Energy Management Training: Motor Management

tarsheedAD.com

Contents

- Explanation of how much energy motors use.
- Highlighting areas where motors waste power.
- Highlighting of how savings can be made.
- Explanation of how a policy can set simple rules to get the basics of motor management in place.

RATIONALE: VALUE TIED UP IN MOTORS

Why should we manage electric motors?

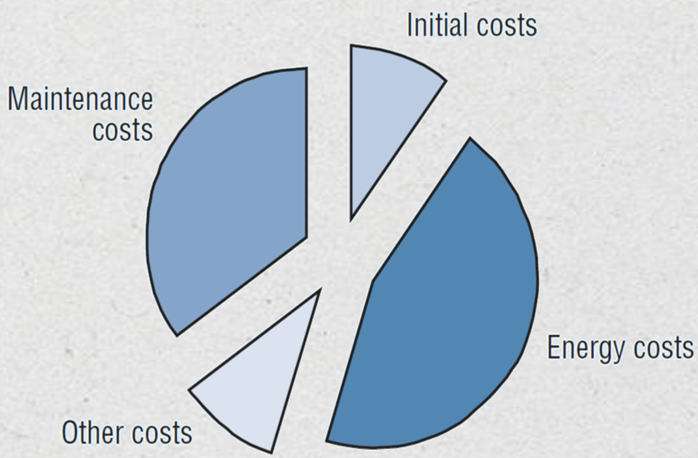
- As much as 60-80% of the electricity on a manufacturing site* passes through electric motors.
  - Lifetime power consumption is frozen in when production systems are designed and motors are procured.
  - However subsequent lifetime management and maintenance of motors and drives also affects efficiency.
- Motor management:
  - Uses life cycle thinking to optimise costs.
  - Uses clear and simple rules to simplify decision making.
  - Manages change to technologies and economics.

* Croner-I, 2020; IPIECA, 2020

Energy dominates whole life costs for motors

- The energy throughput of a motor is surprisingly large.
- In a 20 year lifetime a motor can easily consume more than 100-200 x its price in power*.
- A motor can consume power equal to its purchase price in 2-3 months.

Whole life cost breakdown for an electric pump**



What are the ways in which energy can be wasted in motors?

* Depending on the local power price

**Image sourced from US Department of Energy: PUMP LIFE CYCLE COSTS: A GUIDE TO LCC ANALYSIS FOR PUMPING SYSTEMS

Areas that can waste energy in motors[1]

Baseline: A properly sized and installed High Efficiency Motor:

Waste Category	Typical Losses
• Motor failed and given a low quality rewind:	3%-5%
• Motor and drive misaligned:	3%-8%
• Voltage unbalanced:	1%
• Poor maintenance of output drive:	2%-5%
• Poor motor cooling and overheating:	0.5%
• 50% oversized compared to requirement:	3%
Total:	12.5%

- A 11kW motor costs 3,000 AED[2], but can waste 3,400 AED/year.
- This loss occurs before the energy even goes into the application.
- Using a throttling valve to control delivery can waste much, much more!

1: Sourced from UK Government Guide GPG1: Energy Savings with Motors and Drives.
2: RS online catalog for 11kW IE3 motor,

Inefficiency gets worse over time

- Energy wasted in a motor causes temperatures to rise, leading to higher resistive losses in motor windings, faster physical degradation and a greater chance of catastrophic failure and process down-time.
- As new motors available on the market become more efficient over time, older motors already installed impose worsening process performance relative to newer factories. This progressively reduces the competitiveness of the factory product in the market.
- If power prices rise, the cost of the waste will also rise.

What is your population of motors like?

- If high efficiency is not a procurement requirement, then most of your motors will have been purchased on price and will be low efficiency models.
- Often only a small proportion of motors in critical applications are condition monitored.
- Usually motors and their output drives are left to work until they fail and are replaced or rewound.
- Motors that have failed are often rewound to a poor quality standard, and this reduces their efficiency still further.

MOTOR EFFICIENCY TOPICS

The basics of motors and energy

1. Low efficiency motors waste energy
2. Oversized motors waste energy
3. Poor power correction wastes energy
4. Poor systems design wastes energy
5. Poor mechanical transmission wastes energy
6. Oversized delivery of outputs waste energy
7. Throttled fixed output motors on pumps & fans wastes energy
8. Poorly-maintained motors waste energy
9. Badly rewound motors waste energy

How can we deal with each problem area?

