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Energy Saving Opportunities in Pumps and Compressors

Chirag Rabadia[1], Karan Motwani[2]
[1,2]Mechanical Engineering Department, Marwadi Education Foundation, Rajkot, India

***Abstract:** The economic growth and technological advancement of every nation depends on energy conservation. Energy conservation is a viable tool to promote economic efficiency. The commercial energy consumption percentage rose sevenfold during last four decades in India. Industrial sector consumes around 40% of the total energy in India. Among all the types of energy consuming equipments used in industries, pumps and compressors are selected for this study as these equipments are energy intensive and consume around 30% of the total energy. The main aim of this study is to identify energy saving opportunities in pumps and compressors by energy performance assessment to enhance their energy efficiency. This paper represents the various ways which are suggested to conserve as much as energy in case of pumps and compressors.*
***Keywords--** Energy conservation, Energy efficiency, Energy audit of pumps, Energy audit of compressors, Energy savings, Energy conservation opportunities*

Nomenclature	
cos□	Power factor
D	Diameter of impeller
g	Gravitational acceleration, m/s^2
H	Total head, m
H_1	Specific enthalpy at inlet, kJ/kg
H_2	Specific enthalpy at outlet, kJ/kg
I	Current, Amp
N	Speed of pump, rpm
NPSH	Net positive suction head
P_m	Power input to motor, kW
P_S	Pump shaft power, kW
Q	Flow rate of fluid, m^3/s
Q_1	Free air delivered m^3/hr
V	Voltage, Volt
η_m	Motor efficiency
η_p	Pump efficiency
η_T	Transmission efficiency
ρ	Density of fluid, kg/m^3

I. INTRODUCTION

The increase of energy demand largely observed during the last two decades and it will continue rising incrementally by the same rate. Energy consumption might become twice between 2015 and 2020 referring to low production of energy and high growth of energy [1]. Energy is one of the largest controllable costs in most organizations and there is a considerable scope for reducing energy consumption and hence cost. The benefits are reflected directly in an organization's profitability while also making a contribution to global environmental improvement in terms of energy conservation [2].

India has the world's second largest population and continues to grow at 1.34% per year during the years 2007 and 2008 [3]. India is among the 10 fastest growing economies in this energy hungry world. It is also noticed that commercial primary energy consumption in India has grown by about 700% in the last four decades [4]. Modern energy-carriers account for about 70% of the total consumption, and with economic growth, the share of modern energy is expected to increase rapidly. India is a large and fast growing economy and thus requires rapid rise in modern energy consumption [1]. Energy efficiency is one of the most important measures, among others, to address these challenges. Energy efficiency also reduces energy as well as carbon intensity of the economy, which is a necessary condition for addressing climate change. Therefore, India will have to follow an energy-efficient pathway to conserve energy and to protect environment [1]. Industrial energy efficiency has emerged as one of the key issues in India. In the late 1980s, the energy sector was considered critical to economic growth as it accounted for over 30% of public investments, utilized 25% of export earnings for energy imports and generated about 15% of government revenues [5]. In 2002, India's total primary energy consumption amounted to 538 million tonnes of oil equivalent [6]. The industrial sector used about 40% of total energy in the country [7]. The expenditure in energy among the total production costs in India's industrial sector is generally very high and as a result the Indian Government is interested in developing better policies and measures to supply energy more efficiently and save energy effectively in the Industrial sector [8]. It has been seen that the pumping system is one of the areas where huge amount of energy can be saved [9]. According to a study that the American Hydraulics Institute has made, 20% of the consumed energy has been consumed by pumps in developed countries [10]. It has been explained that 30% of this energy can be saved with good design of systems and choosing suitable pumps. The pumps have high efficiency alone is not enough for a pump system to work in maximum efficiency. Working in maximum efficiency of a pump system depends not only on a good pump design but also a good design of the complete system and its working conditions. Otherwise, it is inevitable that even the most efficient pump in a system that has been wrongly designed and wrongly assembled is going to be inefficient [9].

