

TECHNICAL REPORT



**Switchgear and controlgear and their assemblies for low voltage –
Energy efficiency**

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TECHNICAL REPORT



**Switchgear and controlgear and their assemblies for low voltage –
Energy efficiency**

INTERNATIONAL
ELECTROTECHNICAL
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SWITCHGEAR AND CONTROLGEAR AND THEIR ASSEMBLIES FOR LOW VOLTAGE – ENERGY EFFICIENCY

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IEC TR 63196, which is a technical report, has been prepared by committee 121: Switchgear and controlgear and their assemblies for low voltage.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
121/44/DTR	121/47A/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

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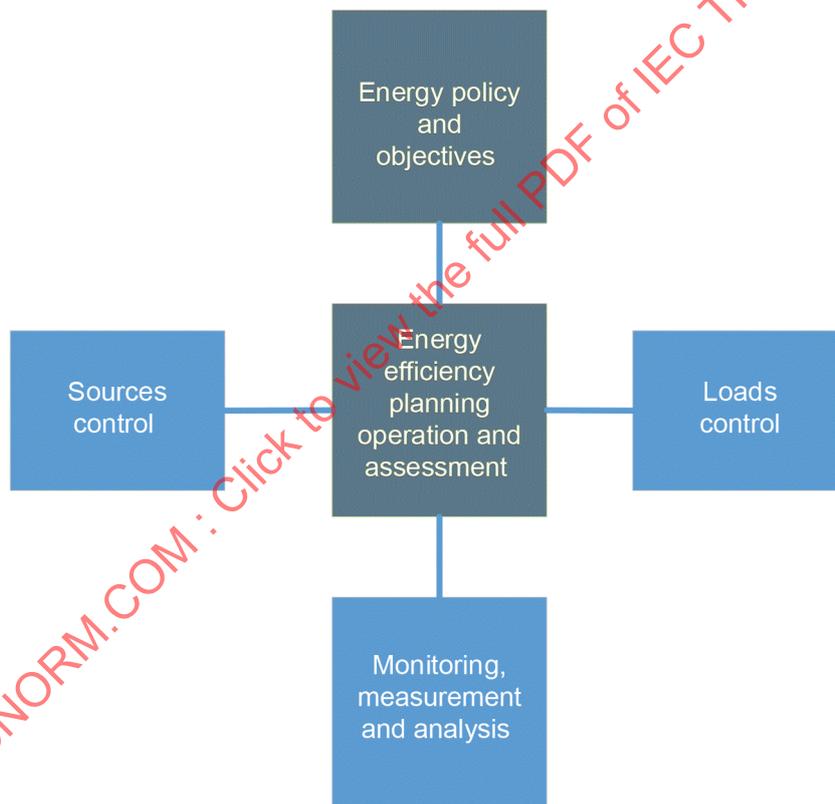
INTRODUCTION

Energy efficiency (EE) is a horizontal topic spanning the IEC domain and may be dealt with in standards in various forms across a wide range of technologies and for different products, processes and services.

The horizontal nature of the topic and increasing integration of products, processes and services entering the market implies that standard writers identify which aspects of energy efficiency are relevant for standardization, and:

- use a systematic approach (see IEC Guide 119);
- adopt a systems approach.

The objective of an energy efficiency management system is to improve continuously the energy performance of an energy using system such as a production facility or an office building. As shown below in Figure 1 (see dark blue boxes), it is based on the particular organization's energy policy, supporting energy objectives and it is implemented by processes (planning, operations, assessment, etc.) to achieve those objectives.



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Figure 1 – Overview of energy efficiency management

Many types of equipment, including switchgear and controlgear and their assemblies, depicted in the light blue boxes in Figure 1, make an important contribution to the overall energy efficiency of a system.

This document aims to give guidance to product standards writers and other interested parties on the way energy efficiency should be considered for switchgear and controlgear and their assemblies.

By following this document, experts in standards will be encouraged to:

- consider energy efficiency aspects in their product standards and any associated publications;
- use a structured method;
- use a systems approach;
- support the dissemination of energy efficient technologies;
- accelerate the uptake of the next generation of energy efficient technologies;
- create the prerequisites for energy efficiency through enabling technologies.

