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Chapter 7
Low voltage electrical installations – energy efficiency functional aspects

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This article is based on IEC 60364-8-1 Energy Efficiency standard. It presents the most important aspects contained in the standard. It describes the procedures for increasing the energy efficiency of existing and new, still being designed, electrical installations. The most important aspects that the designer should pay attention to are presented, concerning the design, construction, operation and verification of all types of low voltage electrical installations. Attention is drawn to the necessity of analyzing the location of elements of installations and receivers already at the stage of designing the structure. The barycentric method of placing loads in the electrical installation is discussed and an example of correct and incorrect placement of the transformer in relation to the bar center is shown. The method of determining the load curve of the building and making measurements necessary for this purpose is described and the possibility of using synthetic load curves is mentioned. Part of the article is also devoted to the selection of appropriate meters for making such measurements and the influence of external factors on their accuracy. The benefits of increasing energy efficiency for companies and the environment are described as well. The article also shows how to manage energy efficiency and the obligations it involves.

Index terms: efficiency classes, electrical installations, energy efficiency, energy management systems

Introduction

The optimization of electrical energy usage can be facilitated by appropriate design and installation considerations. It is important that this can be done in existing electrical installations in buildings and in new installations. An electrical installation can provide the required level of service and safety for the lowest electrical consumption. The design of the whole installation has therefore to take into account inputs from users, suppliers and utilities.

Additional requirements, measures and recommendations for the design, erection, operation and verification of all types of low voltage electrical installations including local production and storage of energy for optimizing the overall efficient use of electricity are included in IEC 60364-8-1: Energy efficiency. According to the definition contained in the standard, electrical energy efficiency EEE is a systemic approach to optimizing the efficiency of electricity usage. Energy efficiency improvement measures take into account:

- both the consumption (kWh) and price of electricity,
- technology,
- environmental impact.

The energy efficiency of an electrical installation is rated into one of the following classes from lower efficiency to higher efficiency: EE0, EE1, EE2, EE3, EE4, and EE5 (Fig. 7.1).

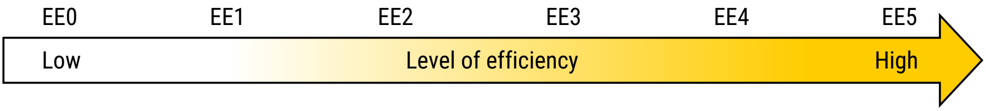

FIGURE 7.1. Level of efficiency of the electrical installation efficiency classes

Design principles

The basic issue to keep in mind when applying all energy efficiency measures is the full electrical availability of the customer and/or service and the level of performance required by the user. However, the electrical installation should have provisions to change the arrangements for the management of energy efficiency by the user, for example when they need to increase the room temperature when they are ill.

The design principles of IEC 60364-8-1 take into account the following aspects:

- load energy profile (active and reactive);
- availability of local generation (PV, wind turbine, generator, etc.) and storage;
- reduction of energy losses in the electrical installation;
- the arrangement of the circuits with regard of energy efficiency;
- the customer's power use distribution over time;
- tariff structure offered by the supplier of the electrical energy.

The assessment of the installation should be carried out preferably by measurement, but a calculation -based assessment is also acceptable.

The intensity of inspections of the electrical installation should be determined taking into account its type, equipment, use and operation, factors and external influences to which it is exposed.

It is recommended that the maximum interval for follow-up assessment does not exceed:

- five years for commercial installations;
- three years for industrial and infrastructure ones.

After assessing the installation, an action plan should be established to improve its energy efficiency.

If the analysis concerned a new installation and showed a lower than required electrical efficiency class, actions should be taken to correct these discrepancies.

If this was a periodic assessment of an existing installation and showed too low a level of energy efficiency in relation to the required value, then an action plan is needed to provide the required or desired energy efficiency class.