Apart from the pumps, the use of compressed air in industry and in service sectors is also common as its production and handling are safe and easy. Compressed air is necessary to produce for most industrial facilities. Compressed-air generation is energy intensive, and for most industrial operations, energy cost fraction of compressed air is significant compared with overall energy costs. Yet, there is a vacuum of reliable information on the energy efficiency of a typical compressed-air system [11].

Compressed air is typically one of the most expensive utilities in an industrial facility. While designing energy saving compressed air systems various methods are applied to reduce energy losses and minimize energy consumption [12]. The compressed air systems require the complex approach towards rational energy consumption by effective production, distribution and application equipment of the compressed air [12].

By considering above reasons, it is observed that there is a strong requirement of energy conservation in pumps as well as in compressors but without affecting their output. This paper presents the methodology for energy performance assessment of pumps and compressors. It also suggests various energy saving opportunities or tips to save enormous energy in Industrial sector.

II. ENERGY PERFORMANCE ASSESSMENT OF PUMPS

As per the principle working of pump, any liquid can be handled by any of the pump designs. Where different pump designs could be used, the centrifugal pump is usually the most economical followed by rotary and reciprocating pumps [13]. Although, positive displacement pumps are in general more efficient than centrifugal pumps, the merit of higher efficiency tends to be offset by rise in maintenance costs [13]. It is noticed that centrifugal pumps are used extensively in industrial sector and so consume huge amount of energy. That's why this paper concentrates mainly on centrifugal pumps to improve its energy efficiency.

The most critical aspect of energy efficiency in a pumping system is matching of pumps to loads. Hence even if an efficient pump is selected, but if it is a mismatch to the system then the pump will operate at very poor efficiencies [14]. Moreover, efficiency drop can also be expected over time due to deposits in the impellers. Performance assessment of pumps would reveal the existing operating efficiencies in order to take corrective actions [14]. A centrifugal pump is not positive displacement type; it will not pump the same volume always. The greater the depth of the water, the lesser is the flow from the pump. In addition, when it pumps against rising pressure, the less it will pump. For these reasons, it is important to choose a particular type of centrifugal pump that is designed to do a particular job.

Since the pump is a dynamic device, it is convenient to consider the pressure in terms of head i.e. meters of liquid column. The pump generates the same head of liquid whatever the density of the liquid being pumped. The actual contours of hydraulic passages of the impeller and the casing are extremely playing a vital role, in order to obtain the highest efficiency possible. The standard convention for centrifugal pump is to plot the pump performance curves which present the Flow on the horizontal axis and Head generated on the vertical axis. Efficiency, Power and NPSH required, are conventionally shown on the vertical axis, plotted against Flow, as illustrated in Fig. 1 [13].

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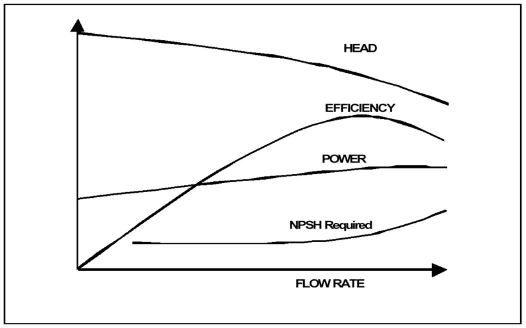

System

Fig. 1 Pump Performance Curve

Given the significant amount of electricity attributed to pumping systems, even small improvements in pumping efficiency could yield very significant savings of electricity. The pump is the most inefficient component among the whole pumping system which comprises a pump, motor, transmission drive, piping and valves.

A. Performance Test of Pumps

The purpose of the performance test of pumps is to determine the pump efficiency during operating condition and compare the same with design. From the measured pump efficiency and by checking flow requirement, recommendations can be given for improving energy efficiency.