Issue 1: During purchasing

Issue 2 - 7: Through design specifications and applications reviews

Issue 8 & 9: Through and good quality maintenance and repair

Purchasing efficient motors

- If only high efficiency motors can be purchased, then this prevents future inefficiency from being frozen in.
- However some motors are not stand-alone units. They are integral to equipment and rolled up in the overall equipment purchase.
- This can be controlled by properly incorporating motor efficiency and general energy efficiency clauses into procurement specifications.

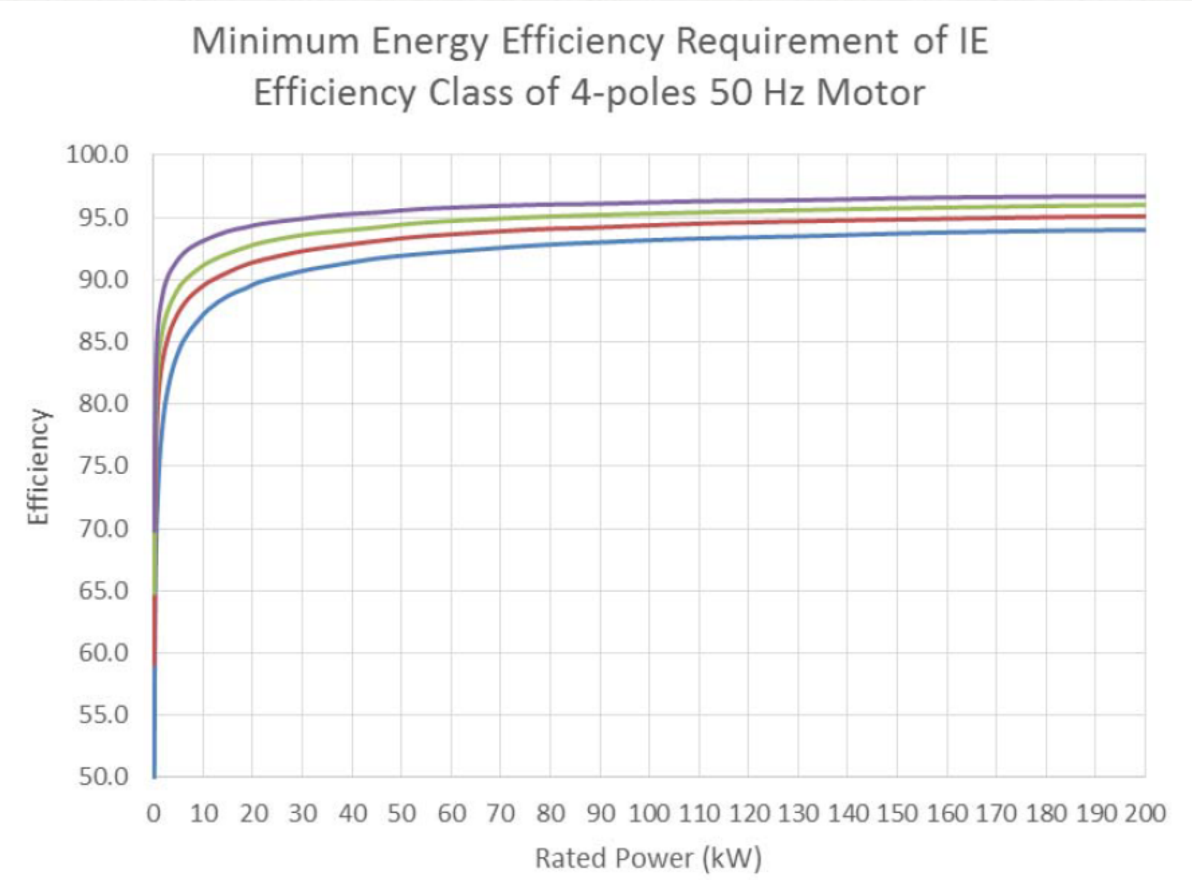
10

Purchasing: efficiency labelling

- The International Electrotechnical Commission (IEC) has developed efficiency standards for electric motors (IEC/EN 60034-30-1) that harmonize with regional motor standards schemes such as within Europe and the USA's NEMA.
- IE3 standard is already the minimum legal specification in some regions, Eg. EU for 0.75-375kW motors since January 2017, (except for VSD motors, where IE2 is allowed).
- An "Ultra Premium" IE5 standard is under development.

