What about controlgear?

No. 2

Motor Regulation - Efficient System Design

Guidance concerning designing energy efficient motor control systems in accordance with the current ecodesign requirements for electric motors in industrial applications.

CAPIEL

european coordinating committee of manufacturers
of electrical switchgear and controlgear assemblies

CAPIEL is the Coordinating Committee for the Associations of Manufacturers of LV Switchgear and Controlgear equipments for industrial, commercial and similar use in the European Union. It is a broad-based group that represents many national associations of manufacturers.

Members of national associations represented by CAPIEL include small, medium and large-sized companies that in total employ more than 100 000 people directly in Europe.

CAPIEL promotes and represents the common professional interests of its members in all areas of its competence. Essential association affairs are in the fields of standardization, legislation and common promotion.

CAPIEL plays an active role in driving emerging technologies, especially regarding innovations in the areas of environmental preservation and sustainability, but also in health and safety.

Philippe Sauer
CAPIEL President

Michael Reichle
CAPIEL Vice-Presidents

A message from the CAPIEL Presidents

Today, in our modern world it is all about energy efficiency and energy management, for a more sustainable environment. This is not a fashion, but a long term trend that will increasingly influence all economic and geopolitical decisions. Carbon footprint, energy policy and economic viability will also increasingly be correlated to our ability to better manage energy and to use it efficiently.

The success of ecodesign – an engineering challenge for today – will strongly contribute to ensuring that we leave a better planet for following generations.

It is our duty, as CAPIEL, to work with regulators to make sure that regulations are consistent with our common objective of more energy efficient systems. It is also our responsibility to make sure that these regulations are well understood and correctly interpreted by all designers and users of electrical products, systems and solutions.

This second brochure provides information concerning the application of the current EU regulation to implement more efficient motors. Furthermore this brochure supports the design of motor driven applications to achieve the best energy efficiency solution.

We hope that you will find it of interest.

Yours sincerely
Philippe Sauer & Michael Reichle

National associations represented by CAPIEL:

ASSOCIAZIONE ENERGIA COMPONENTI, SISTEMI E UTILIZZO DELL'ENERGIA
AFME Asociación de Fabricantes de Material Eléctrico
AGORIA WALLONIE
ANIE FEDERAZIONE
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CONFINDUSTRIA
FEI FACHVERBAND DER ELEKTRO- UND ELEKTRONIKINDUSTRIE
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EU Regulation for Ecodesign of electric motors

The ecodesign requirements of the EU Commission Regulation (EC) No. 640/2009, Ecodesign Requirements for Electric Motors have applied since June 2011. This regulation imposes mandatory minimum efficiencies for many types of three-phase, low voltage electric induction motors.

This European Regulation also introduces the option of using a Variable Speed Drive (VSD) in conjunction with IE2 motors in certain circumstances.

Most Ecodesign Regulations are up to now product oriented, but energy efficiency improvement is necessarily a combination of an energy related product approach (ErP) and a system approach.

Whilst there are some applications in which variable speed drives (VSD) are the better alternative, it is also clear that motor starters offer the most energy efficient solution for fixed speed applications, independently from the efficiency class of the motor (IE2/IE3).

Therefore, an IE2 motor equipped with a variable speed drive is not equivalent to an IE3 motor equipped with a motor starter. Instead, it is always necessary to consider the speed and load requirements of the application in order to choose the best solution.

Regulation EC 640/2009, Article 3

❶ From16 June 2011

motors shall not be less efficient than the IE2 efficiency level, as defined in Annex I, point 1.

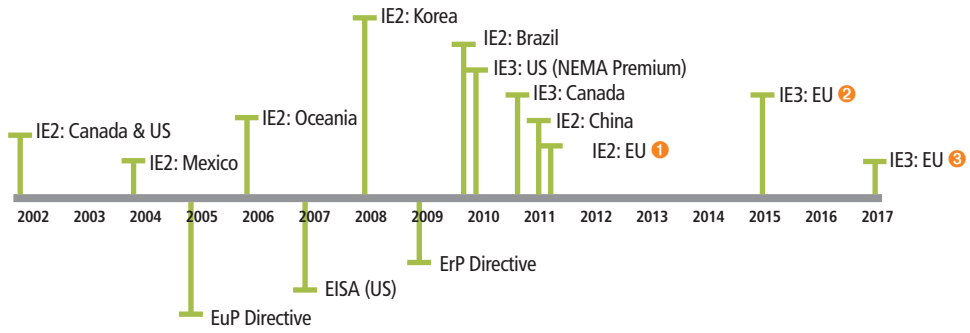
❷ From 1 January 2015

(i) motors with a rated output of 7.5-375 kW shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or meet the IE2 efficiency level, as defined in Annex I, point 1, and be equipped with a variable speed drive.

