Factors that affect efficient & reliable performance of induction motors

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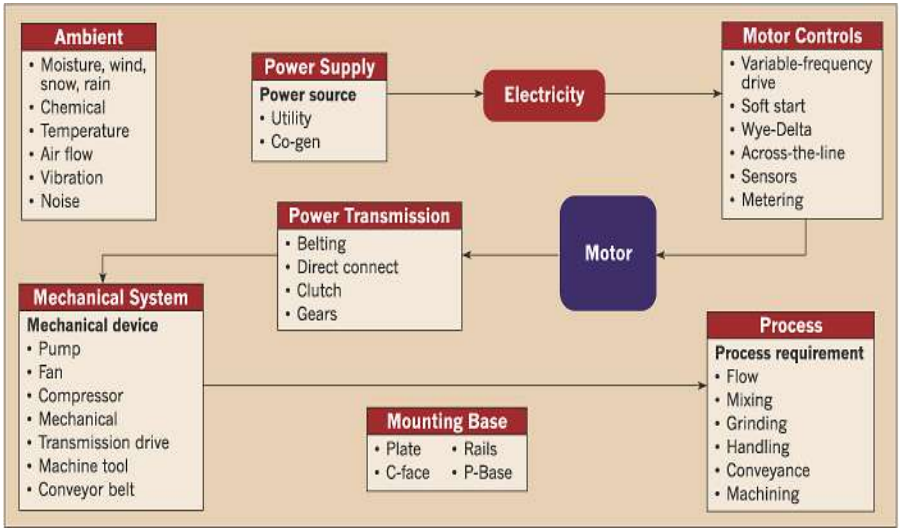
Induction motors are the work horses of the industry

Energy efficient motors are widely in use thanks to the efforts made by BEE, IEEMA and other industry champions

They account for nearly 75% of the energy utilised in industries

Let us look at some factors that affect the performance of the induction motors



Perspectives

Overall perspective

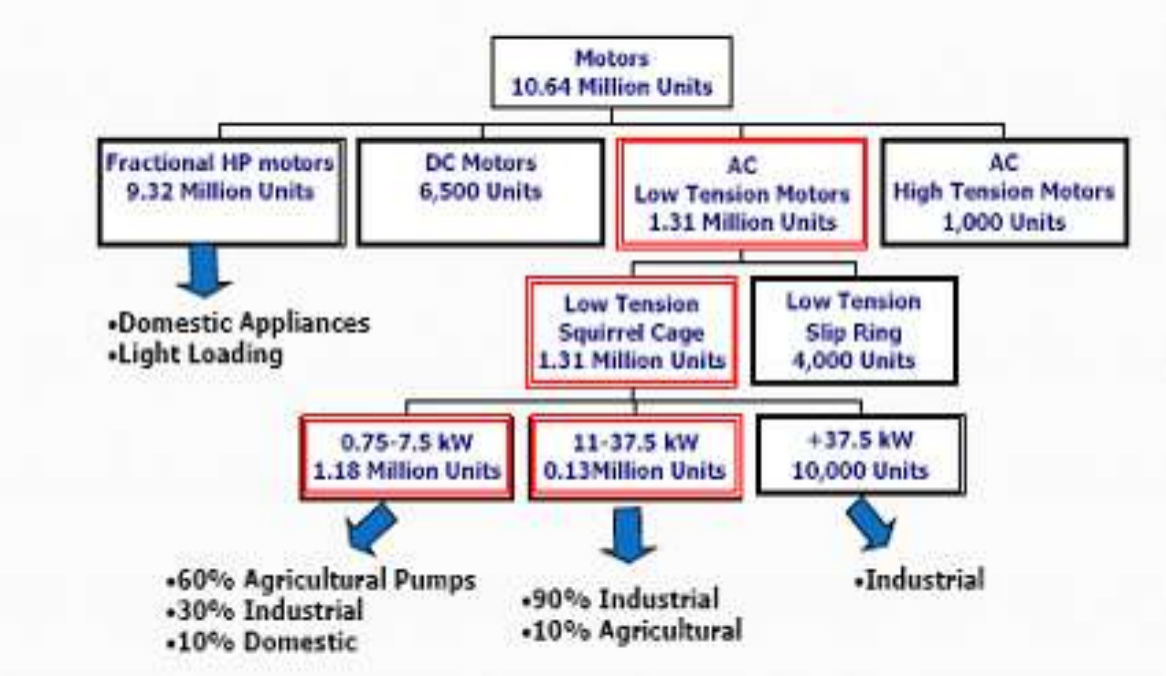
Buyers perspective

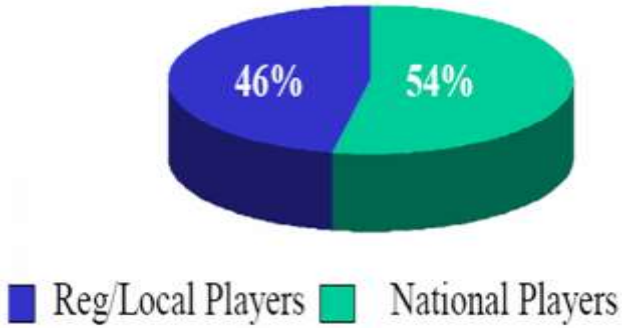
Sellers perspective

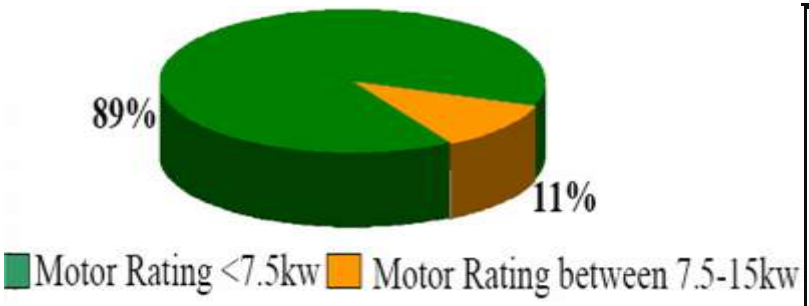
&

End-user perspective

Overall perspective







(<7.5kW) 90% small motors

(11-37 kW) 9% medium motors

(>45 kW) 1% large motors

Source: AFF Estimates, IEEMA Statistics, Primary Survey

Indian Standards

- **IS 8789 : Standard motor- Old & perhaps, Eff3**

  –all small manufacturers “follow” specification

  –most large manufacturers provide higher efficiency than “specified”

- **IS 12615(2004) : Standard for EE motors** (based on CEMEP/EPACT)

  –applicable up to 200 kW motors (315 frame size)

  –minimum efficiency values specified in two levels, Eff1 & Eff2

BEE labeling programme

BUREAU OF ENERGY EFFICIENCY

(A Statutory body under Ministry of Power, Government of India)
4th Floor, Sewa Bhawan, R.K. Puram, New Delhi-110066

NATIONAL ENERGY LABELING PROGRAMME

The voluntary scheme has been introduced for Energy Efficient Induction Motors Three Phase Squirrel Cage for **0.37 kW to 15 kW** (2 Pole and 4 Pole for continuous duty (S1) operation).