Label	Efficiency Level	Minimum Efficiency for 1.1kW 4 pole Motors	Minimum Efficiency for 30kW 4 pole Motors	AED Losses/Year 1.1kW	AED Losses/Year 30kW
IE1	Standard Efficiency	75%	91%	472	4,788
IE2	High Efficiency	81%	92%	351	3,964
IE3	Premium Efficiency	84%	94%	300	3,295
IE4	Super Premium Efficiency	87%	95%	242	2,625

Motor efficiency vs size: bigger is better



Report on Study on International Efficiency (IE) Efficiency Classes for Low Voltage AC Motors, Hong Kong Energy Efficiency Office, 2015

High efficiency motors

- Design changes deliver better efficiency:
  - Heavier conductors and optimum geometry to reduce resistance.
  - Minimum stator-rotor air gap to improve magnetization.
  - Thinner core laminations to reduce eddy current losses.
  - High permeability steel to reduce magnetization losses.
  - Improved bearings for reduced friction.
  - Improved cooling system to reduce windage losses and reduce operating temperatures.
- Outcomes:
  - Better running efficiency.
  - Higher inrush current.
  - Higher starting current.
  - Lower running current.
  - Longer motor length in many cases.

High efficiency motors: starting current

IE3-IE4 motors: selecting the right control and protection components, Adrian Franco and Pierre Dehaut, Schneider Electric

Should existing low efficiency units be replaced?

- Example:
  - 11kW IE1 standard efficiency motor.
  - In good condition and working well.
  - 8000 running hours a year.
- Is it worth changing for a new IE3 motor?
  - Consumption is 88,000kWh per year.
  - Difference in efficiency IE1-IE3: 87.6% - 91.4%*.
  - Consumption saved: 3,344kWh per year.
  - Electricity cost saved: 956AED per year at 0.286/kWh.
  - If a new IE3 motor is 3,000ED, does replacement make sense?
  - What if the efficiencies of the units are different from the minimum values?

- Minimum efficiency levels from IEC/EN 60034-30-1 – may not be representative of actual efficiency of old and new units

Adjusting to using high efficiency motors

- Circuit breakers may need to be changed to allow for higher inrush and starting currents.
  - Inrush current 30 to 50% higher than IE1 motor
  - For a smaller IE3 motor the starting current may be 30% higher than for an IE1/IE2.
- Differences become smaller with increasing motor size.
- Consulting with motor suppliers on the suitability and control of HEMs is crucial.

Better systems design: oversized motors

- When systems are designed, safety factors tend to inflate:
  - +20% oversizing of system to deliver service to the process.
  - +30% safety factor on motor size specified in design to guarantee delivery.
  - +10% as only the next frame size up was available.
  - +10% when motor failed and additional safety factor was added.
- Result: Motor is 50% loaded at best, is inefficient & costlier to buy.