1) Pump Efficiency: Firstly, Pump efficiency should be checked for assessing actual performance of pump. Liquid horse power divided by the power supplied to the pump shaft is known as pump efficiency. Efficiency of the pump can be calculated with the help of equation (1).

$$\eta_p = \frac{\rho \cdot g \cdot Q \cdot H}{P_s \cdot 1000} \qquad (1)$$

For motor driven pumps, pump shaft power and power consumption by motor can be calculated from equations (2) and (3) respectively.

$$P_s = P_m \cdot \eta_m \cdot \eta_{T.} \qquad (2)$$

$$P_m = \sqrt{3} \cdot V \cdot I \cdot COS\phi \qquad (3)$$

For turbine driven pump, power consumption by motor can be calculated from equation (4).

$$P_s = Q \cdot \left(H_1 - H_2\right) \qquad (4)$$

2) Affinity Laws of Pumps: The Affinity Laws of roto-dynamic pump are presented in equations (5), (6) and (7), which represent the relation between pump performance parameters like flow, head and power absorbed with the speed:

$$Q \propto N \qquad (5)$$

$$H \propto N^2 \qquad (6)$$

$$P \propto N^3 \qquad (7)$$

As it can be seen from the above affinity laws, doubling the speed of the centrifugal pump will increase the power consumption by 8 times. Conversely a small reduction in speed will result in drastic reduction in power consumption. Thus, variable speed drive is used for varying the speed of the pump as per the requirement of flow. This forms the basis for energy conservation in centrifugal pumps with varying flow requirements.

Apart from the reduction in speed, changing the impeller diameter gives a proportional change in peripheral velocity, so it follows the equations (8), (9) and (10), which are similar to the affinity laws, for the variation of performance with impeller diameter D:

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$$Q \propto D \tag{8}$$

$$H \propto D^2 \tag{9}$$

$$P \propto D^3 \tag{10}$$

It can be suggested from the above equations that efficiency varies when the diameter is changed within a particular casing. Diameter changes are generally limited to reducing the diameter to about 75% of the maximum, i.e. a head reduction to about 50%. Beyond this, efficiency and NPSH are badly affected. However speed change can be used over a wider range without seriously reducing efficiency.

3) Pump Operating Point

When a pump is installed in a system the effect can be depicted graphically by superimposing pump and system curves. The operating point will always be where the two curves intersect, shown in Fig. 2 [13].

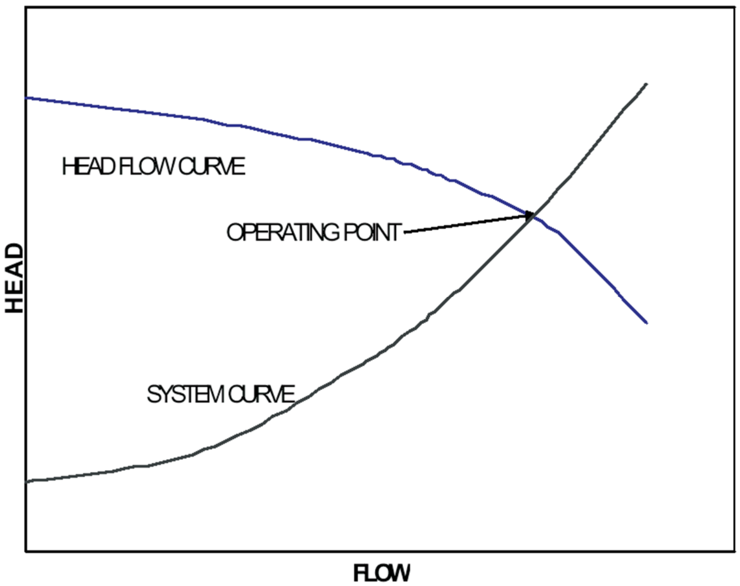

Fig. 2 Pump Operating Point

If the actual system curve is different in reality to that calculated, the pump will operate at a flow and head different to that expected.For a centrifugal pump, an increasing system resistance will reduce the flow, eventually to zero, but the maximum head is limited as shown. Even, this condition is only acceptable for a short period without causing problems. An error in the system curve calculation is also likely to lead to a centrifugal pump selection, which is less than optimal for the actual system head losses. Adding safety margins to the calculated system curve to ensure that a sufficiently large pump is selected will generally result in installing an oversized pump, which will operate at an excessive flow rate or in a throttled condition, which increases energy usage and reduces pump life.