❸ From 1 January 2017

(i) all motors with a rated output of 0.75-375 kW shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or meet the IE2 efficiency level,as defined in Annex I, point 1, and be equipped with a variable speed drive.

Legislative Timeline for Motor Efficiency Class Transition



(data taken from "Motors & Drives Global Market Update 2011", IMS research)

The regulation allows the end user to choose whether to use an IE3 motor (fixed or variable speed), or an IE2 motor controlled by a variable speed drive. However, an IE2 motor equipped with variable speed drive is not equivalent to an IE3 motor from the energy efficiency point of view.

Therefore the manufacturers' associations CEMEP (Motors and Drives) and CAPIEL (Switchgear and Controlgear) together with the EU Commission have committed to the following common understanding:

Applications with fully loaded motors running at the network frequency and controlled by fixed speed motor starters, would consume less energy than if they were controlled by a Variable Speed Drive (VSD). Other applications, particularly variable torque loads, would reduce their energy consumption by using a VSD to match the motor speeds to the variations of the process demands. Both of the above statements apply to either an IE2 motor or an IE3 motor.

Referring to the Regulation (EC) 640/2009, Article 3, sub clauses 2 and 3, the end user has the decision whether to use an IE3 motor (fixed or variable speed), or an IE2 motor controlled by a variable speed drive. The end user should base their decision on which solution offers the lowest energy consumption for the dedicated application.

The determination of the lowest energy consumption for each specific application shall be performed in accordance with the standard (project number 23551) being developed by CENELEC CLC/TC 22X/WG 06. This standard is in response to European Commission mandate M/476 and M/470.

The designer of a specific application has to evaluate the energy losses of both possible solutions and to select the solution which meets the user's requirements and offers the lowest energy consumption.

Does the regulation influence the purchasing of an electric motor?

The main purpose of the Ecodesign Regulation is to reduce the electricity consumption of the electric motor. An additional benefit is the reduction of energy costs which will enable a shorter payback period. IE3 motors are now available from many motor manufacturers.

Whilst the initial purchase price of an IE3 motor is higher, any increase should always be compared to the energy cost savings that will be realised during the life of the motor.

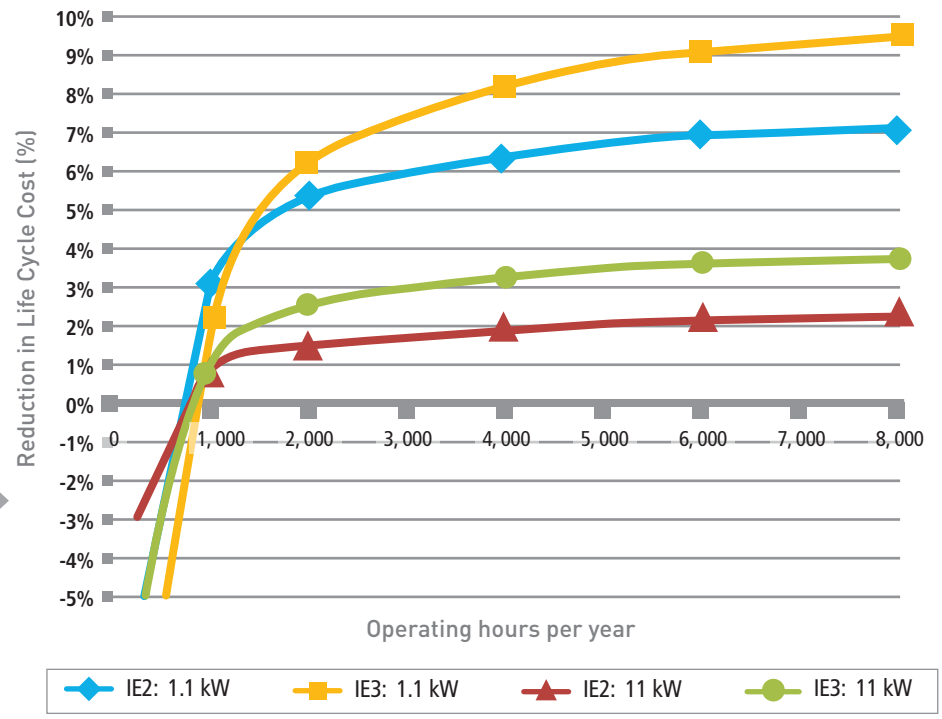
Because energy costs account for over 80% of the life cycle costs of motors, high efficiency motors clearly offer significant life cycle cost reduction as well as benefitting the environment.