EFF-1

EFF-1

Induction Motor
High Efficiency
BEE/XYZ/00/08

S.NO. FRAME

kW/HP PH V A

Hz AMB°C EFF.% rpm INS. DUTY

BEARING DE NDE IP CONN

MONTH YEAR

COMPANY NAME & ADDRESS

The Bureau of Energy Efficiency, a statutory body under Ministry of Power, Government of India invites Manufacturers / Importers / Persons-in-trade of Motors to participate in the scheme by registering with Bureau of Energy Efficiency. The details of the scheme alongwith schedule for the appliances can be downloaded from the following websites: **www.beeindia.nic.in & www.energymanagertraining.com**

For more details, please contact:

Bureau of Energy Efficiency, Ministry of Power, Govt. of India
4th Floor, Sewa Bhawan, R.K. Puram, New Delhi-110 066. Tel.: 011-26179699 (5-Lines) Fax: 011-26178352 E-mail: gpandian-bee@nic.in

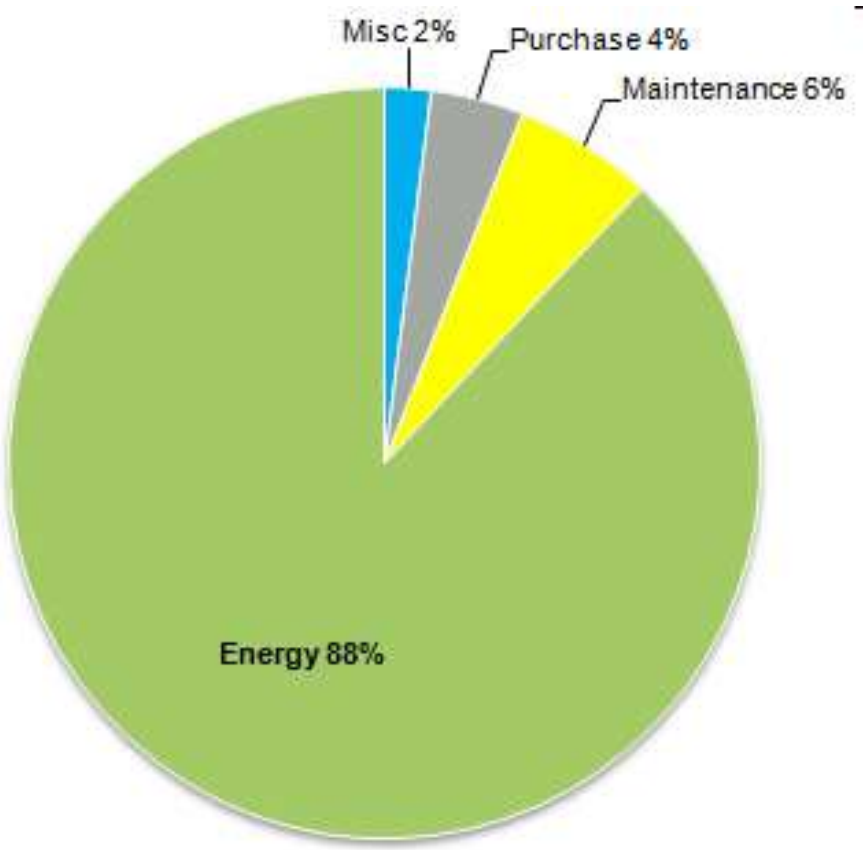
SAVE ENERGY, SAVE MONEY, BEE HAPPY

Buyers perspective

Market Motors

Engineered Motors

Life cycle cost



Induction motors account for >100 times their first purchase cost during their life time

Negotiate the life cycle cost

Capitalized cost

Capitalized cost of motor = Initial cost +[(1 -$\eta_{\text{at running load}}$) x Load Factor x Annuity factor x EC x operating hrs/ annum x Motor rating]

Where,

$\eta_{\text{at running load}}$ = % efficiency from manufacturer catalogue at the likely percentage Loading

Load Factor = Likely percentage loading

Annuity factor = $\frac{(1 + r)^n - 1}{r(1 + r)^n}$

r = Rate of interest

n = No. of years of operation

EC = Energy cost (Rs / kWh)

Capitalized cost… case example

	Eff1	Eff2
Motor rating- kW	75	75
Rate of Interest	12%	12%
Amortization period	15	15
Initial Cost	145000	138000
Motor Efficiency	94.5	93.0
Load Factor	0.50	0.50
Annuity Factor	6.81	6.81
Energy cost	3.50	3.50
Running hours/ annum	8000	8000
Capitalized cost	538327	638599
Difference in capitalized cost		100271

Sellers perspective

Push-Pull Effect

Sellers create market penetration through
Efficiency
and a retention through increasing
Reliability

Motor Selection

Electrical suitability

- Rated output
- Acceleration
- Continuous Running
- Speed variations

Mechanical suitability

- Fixing dimensions
- Shaft stressing
- Bearing life
- Type of transmission

Load Data Needed

Engineered Internal & External features ensure efficiency & long life

Complying with the standard

Indian Standard

ENERGY EFFICIENT INDUCTION MOTORS THREE PHASE SQUIRREL CAGE

(First Revision)

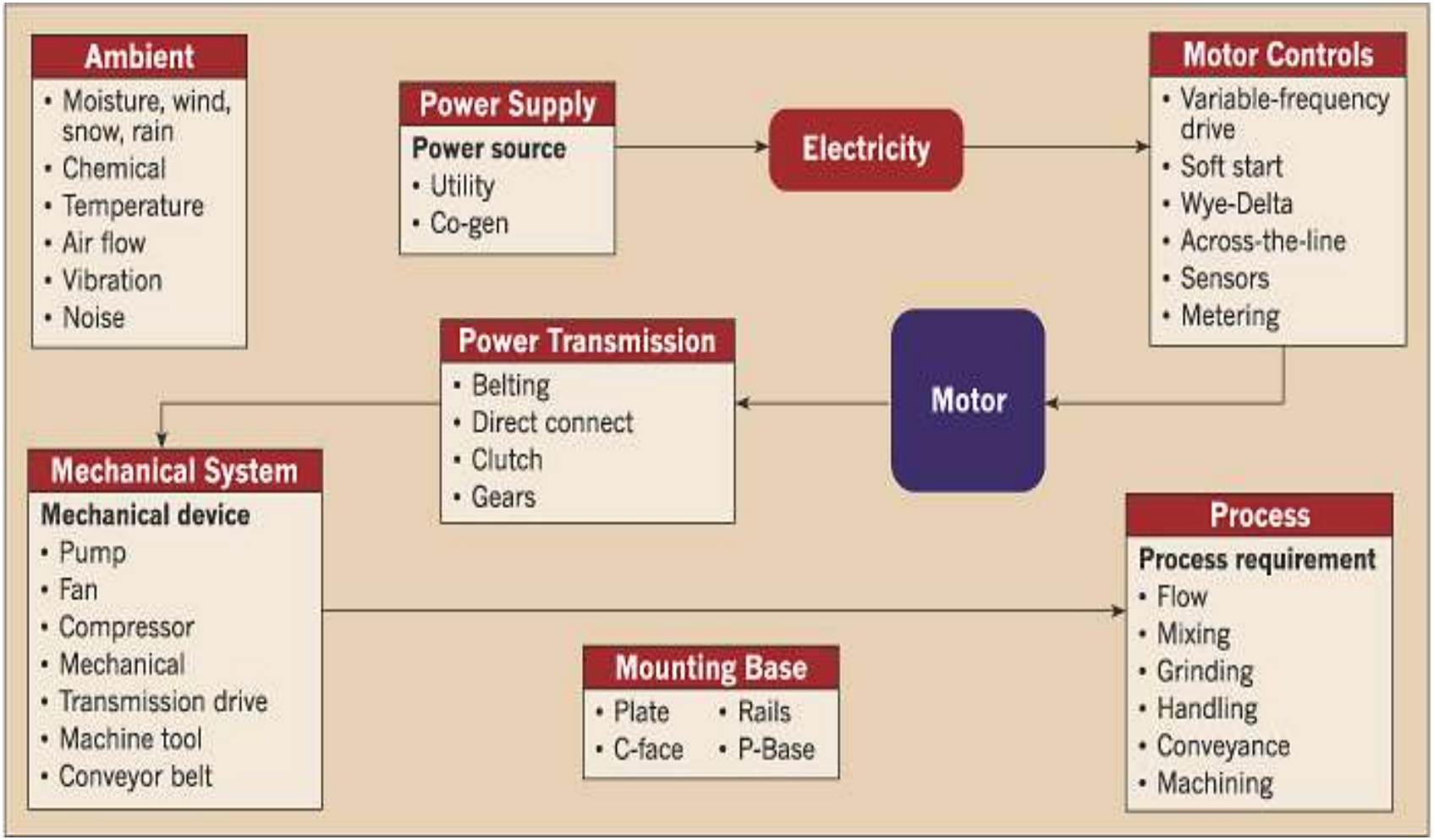
17 EFFICIENCY

17.1 For compliance with the requirements of this standard, the values of efficiency subject to IS 325 tolerance, listed under appropriate efficiency class (either improved efficiency — eff 2 or high efficiency — eff 1) in Tables 1 to 4, shall be met as specified below.

