

Energy Conservative Technologies



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Abstract:

In sugar industry or any process industry energy cost is one of the major components of the production cost. Production cost can be reduced by adopting the energy conservation technologies. This paper explains the efficient utilization of energy by installing energy efficient equipments like Variable frequency drives (VFDs), Thermo compressors, Energy efficient motors, Biogas, Diffuse, Cogeneration, HP boilers and Use of boiler's flue gases/exhaust in economizer

It briefly explains the principle, advantages of aforementioned technologies and compare their performance with that of conventional method but due to time constraints it is not possible to explain all these technologies. So we will discuss only first four technologies. This paper covers the basic function, principle, block diagram, pay back calculations recommendation for good application practices and tells how substantial amount of energy can be save using above mentioned technologies and all these things are elaborated through formulas, calculations and graphs.

Numerous benefits can be taken from above mentioned technologies, but only if the proper attention is given to selecting it correctly. That's why the importance of design is addressed. Concluding the work, application case study results are presented and discussed.

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Introduction

Background

In eighteenth century, most industrial plants generated their own electricity using different type of fuel. Many of the plants used exhaust steam for industrial purpose. But when different electrical power plants and national grids were constructed by government, many industries stopped producing electrical energy and started to purchase electricity from different electric supply companies. Factors that deprive the industry from energy conservative technologies were excessive electricity production and low fuel or energy cost.

Situation changes completely in nineteenth century when power demand crosses the supply limit. Fuel cost rises dramatically that causes the problem of energy crisis. So industries started to think about energy conservative technologies and they are moving towards complete self dependence. The technologies that are energy efficient have become very popular now due to high fuel cost and uncertainty of fuel supply. For these reasons, sugar industry in different developed countries are taking an active role in the increased use of energy conservative technologies.

Today Pakistan is facing the problem of energy crisis and the power supply shortfall of over six thousand mega watts may become worse because the gap between supply and demand is increasing day by day. Several studies and experience in different parts of the world shows that sugar industry is one of the best candidates that can help to overcome this shortfall and can make a measurable contribution to power supply. This report is designed for rapid introduction of energy conservative technologies in sugar industry.

The study in this report goes beyond the previous work in this area by specifying and evaluating the feasibility and pay back calculation. By using energy conservative technologies, sugar industry can produce power not only for its own purpose but also export power to surrounding areas.

Energy conservative technologies

With the advent of power electronics, thousands of new technologies has been invented that can save energy and efficiently utilize the energy. Some of them are given below

- 1) Variable frequency drive
- 2) Multiple motor drive
- 3) Energy efficient motor
- 4) Thermo compressor
- 5) Biogas plant
- 6) Diffuser
- 7) Cogeneration
- 8) Use of boiler's flue gases/exhaust in economizer
- 9) HP boiler

1. The variable frequency drive (VFD)

1.1 Introduction:

“Variable-Frequency Drive” (VFD) is a system for controlling the rotational speed of an AC electric motor by controlling the frequency of the electrical power supplied to the motor”.

The operating speed of a motor connected to a VFD is varied by changing the frequency of the motor supply voltage. There are some basic things that need to be pointed out about VFD's.

1.2 VFD Basics

1. The Hz or frequency of the power going into your motor will control the speed.
2. The voltage being applied to the motor will control the torque of motor

VFD can also be termed as

- ASD(Adjustable Speed Drive),
- VSD(Variable Speed Drive),
- AFD(Adjustable Frequency Drive),
- AC Drive
- Or most common name is **Inverter**.

1.2.1 Principle:

All electrical motors operate at 50Hz frequency. Speed of motor depends upon frequency of the supply. As frequency changes, speed of the motor also changes.

$$n = \frac{120 \times f}{P}$$

1.2.2 How Safe Electrical Energy:

VFD is an energy saving device that can save up to 30%

Power consumed by electrical motor is directly proportional to cube of speed of motor.

$$\text{Power} \propto \text{Speed}^3$$

If motor runs at 90% speed, power consumed will be only 73% (0.9^3)

If motor runs at 80% speed, power consumed will be only 51% (0.8^3)

1.3 Advantages of VFD

The advantages of VFD are

- No need of soft starter or star delta starter.
- Less electrical stress on motor winding

When VFD method is used it initially apply small voltage and frequency that avoids high inrush current that flows if full voltage is applied to motor. It gradually ramps up the voltage to the rated value in a controlled manner without any electric stress on the motor.

- Less mechanical stress on motor bearings

If the motor is driven with motor starter, motor is subjected to abrupt high voltage that causes high torque and high current surge that is 8 times the normal rating current. But if we use inverter it ramp up the voltage to desire level that causes smooth rise in torque and current. In this way motor is subjected to less mechanical

- Increases motor's service life
- No need of mechanical pulleys and gear to change the speed and torque of motor
- Reduces the maintenance by reducing mechanical components.
- VFD's save money on annual maintenance cost of motor.
- It improves power factor

The lower the power factor is on your utility bill, the more it is costing you to run any kind of motor. One of the benefits of using a VFD on any motor is improved power factor..

- Regenerative AC drives have the capacity to recover the braking energy of a load moving faster than the designated motor speed (an overhauling load) and return it to the power system.

Regeneration is only useful in variable-frequency drives where the value of the recovered energy is large compared to the extra cost of a regenerative system. An example would be conveyor belt, crane, where the hoist motor stops and reverses frequently.

- Inverter is environment friendly.

Burning fossil fuels produced carbon emission that is harmful to our environment. Global warming is the principal effect of excessive carbon dioxide in the atmosphere. Any methods such as VFD that could reduce energy consumption could also directly reduce the excessive carbon dioxide in the atmosphere.

- Reduce peak demand charges.

When motor pumps are activated, the power is literally “slammed” to the motor, and the motor that was peacefully at rest, is jolted into action. This abrupt start-up will cause a spike in power consumption which is registered by the power company on your “demand” meter. By using VFD, motor ramps up upon start up, and ramps down during shut-down and reduces peak demand charges.

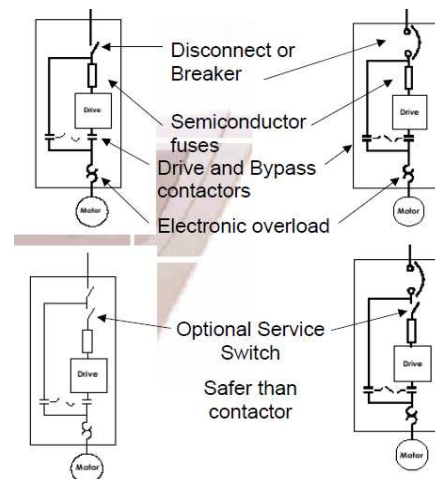
- The biggest advantage of it is saving up to 30% energy through its inherent nature.

The applications with the greatest amount of energy savings in industry are still centrifugal pumps and fans. Experience shows that premium efficiency motor can save energy up to 2-8%. However, the energy saved by VFD can exceed 30% based on several factors .

- Most VFD installations will pay for themselves quickly; normally payback will occur within 12-18 months.
- Removal Of Voltage Sags :
- Eliminates starting inrush current

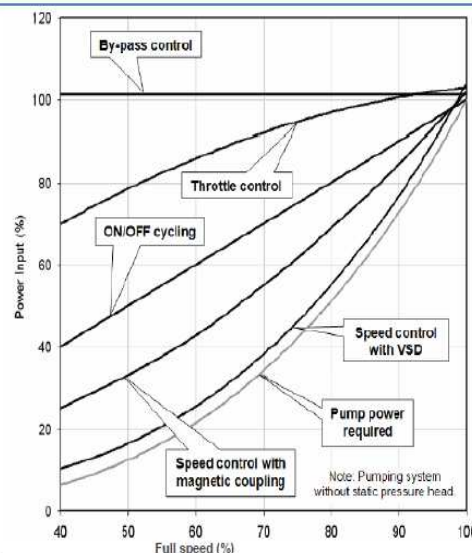
One major problem in sugar industry is that when a heavy motor such as cane cutter motor or feed water pump motor starts it takes high torque load that causes shut down or tripping in the power house. The reason is that motor initially draws high inrush current (torque load) that is 6 to 8 times higher than rated current that produces spike in power consumption. When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. Thus starting at such a low frequency avoids the high inrush current and eliminates unnecessary tripping

- Built In Motor Protection: Under voltage, overvoltage, over current protection, short circuit protection, over heating protection and motor stall protection is built in VFD.
- Bypass option: Bypass" is added to bypass the VFD and to run the motor on main power line to avoid the interruption if VFD get out of order or require maintenance
- Reduced audible noise
- Equipment Life Span Increased exponentially with speed reduction & soft start!
- Reduced wear on motors, belts, and other components.
- Optimize the power usage in response to actual load



VFD provides as much power as need. We assume a motor, driving a pump, directly connected to supply, always running at full speed. The process requirement may change and motor is not required to operate at full capacity. One possible solution is to use throttling valve where opening and closing a valve controls the flow but motor is still running at full power, this is the wastage of power and increases maintenance cost. It is just like that you are driving your car with brakes on. The use of VFD is the optimal and most energy efficient control method. That provides that only energy which is required by the driven mechanical load.