Studies with high efficiency motors have demonstrated that the life cycle cost is reduced such that the additional purchase cost, compared to an IE1 motor, is paid back over its average life time for a duty higher than 800h/year.

For higher duties, IE3 motors offer further savings compared to lower efficiency motors.

The correct sizing of motors (in particular, avoiding over-sizing) is of the utmost importance in order to maximise the environmental benefit at the same time as minimizing the investment.

Life cycle cost reduction compared to IE1 motor



Data from the EC preparatory study with IE1 4000 h/year, 60% load, 12 years for 1.1 kW and 15 years for 11 kW.

Changing to an IE3 motor today will help ensure future compliance to EU legislation as well as providing energy savings.

- All major motor manufacturers already offer IE3 motors.
- Some stakeholders of motor systems have already enjoyed good experiences following the recent introduction of high efficiency motors in their applications.

ANSWER: Yes, the EU regulation requires the use of high efficiency motors. In particular, IE3 motors shall be used. This reduces the environmental impact, reduces life cycle cost and makes the application fit for the future.

Does the regulation change the criteria to use a motor starter?

Some applications are best suited to fixed speed control, some applications are best suited to VSD's, and others require very careful consideration –sometimes leading to a combination of fixed and variable speed control in order to optimise energy efficiency.

Furthermore, from a system standpoint, the overall energy efficiency is determined by the chosen system solution, not the individual system components alone.

Fixed speed	Changing loads depending on application requirements	Variable speed
• pumps in water storage • stirring units in waste water treatment • constant speed conveyors • ventilation	• HVAC of buildings • transportation of goods • water supply	• hoisting • positioner in machine tools • closed-loop control: circular pumping or ventilation (without throttle) or booster pumps
Typical control approach:	**Typical control approach:**	**Typical control approach:**
• switching devices such as contactors or softstarters	• switching devices and/or VSD with an appropriate control strategy	• variable speed drive • complex control electronics

Systems are often characterized by different or varying load conditions.

Such loads are characterized by their speed and torque, both of which are provided by the motor. Both load components – speed and torque – are therefore necessary to describe the load characteristics of a system.

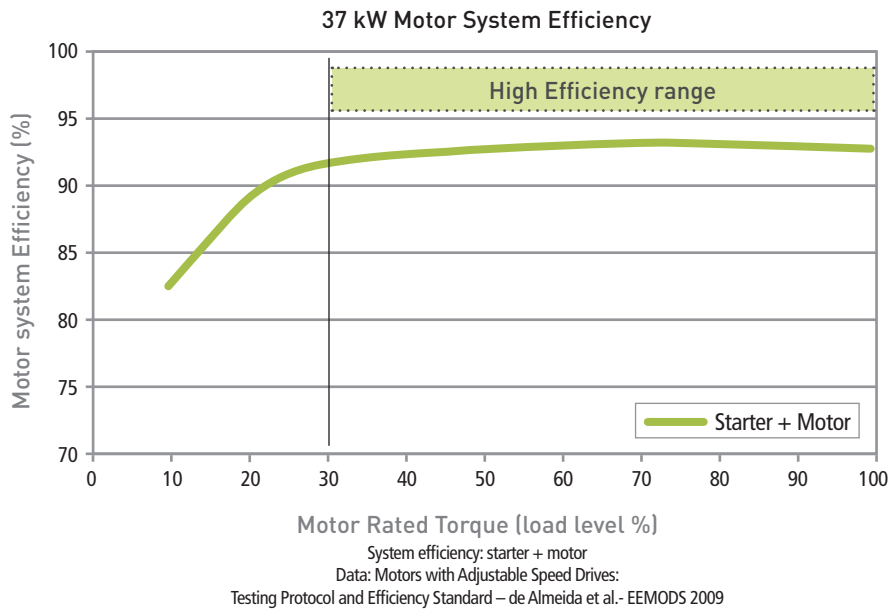
Speed and torque can vary independently (different static loads) or dependently (dynamic load changes in case of acceleration / deceleration).