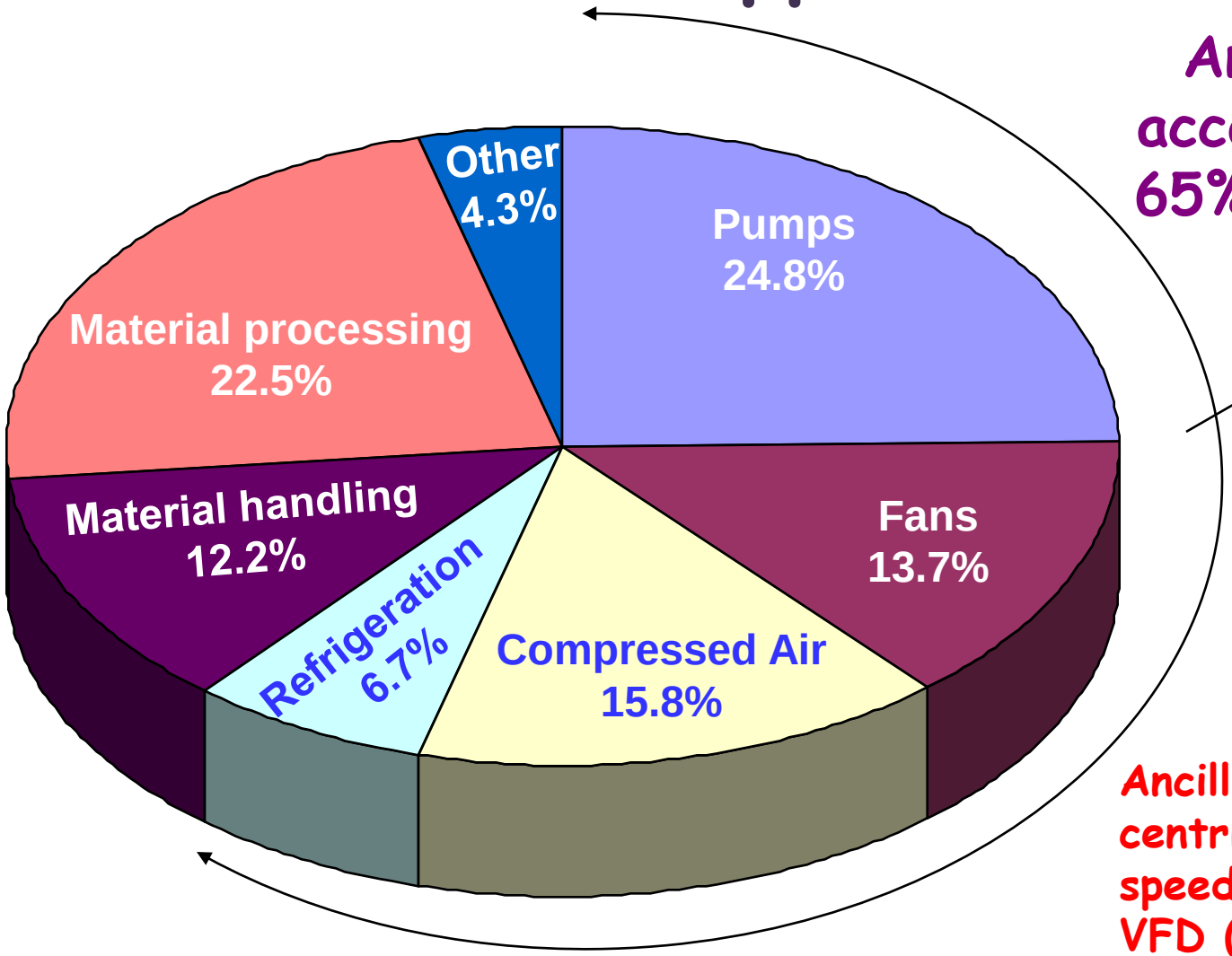
Table 2 Values of Performance Characteristic of 4 Pole Energy Efficient Induction Motors
(*Clauses* 1.2, 1.3, 4.1.1, 4.1.2, 14.1, 17.1, 17.1.1 *and* 17.1.2)

Rated Output	Frame Designation	Full Load Speed	Full Load Current	Breakaway Torque in Terms of Full Load Torque	Breakaway Current in Terms of Full Current, Equal or Below		Nominal Efficiency	
		Min	*Max*	*Min*	For eff 2	For eff 1	For eff 2	For eff 1
kW		Rev/min	Amp	Percent	Percent	Percent	Percent	Percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.37	71	1 330	1.4	170.0	550	600	66.0	73.0
0.55	80	1 340	1.7	170.0	550	600	70.0	78.0
0.75	80	1 360	2.2	170.0	550	600	73.0	82.5
1.1	90S	1 370	2.9	170.0	550	600	76.2	83.8
1.5	90L	1 380	3.8	170.0	550	600	78.5	85.0
2.2	100L	1 390	5.1	170.0	600	700	81.0	86.4
3.7	112M	1 410	8.1	160.0	600	700	84.0	88.3
5.5	132S	1 420	11.4	160.0	600	700	85.7	89.2
7.5	132M	1 430	15.4	160.0	600	700	87.0	90.1
9.3	160M	1 430	18.5	160.0	600	700	87.7	90.5
11.0	160M	1 440	22.0	160.0	600	700	88.4	91.0
15.0	160L	1 440	30.0	160.0	600	700	89.4	91.8
18.5	180M	1 440	36.0	160.0	600	700	90.0	92.2
22.0	180L	1 440	43.0	160.0	600	700	90.5	92.6
30.0	200L	1 450	56.0	160.0	600	700	91.4	93.2
37.0	225S	1 450	69.0	160.0	650	700	92.0	93.6
45.0	225M	1 460	84.0	160.0	600	700	92.5	93.9

End-user perspective



Motor Applications

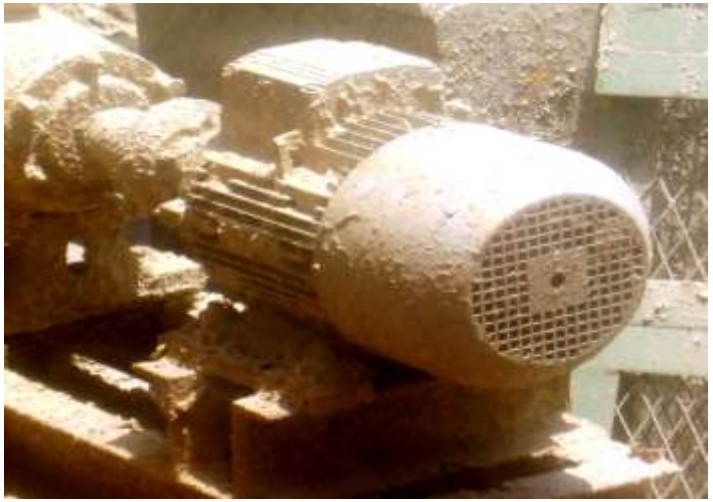


Ancillary loads account for almost 65% of the energy

Ancillary loads are all centrifugal loads where speed variations thro' VFD (optimisation) offer energy saving