4) How To Enhance Energy Efficiency Of Pumps?

To understand a pumping system, one must realize that all of its components are interdependent. When examining or designing a pump system, the process demands must first be established and most energy efficiency solution introduced. For example, does the flow rate have to be regulated continuously or in steps? Can on-off batch pumping be used? What is the flow rates needed and how are they distributed in time?

The first step to achieve energy efficiency in pumping system is to target the end-use. A plant water balance would establish usage pattern and highlight areas where water consumption can be reduced or optimized. Good water conservation measures, alone, may eliminate the need for some pumps.

Once flow requirements are optimized, then the pumping system can be analyzed for energy conservation opportunities. Basically this means matching the pump to requirements by adopting proper flow control strategies. Common symptoms that indicate opportunities for energy efficiency in pumps are given in the Table 1 [13].

TABLE I.
SYMPTOMS THAT INDICATE POTENTIAL OPPORTUNITY FOR ENERGY SAVINGS

Symptom	Likely Reason	Best Solutions
Throttle valve-controlled systems	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower rpm
Bypass line (partially or completely) open	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower rpm
Multiple parallel pump system with the same number of pumps always operating	Pump use not monitored or controlled	Install controls
Constant pump operation in a batch environment	Wrong system design	On-off controls
High maintenance cost (seals, bearings)	Pump operated far away from BEP	Match pump capacity with system requirement

B. Energy Saving Opportunities In Pumps

The following energy saving opportunities are identified for enhancing energy efficiency of pumps [13].

Ensure adequate NPSH at site of installation

Ensure availability of basic instruments at pumps like pressure gauges, flow meters.

Operate pumps near best efficiency point.

Modify pumping system and pumps losses to minimize throttling.

Adapt to wide load variation with variable speed drives or sequenced control of multiple units.

Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.

Use booster pumps for small loads requiring higher pressures.

Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers.

Repair seals and packing to minimize water loss by dripping.

Balance the system to minimize flows and reduce pump power requirements.

Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage:

Conduct water balance to minimize water consumption

Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.

In multiple pump operations, carefully combine the operation of pumps to avoid throttling

Provide booster pump for few areas of higher head

Replace old pumps by energy efficient pumps

In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation.

Optimize number of stages in multi-stage pump in case of head margins

Reduce system resistance by pressure drop assessment and pipe size optimization

III. ENERGY PERFORMANCE ASSESSMENT OF COMPRESSORS

Air compressors account for significant amount of electricity used in Indian industries. Air compressors are used in a various types of industries to supply process requirements, to operate pneumatic tools and equipment, and to meet instrumentation needs. Only 10 – 30% of energy reaches the point of end-use, and balance 70 – 90% of energy of the power of the prime mover being converted to unusable heat energy and to a lesser extent lost in form of friction, misuse and noise [15]. The compressed air system is not only an energy intensive utility but also one of the least energy efficient. Over a period of time, both performance of compressors and compressed air system reduces drastically. The causes are many such as poor maintenance, wear and tear etc. All these lead to additional compressors installations leading to more in-efficiencies [16]. A periodic performance assessment is essential to minimize the cost of compressed air.

A. Performance Test of Compressors

The purpose of the performance test of compressors is to determine the actual free air delivery (FAD) of the compressor, Isothermal power required, volumetric efficiency and specific power requirement. The actual performance of the compressor is to be compared with design or standard values for assessing the plant energy efficiency. From the measured compressor efficiency and by checking the pressure and free air delivery(FAD) requirement, recommendations can be given for improving energy efficiency.

B. Energy Saving Opportunities In Compressors

The following energy saving opportunities have been identified for enhancing energy efficiency of compressors [15].

1) Location Of Compressors: The location of air compressors and the quality of air drawn by the compressors will have a significant influence on the amount of energy consumed. Compressor performance as a breathing machine improves with cool, clean, dry air at intake.