The majority of applications are fixed speed. Varying load levels therefore result in a change of torque only.

Variable speed control is appropriate when applications and processes require the speed to be adjusted.

Variable load in fixed speed applications

In the case of fixed speed applications, load changes are automatically balanced by the self-adjusting characteristic of the motor. Above a load level of about 30% the motor always works at high efficiency when operated with motor starters.



System efficiency: starter + motor
Data: Motors with Adjustable Speed Drives:
Testing Protocol and Efficiency Standard – de Almeida et al.- EEMODS 2009

Typically, within an application there are different load levels. If possible, the motor should be sized such that the application load levels are within the 30% to 100% range of the motor rated power. The big advantage of such a dimensioning is a very wide operating range from 30% to the rated motor power with a very high efficiency.

Motors are designed to withstand an overload condition, for example 120%, for short periods of time.

ANSWER: No, because the selection of a motor starter should always be the result of a system analysis.
As shown above, many applications will achieve higher energy efficiency using a motor starter solution.

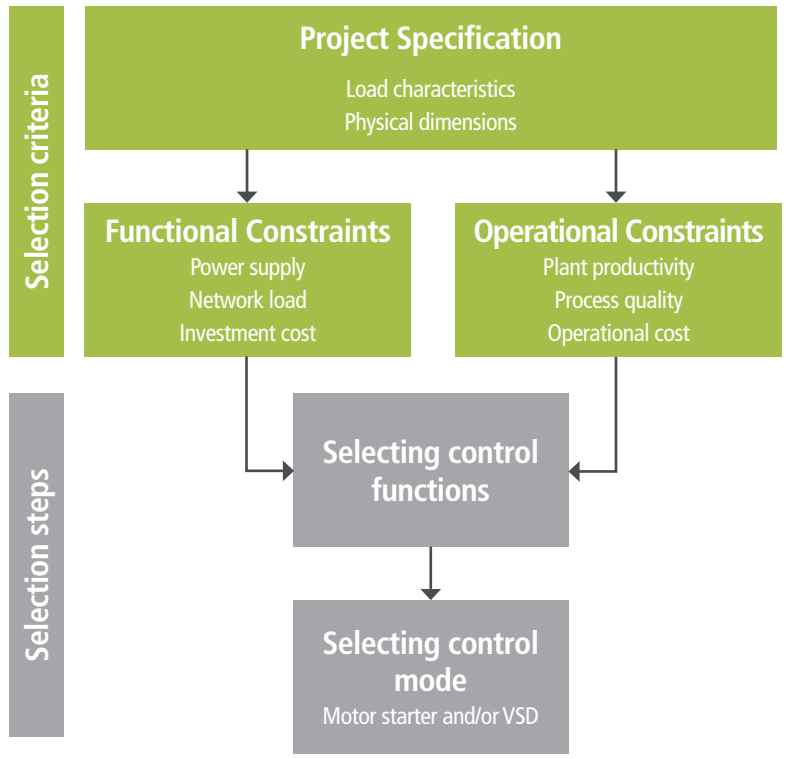
Does the selection of the motor control mode depend on factors other than energy efficiency?

Besides energy efficiency, several other factors and constraints influence the decision whether to use a VSD or a motor starter (contactor, softstarter or star-delta starter).

The following types of motor starter are used for starting and controlling three phase AC induction motors:

- Direct on line starters/reversers provide the simplest, most economical and reliable solution to control motors.
- Star Delta starters offer a simple and economical way to reduce the starting current if the load allows a starting torque of 1/3 rated torque.
- Soft starters offer reduced starting current and therefore reduce the demand on the electrical supply (transformers or generators). Some offer additional features such as pump control, current limit, kick start, creep speed, etc.

The specification of a control architecture should result from the different requirements of the application, including energy efficiency, reliability, and life cycle cost.



In addition to providing the most energy-efficient solution for fixed-speed applications, motors starters have other practical advantages that need to be considered during the selection process:

- **Low costs**
  - Low purchasing, installation, operation and maintenance costs
  - Simpler engineering of the power and control system
- **Optimal control cabinet design**
  - No need of additional cooling due to negligible losses
  - Minimal space required
- **Simple implementation**
  - Easy installation, operation and maintenance
  - No need of additional power supply
- **Robust motor system**
  - No Electro-Magnetic Compatibility issues
  - High level of safety, availability and reliability
  - Long lifetime.