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SWITCHGEAR AND CONTROLGEAR AND THEIR ASSEMBLIES FOR LOW VOLTAGE –ENERGY EFFICIENCY

1 Scope

This document is following the principles of IEC Guide 119. This document defines the energy efficiency aspects of switchgear and controlgear products complying with IEC 60947 (all parts), IEC 61095 and IEC 62626 (all parts), and associated assemblies complying with IEC 61439 (all parts), in the context of the overall system energy efficiency. This document references energy policy aspects, as well as product and system aspects.

This document generally assumes electrical energy input, whereas the output can be a number of different products and/or services.

This document:

- helps to harmonize the energy efficiency requirements and guidance in product standards;
- raises awareness that provisions in publications can generally influence energy efficiency;
- helps to identify energy efficiency aspects;
- promotes the use of a systems approach to energy efficiency.

Other than energy efficiency aspects, this document does not cover environmental impacts (see IEC TS 63058).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 energy management

coordinated activities directing and controlling the energy use of an entity

3.2 energy management system EnMS

set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve those objectives

[SOURCE: ISO 50001:2011, 3.9]

3.3 energy efficiency

EE

ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy taking into account the driving parameters and the boundaries

Note 1 to entry: Both input and output need to be clearly specified in quantity and quality, and be measurable.

EXAMPLE Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.

[SOURCE: ISO/IEC 13273-1:2015, 3.4.1, modified – Insertion of “taking into account the driving parameters and the boundaries”, symbol “ E_f ” renamed to “EE”, and “Efficiency conversion energy” renamed to “Conversion efficiency” in example.]

3.4 recovered energy

energy that is withdrawn from system energy loss to become applied energy at another energy using system

[SOURCE: ISO/IEC 13273-1:2015, 3.1.11.2.1]

3.5 load

electric equipment intended to convert electric energy into another form of energy, for example light, heat, mechanical energy

3.6 peak shaving

process in an electrical system intended to not exceed a maximum overall energy demand

Note 1 to entry: Peak shaving can be obtained by planning of energy needs within the manufacturing system or load shedding or autonomous energy production.

[SOURCE: IEC TR 62837:2013, 3.3.8]

3.7 load shedding

process of deliberately disconnecting preselected loads from a power system in order to maintain a certain performance level

[SOURCE: IEC 60050-603:1986, 603-04-32, modified – “the integrity of the remainder of the system” replaced by “a certain performance level”.]

3.8 energy performance

measurable results related to energy efficiency, energy use and energy consumption

Note 1 to entry: Energy performance can be improved by reducing the energy consumption and/or improving the energy efficiency.

[SOURCE: ISO/IEC 13273-1:2015, 3.3.1, modified – New Note 1 to entry.]

3.9 energy efficiency improvement

increase in energy efficiency as a result of technological, design, behavioural or economic changes

[SOURCE: ISO/IEC 13273-1:2015, 3.4.3]

3.10 energy policy

statement by the organization of its overall intentions and direction of an organization related to its energy performance, as formally expressed by top management

Note 1 to entry: The energy policy provides a framework for action and for the setting of energy objectives and energy targets.

[SOURCE: ISO 50001:2011, 3.14]

3.11 energy control centre ECC

switchgear and controlgear assembly designed to manage different types of energy sources and/or their loads

4 Contribution of low-voltage switchgear and controlgear and their assemblies to energy efficiency

Many energy-efficient technologies and solutions are already available and cost-effective; nevertheless, a lack of awareness may slow down the deployment of these technologies and impedes harvesting their energy efficiency potential. In this context, switchgear and controlgear can be used as resources (see Figure 1) for three different roles:

- 1) controlling the electrical (energy-using) loads in an efficient way;
- 2) source control: selecting, connecting or disconnecting the source of energy, as appropriate;
- 3) monitoring, measuring, analysing such as:
 - the availability of energy sources;
 - the power from each source and the power consumed by each load, including power quality;
 - sensing other environmental inputs (temperature, overload conditions, etc.).