Designing requirements and recommendations

Designing electrical installation it is worth to define its load energy profile. This can be done on the basis of existing similar synthetic profiles (typical load energy curves) derived from loads or load groups. If measurements or synthetic profiles are not available, it is possible to create a load energy profile based on the main loads and their expected operating time.

Because of the energy efficiency and specific features requiring a specific implementation methodology, four basic sectors of electrical installations can be identified:

- residential installations;
- commercial installations;
- industrial installations;
- infrastructure installations.

It is worthwhile for people designing an electrical installation to be able to assign it to one of the above sectors.

Another important point is to determine the position of the transformer and the switchboard using the barycenter method. In looking for the best place to locate them, it is important to pay attention to the use, construction and availability of space in the building. If it is possible, it should be discussed with the owner of the building and the designer before the construction process starts.

Placing the main loads as close as possible to the main switchboards and transformers (according to the building's limitations) will help to reduce wiring losses to the minimum. Thanks to the barycenter method we can determine load distribution (uniform or localized).

The building layout in Fig. 2 shows the building topology. Without using the barycenter tool, the switchboard rooms were originally located in position 1. By calculation of the total load barycenter (purple circle with number 2), the result shows clearly that position 2 is much closer to receptors of high power (utilities) and consequently will improve cable utilization and thereby reduce cable losses.

The next issue that needs to be considered in order to find the optimal solution for the transformer is:

- the optimum number and location of HV/LV substations;
- the working point of transformer;
- the efficiency of the transformer;
- the load energy profile.

The required power, building area and load distribution determine the number of HV/LV substations and their distribution, which affects the length and cross-section of the cables. Having the knowledge of the barycenter location, we can decide whether to choose one or more HV/LV substations.

With a transformer load of 30% to 50% of its rated power the losses in iron and copper are equal. In such a situation we have to deal with the maximum efficiency of the transformer.

On this basis we should choose the point of work of the transformer to ensure the highest energy efficiency of the installation.

A properly selected transformer has a huge impact on the energy efficiency of the entire installation. By choosing a transformer with the highest energy efficiency class, we can make a lot of savings, even though it involves higher initial costs. The cost of a more expensive transformer with a higher energy efficiency class pays for itself in a few years, which in comparison with its whole life is relatively short. More information about the energy efficiency of transformers, installation details and limitations and payback time can be found in the information from manufacturers.

It is also possible to improve energy efficiency through the use of renewable energy sources and related energy storage. We can use warehouses or discharge energy to the grid, which improves the efficiency of local production.

Another aspect that has an impact on the energy efficiency of the installation is the selection of the cable cross-section. Increasing the cross-section of cables in distribution circuits and in end circuits (supplying high power loads) reduces voltage drops. The selection of the cross-section of conductors should be based on the economic and technical analysis. Selecting a cable, one should take into account not only the cost of the cable, but also its installation and assembly, as well as energy losses in the cable during its expected lifetime.

The method that allows to calculate such cost is included in IEC 60287-3-2.

Another important issue is the improvement of power factor and the reduction of harmonic currents.