Motor starters therefore offer best-in-class solutions in terms of overall effectiveness.

ANSWER: Yes, because the selection of the control mode is not a product approach. Instead, it is the result of a system approach considering functionality, availability, maintainability and life cycle cost.

Does the regulation change the way to design a system?

Comparison of the energy consumption of a system controlled by a direct on line (DOL) starter versus a variable speed drive (VSD) for a variable load application.

In this example we consider a conveyor application for carrying bulk material over long distances as it often exists in mining industry. This is a typical fixed speed application which in this example is driven by a 37 kW motor.

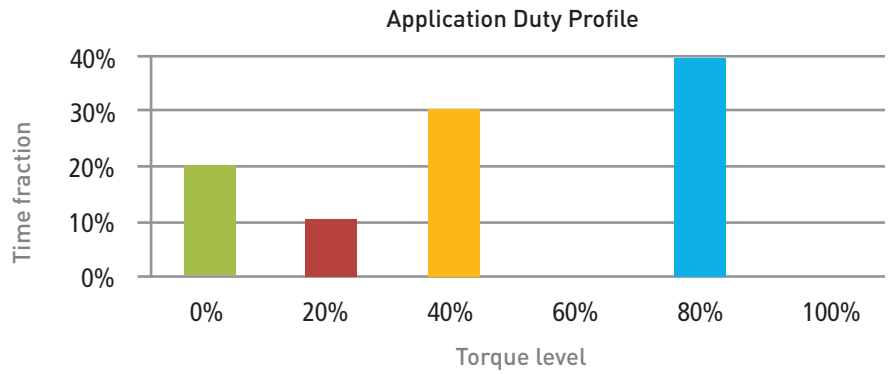
Conveying is a typical example of a fixed-speed application.

The torque depends on the quantity of material being moved at a given time. Therefore, it is a fixed speed, variable load application.

In this example, the application's duty profile is:

- No load for 20% of the time
- 20% load for 10% of the time
- 40% load for 30% of the time
- 80% load for 40% of the time.

A typical duty profile of the application is shown below:



The operating time is assumed to be 3600 hours per year.

The energy consumption of the control components is included in the efficiency comparisons.

(*) In standby mode, the contactor disconnects the motor from the grid, while a VSD needs about 1.6 kW power (in this case) to feed its control board and DC circuit.

Considering the time spent at each power level, and the corresponding efficiencies (see page 5), we can directly compare the energy consumption per year in each case.

	Efficiency		Energy [MWh] per year	
Load	**Contactor + Motor**	**VSD + Motor**	**Contactor + Motor**	**VSD + Motor**
0%	Off	Standby	0.0	1.6 (*)
20%	90%	83%	3.0	3.2
40%	92%	87%	17.4	18.4
60%	93%	91%	0.0	0.0
80%	94%	91%	45.3	46.8
100%	93%	90%	0.0	0.0
Total			**65.7**	**70.0**
			4.3 MWh saved/year	
			6.1% saved	

The direct-on-line motor is more efficient at any load level than the motor and VSD combination, and achieves an energy saving of 6.1%. Even if the application has no standby phase, the savings are still around 5.5%.

ANSWER: No. The design of the system should always result from a system-level analysis. Direct on line control is always more efficient for fixed speed applications.

Summary

EU Ecodesign legislation targets the efficiency of motors, but for overall energy efficiency improvement it is necessary to take into account both the motor efficiency and the system efficiency.

Starting in 2015, the system designer must decide whether to use an IE3 motor (fixed or variable speed), or an IE2 motor controlled by a variable speed drive. He should base his decision on which solution offers the lowest energy consumption for the dedicated application.

Our recommendations

- Consider IE3 motors today even before they become mandatory. This will help future compliance of your design.
- Focus on energy consumption and use motor starters where they provide the most efficient solution. For example, use motor starters in fixed speed applications.
- Apply variable speed drives in applications where they bring an added value or significant energy savings.
- Determine the lowest energy consumption for each specific application in accordance with the future CENELEC standard "Energy efficiency for Power drive systems, motor starters, power electronics and their driven applications".

Select the control mode as the result of a system analysis considering also functionality, availability, maintainability and life cycle cost.

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