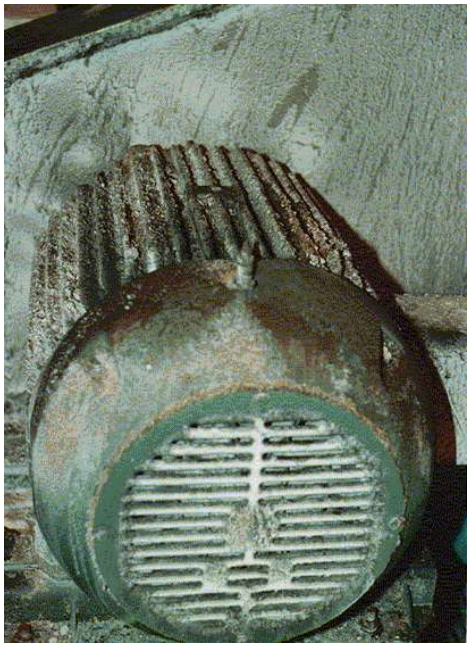
Environment

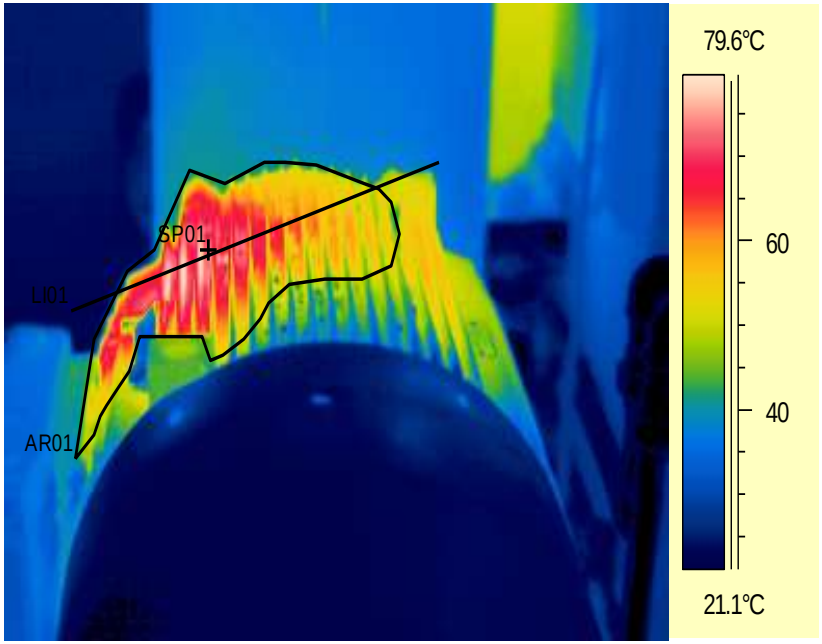
ETP PUMP, 55 KW MOTOR



Provide protection from aggressive atmospheric and site conditions

Insufficient cooling affects efficiency and life





Power Quality… Voltage variation

Maintain Voltage Levels

ALTHOUGH MOTORS ARE DESIGNED TO OPERATE WITHIN 10% OF NAMEPLATE VOLTAGE, LARGE VARIATIONS SIGNIFICANTLY REDUCE EFFICIENCY, POWER FACTOR, AND SERVICE LIFE

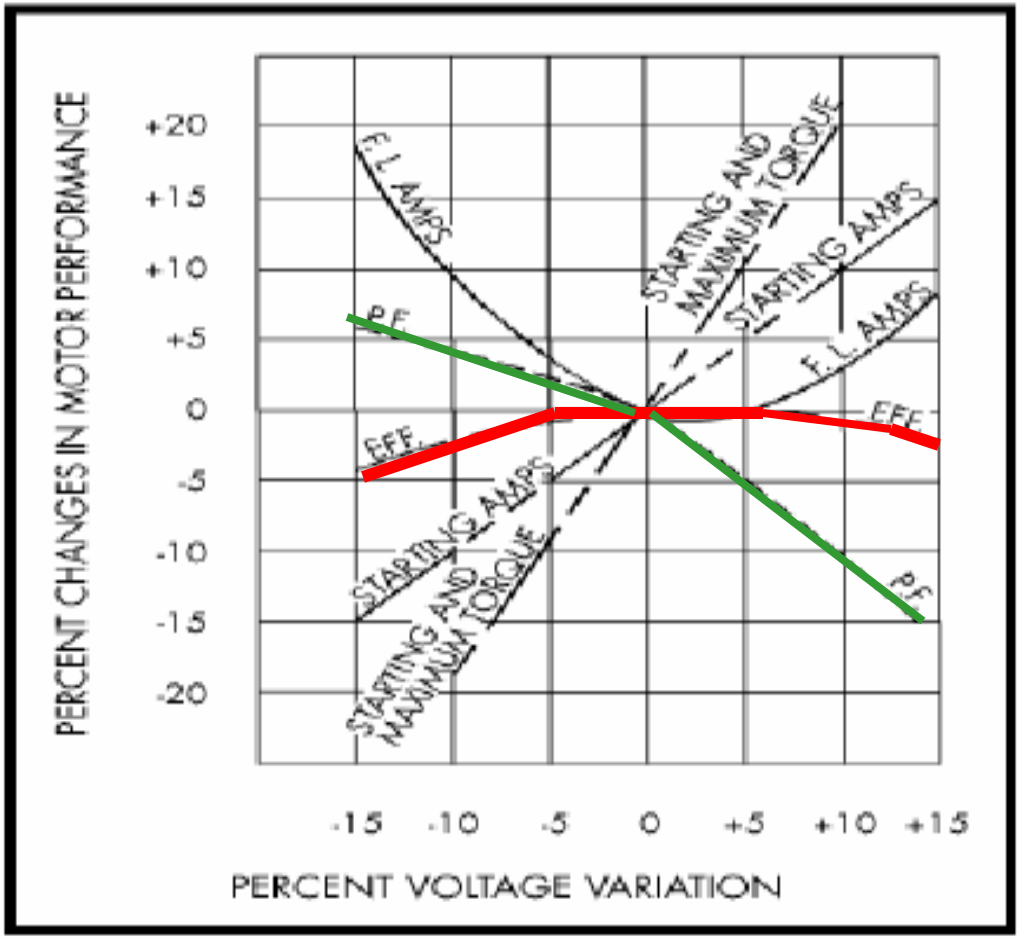
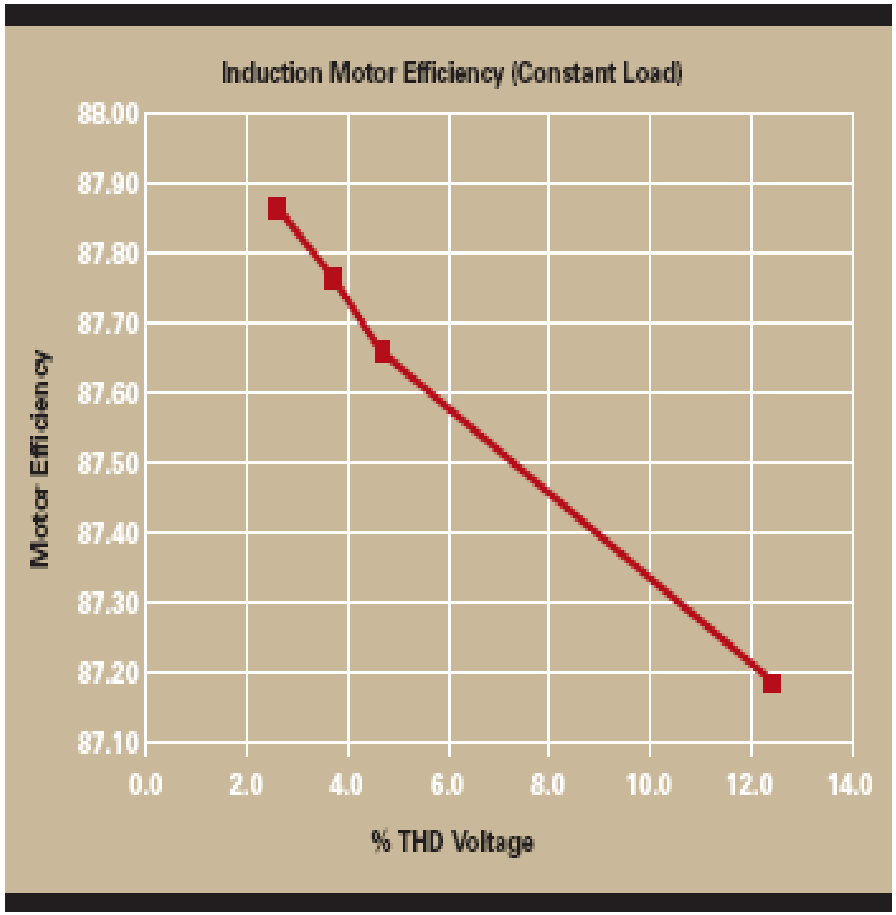