2) Cool Air Intake: As a thumb rule, "Every 4°C rise in inlet air temperature results in a higher energy consumption by 1 % to achieve equivalent output". Hence, cool air intake leads to a more efficient compression process. It is preferable to draw cool ambient air from outside, as the temperature of air inside the compressor room will be a few degrees higher than the ambient temperature.

3) Dust Free Air Intake: Dust in the suction air causes excessive wear of moving parts and results in malfunctioning of the valves due to abrasion. Suitable air filters should be provided at the suction side. Air filters should have high dust separation capacity, low-pressure drops and robust design to avoid frequent cleaning and replacement. Air filters should be selected based on the compressor type and installed as close to the compressor as possible. As a thumb rule "For every 250 mm WC pressure drop increase across at the suction path due to choked filters etc., the compressor power consumption increases by about 2 % for the same output"

Hence, it is advisable to clean inlet air filters at regular intervals to minimize pressure drops. Manometers or differential pressure gauges across filters may be provided for monitoring pressure drops so as to plan filter-cleaning schedules.

4) Dry Air Intake: Atmospheric air always contains some amount of water vapour, depending on the relative humidity, being high in wet weather. The moisture level will also be high if air is drawn from a damp area - for example locating compressor close to cooling tower, or dryer exhaust is to be avoided.

The moisture-carrying capacity of air increases with a rise in temperature and decreases with increase in pressure. Therefore, location of compressor should be selected such that it would have dry air at intake side.

5) Elevation: The altitude of a place has a direct impact on the volumetric efficiency of the compressor. It is evident that compressors located at higher altitudes consume more power to achieve a particular delivery pressure than those at sea level, as the compression ratio is higher.

6) Cooling Water Circuit: Most of the industrial compressors are water-cooled, wherein the heat of compression is removed by circulating cold water to cylinder heads, inter-coolers and after-coolers. The resulting warm water is cooled in a cooling tower and circulated back to compressors. The com- pressed air system performance depends upon the effectiveness of inter-coolers, after coolers, which in turn are dependent on cooling water flow and temperature.

Further, inadequate cooling water treatment can lead to increase, for example, in total dis- solved solids (TDS), which in turn can lead to scale formation in heat exchangers. The scales; not only act as insulators reducing the heat transfer, but also increases the pressure drop in the cooling water pumping system.

Use of treated water or purging a portion of cooling water (blow down) periodically can maintain TDS levels within acceptable

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limits. It is better to maintain the water pH by addition of chemicals, and avoid microbial growth by addition of fungicides and algaecides.

7) Efficacy Of Inter And After Coolers: Efficacy is an indicator of heat exchange performance- how well intercoolers and after coolers are performing. Inter-coolers are provided between successive stages of a multi-stage compressor to reduce the work of compression (power requirements) - by reducing the specific volume through cooling the air - apart from moisture separation.

Ideally, the temperature of the inlet air at each stage of a multi-stage machine should be the same as it was at the first stage. This is referred to as "perfect cooling" or isothermal compression. The cooling may be imperfect due to reasons described in earlier sections. Hence in actual practice, the inlet air temperatures at subsequent stages are higher than the normal levels resulting in higher power consumption, as a larger volume is handled for the same duty.

It is noticed that an increase of 5.5°C in the inlet air temperature to the second stage results in a 2 % increase in the specific energy consumption. Use of water at lower temperature reduces specific power consumption. However, very low cooling water temperature could result in condensation of moisture in the air, which if not removed would lead to cylinder damage.

Similarly, inadequate cooling in after-coolers (due to fouling, scaling etc.), allow warm, humid air into the receiver, which causes more condensation in air receivers and distribution lines, which in consequence, leads to increased corrosion, pressure drops and leakages in piping and end-use equipment. Periodic cleaning and ensuring adequate flow at proper temperature of both inter coolers and after coolers are therefore necessary for sustaining desired performance.