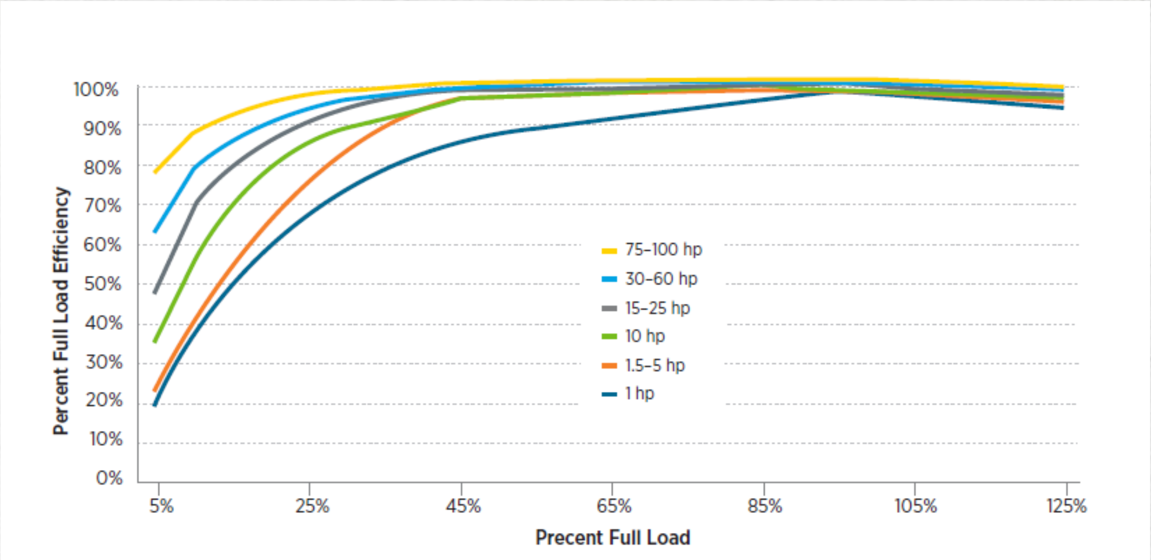


Diagram from Premium Efficiency Motor Selection and Application Guide, US Department of Energy/Copper Development Association Inc., February 2014.

Better systems design: correcting oversizing

- Barriers to solving the problem:
  - The real cash losses may not be clear.
  - Removing functioning equipment appears very negative.
  - Better sized systems may be seen to be less robust.
- Solutions:
  - Present reliable and well-structured financial data.
  - Show that reliability is unaffected beyond a certain safety factor.
  - Slowly solve the problem through natural wastage, targeted redesign and during maintenance.

Better design: drive systems

Direct drive fans:

- Direct connection between motor and load.
- No possibility for mechanical speed variation, but VSDs viable.
- No transmission losses.

Belt drive fan:

- Indirect transmission of power.
- Low cost mechanical speed control is possible by varying relative sizes of pulleys.
- Power transmission losses caused by friction of 2% to 5% depending on the size of the motor, but may be higher if poorly maintained.

*https://eldridgeusa.com/blog/which-are-better-direct-or-belt-drive-fans/

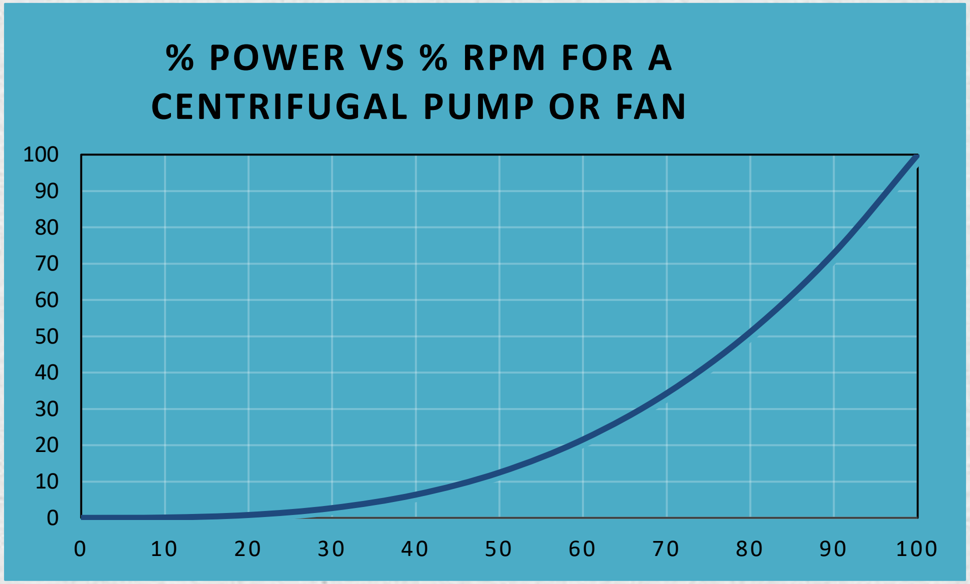
Better systems design: over delivery of outputs

- Delivery is set by design and links to motor speed
- Design may dictate a particular method of delivery – either displacement pumps or centrifugal.
- But does the designed delivery match the real process requirements?
- How much of an effect does over-delivery have?

