.5 V

1.	Formula applied, Ia	:	(Vm/Vr)*Ir
		:	(109.5/440)*131.2
		:	122.11 Amp
2.	% Reduction in capacitor output	:	((Ia-Im)*100)/I
		:	((122.11-96.9)*100)/122.11) : 20.64

As percentage reduction is 20.64%, the capacitor bank is partially faulty. **Generally, the capacitor is considered healthy, if measured current is found reduced by less than 5 % from calculated current at that specific system voltage.**

13 OPTIMIZATION OF SLUICE VALVE/BUTTERFLY VALVE & NRV AS PUMP DELIVERY SIDE FOR ENERGY CONSERVATION POINT OF VIEW

"K" value of valves & speed of liquid play major role in energy saving on delivery side.

Example: K value of sluice valve = 0.35

K value of NRV = 2.5

K value of combination = 2.85

Flow rate = 2160 m^3/hr (60 lps), Pump efficiency = 80%, head losses = k * (v^2/2g)

Calculate head loss & energy loss for speed of 2 m/s & 2.5 m/s

Sr. No.	Particular	V1 speed 2 m/s	V2 speed 2.5 m/s
1	Head loss = k*(v^2/2g)	2.85*(2^2/2*9.81)=0.581 m	2.85*((2.5)^2/2*9.81)=0.907 m
2	Kw consumed due to head loss = ((Q*head loss)/(367.2*ηp))	(2160*0.581)/(367.2*0.8) = 4.272 kw	(2160*0.907)/(367.2*0.8) = 6.675 kw
3	Extra energy consumption to higher speed i.e. 2.5 m/s against 2 m/s = 6.675-4.272 = 2.4036 kwhr		
4	Extra energy cost/annum = 2.4036*24*365*5.5 =Rs 277932/annum say Rs 2.78 lacs		

Imagine energy saving in thousands of pumps.

Note: while purchasing valves K value of various types & size of valves must be obtained from the reputed manufacturers and minimum values should be in put in the tender specifications to save energy. Similarly follow optimal velocity should be kept in design of size of pipes & valves.

Suction pipes & valves - 1.5 to 1.7 m/s

Deliver pipes & valves - 1.5 to 2.0 m/s O & M manual, G.O.I. CPHEEO. Jan 2005

14 ENERGY SAVING BY AVOIDING THROTTLING OF SLUICE VALVE

Valve throttling becomes necessary due to the following situations.

a). Pump design head is higher than system head.

b). solo running of pump when header is designed for two/three pump sets.

Throttling valve is waste of energy &should be avoided by following means.

1) Trim the impeller /change the impeller to match the required head.

2) Select pumps properly to suit parallel operation & solo operation when necessary.

Energy loss in throttling can be calculated as follows.

Required Parameters: Q = 68 m3/hr H= 47 mtr.

For this pump efficiency will be 60%

WKW = 68 x 47 = 8.7kw

367.2

BKW = 8.7 / 0.60 = 14.5 kw

Motor input power (motor Eff : 90%) =14.50/0.90 = 16.1 kw

Designed Parameters: Q = 68 m3/hr H= 76 mtr.

For this pump efficiency will be 50%

WKW = (68 x 76)/ (367.2) = 14 kw, BKW = 14 / 0.50 = 28 kw

Motor input power (motor Eff : 90%) =28.00/0.90 = 31 kw

Energy wastage: 31-14.9 = 14.9KW

COST EXTRA energy used / annum at rate 5.5 RS/- /unit = 14.9 x24 x365 x5.5 = 717882Say Rs.7.17 lacs

This reveals we have not cared to design the pump properly so only CURE is to replace it by pump having head of 47 mh. Payback period will be less than one year.

15 ENERGY SAVING BY DECREASING VELOCITY IN DELIVERY LINES

The formula for head loss due to friction in pipe line is as given below:

Head loss in meters = (f*l*v^2)/ (d*2g)

Where f = friction factor, l = length of pipe, v = velocity of flow, d = inside diameter of pipe

For a particular case f, l, d & g remain constant

Only (velocity) ^2 governances head loss

So the head loss in 2 m/s Vs 2.5 m/s will be as follows:

2 m/s = 2*2 = 4

2.5 m/s = 2.5*2.5 = 6.25 (56.25% more)

3 m/s = 3*3 = 9 (say 125% more)

So head loss in velocity of 2.5 m/s will be 56.25% more & in 3 m/s it will be 125% more.

Power consumption = (Q*H)/ (367.2*?o)

Where H = (H-static +H-dynamic)

As power consumption is proportionate to H, there will be considerably loss of energy consumed by friction head element in total head of the pump (H-static +H-dynamic)

16 SPECIFIC POWER CONSUMPTION (S.P.C) KWH/M3 AS BENCH MARK FOR ECONOMICAL VIABILITY AND OPERATIONAL RELIABILITY OF PUMPING MACHINERY

By and large S.P.C should be studies & bench marked on every pumping station & mentioned on the board or wall of the pumping stations:

S.P.C = Total power consumption per Hr/Total discharge per Hr

As total head is fixed higher S.P.C means extra motor input power.

This should be treated as signal for repair/over haul or replace the pumping machinery should be renovated or replaced.