Figure 24: Energy savings with speed control for a centrifugal pump without static pressure head



Source: Ferreira, 2009.

Comparison of Different Speed Controlling Methods

1.4 Disadvantage of damper:

Flow generating equipments like fan, pumps and compressor are often used without the control of motor speed. Instead, flow is traditionally controlled by throttling with a valve or damper. If the valve restriction method is used to control the flow rate or flow rate is controlled by discharge throttle valve or through dampers there is a lot of energy wastage. It is just like that you are driving your car with brakes on. VFD harnesses that energy by matching the speed of motor with flow rate.

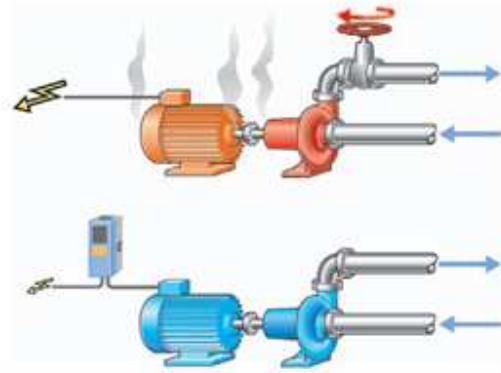


Fig. 1: The principle of energy saving with VFD speed control.

1.5 How VFD reduce electric consumption

Formula for Affinity Law of centrifugal loads is

$$\frac{P_2}{P_1} = \left(\frac{n_2}{n_1} \right)^3$$

Where P= power and n= speed.

In centrifugal pumps, energy consumption is proportional to the cube of the flow rate. The reduction of speed of motors used in centrifugal applications has corresponding power reduction as described in the relation that the power is directly proportional to the cube of the shaft speed. This scientific law is commonly known as **law of affinity**.

1.6 Affinity Laws:

The **affinity laws** are used in hydraulics and HVAC to express the relationship between variables involved in pump or fan performance (such as head, volumetric flow rate, shaft speed) and power. They apply to pumps, fans, and hydraulic turbines.

Law 1. With impeller diameter (D) held constant:

Law 1a. Flow is proportional to shaft speed.

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2} \right)$$

Law 1b. Pressure or Head is proportional to the square of shaft speed:

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2} \right)^2$$

Law 1c. Power is proportional to the cube of shaft speed:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2} \right)^3$$

Where

- Q is the volumetric flow rate (e.g. CFM, GPM or L/s),
- D is the impeller diameter (e.g. in or mm),
- N is the shaft rotational speed (e.g. rpm),
- H is the pressure or head developed by the fan/pump (e.g. ft or m), and
- P is the shaft power (e.g. W).

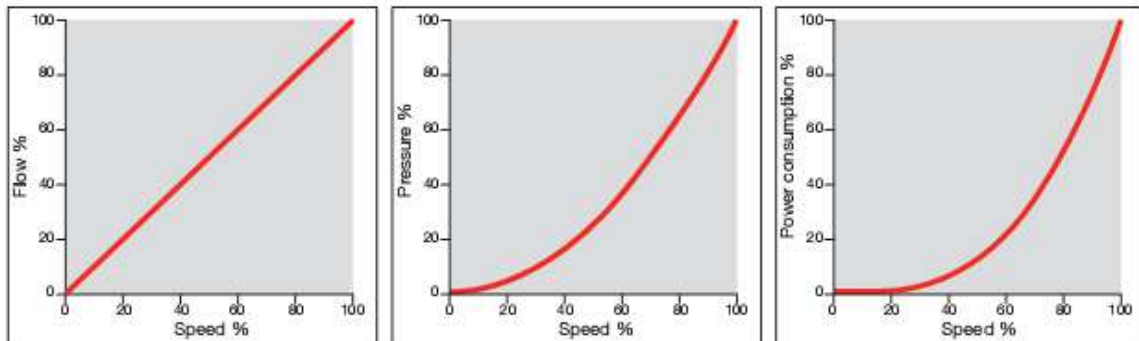


Fig. 2: Affinity laws express relationship between rotational speed and other variables.

1.7 How great are the savings?

A motor running at 50% of full speed capacity has a motor torque of 25% of full speed. In addition, electricity required to operate the motor at 50% of full speed is 12.5% of the amount of electricity required if the motor was running at 100% full speed capacity. Thus, reducing motor speed can significantly reduce the electrical energy consumption

1.8 How it reduces current?

As we know the power of three phase motor is given as

$$P = \sqrt{3} V_L I \cos \theta$$

Let suppose we have motor with following characteristics

Power = 100 hp

Speed = 1,785 rpm

Voltage = 460 V

Full load current = 115 A

Power factor = 0.86

“A VFD will convert its incoming power, a fixed voltage and frequency, to a variable voltage and frequency.”

Suppose that motor is operating at half of the rated speed producing full load torque and drawing full load current. Frequency has to be half (30Hz). In order to keep the V/F ratio constant the voltage will also be half (230V) so frequency and voltage at the output of VFD is 30HZ and 230V respectively. So the power at the output will be

$$P_{OUT} = \sqrt{3} \times 230 \times 115 \times 0.86 = 39.4KW$$

For ideal VFD device

$$P_{IN} = P_{OUT} = 39.4KW$$

$$V_{IN} = 460V$$

$$\text{Power factor}_{IN} = 0.89$$

$$P_{IN} = \sqrt{3} \times 460 \times I_{IN} \times 0.89 = 39.4KW$$

$$I_{IN} = \frac{39.4 \times 1000}{\sqrt{3} \times 460 \times 0.89} = 55.5$$

Note that the input current is now less than half of the rated current.

Suppose that motor is operating at rated speed then

F=60Hz

V=460V

P.F=0.86

So power at the output will be

$$P_{OUT} = \sqrt{3} \times 460 \times 115 \times 0.86 = 78797.9W$$

$$P_{IN} = P_{OUT} = 78.797KW$$

$$V_{IN} = 460V$$

$$\text{Power factor}_{IN} = 0.89$$

$$P_{IN} = \sqrt{3} \times 460 \times I_{IN} \times 0.89 = 78.797KW$$

So

$$I_{IN} = \frac{78797.9}{\sqrt{3} \times 460 \times 0.89} = 111.12A$$

This is lower than rated current by 4A. Difference in power factor makes it possible to have high output current.

Side	Power (kW)	Voltage (V)	Current (A)	Frequency (Hz)	Power Factor
Input	39.4	460	115	60	0.89
Output at half speed	39.4	230	55.6	30	0.86
Output at half speed	39.4	460	111.12	60	0.86

Note

- By VFD we can improve P.F
- Difference in current is more when motor is operating at half or lower then rated speed
- There is a little difference when operating at full speed so before choosing inverter for a particular application, we have to check that either it will be suitable for that particular application or not.

1.9 Selection of VFD

Variable frequency drive is an electrical device that can be used to reduce speed of an induction motor from rated speed down to zero speed. Since this equipment is relatively expensive therefore a well trained engineers in this field should be consulted in selecting the type of VFD to be used in a particular installation. Improper selection of VFD may result into undesirable result and could damage other equipments in the vicinity. When looking to apply VFD control to an existing pump, a basic overview of the application should be investigated. The motor drives that do not require to operate at full speed can save energy by using adjustable speed drive energy. Cost saving will be

more with variable torque. If motor operate at constant speed, there will be limited save in energy (may be only 5%).

1.10 Where VFD can be used

Feeder table	Primary cane carrier
Clear and raw juice pump	Cane cutter motor
ID, FD, Secondary Fans of boiler	Sugar elevator
Feed water pump	Hot and cold air blowers
A centrifugal drive	Mill house motors

1.11 Disadvantages of VFD:

- If motor has to run at lower speed, some cooling method must be used other wise overheating of the winding may occur.
- Since the transmission-line impedance of the cable and motor are different, pulses tend to reflect back from the motor terminals into the cable. The resulting voltages can produce up to twice the rated line voltage for long cable runs, putting high stress on the cable and motor winding and eventual insulation failure. Increasing the cable or motor size/type for long runs and using 480V or 600V motors instead of 230V will help offset the stresses imposed upon the equipment due to the VFD.
- Motors and VFDs must be compatible.
- The high frequency current ripple in the motor cables may also cause interference with other cabling in the building. This is another reason to use a motor cable designed for VSDs that has a symmetrical three-phase structure and good shielding. Furthermore, it is highly recommended to route the motor cables as far away from signal cables as possible.
- VFD is expensive equipments.
- VFD are complex
- Experienced, trained and qualified personnel are required for its maintenance.

