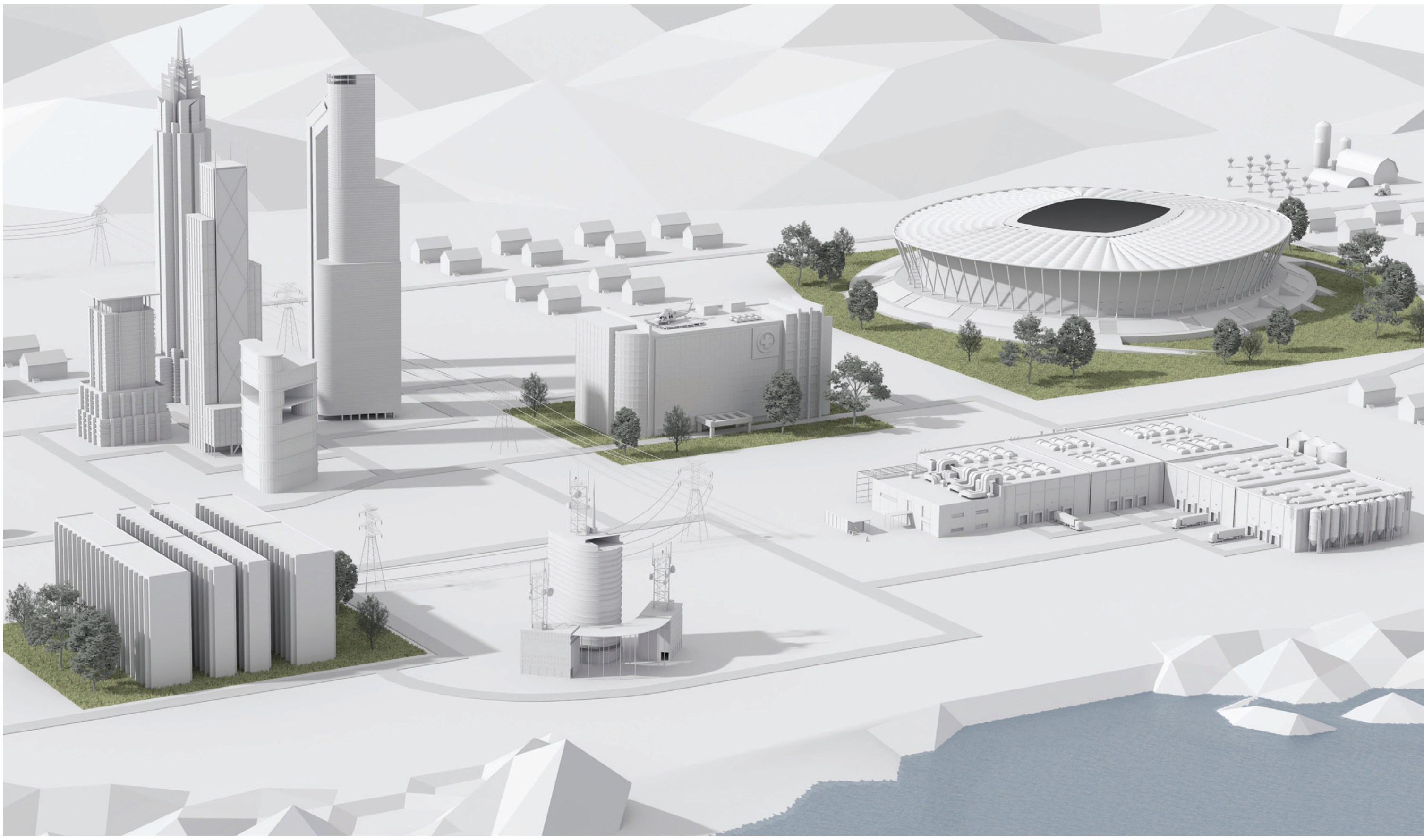
WHITE PAPER

Efficiency of Electrical Systems

Introduction to IEC 60364-8-1



Contents

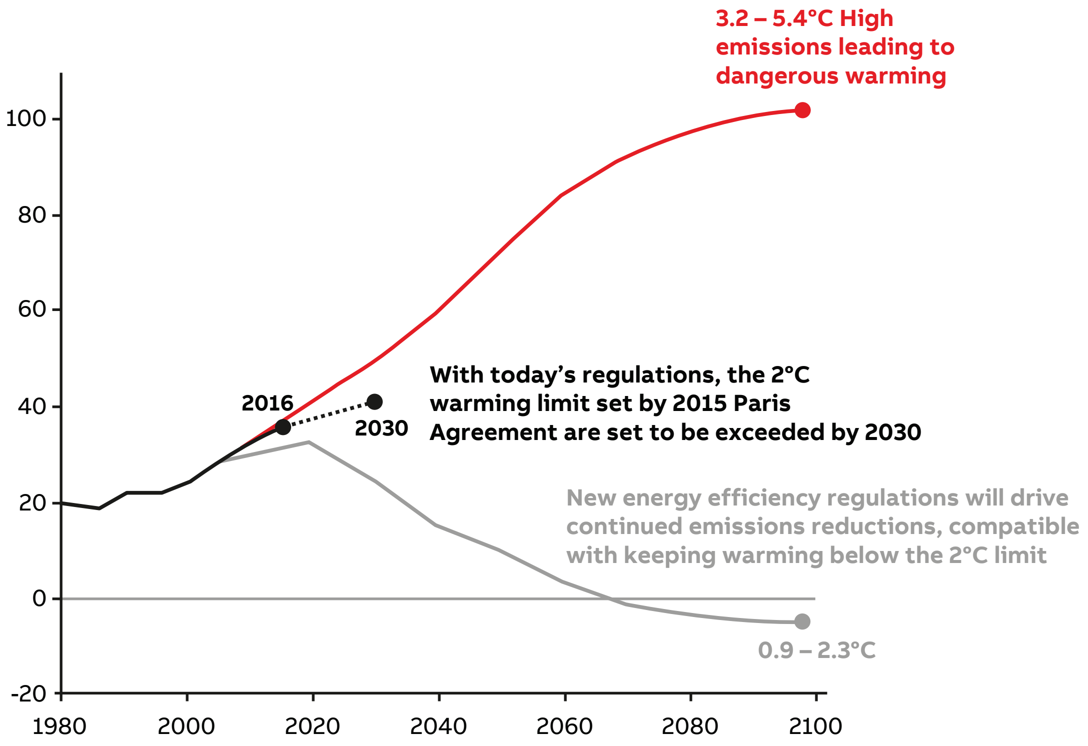
1. Introduction

Some progress has been made to address global warming since the Paris Agreement of 2015. CO2 emissions have increased by only 0,2% in 2017 in comparison to 2016[1], despite continuous increases in power consumption.
Energy efficiency has played the biggest role in this achievement, contributing also to increases in productivity for the energy used. Worldwide 140 Codes and Directives to improve energy efficiency have been published and governments have promoted their adoption through more than 90 incentive programs.
Nevertheless, these encouraging results are not enough. Projections estimate that in the period to 2040[2] the world's population will increase by 22,9% and power consumption will grow by 60%. In the event these projections prove correct, with the current efficient measures already in place, the limit of a 2°C temperature increase will be exceeded in 2030[3].

In this scenario, the International Electrotechnical Committee has developed the Standard IEC 60364-8-1 with the aim of sharing best practice for electrical energy management.

This is not a product Standard; IEC 60364-8-1 instead considers the complete electrical system, analyzing system architecture, monitoring and control. It also provides guidelines for implementing efficiency measures, considering the state of the art in the efficiency of low voltage electrical systems. The scope of this document is to briefly introduce the structure and the requirements of the Standard.
This introduction also provides, through application examples, an overview of ABB solutions for energy efficiency in low voltage systems, explaining how these solutions comply with the Standard's requirements.

Figure 1. CO2 emissions and temperature increases



Without further efficiency measures, limiting warming to **2°C** is impossible

[1] Iea https://www.iea.org/weo2017/
[2] www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf
[3] Le Quéré, C. et al. (2016) based on Rogelj et al, (2016)

2. European Energy Efficiency Plan

With persistent increases in energy consumption and greenhouse emissions, the European Union has agreed on the implementation of energy policies designed to:

- Secure Europe's energy supplies, considering that stocks of fossil fuels (oil, gas and coal) will not last forever and that the EU is the world's largest importer
- Ensure that energy prices do not make Europe less competitive. Energy costs continue to rise, so Europe needs to diversify its energy sources and supply channels. This will ensure affordable prices for business, industries and homes
- Protect the environment and combat climate change; more than 80% of energy sector outputs are from fossil fuel sources, a major cause of CO2 emissions and of the exorbitant cost of climate change
- Improve energy grids. Energy grids must modernize to cope with the growing demand for power and to connect the increasingly diverse range of energy resources

Table 1 EU Target 2020, 2030 and 2050

Target 2020	Target 2030	Energy Roadmap 2050
20% reduction in greenhouse emissions	40% greenhouse emission reduction versus 1990 levels	Reduction in greenhouse gas emissions to levels of around 80-90% of 1990 values
20% increase in energy produced from renewable sources	At least 27% of energy consumed generated from renewable sources	
At least 20% increase in energy savings	At least 27% energy saving in comparison to benchmark data	
All European Countries shall source 10% of transport sector energy from renewable sources		

The European Union began by defining of targets for 2020 concerning the reduction of greenhouse emissions, the share of renewable energy and for energy savings. Higher targets have been fixed for 2030, and they will not be the last.

A complete energy roadmap has been developed for the period up to 2050, with the aim to reach a scenario where greenhouse gas emissions are at least 80% lower than 1990 levels[4].

European objectives are so challenging, many will wonder if these targets are attainable.
It's been measured that about 80% of the energy produced from fossil does not reach even the end user, but it is drawn along the chain from production passing through transmission, distribution and finally to the end user. However, there are technologies, which if used, can help to reduce energy waste by ensuring increased productivity at each level.

It has been estimated that energy savings of between 20 and 30% are possible by applying measures based on already existing technologies[5].

[4] Source : https://ec.europa.eu/energy/en/topics/energy-efficiency
[5] ABB "Energy efficiency –the fast track to a sustainable energy future", 2015

2. European Energy Efficiency Plan

2.1. European Directive on the energy performance of buildings[6, 7]

Buildings are one of the main sectors affected by the EU's energy efficiency policy, as they account for nearly 40% of all energy consumption. The Energy Performance of Buildings Directive (EPBD) is the main legal instrument for addressing energy efficiency in buildings, and it was developed with the aim of achieving the 2020 energy efficiency targets.
Under this directive, it is possible to find the following:

- Article 9 of EU Directive on the Energy Performance of Buildings states that by 31 December 2020, all new buildings should be Near-Zero Energy Buildings (NZEBs); and after 31 December 2018, new buildings occupied and owned by public authorities should be near-zero energy buildings.

- In addition to requirements for new construction, Article 2a (added in May 2018) states that each Member State shall establish a long-term renovation strategy for residential and non-residential buildings, both public and private, to facilitate the decarbonization of existing buildings.

- The support for the deployment of e-mobility, as a measure to reduce carbon emission, is contained in Article 8 of EU Directive 2018/844, where targets for recharging units in non-residential buildings and for ducting infrastructure in residential buildings are defined. Current regulation foresees the provision of at least one recharging unit point and conduits for electric cables for every five car parking spaces in all new non-residential buildings (and those under renovation) that have more than ten car parking spaces. For new residential buildings and those under renovation with more than ten car parking spaces, conduits for electric cables are required for each car parking space.

- Article 8 of the European Directive recognizes that “the digitalization of the energy system is quickly changing the energy landscape, from the integration of renewables to smart grids and smart-ready buildings”. The Directive defines the smart readiness of a building as the capability to adapt its operation to the needs of the occupant and the grid, and to improve its energy efficiency and overall performance.

[6] “Directive 2012/277EU of the European Parliament and of the council of 25 October 2012 on energy efficiency, amending Directives 20097125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[7] Directive EU 2018/844 of the European Parliament and of the council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of building and Directive 2012/27/EU on energy efficiency.

3. Standards and certifications

Driven by the EU's climate targets, national governments and associations have developed many standards, codes and guidelines for energy efficiency, creating the environment for the new and growing business of energy certification.

These codes deal with building design and contain prescriptions on building structures such as construction materials, cooling systems, and also include advice on electrical systems.

ABB is assisting on the growing number of Standards focusing solely on electrical installations.