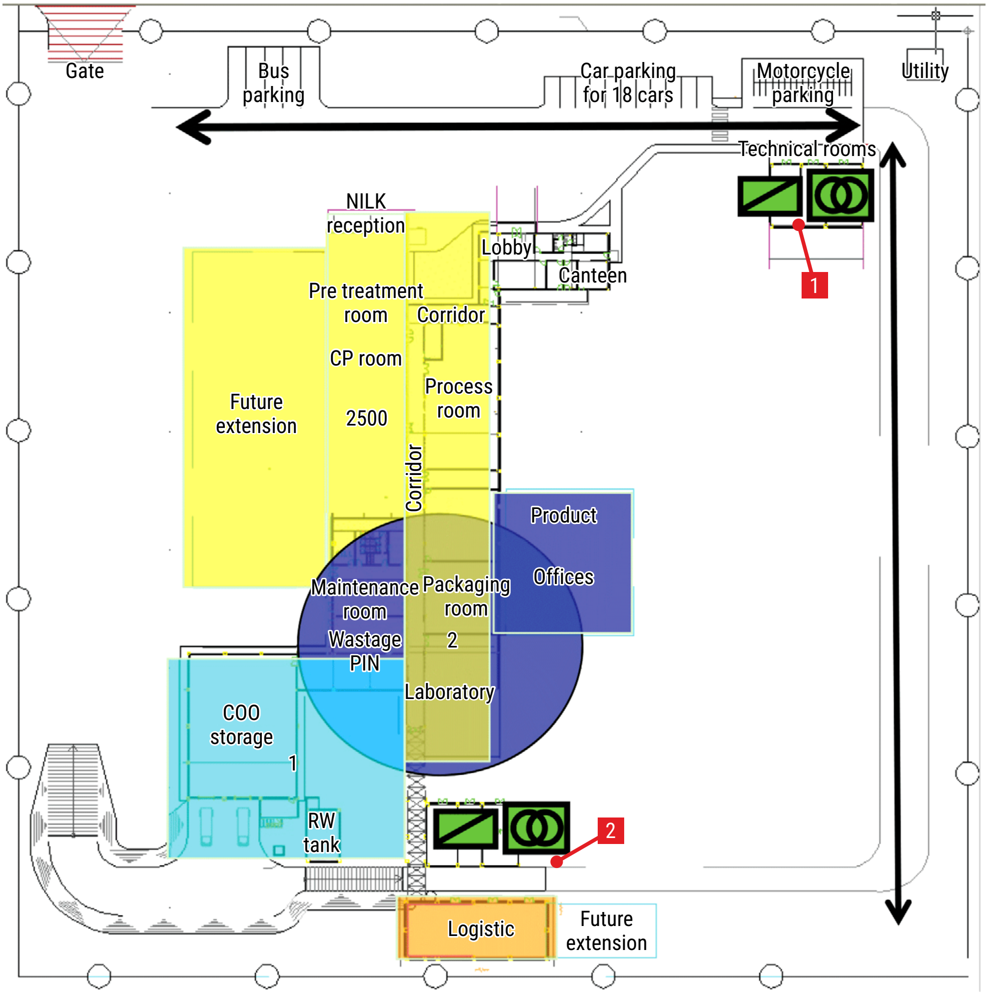

FIGURE 7.2. **Example of location of the barycenter in an industrial building**

The power factor can be reduced by reducing reactive power consumption. Reducing it at a load level reduces heat loss in the power side wiring. The power factor can be improved centrally or at a load level.

The reduction of harmonics at a load level is possible by selecting suitable consumers free of harmonics. This can also be done by:

- using harmonic filters at respective load circuits;
- increasing the cross-sectional area of the conductors;
- using methods that produce less harmonics, like Sinusoidal Pulse Width Modulation (SPWM), in the renewable energy resources' inverters connected to the Point Of Connection (POC).

Energy efficiency and load management system

An energy efficiency and load management system controls the usage of the consumed energy, taking into account the loads, local production and storage and user requirements (Fig.3).

The basis for determining and evaluating the efficiency of a building is the performance of measurements. The measurement of electrical parameters is required to determine electricity consumption and has to be completed by the measurement of forcing parameters, such as:

- presence of people;
- temperature;
- quality of air (e.g. CO_2);
- day light;
- operating time;
- cost of energy.

Another very important aspect is the selection of an appropriate device. Thanks to this, the installation user knows what the energy consumption is. In buildings such as apartments, stores or offices the highest precision of measurement is necessary at the origin of the installation. It is this measurement that is used for billing and on its base we pay the bills, and also thanks to such measurement we can assess the energy efficiency of the whole installation. These measurements, as well as the measurements of power quality in the connector can be part of the process of evaluating the energy efficiency of the installation.