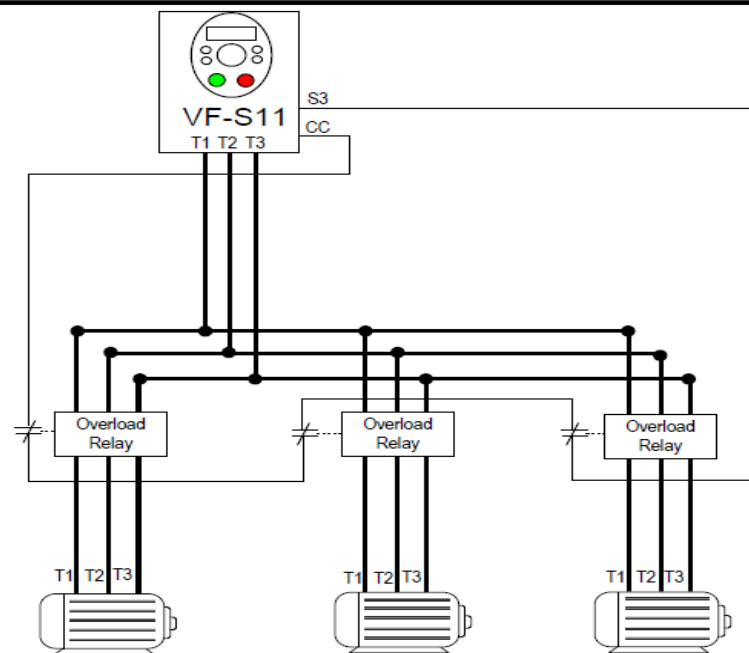
1.12 Our Practical Experience:

In Ramzan sugar, we have implemented VFDs on feed table and ID, FD and Secondary motors of boilers. We avail many tangible advantages such as:

- Load on boiler has reduced by 30%
- It has reduced the maintenance of feed table motor that previously requires lot of maintenance due to frequently stop and start that usually damaged their bearing and motor insulation.
- VFD has reduced the steam consumption.

- It removed the torque load of ID, FD and secondary motors that causes unnecessary tripping and unbudgeted repair cost.

2. Multiple Motor Drive:



Multiple Motor Running With One VFD

One VFD can be used to run multiple motors running parallel at same desired speed at same time.

2.1 Where it is used?

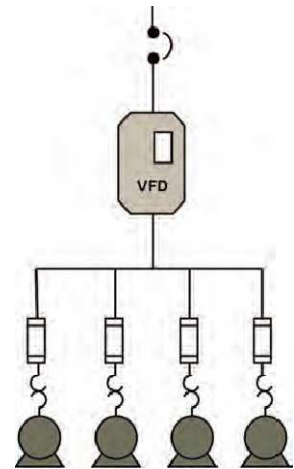
Applications that use dual pump or fans are good candidate of multiple motor drive. Multiple motor drive can also be used in overhead traveling cranes where two drive wheel motors must run at the same speed. In addition to it Exhaust supply fans or array of fans can also be drive by one VFD.

2.2 Design constrains.

There are some design constrain that must be considered and special attention must be given while selecting multiple motor drive for a particular application.som design constrain are explained below

- All motors must be of same rating i.e power rating of the motor, rated speed of motor and voltage must be same because all motors are connected to the same VFD

- Provide overload protection to each motor individually.
VFD can not sense the current of each motor separately; it can sense only total current drawn by all motors. VFD does not know which motor is drawing more current. So it can not provide overload, over current or short circuit protection to each motor that's why it is imperative to apply over load protection to each motor separately.
- With individual motor protection, only the motor that faults is disconnected, and the remaining motors continue to run. This is a must in applications that can't afford to have the entire system shut down while a single motor is repaired or replaced.
- Current rating of VFD must be equal to or more than the sum of all motor current ratings i.e.



Current rating of VFD = $n \times \text{Motor Current Rating}$
Where n is the number of motors running parallel

This formula is valid only if you start all motors at same time. If motor are not required to run simultaneously, you must increase the rating of VFD as explained in example given below.

- Total motor lead length must be less than the critical length as specified by the manufacturer.
- Auxiliary contacts on the overload relay should be in series including the emergency stop button.
- To minimize the size of VFD all motors must be started at same time. One of more motors can not be started while one or more motors are already running unless VFD is sufficiently oversized.

2.2.1 EXAMPLE:

Suppose we have 3 motors of rating

5 HP with an FLA 6.2A, 460 volts AC

5 HP with an FLA 6.2A, 460 volts AC

10 HP with an FLA 14A, LRA = 86.5, 460 volts AC

If all motors are accelerated, decelerated and run in unison, the sum of the connected motor FLA allows use of a 20 HP drive. If it were necessary to accelerate and run the 5 HP motors and then start the 10 HP, the sum of the FLA must be recalculated. The FLA figures of 5 HP motors would be used, but the Locked Rotor Amps (LRA) for the 10 HP must be used. As this motor would not be accelerated from zero frequency and voltage to its running condition, it would require its full LRA rating to accelerate to drive's output frequency. This effect on sizing is shown below:

$$6.2 + 6.2 + 86.5 = 98.9 \text{ AMPS}$$

In this example, a 75 HP drive with 112 Amp continuous rating would be required.

2.3 Advantages of multiple motor drive :

- Saves money
 - Reduces maintenance time and cost
 - It requires less space
 - Reduces control system complexity
 - One big VFD produces less heat as compared to multiple smaller units.
 - The overall system becomes much simpler, instead of connecting many VFDs to the main controller, usually a PLC, and synchronizing their operation, only one VFD speed control loop is needed.
 - If one motor fails, it is possible to continue the operation with rest of the motors
- All above advantages justify the use of multiple motor drive.

2.4 Case Study:

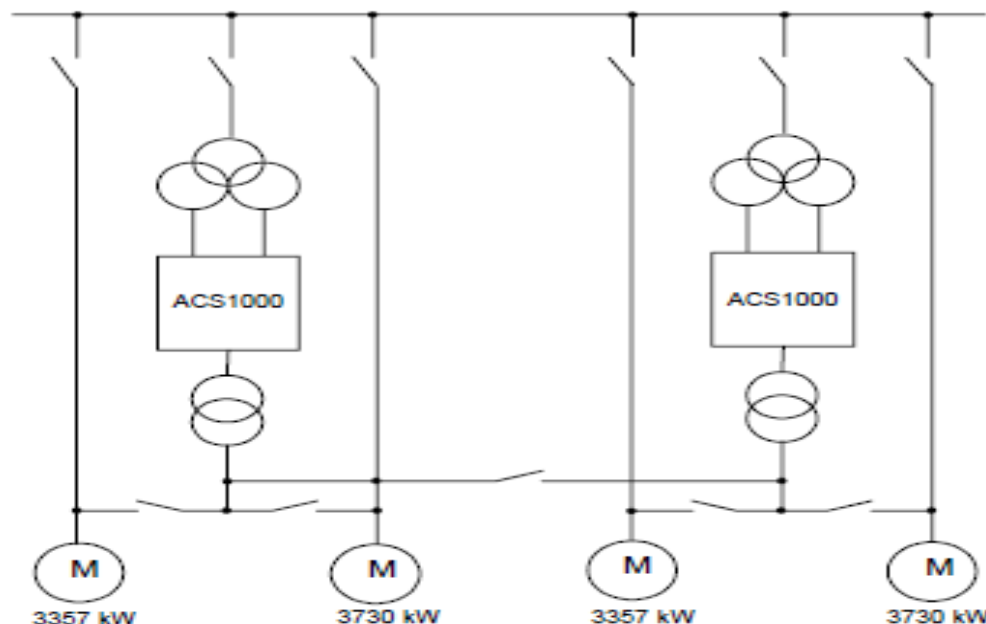
2.4.1 VFD as Soft start for mechanical vapor compressor :

AL-Khaleej sugar in Dubai, UAE has been using VFD for mechanical vapor compressor. The installation of mechanical vapor compressor to reuse waste vapor is the latest ongoing innovation project at AL –Khaleej sugar. Two air cooled ACS 1000 MV-VFD are used as soft starting device to avoid high inrush current and voltage dips during motor start. Operation is completed in following steps:

Step 1: Motor is smoothly accelerated with VFD from standstill up to nominal speed.