The regulations and guidelines divide into three main groups:

- Standards developed by international electro-technical committees, such as the IEC, ANSI or European electro-technical committees.
- Regulations with national validity, generally developed by national electro-technical committees on behalf of national governments.
- Certification systems that might be internationally recognized or have national validity. Certifications might be applicable to products or constructions.

Among international Standards, the key documents are:

- IEC 60364-8-1, the section of the low-voltage electrical installation Standard dealing with energy efficiency.
- ANSI/ASHRAE/IES/USGBC Standard 189.1 is the American Standards for the design of high-performance green buildings.
- EN 15232 is the harmonized European Standard concerning the calculation of the impact of automation on a building's energy performance.

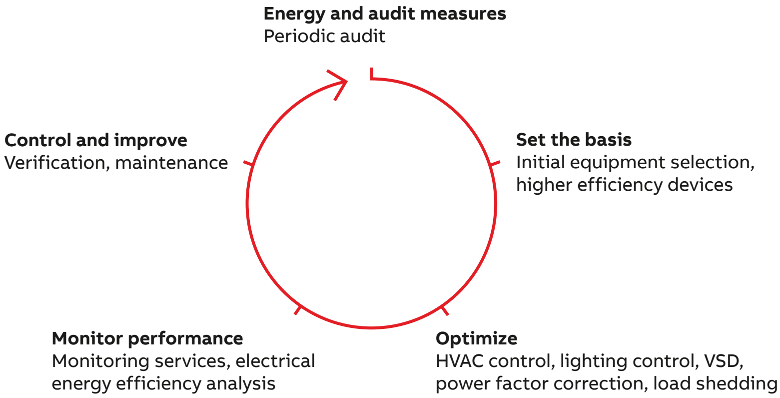
At national level many authorities have developed guidelines that provide classification of efficiency classes for buildings and that create efficiency labels for construction. In most countries, building efficiency certification has become mandatory.

Additionally, there are voluntary certifications from accreditation bodies.
Certification requires compliance with a guideline and the application of efficiency measures to achieve a score that identifies the appropriate efficiency class. Energy Star, Green Globes, the International Energy Agency, ASHRAE, LEED and BREEAM are among the most widely recognized certification bodies.

4. Introduction to IEC 60364-8-1

The main Standard for the energy efficiency of electrical installations is the IEC 60364-8-1 international Standard. The first edition of this Standard was issued in October 2014 and the second was issued on February 2019.
The Standard presents requirements, measures and recommendations for the design, erection and verification of all types of low voltage electrical installations, including local production and energy storage systems, to make energy use more efficient.
The recommendations are additional to those in other parts of the installation Standard and can be applied to residential, commercial, industrial and infrastructure – both new and existing projects.
The IEC 60364-8-1 presents a method to optimize the use of electricity considering the efficiency, reducing both the consumption and the cost, improving the sustainability and the environmental impact.
Energy Efficiency Measures (EM) are applied to the electrical system. These can be passive measures, such as the definition of the parameter and performance levels that influence the choice of equipment and components. They can also be active measures such as methods for the optimization of the production, supply, distribution and consumption of energy.
Active measures are related to the new energy efficiency cycle concept that the regulation introduces. This implies that to ensure a system achieves a certain level of energy efficiency, it is no longer enough just to implement provisions to improve efficiency. Permanent monitoring is required to guarantee the effectiveness of any measures taken.

Figure 2. Iterative process for management of electrical energy efficiency



This cycle, shown in Figure 2, is permanent. For an electrical installation to comply with the Standard, any energy efficiency strategy should cover the installation's whole life. The cycle starts with an initial audit of the system, followed by the definition of passive measures (the selection of high-efficiency energy devices) and active measures (optimization, control and management). Once measures have been implemented, performance must be verified, and the system must be maintained on a regular basis. Finally, the tenant continues to repeat the loop: measuring, identifying new opportunities for improvement, and implementing new measures and verifications. Anyone wishing to apply the concept of energy efficiency to electric installations should follow a program like this for the entire life cycle of the plant.

4.1 Standard principles

Chapter 4 of the Standard shares the fundamental principles, which state that efficiency measures should not reduce the level of safety of the plant and that the availability of energy must anyhow be guaranteed to the user.

The electrical designer should consider the installation's load profile, the availability of local energy production and local energy tariffs to define an electrical system in which losses are minimized, without compromising performance and quality.