It is also important to remember to use the measuring devices properly in according to their purpose and location in the installation. Where applicable, measurements and monitoring shall be carried out in each phase.

The standard IEC 61557-12 defines power metering and monitoring device (PMD) classification with minimal required functions according to its application:

- PMD-1: Energy efficiency: energy usage analysis for energy efficiency assessment;
- PMD-2: Basic power monitoring: power monitoring for electrical energy distribution monitoring and control within the installation;
- PMD-3: Advanced power monitoring and network performance: advanced power monitoring and network performance monitoring.

It is very important that all activities related to the energy management system with regard to energy efficiency do not interfere with the communication ensuring safety, control or operation of the equipment or devices.

Information on expected loads can also be found from historical data. This can be very helpful. According to IEC 62974-1, a communication system between all required and predicted data must be provided.

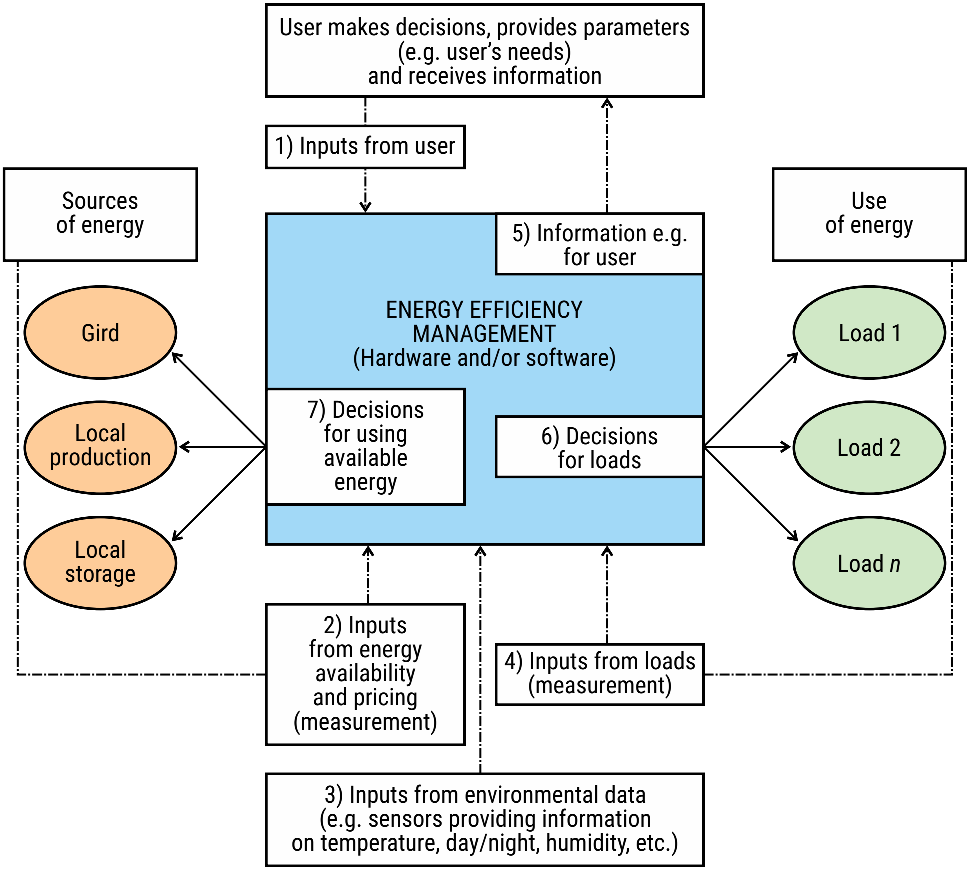

FIGURE 7.3. **Energy efficiency and load management system overview.**

The main parameter that defines energy efficiency is active energy (kWh). The complete system for measuring electrical energy is made up of measuring devices associated with external current and/or voltage sensors. The performance class of the system depends on the sensor class and on the performance class of the meter. The class shall be selected so that it is equal or lower than the meter or PMD class.