8) Pressure Settings: Compressor operates between pressure ranges called as loading (cut-in) and unloading (cut-out) pressures. For example, a compressor operating between pressure setting of 6 – 7 kg/cm^2 means that the compressor unloads at 7 kg/cm^2 and loads at 6 kg/cm^2. Loading and unloading is done using a pressure switch.

For the same capacity, a compressor consumes more power at higher pressures. They should not be operated above their optimum operating pressures as this not only wastes energy, but also leads to excessive wear, leading to further energy wastage. The volumetric efficiency of a compressor is also less at higher delivery pressures.

9) Reducing Delivery Pressure: The possibility of lowering (optimizing) the delivery pressure settings should be explored by careful study of pressure requirements of various equipments, and the pressure drop in the line between the compressed air generation and utilization points. The pressure switches must be adjusted such that the compressor cuts-in and cuts-out at optimum levels. A reduction in the delivery pressure by 1 bar in a compressor would reduce the power consumption by 6 – 10 %.

10) Compressor Modulation By Optimum Pressure Settings: Very often in an industry, different types, capacities and makes of compressors are connected to a common distribution network. In such situations, proper selection of a right combination of compressors and optimal modulation of different compressors can conserve energy.

Where more than one compressor feeds a common header, compressors have to be operated in such a way that the cost of compressed air generation is minimal.

If all compressors are similar, the pressure setting can be adjusted such that only one compressor handles the load variation, whereas the others operate more or less at full load.

If compressors are of different sizes, the pressure switch should be set such that only the smallest compressor is allowed to modulate (vary in flow rate).

If different types of compressors are operated together, unload power consumptions are significant. The compressor with lowest no load power must be modulated.

In general, the compressor with lower part load power consumption should be modulated.

Compressors can be graded according to their specific energy consumption, at different pressures and energy efficient ones must be made to meet most of the demand.

11) Segregating Low And High Pressure Air Requirements: If the low-pressure air requirement is considerable, it is advisable to generate low pressure and high-pressure air separately, and feed to the respective sections instead of reducing the pressure through pressure reducing valves, which invariably waste energy.

12) Minimum Pressure Drop In Air Lines: Excess pressure drop due to inadequate pipe sizing, choked filter elements, improperly sized couplings and hoses represent energy wastage. *Typical acceptable pressure drop in industrial practice is 0.3 bar in mains header at the farthest point and 0.5 bar in distribution system.*

13) Blowers In Place Of Compressed Air System: Since the compressed air system is already available, plant engineer may be tempted to use compressed air to provide air for low-pressure applications such as agitation, pneumatic conveying or combustion air. Using a blower that is designed for lower pressure operation will cost only a fraction of compressed air generation energy and cost.

14) Capacity Control Of Compressors: In many installations, the use of air is intermittent. Therefore, some means of controlling the output flow from the compressor is necessary. The type of capacity control chosen has a direct impact on the compressor power consumption. Some control schemes commonly used are dis- cussed below:

a) *Automatic On / Off Control*: Automatic On /Off control, as its name implies, starts or stops the compressor by means of a pressure activated switch as the air demand varies. This is a very efficient method of control- ling the capacity of compressor, where the motor idle-running losses are eliminated, as it completely switches off the motor when the set pressure is reached. This control is suitable for small compressors.

b) *Load And Unload:* This is a two-step control where compressor is loaded when there is air demand and unloaded when there is no air demand. During unloading, a positive displacement compressor may consume up to 30 % of the full load power, depending upon the type, configuration, operation and maintenance practices.

c) *Multi-Step Control*: Large capacity reciprocating compressors are usually equipped with a multi-step control. In this type of control, unloading is accomplished in a series of steps, (0%, 25 %, 50 %, 75 % & 100 %) varying from full load down to no-load.

d) *Throttling Control*: The capacity of centrifugal compressors can be controlled using variable inlet guide vanes. However, another efficient way to match compressor output to meet varying load requirements is by speed control.

At low volumetric flow (below 40 %), vane control may result in lower power input com- pared to speed control due to low efficiency of the speed control system. For loads more than 40 %, speed control is recommended.