4.2 Load profiles

To define an energy efficiency plan it is also necessary to group loads according to their zones or services. To group loads by service or application means the identifying the consumption of all devices that serve a specific application, such as IT loads, lighting, heating, printers, etc.
Subdivision by zone should only consider the surface position of consumers, such as first floor, second floor, office, canteen, etc. Further grouping of loads is possible with the creation of custom meshes, but each load should belong to one mesh only.
The grouping of loads should help the creation of

the installation's load profile.
The designer should foresee installation of the metering and monitoring device for each defined mesh. Switchboards should enable the segregation of each mesh.

4.3 Minimizing power losses

The first part of the Standard focuses on best practices to be applied during electrical design to minimize power losses.
The first practice suggested is the barycenter method (explained in detail in Annex A of IEC 60364-8-1), which enables the reduction of power losses through the reduction of cable lengths. This can be achieved by analyzing the position of loads and locating the power sources and the main switchboards in order to minimize current path length.
The second practice suggested is the selection of efficient equipment considering the installation. For example, a transformer should be selected according to its efficiency at its working point and not only at no-load.

Finally, it considers power losses from cables, which can be limited following three main actions:

- Increasing cable cross-section reduces the voltage drop and the power losses. The additional initial cost can be compensated over time by the reduction in consumption.

- Increasing power factor correction, as well as reduction of reactive power, supports the reduction of thermal power losses from cables

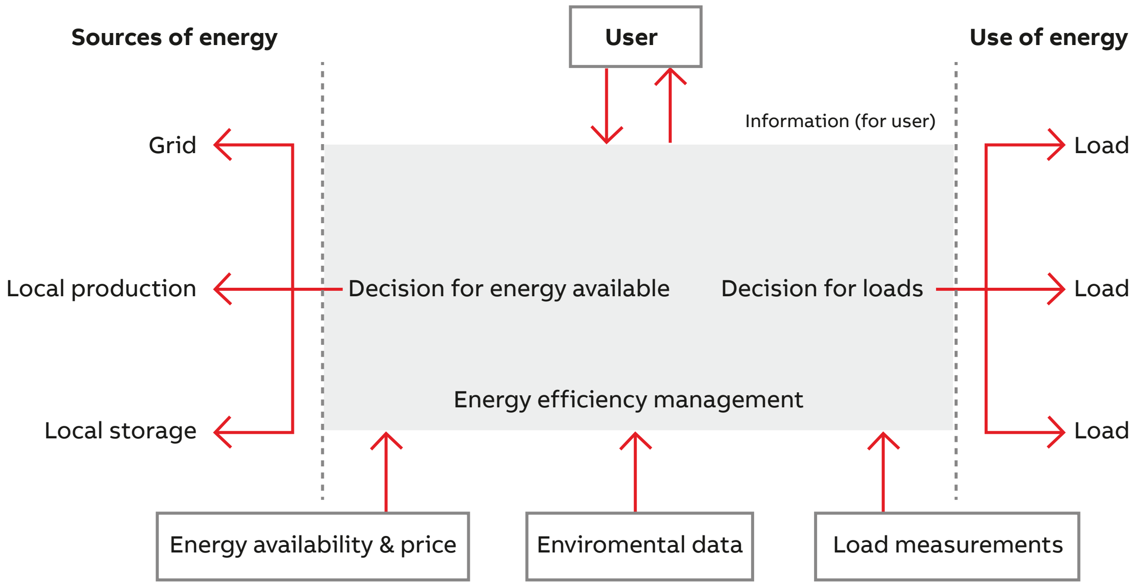
- Reducing current harmonics by selecting harmonic-free devices or foreseeing harmonic filters

4.4 Energy efficiency management system

The second part of the Standard deals with the optimization of electrical systems, namely energy efficiency management and load shedding. To adopt these kinds of systems, the designer should prepare a measurement system able to collect real-time data from loads on power consumed, and receive inputs such as power availability from power sources such as solar systems, local storage systems, as well as utility energy price. Environmental data such as temperature and humidity might complete inputs. Users should then identify a group of sheddable loads, indicating also the maximum power disconnection time, to enable the management system to perform the energy efficiency logic.

The process is shown in figure 3.
The efficiency management system should be able to control loads and privilege the usage of available power sources, considering also the price of energy. It should provide users or energy managers reports, alarms or warnings indicating any malfunctioning equipment that might have an impact on installation efficiency.