“The paper reports on the marginal improvement in energy consumption at reduced supply frequency for motor replacement only, (not surprising), but a very impressive 46% saving in energy consumption by controlling pumped water at a reduced but constant delivery rate”

Utilising high and premium efficiency three phase motors with VFDs in a public water supply system*, Van Ryn and Pretorius, 2015 IEEE 5th International Conference on Power Engineering, Energy and Electrical Drives (POWERENG)*

Better systems design: the affinity laws



- For centrifugal pumps & fans:
  - Volumetric flow α RPM.
  - Pressure α RPM^2
  - Power α RPM^3

Consequently slight volumetric over-delivery wastes significant power.

Volumetic over-delivery	% Power Wasted
5%	12%
10%	22%
20%	37%
50%	62%

Better systems design: power wasted by throttling:

- A low efficiency 10kW motor that is poorly-maintained uses 87,600 kWh of power every year running a pump.
- The system uses a throttle valve to control the output.
- Total annual energy cost is 25,054 AED.
- The proportion wasted depends on the level of throttling.

% Throttling of flow	kWh needed	kWh losses in motor	Kwh actually needed by pump	kWh wasted in throttle	AED wasted in total
5%	87,600	10,950	66,213	10,437	6,117
10%	87,600	10,950	57,588	19,062	8,583
15%	87,600	10,950	50,399	26,251	10,640
20%	87,600	10,950	44,358	32,292	12,367
50%	87,600	10,950	22,711	53,939	18,558

Better systems design: eliminate throttled delivery

- Issue:
  - Using a throttled centrifugal pump or fan can waste up to 80% of the power.
  - Removing the valve and using motor speed control can save most of this.
- Barriers:
  - Speed control requires additional investment and business case is complex.
  - Speed control may be seen as introducing another point of failure.
- Solutions:
  - Analysis of consumption that gives a clear financial case for change.
  - Provide transparent rules and tools to support decision making.
  - Offer sensible solutions to cover all cases for better match, allowing for:
    - Changing the pump or fan capacity.
    - Change drive pulley ratios to reduce delivered RPM.
    - Using multispeed motors.
    - Installing full Variable Speed Drives ("VSDs") – either for manual or automatic speed control (sometimes real time control of flow is not important, but a VSD without control feedback allows the speed to be easily manually adjusted to the optimum value.

23

Better maintenance: motors

- Poorly maintained motors waste energy.
- Areas for waste:
  - Degraded bearings.
  - Electrical breakdown of windings.
  - Blocked fan inlets.
  - Dirty heat exchange surfaces.
- This wasted energy emerges as excess heat. Thermal imaging is a fast and effective method for detecting it.
- Vibration monitoring detects bearing degradation and off balance outputs.

Better maintenance: output shafts & couplings

Issue:

- Poorly aligned and maintained couplings waste up to 10% of power.
- Create greater mechanical wear, accelerating failure.
- Alignment-tolerant couplings are inherently wasteful.

Barrier:

- However changes to key equipment may be seen as adding to risks.
- The business case for improvement may not be clear.

Solution:

- – Present business cases that clearly define the risks.
- – Replace inefficient couplings and set up using laser alignment.
- – Detect using diagnostic tools, such as thermal imaging, vibration analysis, or motor-level energy consumption monitoring.
- – Planned maintenance regimes with clear procedures.
- – Ensure that equipment and supplies are readily available.

25

Better maintenance: replace or rewind?

Issue:

- Motors can burn out and rewinding is a fast, low cost repair.
- Rewinding to low quality standards wastes several percent of energy.

Barriers:

Solution:

- Remove existing poor quality rewinds and prevent poor quality rewinds from happening.
- However practical considerations can prevent this:
  - Existing rewinds are functional and fast to get.
  - Existing rewinds and salvaged motors may be "free".
- Remember that a good rewind on an HEM is still very efficient.
- However, if in doubt of rewind quality, a failed motor should be scrapped and replaced with a new high efficiency unit wherever possible.

26

Maintenance: replacement or rewinding

- Solving the rewind problem requires that several specific solutions are available to engineers:
  - Clear evidence of the high life cycle cost of poor quality rewinds.
  - A clear decision tree based on economics.
  - Availability of a fast response local motor replacement service for new high efficiency units.
  - Partnerships with suppliers of high quality rewinding services.
- Quotation from a large local manufacturer:

  "We cannot guarantee that motors will be rewound to a high standard, so we play safe and automatically scrap and replace them with new IE3 units".
- At least one large industrial player in Abu Dhabi has failed units rewound by the OEM motor supplier.