15)Avoiding Misuse Of Compressed Air: Misuse of compressed air for purposes like body cleaning, liquid agitation, floor cleaning, drying, equipment cooling and other similar uses must be discouraged. Wherever possible, low- pressure air from a blower should be substituted for compressed air, for example secondary air for combustion in a boiler / furnace.

IV. CONCLUSION

At the end, this paper concludes that there is vast potential of savings possible in various industrial applications of pumps and compressors through the implementation of recommendations given for appropriate application. It can be suggested that approximately 30% and 40% energy can be conserved in pumps and compressors respectively by reducing various losses occur during their operation. It is strongly recommended that pump should be operated near best efficiency point. Moreover, variable speed drive, two-speed motor and impeller trimming, are better option if pump is oversized. Variable speed drive is one of better choice if there is requirement to vary flow. It is also suggested to use particular type of pump for particular application otherwise it is advisable replace pump with other energy efficient pump.

It is found that compressed air system is one of the energy intensive utility in industries. The capacity of the compressor can be varied by methods such as automatic on/off control, loading/ unloading method, multi-step control and throttling control. Besides this, variable speed drive has been proven as one of the better option for controlling flow by reducing speed of the compressor. It is advisable to consider ambient condition, elevation, efficacy of inter coolers, after cooler and cooling water system at the time of location selection and designing of compressor. It is evident from the study that around 10 to 40% of energy could be saved by reducing discharge pressure and by setting up optimum pressure in the compressor.

REFERENCES

[1] P.Balachandra, Darshini Ravindranath, N.H.Ravindranath, “Energy efficiency in India:Assessing the policy regimes and their impacts”, Energy Policy, Article in press, 2010.
[2] K.AlQdah, “Potential opportunities for energy savings in a Jordanian poultry company”, Energy Conversion and Management, vol. 51, pp. 1651-1655, 2010.
[3] The World Bank (2015), “Total Population (in number of people)”. [Online], Available: http://data.worldbank.org/indicator/SP.POP.TOTL
[4] Central Intelligence Agency (2015), “The World Fact book: India: Energy”. [Online], Available: https://www.cia.gov/library/publications/the-world-factbook/geos/in.html
[5] Asian Development Bank, “Project Completion Report for Industrial Energy Efficiency Project-Loan 1343-IND”, Manila, 2001.
[6] International Energy Agency (IEA), “World Energy Outlook”, Paris, 2004.
[7] Ming Yang, “Energy efficiency policy impact in India: case study of investment in industrial energy efficiency”, Energy Policy, vol. 34, pp. 3104–3114, 2006.

[8] Rao, K. M., "Financing of energy efficiency investment: principal options for industrial investors", Promotion of Energy Efficiency in Industry and Financing of Investment, Published in http:// www.unescap.org/esd/energy/publications/finance/part2.html, 2004.

[9] Durmus Kaya, E. Alptekin Yagmur, K. Suleyman Yigit, Fatma Canka Kilic, A. Salih Eren, Cenk Celik, "Energy efficiency in pumps", Energy Conversion and Management, vol. 49, pp. 1662–1673, 2008.

[10] Erto¨z AO¨, Energy efficiency in pumps, In: 6th national installations engineering and congress, Istanbul; 2003.

[11] R. Saidur, N.A. Rahim, M. Hasanuzzaman, "A review on compressed-air energy use and energy savings", Renewable and Sustainable Energy Reviews, vol. 14, pp. 1135–1153, 2010.