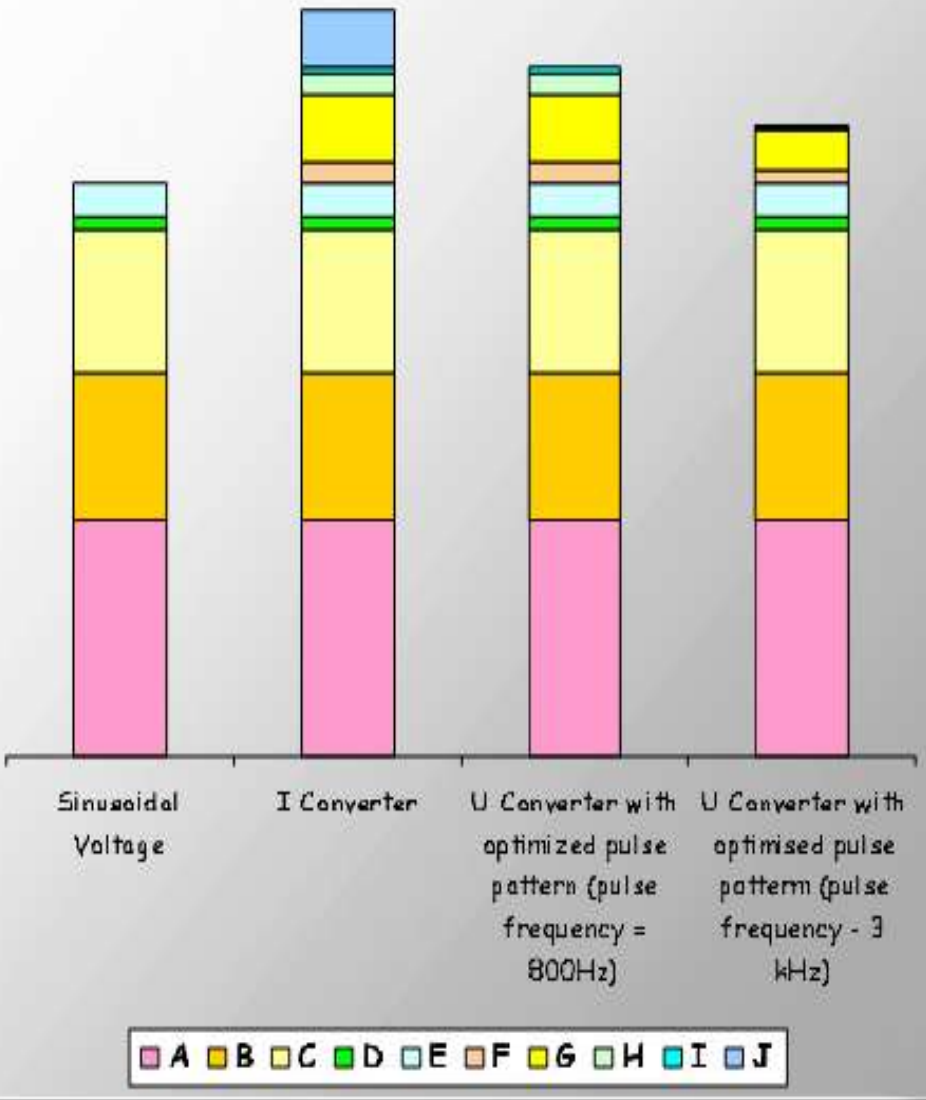
Figure 1
Voltage Variation Effect on Motor Performance

Power Quality….
Effect of Harmonics



- IEEE 519/1992 gives the limits for both THD-U and THD-I at the PCC level
- There are many effects of harmonics
- The motor efficiency can be nearly 0.5% lower

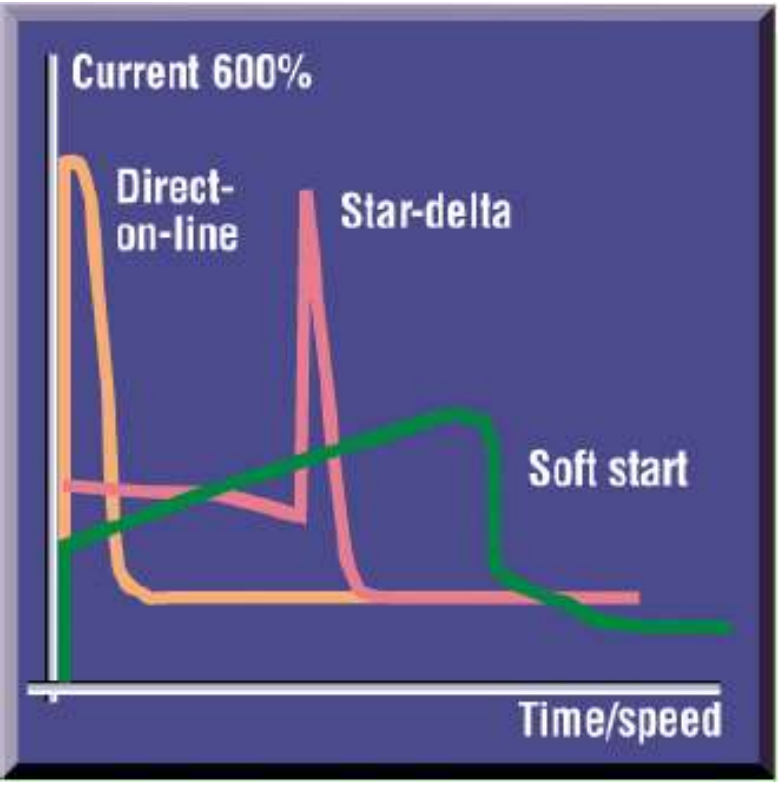
Increased Losses in the motor on account of Harmonics



J	Commutation Losses	Losses caused by Harmonics
I	Additional Load Losses	
H	Iron Losses	
G	Rotor Winding Losses	
F	Stator Winding Losses	
E	Frictional Losses	Losses caused by fundamental frequency
D	Additional Load Losses	
C	Iron Losses	
B	Rotor Winding Losses	
A	Stator Winding Losses	

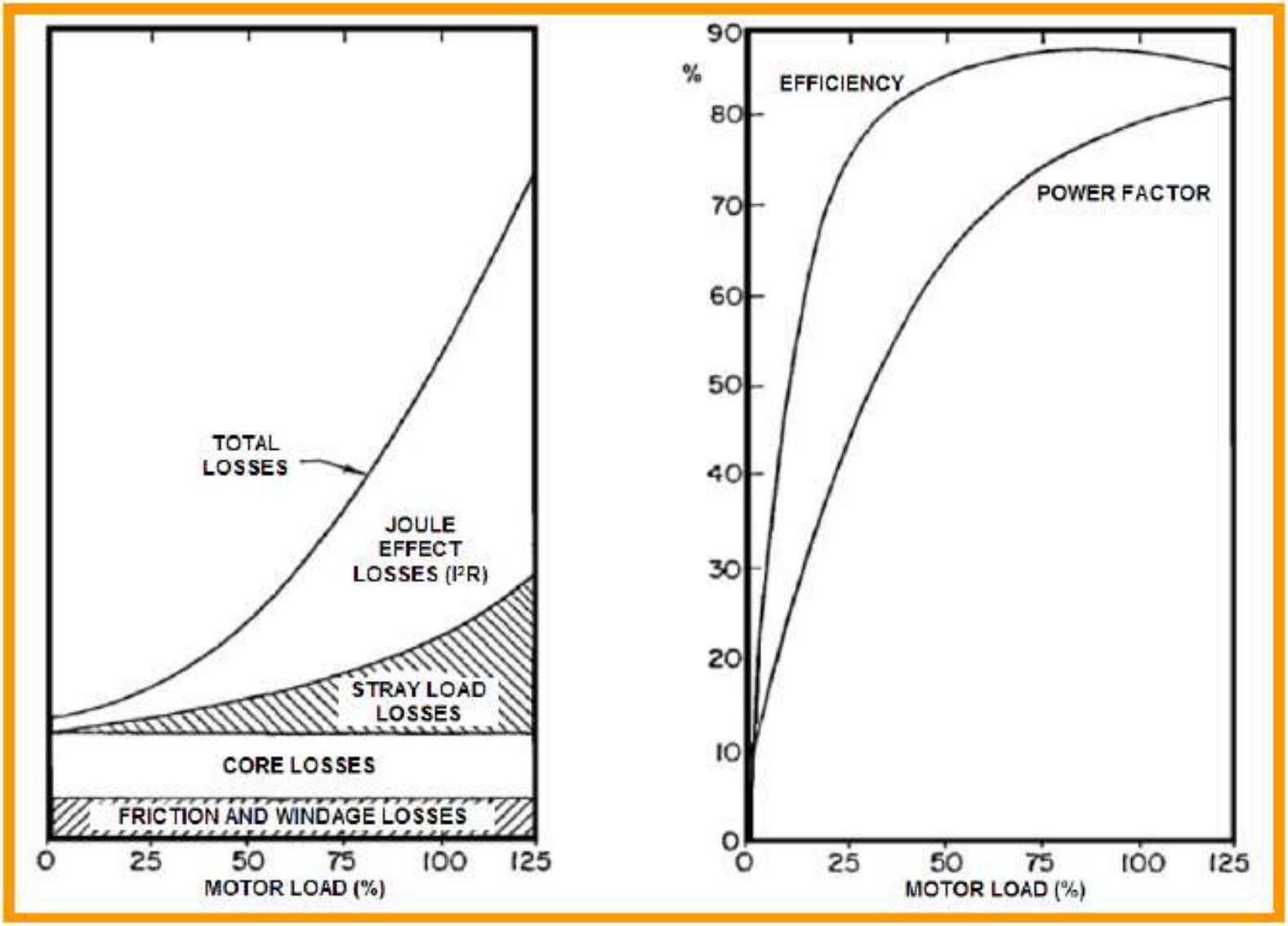
Total Losses %	100	130	120	110
Efficiency	95.3	93.89	94.36	94.83
	Sinusoidal Voltage	I-Converter	U-Converter with optimized pulse pattern (pulse frequency = 800Hz)	U Converter with optimised pulse pattern (pulse frequency - 3 kHz)