5 General concepts of energy efficiency

5.1 Concept of energy efficiency system

5.1.1 System considerations

Energy efficiency relates the output of an activity to its energy input, for a given system. The input can be expressed in various energy units (kWh, etc.), while the output may not be necessarily expressed in energy units and covers a wide range of activities and services, for example controlling a load (switch on/switch off/protect/monitor), providing data, etc. See Figure 2.

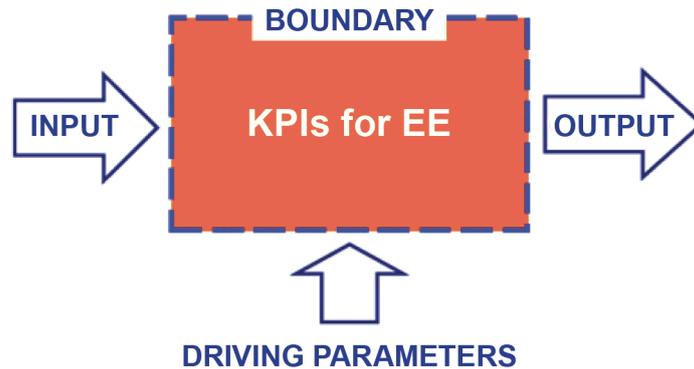
It is key for energy efficiency not to reduce the given service but to optimize the energy input for a given service.

NOTE Implementation of energy efficiency measures can be based on energy price consideration.

It should be noted that:

- energy efficiency may vary when the system changes;
- energy efficiency may vary and degrade in time.

EXAMPLE A system boundary to measure EE could be an electric motor itself or a motor-pump combination or the whole pumping system, consisting of a motor, a pump and the pipe installation.



SOURCE: Figure 1 of IEC Guide 118:2017.

Figure 2 – Key elements in energy efficiency definition

5.1.2 System boundary description

5.1.2.1 General

The system boundary should be adequately described in any publication dealing with energy efficiency.

System boundaries should be defined in terms of:

- intended use (relevant applications);
- energy inputs;
- outputs;
- driving parameters;
- EE related key performance indicators (KPIs);
- interactions between components of the system;
- possible interactions with other systems.

Boundaries can include a device, a product or a system depending on the application considered. System boundaries may include:

- the physical limits;
- communication interfaces;
- any measurable inputs and outputs.

5.1.2.2 Input

Amount of electrical power input to the system.

5.1.2.3 Output

Output is the intended service plus any recovered energy for subsequent use.

5.1.2.4 Driving parameters

The driving parameters shall be defined. These are all external factors that affect energy efficiency and include, for example: regulation, environmental conditions, energy prices and management requirements, mode of operation, duty cycle, load curves, state, operating parameters, indoor temperature, lighting levels, production volume, range of products.

5.1.2.5 Energy efficiency related KPI(s)

Suitable key performance indicators (KPIs) should be provided, typically as defined by the energy policy (see Figure 1).

EXAMPLE KPI = quantified amount of service/unit of energy used.

5.2 Limits of the energy efficiency concept

5.2.1 Electrical energy efficiency and safety

The safety of persons, property and livestock remains of prime importance compared to the energy efficiency statements. Consequently, all guidance to achieve energy efficiency shall not impair the safety requirements included in relevant standards.

5.2.2 Availability of electrical energy and user decision

Energy efficiency management shall not reduce electrical availability and/or services or operation below the level needed by the user and/or defined by the product standard.

It is recognized that the users of the electrical system should be able to take the final decision whether or not to use the most efficient service.

At any time, the users should be able to make an exemption and to use the service in accordance with their needs while being aware that this can be less efficient than expected.

EXAMPLE 1 If someone is ill, the user can decide to heat the room at a higher temperature, even during peak consumption.

EXAMPLE 2 If a company receives an urgent delivery order, the workshop can need to work at an unscheduled hour.