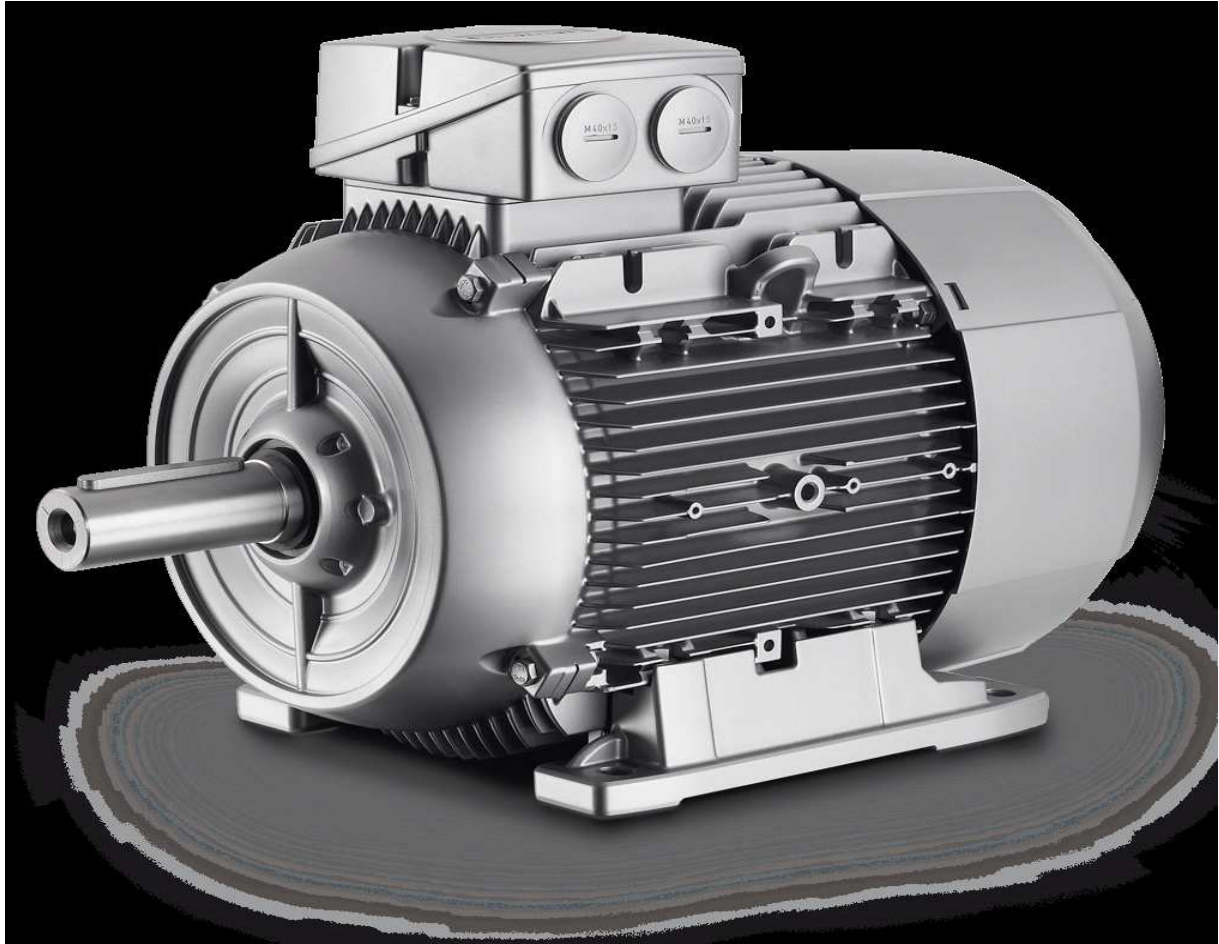
Step 2: Motor is synchronized with supply network.

Step 3: Motor is then transferred to grid or main supply



VFD Installed at AL-Khaleej sugar industry for mechanical Vapor compressor

3. Energy Efficient Motors



3.1 Introduction:

The problem of energy crisis can be reduced by two ways. One way is to increase the capacity which is not possible due to limited fuel resources and second ways is to efficiently utilize the existing energy sources by the use of energy efficient technologies that will automatically increase the power capacity.

Electrical motor consumes 70% of the total electricity produced in industry. Motors are the largest consumer of electricity in industry so even a small efficiency improvement can lead to very large saving. EEM is a specially designed motor having high efficiency as compared to standard efficiency motor and losses are negligible. EEM have following characteristics:

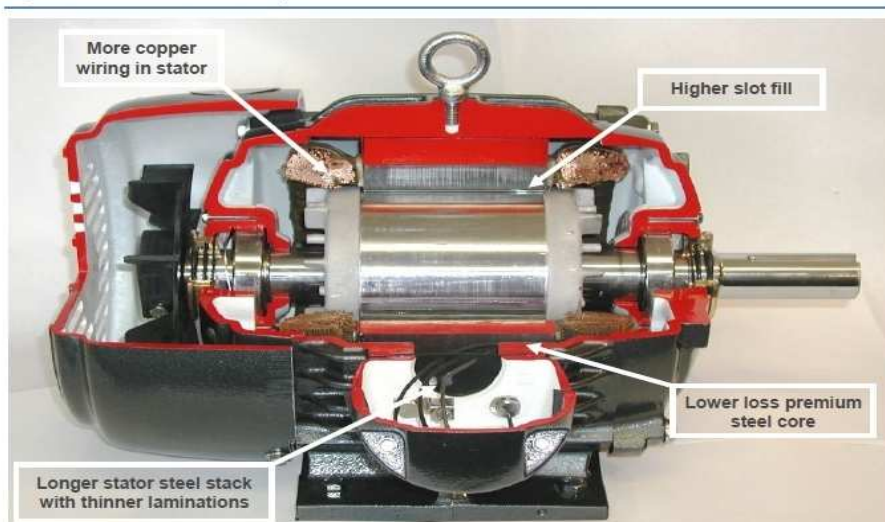
- High Efficiency
- Low Losses
- Continuous Duty
- Enclosure Protection IP55

- Insulation Class F(155°C)
- Temperature Class B (105°C)

3.2 Characteristics of Energy Efficient Motor

In energy efficient motors different changes has been made that increases its efficiency. Bars on the rotor are made of copper instead of aluminum that reduces I^2R . High quality steel core is used that reduces hysteresis losses. Core is made up of thin laminated sheet that reduces the eddy losses. Thicker conductors and more copper contents are used that reduce copper loss due to lower resistance. Longer core length, reduced and uniform air gap between stator and rotor reduces the stray losses.

Figure 16: IE3 Premium-Efficiency motor



Source: Emerson. Reproduced with permission from US Motors/Emerson.

3.2.1 Losses in Induction Motor

Different losses in motor and their percentage are given below

Typical losses in an AC induction motor

	Typical losses in 4-pole motors	Factors affecting these losses
Stator losses	30 - 50%	Stator conductor size and material
Rotor losses	20 - 25%	Rotor conductor size and material
Core losses	20 - 25%	Type and quantity of magnetic material
Additional load losses	5 - 15%	Primarily manufacturing and design methods
Friction and windage	5 - 10%	Selection/design of fan and bearings

Abbreviation: AC = alternating-current.

Source: IEC 60034-31, draft 2009.

3.3 Motor initial cost:

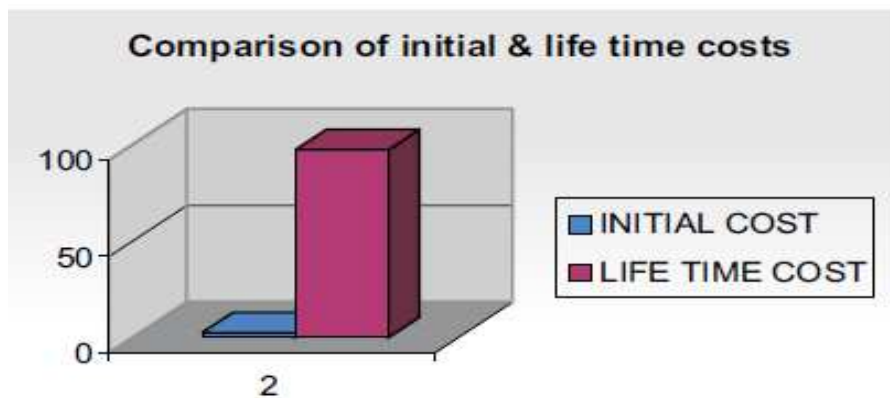
Despite being slightly more costly to purchase than standard motors, higher-efficiency motors (HEMs) with over 1 000 hours of operation per year are more cost-effective over

the system life for end-users in all applications because motor initial cost is only 8% of whole life cycle cost.

For Example:

If we have a 30HP motor then:

- Initial Purchase price = Rs. 80,000
- Operating hour = $24 \times 120 \times 15 \text{ hr} = 43200 \text{ hr}$
- KWH = $43200 \times 0.746 \times 30 = 966816 \text{ KWH}$
- Running Cost = $966816 \times 10 = \text{Rs. } 9,668,160$



3.4 Motor Efficiency Classes In Different Countries:

Keeping in view the shortage of fuel, many develop countries are moving towards energy efficient motors. They have made some standards that motor must fulfill otherwise not allowed to operate in the country New energy efficiency laws are being drawn up in many countries to protect our environment. Different efficiency standards are given below

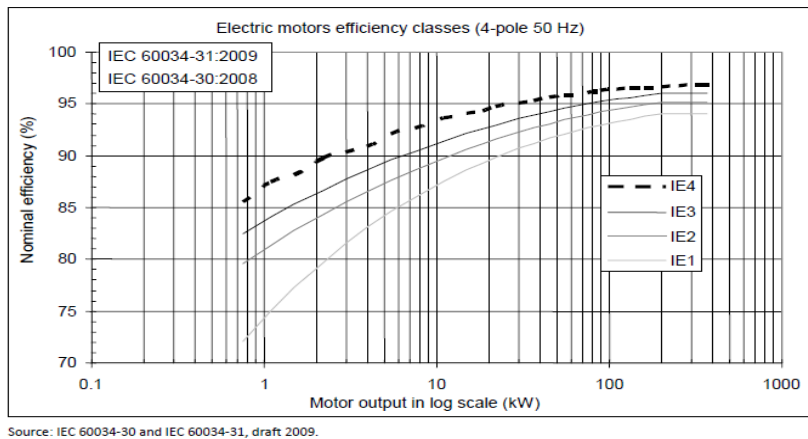
Motor efficiency classes in different countries and the corresponding international standard