Effect of starting on motor life



- Motors are suitable for DOL start unconditionally
- Suitability for Star-Delta starting requires prior selection (stressful start)
- Soft starter too requires driven machine details…. Unsuitable for high inertia loads
- VFD is the most comfortable. The motor needs to be protected against insulation failure

INDUCTION MOTORS – Part Load Operation



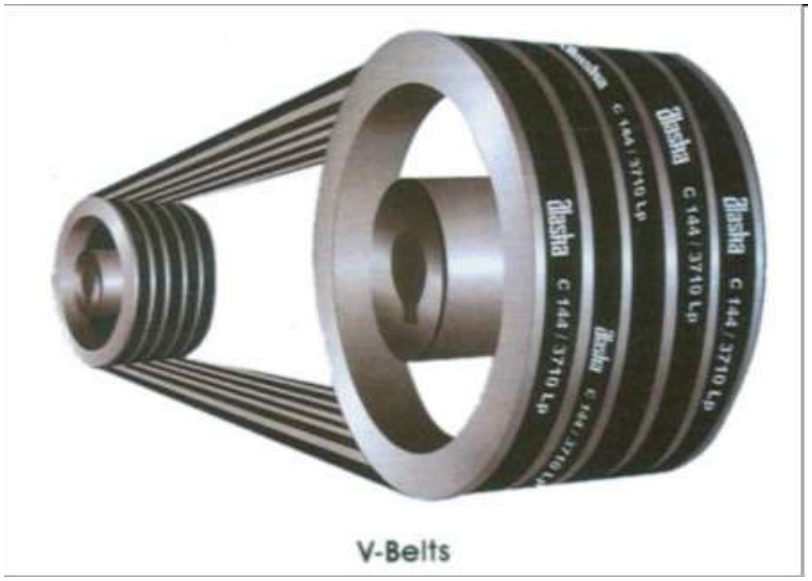
Savings with DelStar converter

LOAD %	SAVINGS %		
	1 TO 15 HP	16 TO 40 HP	41 TO 150 HP
NO LOAD	76%	60%	45%
10%	40%	30%	22%
20%	26%	22%	20%
30%	15%	13%	12%
40%	9%	8%	7%
50%	6%	5%	4%

MODEL EM 1

MODEL EM 2

Power transmission belts



habasit

Synthetic flat belts are recommended for reduced transmission losses and energy saving of 3 to 5%

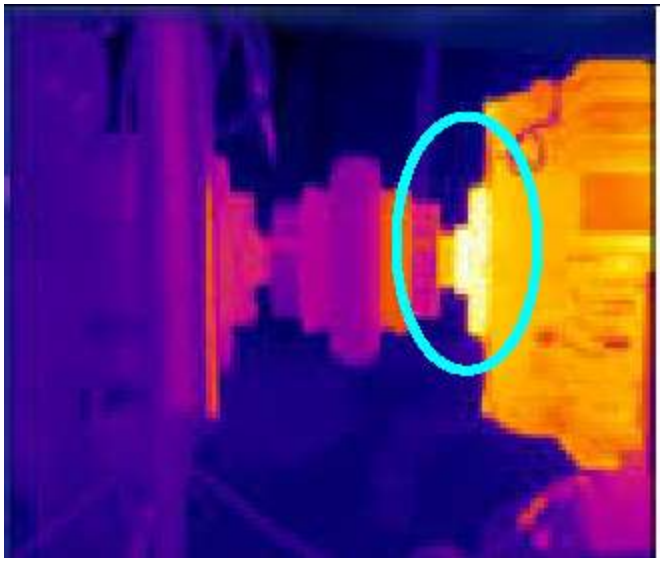
Optimize Transmission Efficiency

TRANSMISSION EQUIPMENT INCLUDING SHAFTS, BELTS, CHAINS, AND GEARS SHOULD BE PROPERLY INSTALLED AND MAINTAINED. WHEN POSSIBLE, USE FLAT BELTS IN PLACE OF V-BELTS. HELICAL GEARS ARE MORE EFFICIENT THAN WORM GEARS; USE WORM GEARS ONLY WITH MOTORS UNDER 10 HP.

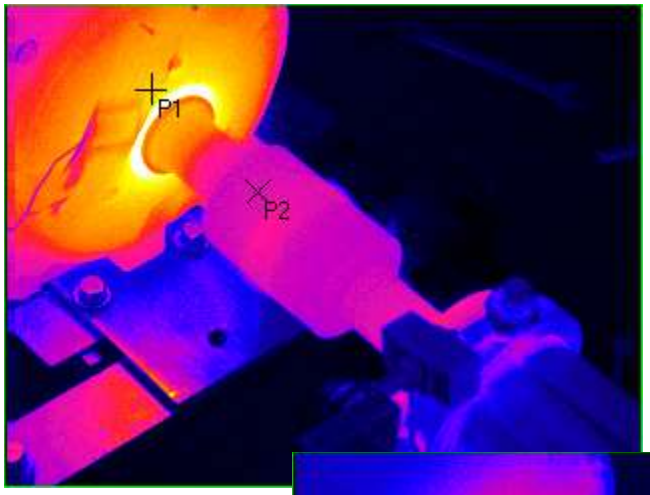
Standard Motor	→	HEM Motor	+1% to 3%
Worm Gearbox	→	Helical Gearbox	+8% to 10%
"V" belt drive	→	Flat belt drive	+5% to 6%