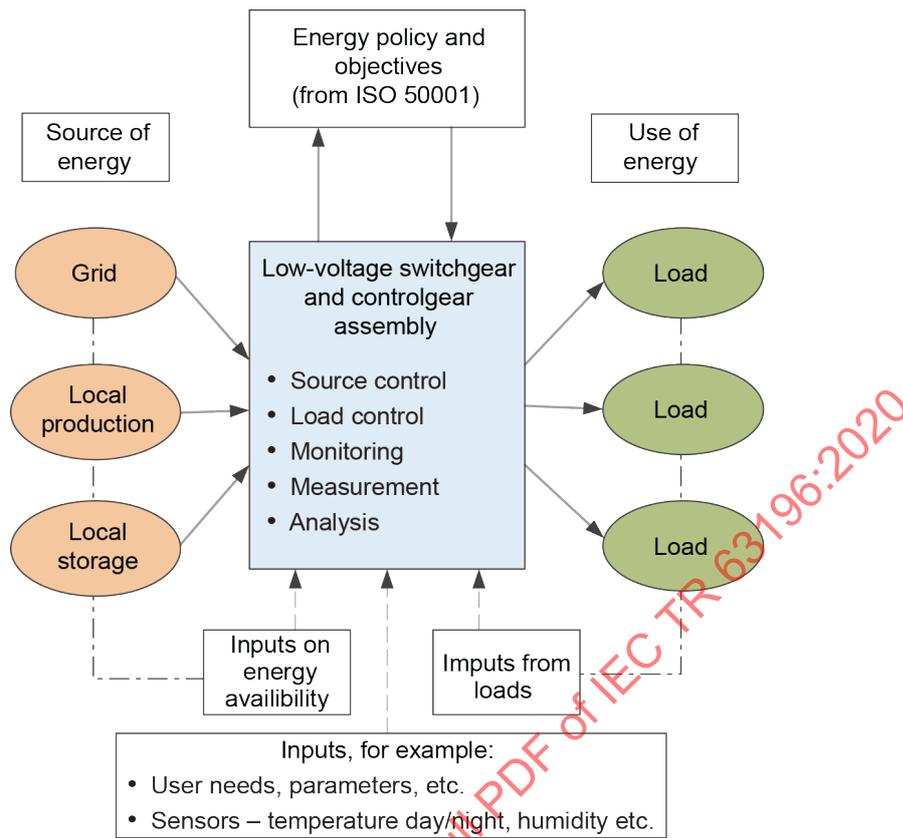
6 Energy efficiency for switchgear, controlgear and their assemblies

6.1 General

An energy efficiency and load management system optimizes the usage of the energy consumed, taking into account the loads, local production and energy storage and user requirements.

Low-voltage electrical installations are evolving towards prosumer's electrical installations (PEI) as reported in IEC 60364-8-2. The concept of a PEI includes local (renewable) energy sources and/or storage units. This concept is based on the central role of the end-user to control (via an ECC) its usage of electrical energy considering its needs and the effects on the distribution system operator's supply requirements (DSO). The end-user should be able to permanently monitor and control its own electricity consumption and its own electricity production through an active energy management system. This system is intended to balance the local consumption with the local production and the supply from/to the DSO.

Figure 3 shows the scheme of the energy management system to be implemented in an electrical installation in accordance with IEC 60364-8-1 in order to enable the energy efficiency to perform source switching and load shedding coordinated operations (see 6.3.1). These operations are needed to optimize the overall use of electrical energy.



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SOURCE Figure 3 is adapted from Figure 1 of IEC 60364-8-1:2019.

Figure 3 – Role of low-voltage switchgear and controlgear in energy efficiency management

Switchgear and controlgear can be used in such energy efficiency and load management systems by their intrinsic functionalities and combinations of the different capabilities. Figure 4 shows how these energy efficiency measures are situated in the landscape of switchgear and controlgear and their assemblies.