Motor efficiency class	International	United States	European Union (old system 1998 ¹)	European Union (new system 2009)	China	Australia
Premium	IE3	NEMA Premium	–	IE3	–	–
High	IE2	EPAct	Eff1	IE2	Grade 1 (under consideration)	AU2006 MEPS
Standard	IE1	–	Eff2	IE1	Grade 2	AU2002 MEPS
Below standard	IE0 (used only in this paper)	–	Eff3	–	Grade 3 (current minimum)	–

Abbreviations: EPAct – US Energy Policy Act, 1992; MEPS – minimum energy performance standard;

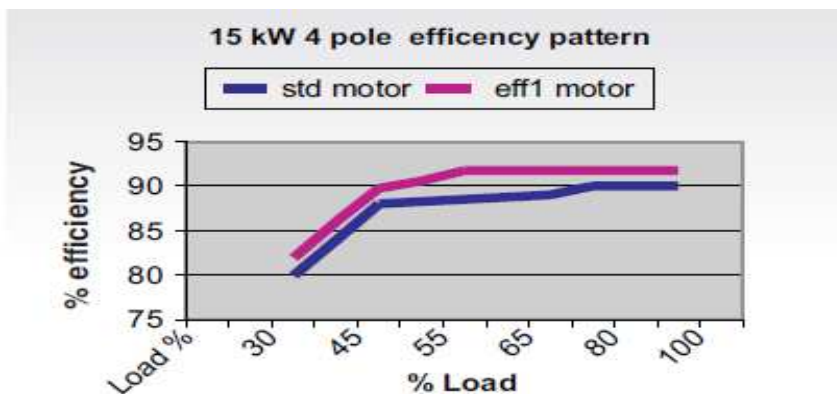
3.5 International Efficiency Standards

- There are different efficiency standards. International standard of efficiency are as follow
- IE1 (standard efficiency)
- IE2 (high efficiency)
- IE3 (premium efficiency)
- IE4 (super premium efficiency)



IEA (international energy agency) pass laws to set compulsory energy efficiency standard to protect environment and allow us to reduce operating cost.

3.6 Comparison of Standard and Energy Efficient Motor



The following chart shows that different countries have made it compulsory for every motor to fulfill the efficiency class standard. Even india is thinking about it.

Country		Voltage/ Frequency	Power range	No. of Poles	Law / Regulation	Regulation of Minimum efficiency
Europe		400 V +/-10 %; 50 Hz	0.75 kW– 375 kW	2–6	EC No. 640/2009	IE2 compulsory 16.06.2011
Russland		up to 690 V +/-10 %; 50 Hz	1 kW– 400 kW	all	GOST R 51677-2000	No
Switzerland		400 V +/-10 %; 50 Hz	0.75 kW– 375 kW	2–6	EnV	IE2 compulsory 01.07.2011
Turkey		400 V +/-10 %; 50 Hz	0.75 kW– 375 kW	2–6	EC No. 640/2009	IE1
USA		480 V +/-10 %; 60 Hz	1 HP– 200 HP	2–6	Nema EAct EISA 2007	IE3 compulsory 19.12.2010
Canada		480 V/575 V +/-10 %; 60 Hz	1 HP– 200 HP	2–6	CSA C390	IE3 compulsory 01.01.2011
Mexico		460 V +/-10 %; 60 Hz	1 HP– 200 HP	2–6	Nema EAct EISA 2007	IE3 expected
Brazil		220 V/380 V/ 440 V/460 V/480 V +/-10 %; 60 Hz	0.75 kW– 250 kW	2–8	NBR 17094-1 Regulation 553	IE2 compulsory 08.12.2009
Chile		380 V/400 V/420 V/ 440 V/460 V/690 V +/-10 %; 50 Hz	0,75 kW– 7.5 kW	2–6	NCH 3086	IE2 compulsory 04.01.2011
China		380 V +/-10 %; 50 Hz	0.55 kW– 315 kW	2–6	GB 18613-2006	IE2 compulsory 01.07.2011
Hong Kong		380 V +/-10 %; 50 Hz	0.75 kW– 375 kW	2–6	Mandatory Buildings Energy Efficiency Bill	IE2 Introduction stage since Dec 2009
India		415 V/690 V +/-10 %; 50 Hz	0.37 kW– 315 kW	2–8	IS:4889/ IS:12615-2004	IE2 expected 2013
Israel		400 V +/-10 %; 50 Hz	0.75 kW– 185 kW	2–8	SI 5289	IE2 compulsory 01.02.2008
Japan		200/220/400/440 +/-10 %; 50/60 Hz	0.2 kW– 160 kW	2–6	JIS C 4210 JIS C 4212	IE2 expected
Korea		Up to 600 V +/-10 %; 60 Hz	0.75 kW– 200 kW	2–6	KS C 4202	IE2 compulsory 01.07.2008

The following chart gives the efficiency of different motors according to their power and number of poles

Table 32: Nominal minimum efficiencies (η) for electric motors in Europe (50 Hz)

Rated output power (kW)	Number of poles					
	IE2 efficiency level ¹			IE3 efficiency level ²		
	2 poles	4 poles	6 poles	2 poles	4 poles	6 poles
0.75	77.4	79.6	75.9	80.7	82.5	78.9
1.1	79.6	81.4	78.1	82.7	84.1	81.0
1.5	81.3	82.8	79.8	84.2	85.3	82.5
2.2	83.2	84.3	81.8	85.9	86.7	84.3
3.0	84.6	85.5	83.3	87.1	87.7	85.6
4.0	85.8	86.6	84.6	88.1	88.6	86.8
5.5	87.0	87.7	86.0	89.2	89.6	88.0
7.5	88.1	88.7	87.2	90.1	90.4	89.1
11.0	89.4	89.8	88.7	91.2	91.4	90.3
15.0	90.3	90.6	89.7	91.9	92.1	91.2
18.5	90.9	91.2	90.4	92.4	92.6	91.7
22.0	91.3	91.6	90.9	92.7	93.0	92.2
30.0	92.0	92.3	91.7	93.3	93.6	92.9
37.0	92.5	92.7	92.2	93.7	93.9	93.3
45.0	92.9	93.1	92.7	94.0	94.2	93.7
55.0	93.2	93.5	93.1	94.3	94.6	94.1
75.0	93.8	94.0	93.7	94.7	95.0	94.6
90.0	94.1	94.2	94.0	95.0	95.2	94.9
110.0	94.3	94.5	94.3	95.2	95.4	95.1
132.0	94.6	94.7	94.6	95.4	95.6	95.4
160.0	94.8	94.9	94.8	95.6	95.8	95.6
200 - 375	95.0	95.1	95.0	95.8	96.0	95.8

3.7 Advantages of Energy Efficient Motor

- Saves energy and money
- Short pay back period
- Substantial saving after pay back period
- Reduces pollution
- Enhance motor life
- Increases the plant capacity
- High power factor
- Low noise and vibration

3.8 Energy Saving and Payback Calculation

Let's suppose we have 30HP motor with following data:

- Motor power = 30HP
- Cost of energy efficient motor = Rs 60,000
- efficiency of old standard motor = 83%
- Efficiency of energy efficient motor = 93%
- No of operating hours = 24 x 120 = 2880 hr
- Tariff Rate = C = Rs.10/KWH
- Load factor = L = 0.75

$$\begin{aligned} KWH_{Saving} &= HP \times 0.746 \times L \times \text{working hours} \times \left[\frac{100}{E_{std}} - \frac{100}{E_{EEM}} \right] \\ KWH_{Saving} &= 30 \times 0.746 \times 0.75 \times 2880 \times \left[\frac{100}{83} - \frac{100}{93} \right] \\ &= 6275/\text{Year} \end{aligned}$$

$$\begin{aligned} \text{➤ Savings} &= KWH_{Saving} \times \text{Tariff Rate} \\ &= 6275 \times 10 \\ &= \text{Rs. } 62,750/\text{Year} \end{aligned}$$

Pay Back Period = Investment/Saving

$$\begin{aligned} &= 60,000/62,750 \\ &= 0.95 \text{ Year} = 11 \text{ Month} \end{aligned}$$

3.9 Misconception about Motor

Major losses occur in motor due to mismatch between load and motor. There is misconception about motor that Oversized motor works efficiently! Which is wrong. Peak efficiency of the motor occurs between 75% to 100% load. Below 50% load, efficiency decreases rapidly and P.F decreases sharply below 75% load. So you must replace the oversized motor with proper sized motor.