The sensors should also be selected based on the maximum current in the circuit and the minimum current that needs to be monitored, they must also be selected in accordance with IEC 61869-2.

Choosing the sensors, one should also remember about possible external influences. Deviations from the accuracy of measurements can be influenced by factors such as temperature. The factors that may generate such deviations are specified in IEC 61557-12. If the sensor complies with the measurement class defined in these standards, it meets the requirements for maximum deviations under these values.

Electrical energy management system (EEMS)

The energy efficiency management system manages the entire electrical installation, including loads, local production and storage. It can monitor the electrical installation manually (in the simplest cases) or automatically (in most cases) in order to optimize the total cost and consumption of the system, taking into account user requirements and input parameters from the network, local electricity generation and storage, loads, sensors, forecasts, etc.

The Electrical Energy Management System includes:

- measurement (e.g. energy consumption) and mesh monitoring;
- control;
- energy quality;
- reporting;
- warnings: status of monitoring devices;
- tariff management, if any;
- data security;
- display function for users and/or public awareness.

It is possible to maintain and increase the efficiency of the installation by implementing appropriate energy efficiency measures, active or passive. This requires an integrated approach to the electrical installation and the consideration of all the ways the installation operates. The energy efficiency claim process and responsibilities are presented in Table 7.1.

TABLE 7.1. Process for electrical energy efficiency management and responsibilities

Action	Details	Generally performed by
Energy audit and measure	• Analysis of data from installed power metering and monitoring devices and/or non installed measurement equipment	Auditor or energy manager
Set the basics	• Initial equipment selection, higher efficiency consumption devices • Initial service settings, etc.	Designer and/or installer
Optimize	• HVAC control • Lighting control • Variable speed drives • Automatic power factor correction, etc.	Installer/tenant or user, energy manager
Monitor, maintain the performance	• Power metering and monitoring devices installation • Monitoring services • Electrical energy efficiency analysis, software, etc.	Energy manager/tenant or user
Control, improve	• Verification, maintenance, etc.	Energy manager/tenant or user

Measurement, optimization and monitoring are important for energy efficiency:

a) Audit of energy consumption by means of measures that will provide an indication of the situation and the main routes leading to savings (where the main consumptions are located, what is their pattern). An initial assessment can be carried out based on a set of measurements for the different meshes within the installation and a comparison with the comparative energy consumption criteria established for a combination of appliances within the network or installation. Although this may help to identify areas that can be analyzed in more detail, determining whether an installation is efficient will depend on more precise measurements and an evaluation of parts of the installation compared to the overall energy consumption.
b) Optimization through continuous automation or control. As already highlighted, everything that consumes energy needs to be actively addressed in order to achieve sustainable benefits. Continuous control is crucial to achieve maximum efficiency.
c) Monitoring, maintenance and improvement of the electrical installation. As targets are set for a long period of time, energy efficiency programs represent a lasting improvement over time.

Conclusion

The energy efficiency of the installation requires a lot of work on the part of the designer. The above standard definitely helps to determine the most important elements of the installation and how they will affect its energy efficiency. An important effect of these procedures is to reduce the negative impact on the environment.

By the maximization of energy efficiency we reduce the consumption of energy resources. Thanks to this, companies or businesses operate more efficiently and economically, and become more competitive. Moreover, thanks to such measures we can contribute to the reduction of electricity imports from other countries and aspire to energy independence.

From the presented contents it follows that when planning an electrical installation, its location and the chosen equipment, it is worth paying higher costs of such an installation in return for better energy efficiency and reduction of operating costs in the future.

Continuous improvement is also important because it is essential to ensure energy efficiency. In the last stages the differences decrease due to the elimination of the most significant losses. Thanks to such measures, the electrical installation generates the smallest possible losses.

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