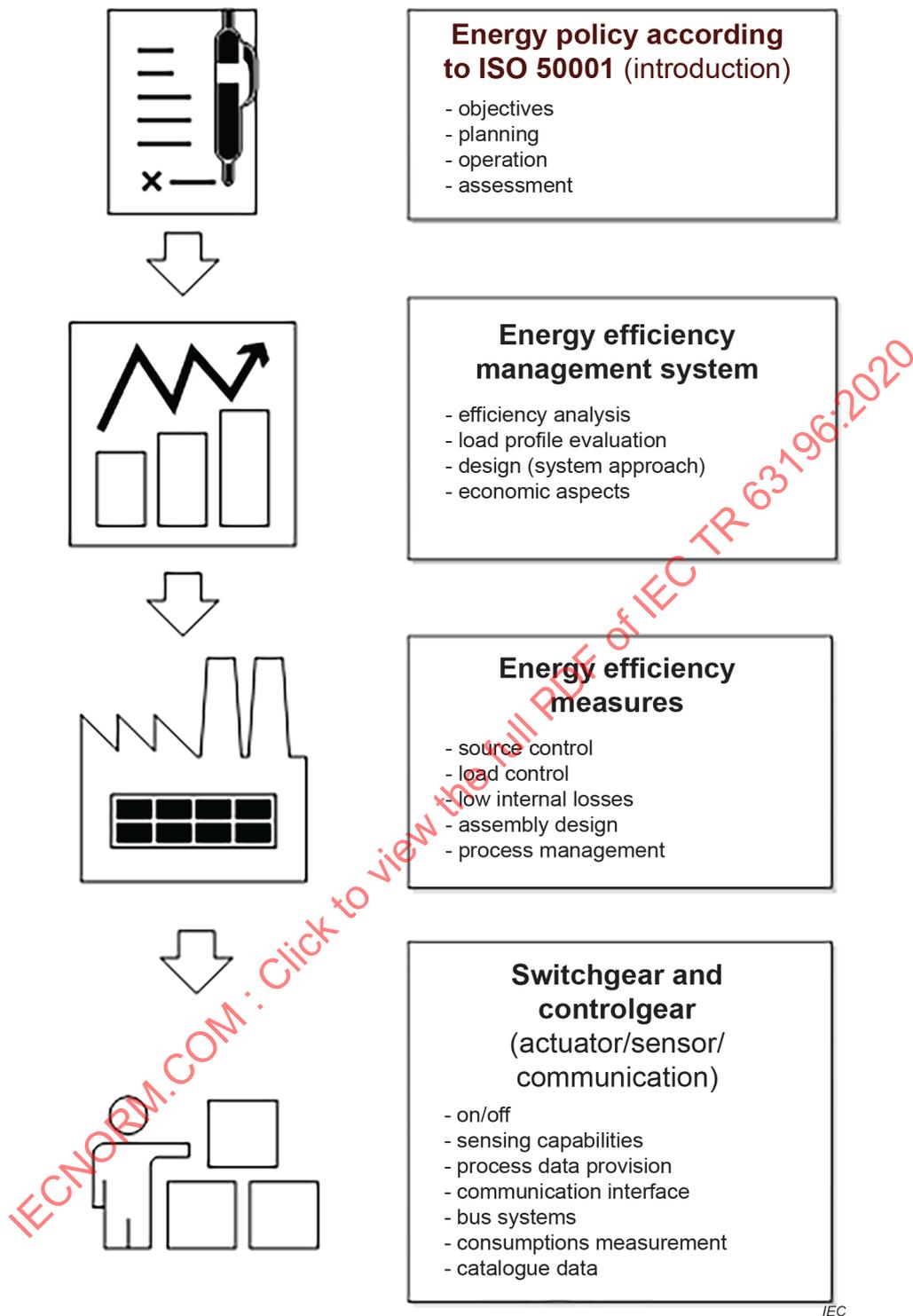


Figure 4 – Energy efficiency landscape concerning switchgear and controlgear and their assemblies

6.2 Energy efficiency management system/optimization of the overall energy consumption

6.2.1 Optimization of energy consumption

6.2.1.1 General

The main task of an energy efficiency management system is to optimize the energy availability, use energy economically and improve energy efficiency. A description of an energy efficiency improvement process is given in IEC Guide 118.