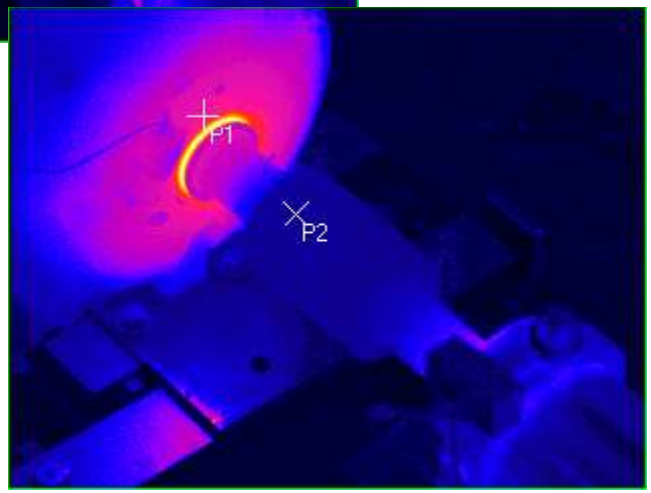
Efficiency gain = 14% to 19%

Bearings, alignment issues



Over heated bearing





Angular misalignment corrected

Mechanical driven system

Big ticket saving potential

System approach- Fan system

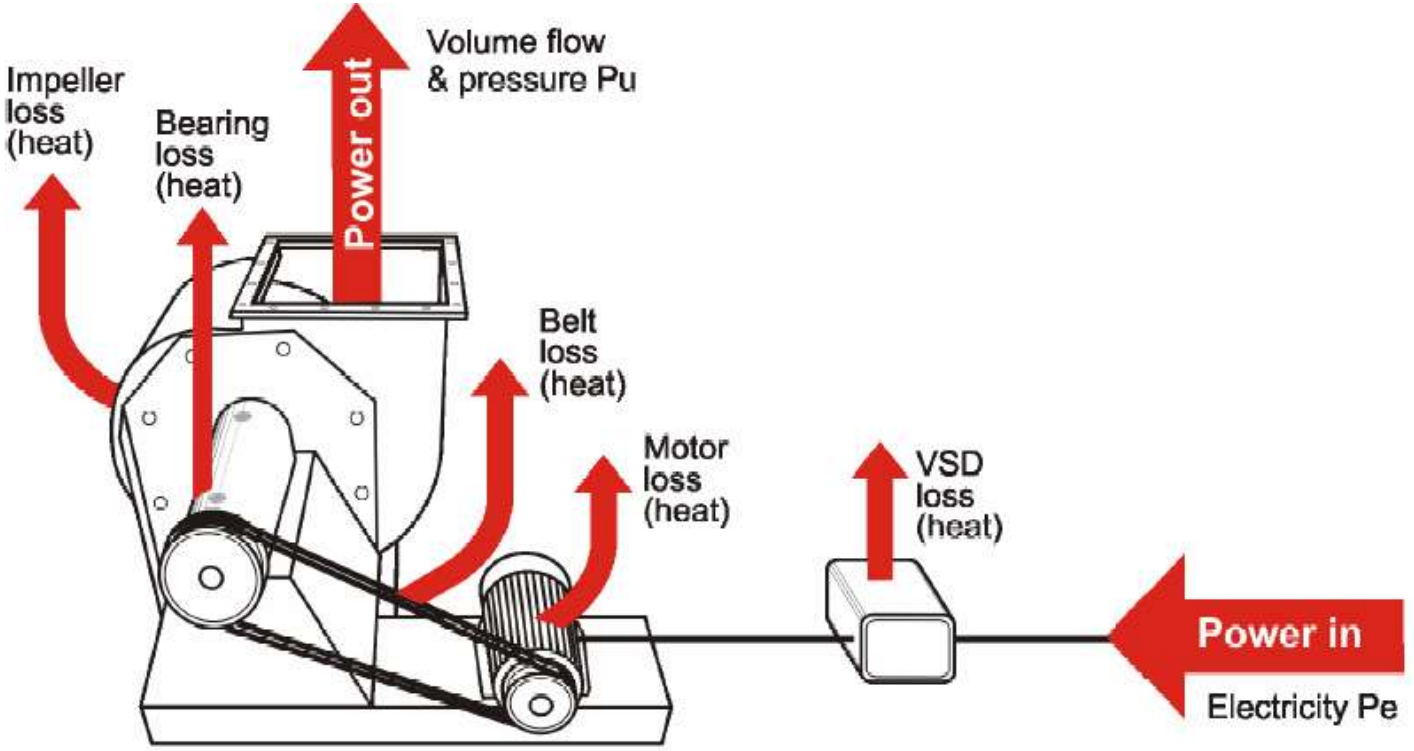
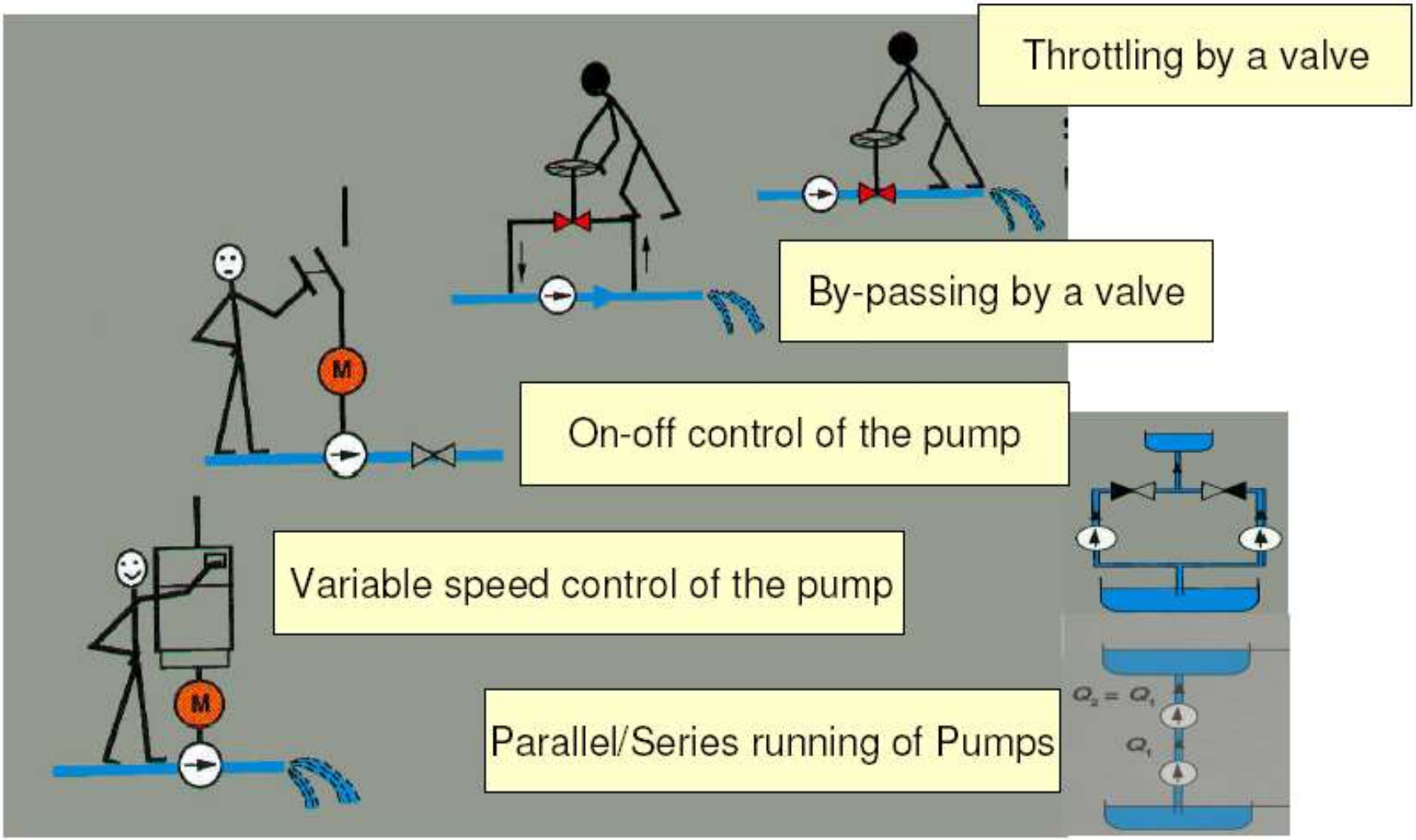