3.9.1 Comparison of Efficiency at Full Load and at Partial Load.

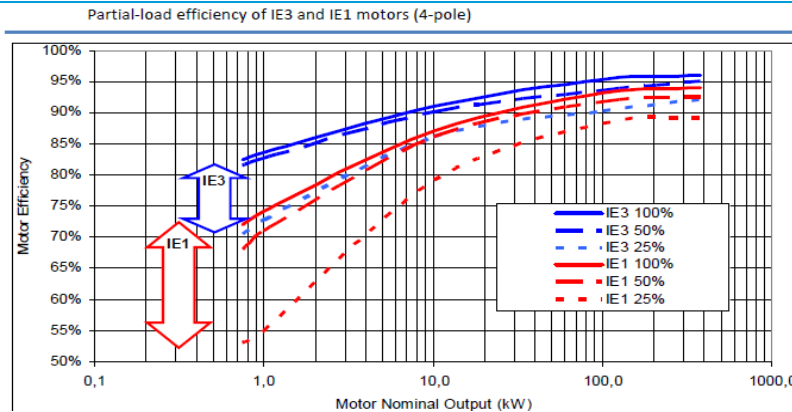
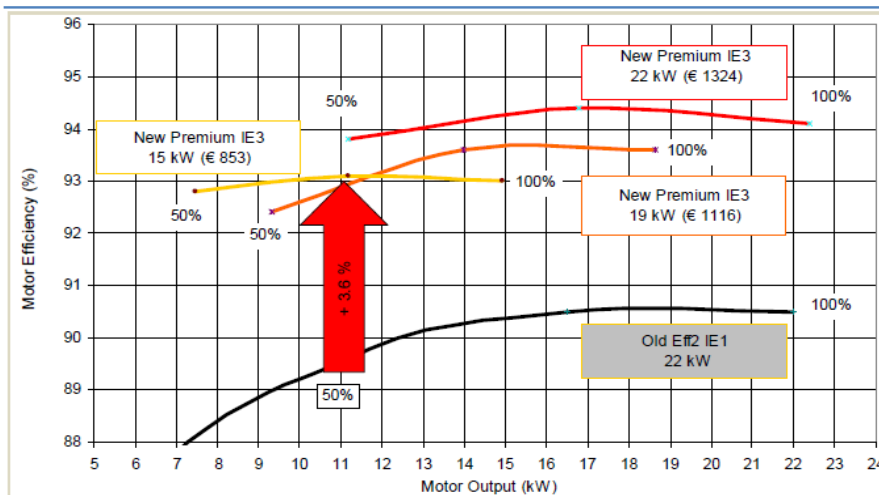


Figure 38: Example of how downsizing can pay for a more-efficient motor



Source: A+B International, 2007.

Comparison of Oversize and Proper Size Motor

3.10 Make the Motor System Efficient instead of Only Motor.

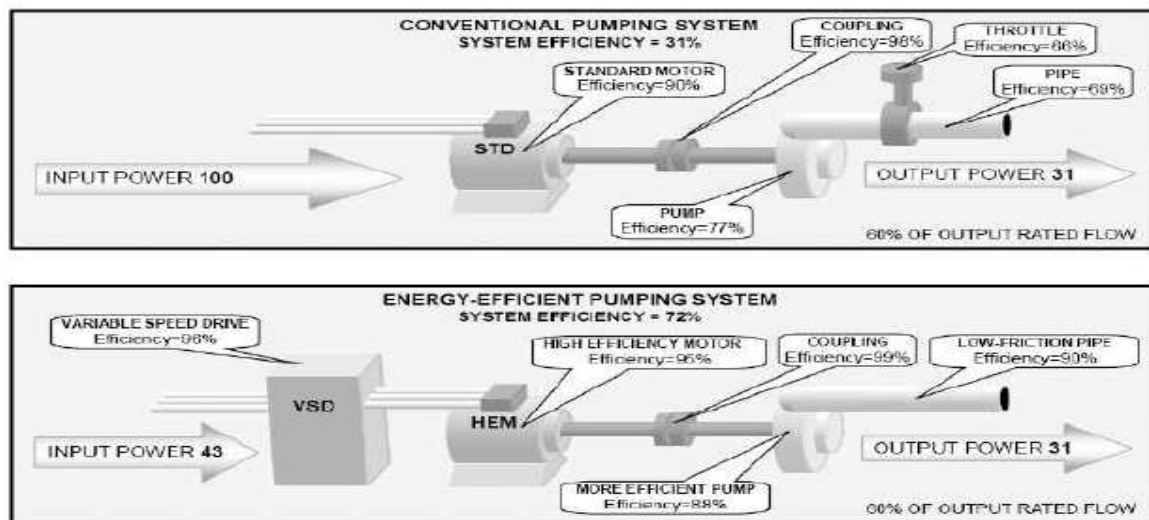
The three major routes to achieving these savings are:

- Use of properly sized and energy-efficient motors.
- Use of adjustable-speed drives (ASDs)², where appropriate, to match motor speed and torque to the system mechanical load requirements. This makes it possible to replace inefficient throttling devices and, in some cases with “direct-drive”, to avoid wasteful mechanical transmissions and gears.
- Optimization of the complete system, including correctly sized motor, pipes and ducts, efficient gears and transmissions, and efficient end-use equipment (fans, pumps, compressors, traction, and industrial handling and processing systems) to deliver the required energy service with minimal energy losses.

Motor System includes Electric motor, VFD, Cooling fan, Gear, Transmission belt.

Some energy losses occur in motor itself but energy losses are greater in rest of mechanical system to which motor is coupled.

3.10.1 Motor System



Source: De Keulenaer H. et al. 2004

10-year-old motor



Note that the efficiency of all components are multiplied together to find the system efficiency.

Brand new, premium-efficient motor



Note although you have improved the efficiency of motor but still system efficiency is very low due to low efficiency gear system that are still wasting energy. To improve system efficiency you must improve the efficiency of each component involved



So by improving the efficiency of each component, you can make the motor system more efficient.

3.11 What are the barriers?

- Lack of awareness Lack of awareness among motor purchasers of the potential for energy and cost savings by using more efficient motors within energy-efficient EMDS. When a new and higher motor-efficiency class is introduced, it diffuses slowly into the national market.
- Limited knowledge of energy efficiency options
- High initial cost
- Short time thinking
- International trade barriers

3.12 When I should consider buying an energy efficient motor?

- For all new installation
- When major modifications are required
- Instead of rewinding old standard efficiency motor
- To replace oversized and undersized motor

3.13 Either I should rewind a failed motor?

Although failed motors can usually be rewound, it is often worthwhile to replace a damaged motor with a new energy-efficient model to save energy and improve reliability. When calculating operating costs for rewind motors, deduct one efficiency point for motors exceeding 40 hp and two points for smaller motors. Motors should be rewound only at reliable repair shops that use low temperature (under 700°F) bake out ovens, high quality materials, and a quality assurance program. Ask the repair shop to conduct a core loss or loop test as part of their rewind procedures.

Different problems that occur during rewinding are

- If winding wire is of smaller diameter, increases I^2R losses
- Decrease in turn in stator winding reduces winding resistance so
 - Increases stator current
 - Increases the magnetic field
 - Increases starting current by 23%
- During rewinding due to overheating stator insulation damages that increases the core losses

So rewind only if you have qualified rewinding shop

4. Thermocompressor

4.1 Back ground



Steam is a common source of heat in sugar industry. Therefore it is imperative that sugar industry focus on steam utilization and take action to minimize or optimize the use of steam. One way is to maximize the use of LP steam. The sugar industry has many processes and system that uses both live and exhaust steam. Some of the systems that are live steam user can be totally or partially replace with exhaust steam.

One such live steam user in a sugar mill is adjoining distillery but most of the sugar industry reduces the pressure of live steam through pressure reducing valve, for use in distillery which is highly inefficient method. If somehow we are able to use exhaust steam in distillery, there will be a great saving of energy. One such method of reducing the use of live steam is the use of Thermocompressor. Thermocompressor increases the pressure and temperature of LP steam by mixing it with HP steam through the principle of energy conversion. The resultant LP steam can be used in any other process such as distillery. This modification can result in minimizing the use of MP steam consumption by effectively utilizing the heat or energy of exhaust steam.

4.2 Case study

A 4000TCD sugar industry in india (Maharashtra) uses a back pressure turbine that produces exhaust of at rate 6300Kg/h at 0.4 Kg/cm^2 . there was no processes in sugar industry that could utilize this exhaust steam of 0.4 Kg/cm^2 the distillery required 10TPH steam at 1.5 Kg/cm^2 this requirement could be met either by a new boiler or by reducing the live steam pressure through pressure reducing valve which is not a good system.