Figure 3. Energy efficiency and load management system



4. Introduction to IEC 60364-8-1

4.5 Metering

The measuring system is fundamental to defining the installation load profile and collecting all data required for operation of the energy management system. This key system must therefore be carefully designed by electrical specialists.

Accuracy is a key parameter for metering: unreliable measurements will affect any efficiency considerations.

The highest measurement accuracy is required at the installation's origin to support invoicing, and also to assess the installation's total power consumption and its efficiency level in comparison to other, similar installations. The minimum accuracy suggested at this point is 1%. In main distribution boards, a good level of accuracy and network analyzer functions are required to monitor power quality.

At the terminal level, it is sufficient to monitor the duration and trend of power consumption. There is therefore no specific suggestion for accuracy level.
Depending on the application type and the importance of the specific load, sub-billing needs can require high accuracy even at sub-distribution level. For contractual sub-billing applications, metering devices are required to have an accuracy level compliant with IEC 62053- 21 or 62053-22.

For energy usage analysis and power monitoring purposes the accuracy of metering device sensors are required to comply with Annex D of IEC 61557-12, as the phase error of the sensors affects the measurements for power factor different from 1, resulting in lower accuracy of power and energy measurements.

For any data to be monitored, the Standard refers to the metering classifications of IEC 61557-12, reported in the tables below.

Table 2. Metering

Level in the network	Measurement objective	Accuracy
Incomer	Revenue metering, billing checking, energy usage, analysis and optimization.	Class 0.2 ÷ 1
Main LV switchboard	Cost allocation, energy usage analysis and optimization, efficiency assessment.	Class 0.5 ÷ 2
Intermediate distribution board	Cost allocation, energy usage analysis and optimization, efficiency assessment.	Class 1 ÷ 3
Final distribution board	Energy usage analysis and optimization. Energy usage trends assessment	Reliable

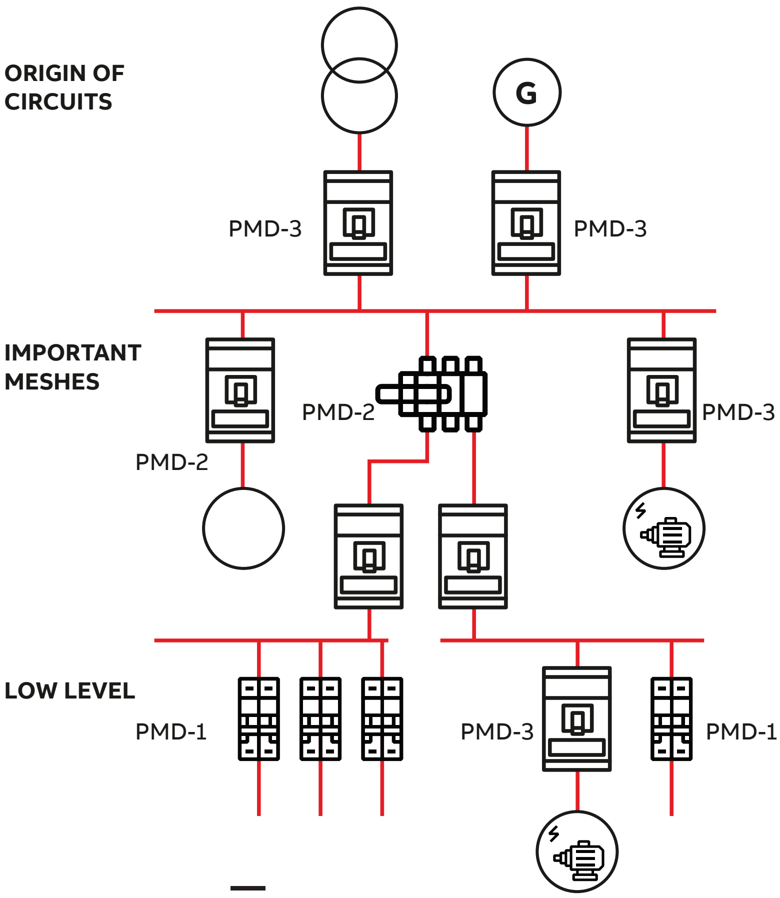
Table 3. Minimal requirements for PMD classification according to IEC 61557-12.