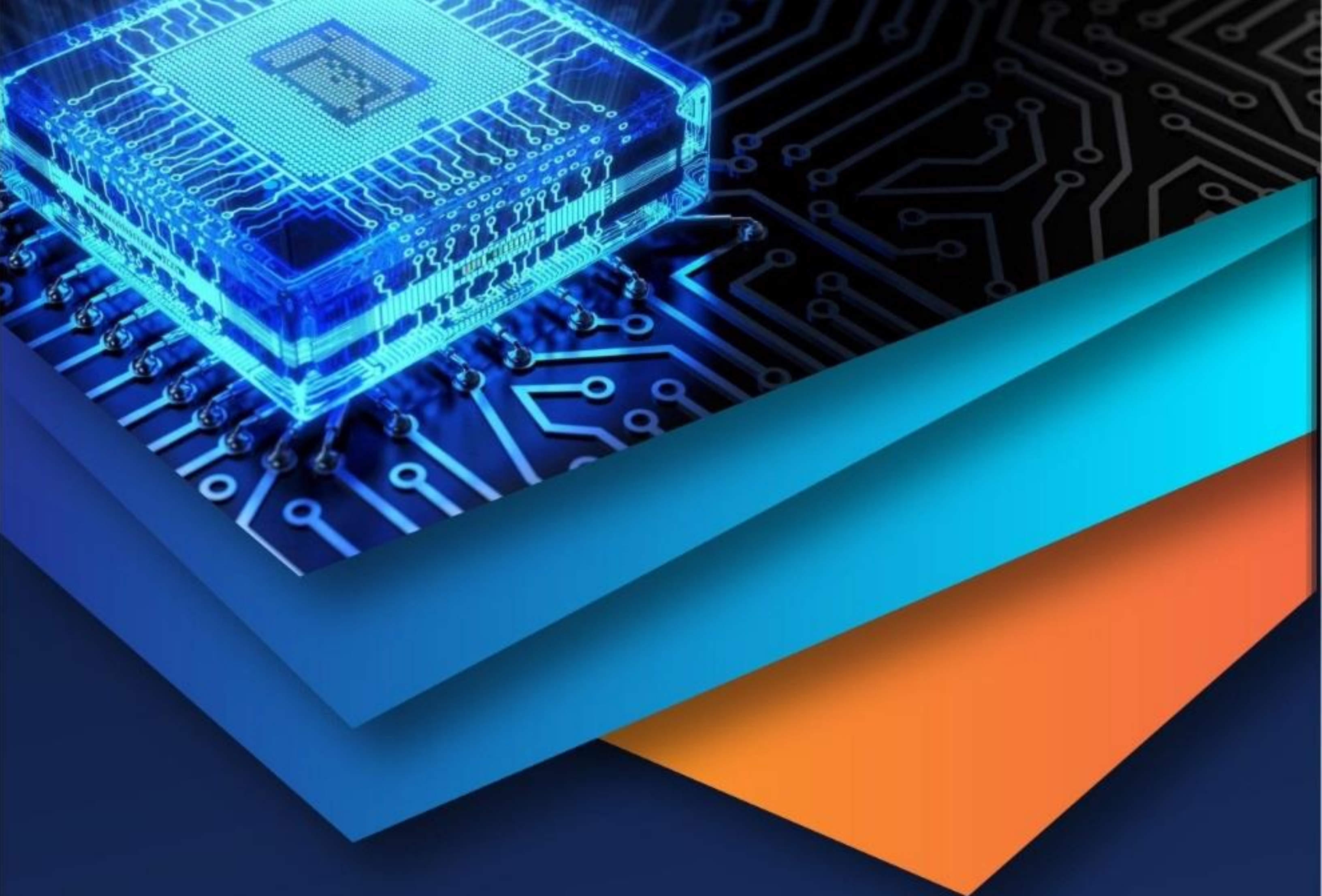
[12] Ryszard Dindorf, "Estimating Potential Energy Savings in Compressed Air Systems", Procedia Engineering, vol. 39, pp. 204 – 211, 2012.

[13] BEE, India. "Pumps and Pumping system", Ministry of Environment and Forests, Ministry of Power. Government of India, New Delhi, 2007.

[14] BEE, India. "Energy Performance Assessment of Water Pumps", Ministry of Environment and Forests, Ministry of Power. Government of India, New Delhi, 2007.

[15] BEE, India. "Compressed air system", Ministry of Environment and Forests, Ministry of Power. Government of India, New Delhi, 2007.

[16] BEE, India. "Energy Performance Assessment of Compressors, Ministry of Environment and Forests, Ministry of Power. Government of India, New Delhi, 2007.



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