The turbines exhaust steam, instead of vented out into atmosphere, could be converted into MP steam through Thermocompressor and used to meet the steam requirement of distillery. Thermocompressor was installed that increases the pressure and temperature

of exhaust steam and the resultant LP steam saved is given to steam turbine that produces additional power

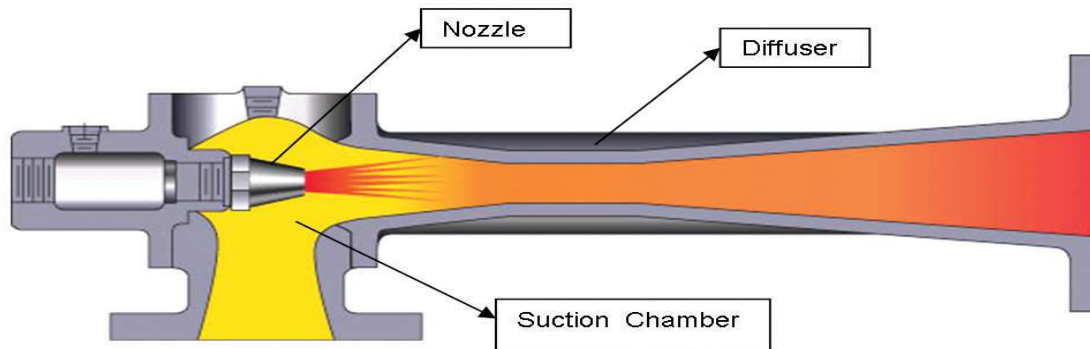
4.2.1 Implementation and methodology

Motive steam	3700 Kg/h at 20 Kg/cm ²
Suction steam	6300 Kg/h at 0.4 Kg/cm ²
Discharge steam	10000 Kg/h at 1.5 Kg/cm ²

4.3 Construction of Thermocompressor

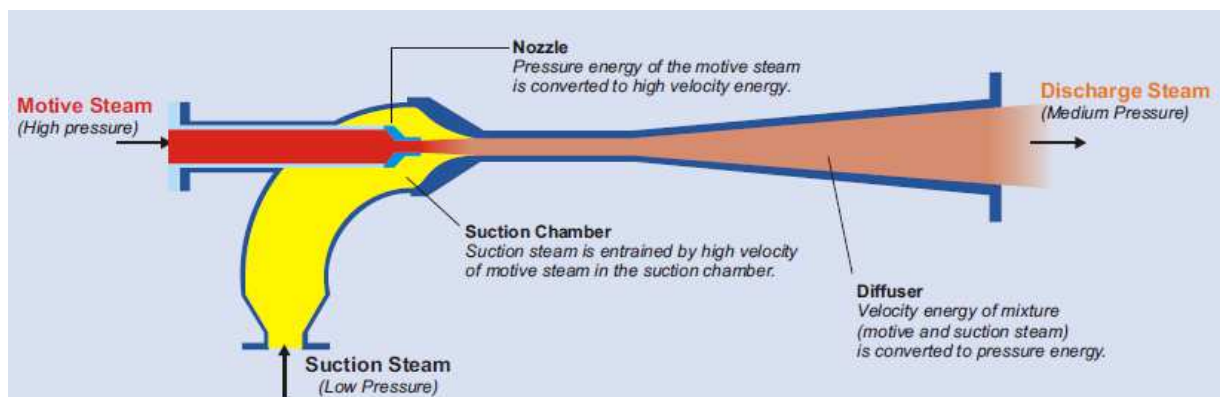
Thermocompressor essentially consist of three main parts.

- Nozzle
- Suction chamber
- Diffuser



4.4 Working Principle of Thermocompressor

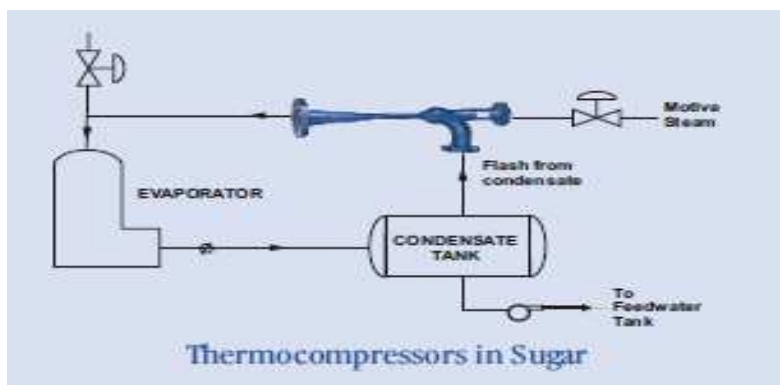
- Motive steam (High pressure steam) enters through converging-diverging nozzle.
- Low pressure steam (suction steam) enters through suction inlet
- High pressure steam mixes with low pressure steam in suction chamber
- The resultant steam mixture enters the diffuser where its velocity reduces and its kinetic energy is converted into pressure energy.
- The resultant steam called discharge steam is then used in process. Discharge steam pressure is between the pressure of motive and LP suction steam.



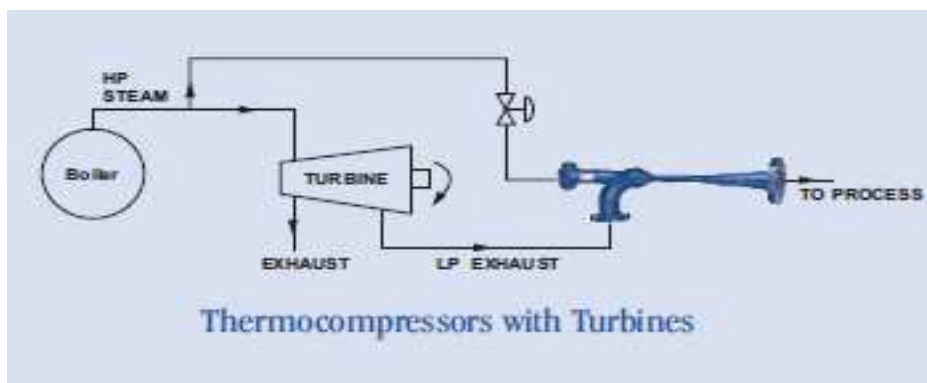
4.5 Applications of Thermocompressor

1. Thermocompressor can be used to compress or boost the vapours by mixing HP steam with vapours
2. Low pressure steam from turbine exhaust can be boosted for reuse in the distillery
3. It can also be used to recover the flash steam.

4.5.1 Thermocompressor in Sugar Industry



4.5.2 Thermocompressor with Back Pressure Turbine



4.6 Things to be considered before installing

- Thermocompressor is a useful but delicate apparatus and can give the desired steam economy in sugar mills under following conditions.
- The exhaust of turbine must necessarily be 15-20% short of steam requirement of the process.
- The live steam feed to Thermocompressor is regulated to suit the variation in exhaust.
- The apparatus is designed taking into account the correct temperature and pressure of vapours to be compressed.

4.7 Advantages of Thermocompressor

- Thermo compressor involves no moving part.
- No external power supply is required
- Require very little maintenance
- Easy installation
- Low capital and installation cost
- Longer useful operating lives
- Suitable for hazard areas
- Reduces overall steam consumption
- It can improve the thermal efficiency of a factory by 1-3%
- Vapour recovery from last stage of multi stage evaporator results in substantial cost saving in sugar plant

4.8 Energy Saving and Pay Back Calculation

Example:

- Steam vent into atmosphere = 300KG/hr at 0.5 barg
- It is required to compress this steam to 3 barg using motive steam of 9 barg.
- Cost of steam per Kg = Rs. 1.5
- Operating hours = 2880 hr
- Annual saving = $300 \times 2880 \times 1.5$
= Rs. 1,296,000
- Estimated investment = Rs. 3,00,000
- Pay back = $91000/144000 = 3$ months

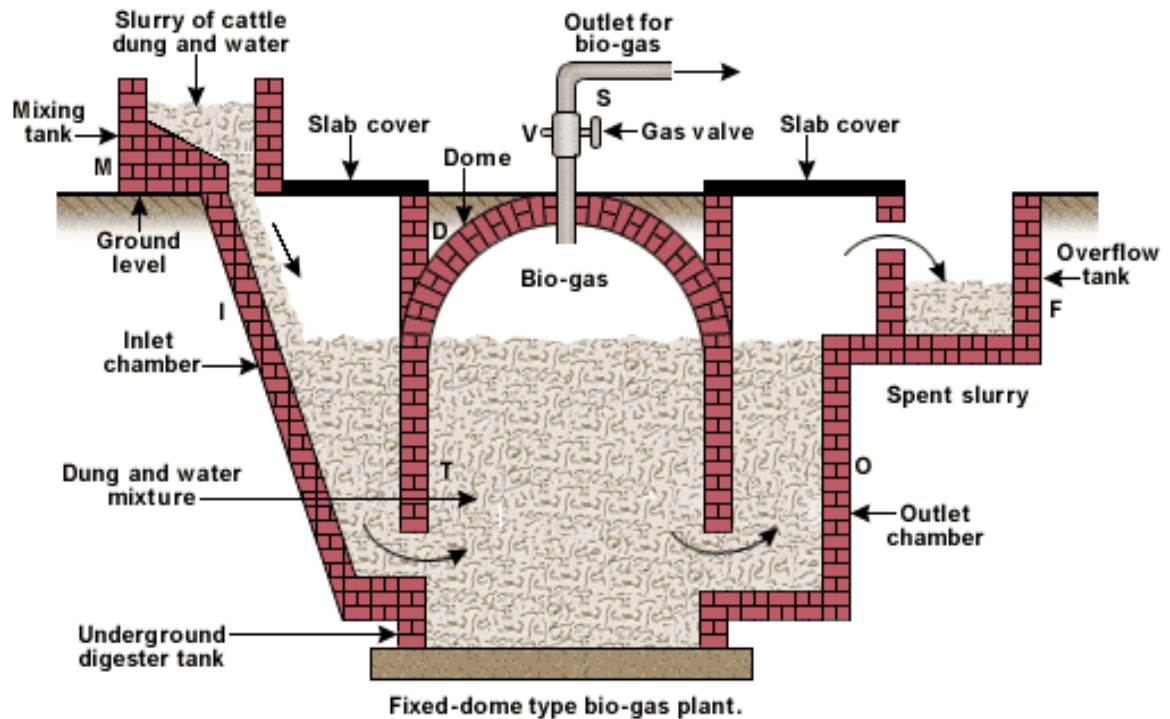
5. Biogas plant:

5.1 Introduction:

Fossil fuel includes oil, gas and coal. Fossil fuel resources are depleting so dramatically that we can not rely on them in future and even it is also possible that in near future these resources may exhaust. Fossil fuel can not fulfill our future demands so we should focus our attention on other energy resources that are more reliable and environment friendly such as biogas plant.