The goal of an energy efficiency management system is to realize the saving and improvement of the existing energy consumption through intelligent system integration.

6.2.1.2 Composition of energy efficiency management system

An energy efficiency management system consists of three parts: decision-making system, control system and data measurement system.

6.2.1.3 Functions of energy efficiency management system

An energy efficiency management system may have the following functions:

- remote real-time transmission of energy data;
- fault alarm: abnormal energy consumption alarm;
- dynamic energy consumption monitoring;
- analysis and evaluation of energy efficiency;
- analysis of energy use;
- operation control / load management of equipment;
- prediction and control of energy saving targets;
- decision-making of energy optimization strategy.

6.2.1.4 Energy consumption diagnosis

Real-time monitoring and data acquisition is conducted by means of an analysis and diagnosis module in energy management, and the acquired results are analysed statistically and diagnosed intelligently to support the optimization of the operation mode and energy consumption distribution and thus reduction of electric energy loss.

6.2.1.5 Energy consumption monitoring

An energy consumption monitoring device is used to regularly acquire every kind of information on energy consumption, such as voltage, current, reactive power, harmonics, etc., and upload this information to the energy efficiency management system.

6.2.2 Electrical energy efficiency management

6.2.2.1 General

The electrical energy optimization needs a global approach of the management of the electrical energy consumption, generation, storage, etc., including consideration of all operating modes.

6.2.2.2 Strategy of energy management

Energy efficiency should firstly be applied to loads and their usage.

Motor loads account for 70 % of the electricity consumed by industry (figure from the European Community Commission Regulation No 640/2009). Improving the load profile by a system analysis and afterwards selecting the most appropriate motor should be the first focus.

The electrical distribution architecture (generation and transmission) should also be considered, as well as power supplies and wiring systems.

6.2.2.3 Energy management using automation and control

Energy management through automation is a significant contributor to energy efficiency. Automation design over the past decades has continued to evolve, introducing new methods that are of increasing importance in energy saving (availability and cost).

Status information, measurements from sensors, commands from the operator and information from the environment are necessary inputs to the energy management system (EnMS). The automation function of the energy management system should ensure that the energy is consumed at the right moment, for the right purpose and in the right quantity. The EnMS may be very simple or complex (contactor relays, simple control loop, extended functions of circuit-breakers or motor management systems, programmable logical controllers, etc.). Contactors and starters are essential for managing power by switching remotely individual loads or groups of loads without adding significant power losses.

It applies in all sectors including manufacturing, process control, industrial facility management, building automation.

EXAMPLE 1 In building automation, it is a common idea that the management system optimizes the usage of energy, taking into account the occupancy schedule, the outside conditions (temperature, light) and the real presence of persons. From the idea to the effective realization, there might be a gap due for example to the difficult modelling of the thermal response of the building, to inaccurate detection of individuals, to not interoperable communication interfaces.

EXAMPLE 2 In discrete manufacturing industry, saving the useless consumption of the standby energy of the loads is an important field of improvement. It consists in switching off totally or partially the loads during short, long or unscheduled breaks. The challenge is to ensure a restart in the time constraints for the production facility.

6.2.2.4 Approach of energy efficiency management

Energy efficiency management and optimization should focus on a systems approach rather than optimization of single components. A systems approach to energy efficiency evaluates how to use components effectively and efficiently in the application.

First, study the energy consumption mode of the whole electrical system and each device through assessment or practical measurement to get an overview of the energy consumption and then look for ways of reducing electrical energy losses. Changing the electricity consumption habit is the easiest way to save energy.

Efficient use of electrical energy requires optimization of systems and components. Electrical energy efficiency optimization of systems requires the study of operating conditions and understanding the reasons for energy losses. Once the system is well understood, ways of improving energy efficiency should be determined without affecting minimum service level(s). Where individual components have significant losses, alternatives should be used providing the function of the system is not affected.

Significant measures to improve energy efficiency should include the following:

- most energy efficient systems are generally those where energy efficiency is considered at a project concept stage;
- energy efficient systems should consider and optimize the use of all energy sources available for example utility, renewable and energy storage;
- analysis of the major part of energy consumption within the system.