MOTOR MANAGEMENT POLICY

What a motor management policy delivers

- The policy manages the key questions:
  - What do you have in place?
  - How are you using it?
  - How do you manage it over time?
- A formal policy and rule book manages the issue, taking the guess work out of day-to-day decision making for managers.
- What do the detailed points of the policy look like?

29

General policy principles and key points

- Principles of a motor management policy:
  - Buy efficient motors,
  - Make sure applications are correctly sized and controlled.
  - Maintain for maximum efficiency.
  - Understand where and what your motors are, and why.
- In developing the policy, consider:
  - Who owns and drives the policy?
  - Where will the financial aspects of the policy fit?
  - Where will the policy, its evolution, and its implementation fit?
  - Where will the resource come from to manage the tasks?

Policy points: establishing a motor registry

- A motor registry helps to organise improvement activities.
- It may already partially exist in the form of an asset inventory.
- For each motor, the record should contain:
  - Drive Data:
    - Circuit Reference
    - Serial Number
  - Duty Description:
    - Brief Description (i.e Pump Duty, HVAC Fan etc).
    - Control Method (If any).
    - Rating (kW, Full Load Current).
    - Estimated Running Hours Per Annum.
    - Installed Max. Running Load (Actual Current).
    - Zone Classification Requirements.
  - Pre-decided action on failure:
    - Replace With HEM or Re-Wind as appropriate.

Policy points: managing existing motors

- Most sites will already have a large inventory of low efficiency motors that waste energy compared to HEMs.
- Barriers to solving the problem:
  - It does not appear to be “Common sense” to replace working equipment.
  - Depending on energy prices and payback periods, the financial case often does not work either.
- Policy solution:
  - The policy should certainly be for failed low efficiency motors to be replaced with new high HEMs.
  - Policies must be flexible however:
    - Note that frame size and other size constraints may limit the options for changing low efficiency to high efficiency motors.
    - If HEM replacements cannot be found, rewinding/repair is inevitable, even for low efficiency motors.
    - If rewinding is inevitable, it must be to a high efficiency standard.
    - For larger motors, the difference between a good quality rewind and a new HEM may not justify replacement.
    - The policy should assess the economics and monitor power prices over time.

Policy points: procurement of new motors

- Motors must be suitable for areas of use, such as those with explosive atmospheres (ie. IEC Ex, ATEX Zones 0 - 2, Safe etc.)
- Efficiency standards:
  - Specify efficiency class IE3 motors if possible for safe areas.
  - Specify closest efficiency to IE3 available for hazardous area duties (see manufacturers data).
- Motors to be rated for continuous duty (S1) as per the IEC 60034 standard.
- Motors must be suitable for direct on line starting.
- For purchasing fixed speed drives, equipment design should ensure that absorbed power is 75% of motor rated power.
- Motors for use with VSD’s to be rated according to standards (IE2 is acceptable).
- Ensure consultation mechanism is in place with suppliers to ensure that motor and ancillary specifications meet needs.
  - Where a VSD is in place, motor should be size rated and/or designed for compatibility.
  - Where a high efficiency motor is being subsitituted for an original standard efficiency model, the switchgear specification should be checked.

33

Policy points: recalibrating supply with demand

- Issues that must be taken into consideration:
  - Reducing delivery may require process changes and entail risks.
  - Changes may challenge established HSE or production protocols.
  - The policy must ensure that pros and cons are dealt with.
- Policy solution:
  - Optimise the system design at the outset.
  - Review the applicability of the design if the process changes.
  - Account for economic costs and risks in any proposed process changes.
  - Go through a risk-based evaluation to revisit existing applications in the motor registry.
- Apply screening rules to simplify processes.

  eg. For VSDs:
  - Look for applications where speed can fall by at least 20%.
  - Look for applications weher speed may need to vary frequently.
  - Look for applications operating at least 4,000 hours per year.
  - Look for applications with high static heads.

  e/g. for pumps and fans:
  - Use criteria similar to those above for VSDs, but where the delivery requirement is constant and not likely to change.


فكّر
RETHINK