Biogas energy is a very good alternative of fossil fuel that reduces global warming and green house gases. Biogas is clean environment friendly fuel that can be obtained by anaerobic digestion of animal residues, domestic and farm waste, abundantly available in countryside.

5.2 Construction of biogas plant



5.2.1 Types of gasholder or Dome

There are two types of gasholder.

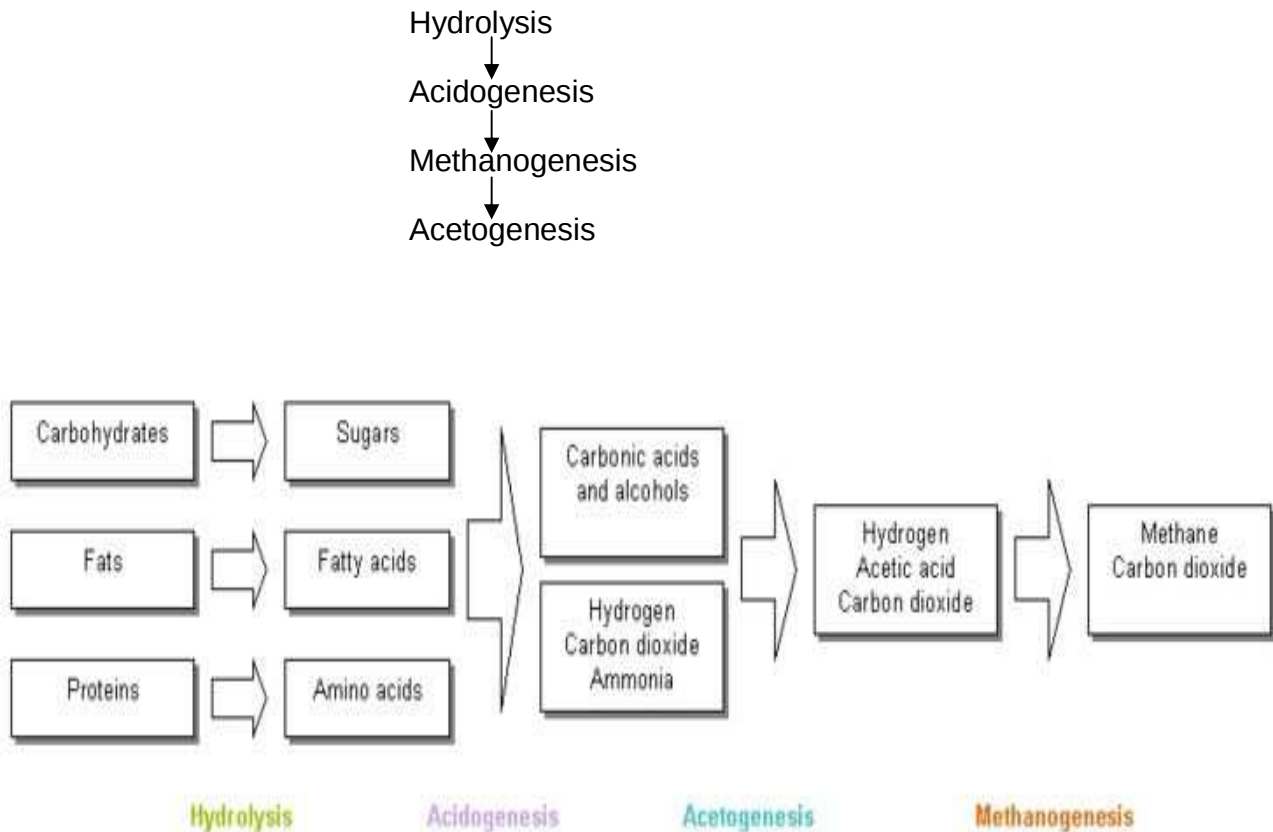
1. Moveable gasholder
2. Fixed dome gasholder



Moveable gasholder

Fixed dome gasholder

5.3 Biogas Generation Process



5.4 Properties of Biogas at 0°C and 1 atm pressure

CH ₄ Content:	65-70%
CO ₂ Content:	30-35%
H ₂ S Content:	1,000ppm
Heat value:	24.48MJ/m ³
Flame speed:	25cm/s
A/F Ratio (Theoretical):	6.19m ³ a/m ³ g
Combustion Temp:	650o C
Specific Heat (Cp):	1.6 kJ/m ³ o C
Density (p):	1.15 kg/m ³

5.5 1 Cubic meter of Biogas Heat Replacement Value

LPG	0.46Kilogram
Gasoline	0.67Litre
Diesel	0.60Litre
HeatingOil	0.55Litre
Firewood	1.50Kilogram
Electricity	1.20KW-h

5.6 UTILIZATION OF BIOGAS

- **Cooking:** Biogas can be used in a specially designed burner for cooking purpose. A biogas plant of 2 cubic meters capacity is sufficient for providing cooking fuel needs of a family of about five persons.
- **Lighting:** Biogas is used in silk mantle lamps for lighting purpose. The requirement of gas for powering a 100 candle lamp (60 W) is 0.13 cubic metre per hour.
- **Power Generation:** Biogas can be used to operate a dual fuel engine to replace up to 80 % of diesel-oil. Diesel engines have been modified to run 100 per cent on biogas. Petrol and CNG engines can also be modified easily to use biogas.
- **Transport Fuel:** After removal of CO₂, H₂S and water vapor, biogas can be converted to natural gas quality for use in vehicles.

5.7 Is biogas safe?

Biogas is not poisonous. The only danger is from explosion if it is mixed with air and lit by fire. However, it only explodes if mixed with air or oxygen with a lighted match or fire very close by. For example, you shouldn't ever lean into the tank with a lighted match! If you have a biogas leak in the house, and have good ventilation (windows, fresh air blowing through the house), it should not pose much danger of explosion although you would lose your stored biogas. This is why good maintenance is important.

5.8 Advantages OF BIOGAS

- Short payback period
- Reduces pollution by replacing fossil fuel.
- Biogas produces excellent fertilizers for use on the farms
- Biogas can help in the fight against global warming
- Biogas reduces green house gases

5.9 Energy Saving and Pay Back Calculation

Average dung produced by a cow = 5Kg/day

Average dung produced by 1000 cows = 5000Kg/day

1 Kg of dung produces biogas = 0.06510 m³/day

5000 Kg of dung produces biogas = 0.06510 x 5000 m³ = 325.5 m³/day

1m³ of biogas produces = 24.48MJ/day

325.5m³ of biogas produces = 24.48 x 325.5MJ = 7968.5MJ

As 1KWh = 3.6 x 10⁶J = 3.6MJ

So 7968.5MJ = 2213.5KWh = 2.2MWh

Hence MWh produced in one day = 2.2MWh = 2213.5 KWh

Annual saving = Rs. 8 x 2213.5 x 365 = Rs. 64, 63,330

Investment = 10, 00,000

Pay back period = 5, 00,000/64, 63,330 = 2 months

CONCLUSION:

There are main two purposes of energy conservative technologies. One is to save environment from hazard gases and second is to save energy. Experience obtained from different parts of the world and energy auditing programmes show that by installing above mentioned technologies we can save a large amount of energy and can contribute positively towards environment. Many studies around the world have identified Energy conservative technologies as an attractive low-cost option to generate power. Energy conservative technologies have long term advantages. Any new technology diffuses very slowly in the industry but they don't have apparent advantages but experience of such technologies in different industries can help us to explore the advantages of such technologies and our sugar industry is the example of it that adopt these technologies save energy and of course lot of money. Many developing countries are moving towards energy efficient technologies because if you install a low price inefficient technology it will remain round about for 20 year so your plant will run inefficiently for 20 years.

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23. Transvac Systems Ltd., Monsal House, 1 Bramble Way, Alfreton, Derbyshire, DE55 4RH, England **Telephone:** +44 (0) 1773 831100 **Facsimile:** +44 (0) 1773 831123 Registered in England No. 1526398 **Email:** sales@transvac.co.uk **Web:** www.transvac.co.uk
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