Energy efficiency aspects (categories and examples) are presented in Table 1 of IEC Guide 118:2017.

6.2.3 Economic aspects

The cost of electricity often varies contractually with the time of use and with the maximum power demand. To better match the demand with the supply capacity, utilities are using smart grid technologies to implement demand-response management where users and utilities respond in real time to changes in demand, supply, cost and quality of electricity. Users use this real-time information flow to manage their use of power so that it meets their needs. The smart grid integrates demand-response technologies enabling to reduce or reschedule the power use during peak times. Empowered by smart electrical systems, users cease to be mere consumers. They become prosumers, proactively consuming and even producing electricity for sale.

Smart devices (circuit-breakers, relays, motor-starters, etc.) do more than protect and control loads. They are communicant, include measurement capabilities and give users load control capabilities. With these devices, assemblies are getting smart. They are allowing to monitor load-profile, peak consumption, power quality, as well as any relevant electrical distribution parameters, in order to optimize the cost of energy.

6.2.4 Systems approach

Energy efficiency needs to be analyzed using a systems approach rather than seeking to optimize each single component. A systems approach to energy efficiency does not only consider the energy performance of the single components, but, and essentially, how efficiently these components are used within the application/boundary.

A systems approach to energy efficiency implies that the energy efficiency of one or more components may be de-optimized in order to achieve the maximum efficiency in the considered application/boundary.

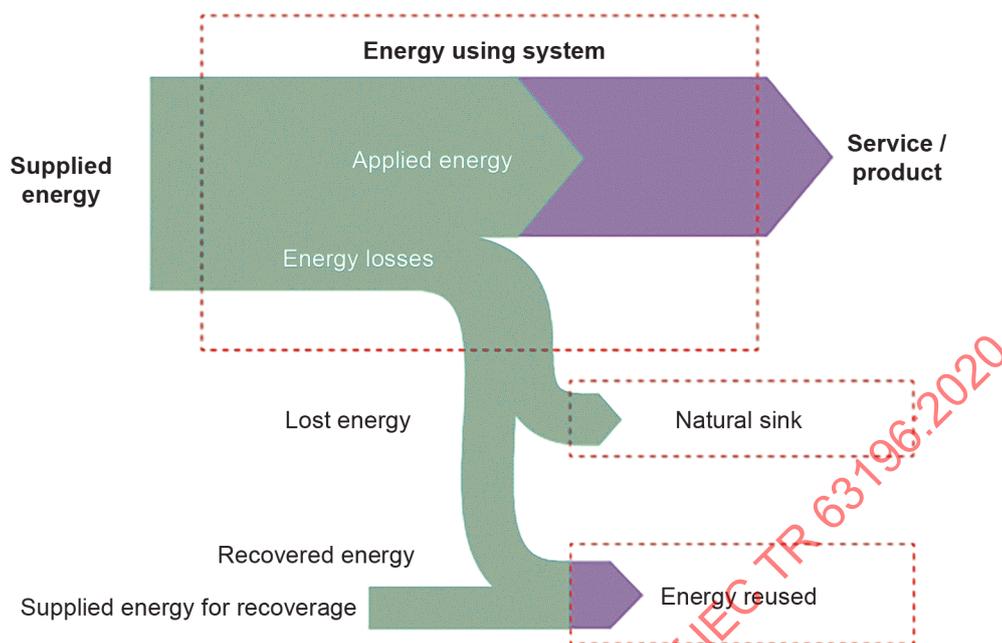
A systems approach to energy efficiency is likely to optimize energy efficiency improvements as:

- the components and the application are considered together;
- the incremental increase in terms of energy efficiency of individual components may be sometimes fairly modest;
- an energy efficiency improvement at components level can be totally spoiled if this high efficient component is used in poor operating conditions.

An example of systems approach can be to put the machine in standby mode or to switch it off, if possible.