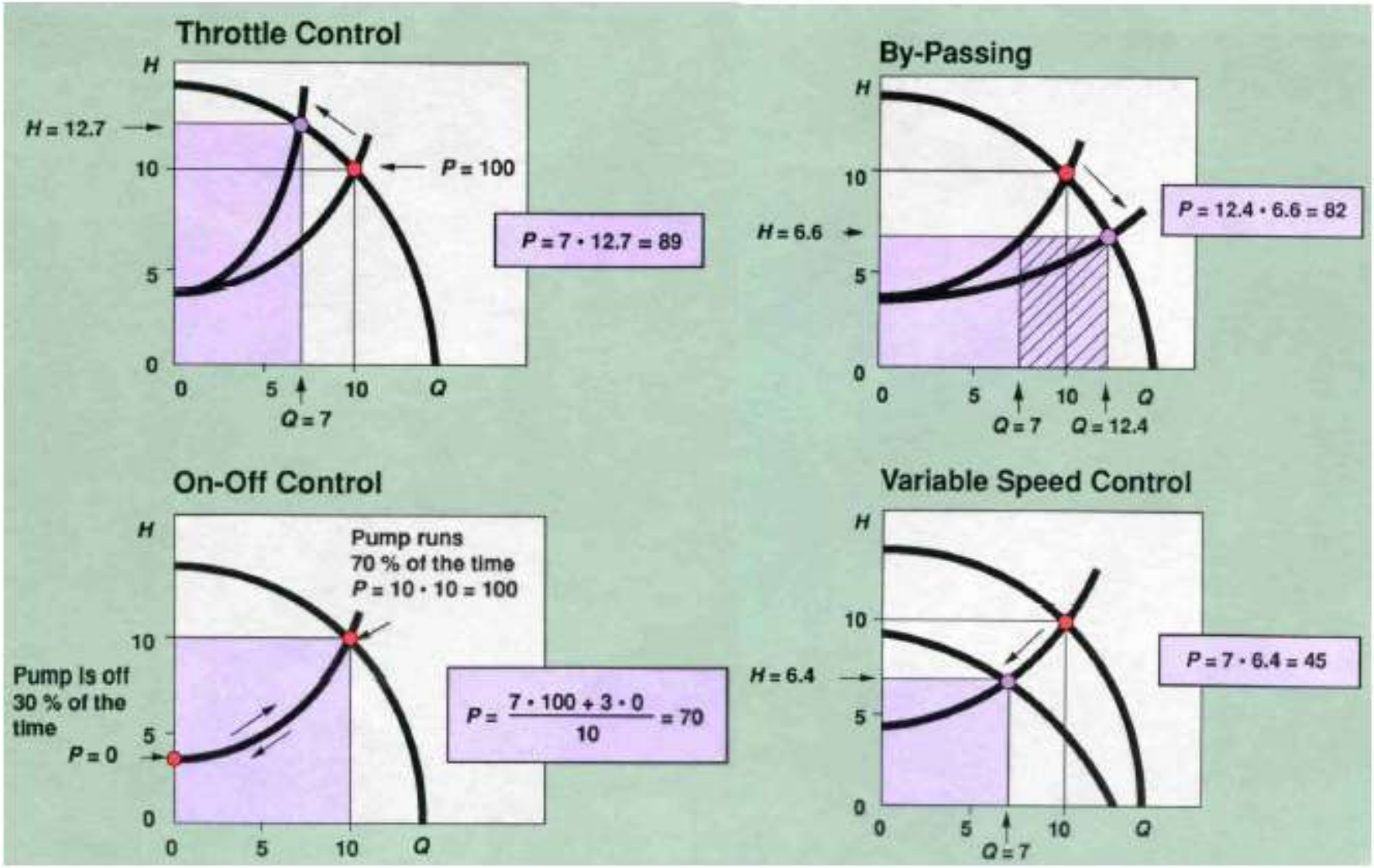
Diagram showing the losses from a fan system including VSD, motor and belt drive.

As high as 30% saving potential

Pump controls for energy reduction



How much is there to reduce



International standards for VFD duty motors are provided by NEMA and IEC

***NEMA MG1* - Motors and generators / "United States"**

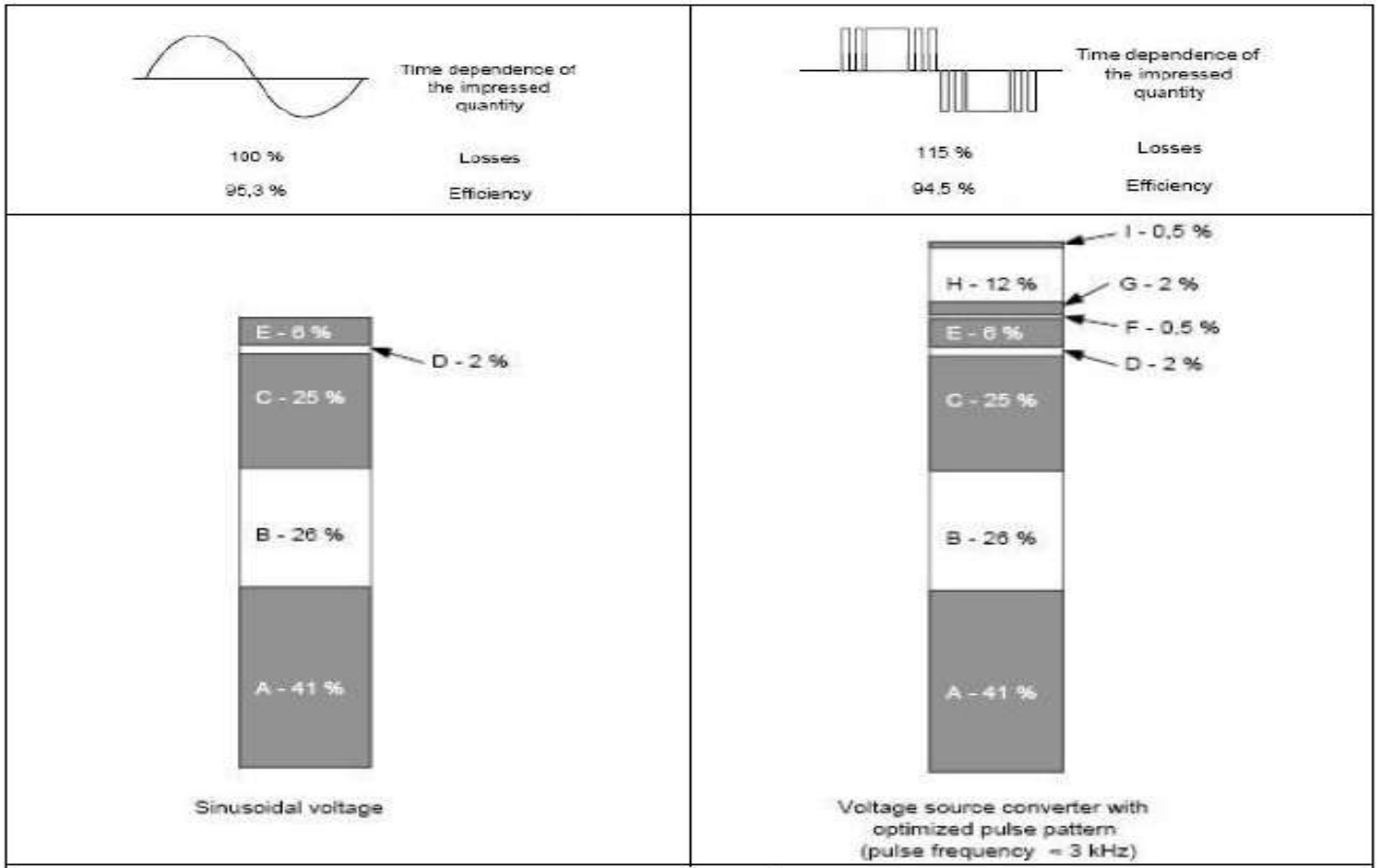
- **Parte 30** - Application considerations for constant speed motors used on a sinusoidal bus with harmonic content and general purpose motors used with adjustable-frequency controls or both (2003)
- **Parte 31** - Definite-purpose inverter-fed polyphase motor (2003)

NEMA - Application Guide for AC Adjustable Speed Drive Systems (2001)

***IEC 60034* - Rotating Electrical Machines / "International"**

- **Parte 17** - Cage induction motors when fed from converters – application guide (2002)
- **Parte 25** - Guide for the design and performance of cage induction motors specifically designed for converter supply (2004)

IEC 60034-17 provides an example of motor losses increase owing to PWM supply. Motor info: 315 IEC frame, rated torque and speed values.



Losses caused by fundamental frequency

- A – Stator winding losses
- B – Rotor winding losses
- C – Iron losses
- D – Additional load losses
- E – Frictional losses

Losses caused by harmonics

- F – Stator winding losses
- G – Rotor winding losses
- H – Iron losses
- I – Additional load losses
- J – Commutation losses

NOTE: frame 315 (IEC) motor operating at rated speed and torque.

Key pointers from the IEC standards

1. Under PWM supply, the winding temperature rise can not be limited to class B level. To limit temperature rise from class F to class B, one size derating should be applied

2. The winding wire should be dual coated

3. Winding insulation should be vacuum pressure impregnated (VPI)

Conclusion

All players should contribute to selecting, buying, commissioning and maintaining a ***Sound Motor System*** in order achieve high efficiency and long service life from induction motors