This systems approach allows the system integrator or the end user to evaluate the energy efficiency of a system by assessing its service/product produced in relation to the supplied energy needed for the operation of the system as shown in Figure 3. This assessment can be realized globally but also by aggregating the assessment results of the subsystems, providing that there are using the same operating parameters and external factors, including all auxiliary services, for example necessary cooling systems. An example of such a methodology is given in IEC 61800-9-1.

In addition, the energy losses shall be considered more specifically. As shown in Figure 5, a part of them which would normally be wasted can be reused, usually by converting them into electricity or thermal energy. This recovered energy is usually done in the form of combined heat and power (also called co-generation) or waste heat recovery.



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Figure 5 – Useful energy, energy loss and recovered energy

6.3 Energy efficiency measures

6.3.1 Load shedding system (in combination with peak shaving)

When load shedding is initiated, the total load is systematically reduced until the required level of power consumption is reached, either by manually reducing or by shutting off individual loads, or by an automated system. All loads in a facility shall be defined in different categories including critical, essential, and nonessential loads. Usually only nonessential loads are shed, and the order of shedding can be configured.

This energy management system, based on load shedding and source switching, should also guarantee the availability of energy and, as a consequence, the continuity of service. These aspects are fundamental in industrial installations.

Load shedding equipment (LSE) and source switching equipment (SSE) fulfil specific requirements to implement the energy management with no significant effects on the load (e.g. no voltage fluctuations nor dips).

The source switching function can be implemented by dedicated transfer switching equipment (TSE according to IEC 60947-6-1).

The load shedding function, to release LSE, can be implemented in switchgear and controlgear.

LSE is intended to control one or more load, circuit or mesh when:

- defined conditions of time and/or current or power are reached;
- a command of an external system is received.

LSE can be realized:

- either in a single equipment having all the necessary means able to control the loads (e.g. the electrical energy management function is embedded in such an equipment); or
- as a function integrated in a single switching device (e.g. contactor, circuit-breaker); or
- as a function being part of an electrical energy management system (EEMS); or
- as a combination of independent components forming an LSE (e.g. with external current sensors); or
- as a combination of the above items.

LSE is intended for use in circuits where the fault and additional protections compliant with the installation standards (see IEC 60364 (all parts)) are already assured by the electrical installation.

Consideration should be given as to how the implementation of load shedding can impact the lifetime of the controlled load. LSE may be suitable for selected types of loads and/or with limitations in operations and/or shedding conditions (e.g. loads with high inertia are inherently suitable for load shedding).

Monitoring relevant data/parameters is essential to conveniently perform load shedding.

EXAMPLE Examples of such parameters are:

- load current and/or power;
- load profile (e.g. expected current/power demanded by the load versus time);
- external conditions (e.g. weather conditions, energy price).

6.3.2 Benefit of fixed speed motor control systems

AC induction motors are the most common motors used in industry. They are primarily designed as fixed speed devices. For fixed speed applications, the motor-starter (direct-on-line, star-delta, two-step, soft-starter) is the most energy-efficient solution.

The power dissipation of the various fuseless switching devices is in the range of 0,1 % of the power of the load to be switched.

An AC induction motor can consume more energy than it needs to perform its work, especially when operated with less than 30 % of the rated load or by unnecessary idling and jogging.

Direct-on-line controlled motors draw a current as determined by the mechanical load. With loads greater than 30 % of motor full load, the motors are nearly as efficient as at full load. At loads less than 30 % the efficiency reduces significantly.

When a motor has a duty profile such as generally lightly loaded (less than 30 % of nominal full load), the efficiency of a motor can be improved by using a smaller motor. It is important to avoid oversizing motors to cope with short-time peak loads (induction motors are able to operate at 150 % of rated load for periods of up to 2 min).

The appropriate choice of the motor and of the applied motor control will improve the global energy efficiency of the electric motor system.

When it is necessary to provide a variable speed system, there are practically only three methods to change the rotation speed of the system: use of frequency converter, mechanical transmission system or use of motor with separate windings for different speeds. The latter two methods result in fixed speed arrangements for the motor when the motor is used with a motor-starter. Only for applications where fully variable speed control is needed, a frequency converter with an induction motor shall be used.