Power Meter Device	Description	Minimum measure
PMD-1	Energy efficiency: energy usage analysis for energy efficiency assessment	Ea
PMD-2	Basic power monitoring: power monitoring for electrical energy distribution monitoring and control within the installation	P, Q, S, Ea, Er, Eap, f, I, IN, U and/or V, PF,
PMD-3	Advanced power monitoring and network performance: advanced power monitoring and network performance	P, Q, S, Ea, Er, Eap, f, I, IN, U and/or V, PF, THDU and/or THDV and/or THD-RU and/ or THD-RV, THDI and/or THD-RI

Note:
Ea = Active Energy, P= Active Power, Q= Reactive Power, S= Apparent Power, Eap = Appar-ent Energy, Er= Reactive Energy, f= frequency, I= Phase Current, IN= Neutral Current, U= Line to Line Voltage, V= Line to Neutral Voltage, PF= Power Factor, THDU = Total Harmonic Distortion relative to fundamental , THD-RU = Total Harmonic distortion rms, THDI =Total Harmonic distortion current relative to fundamental, THD-RI = Total Harmonic distortion current rms.

For energy efficiency purpose, meters should be installed at different levels of the installation to enable the measuring of individual loads or group of loads (homogeneous) to cover at least 70% of power consumption; furthermore, measurements should be monitored for each hour of the day and stored for at least one year at disposal of the user.
Choice of class of PMD is let to designer, who will have to consider the purpose of measure and the type of load. in picture below is shown a possible installation of metering devices for efficiency purpose.

Figure 4. Example of metering in an installation



4.6 Electrical installation efficiency classes

Annex B of IEC 60364-8-1 introduces the concept of electrical installation energy efficiency classes (EIEC). This is an assessment method used to clearly identify the level of efficiency of an electrical system.

The efficiency class is obtained from the sum of the points corresponding to the efficiency measures implemented in the installation.

Table 4. Electrical installation efficiency class

EIEC Level	Residential	Industrial	Commercial	Infrastructure
EE 0	0 ÷ 14	0 ÷ 19	0 ÷ 18	0 ÷ 18
EE 1	15 ÷ 30	20 ÷ 38	19 ÷ 36	19 ÷ 36
EE 2	31÷ 49	39 ÷ 63	37 ÷ 60	37 ÷ 59
EE 3	50 ÷ 69	64 ÷ 88	61 ÷ 84	60 ÷ 83
EE 4	70 ÷ 89	89 ÷ 113	85 ÷ 108	84 ÷ 106
EE 5	90 or more	114 or more	109 or more	107 or more

4.7 Parameters for efficiency measures

Here below we analyze some parameters that electrical designers or energy managers can consider for electrical installation efficiency class assessments.

4.7.1 Motor solution

Around 70% of industrial energy consumption is used to power engines. The use of a high efficiency motor and drive can produce a reduction in the motor's energy consumption of between 20% and 50% in most applications.

A saving of around 10% can be achieved by using motors of a higher efficiency class level.
A further 30% saving can then be derived from the drive system[8]; the European Directive N° 640/2009 has made it mandatory for motors connected directly on line with power ranging from 0, 75kW to 375kW to be either classified as Energy Class IE3 or to use motors with efficiency IE2 controlled by a drive.

Where motor speed control is not required and the motor can be used at its optimum efficiency point and switched off the rest of the time, a soft-starter can be the most energy-efficient and cost-effective solution that does not generate harmonics. The efficiency of soft-starters is practically 100% when the motor bypass is activated.

[8] ANIE "Guida Tecnica sistemi di azionamento per l'efficienza energetica", 2014.

4. Introduction to IEC 60364-8-1

4.7.2 Lighting

Efficiency is easily applicable to lighting systems, enabling power consumption reductions of up to 50% or more. Designers can specify low power consumption lamps, for example, using LEDs, and additional savings are possible through control – by using presence-detector sensors, timers and light-sensitive switches.

Basic solutions are achievable using timer controls: the opening of the light switch is controlled by a timer. This solution can generate savings of up to 10% and is suitable for environments not permanently occupied or for locations with predefined breaks and working hours.
Another solution available for rooms that are not permanently occupied, such as corridors, is the use of presence detectors. This solution enables savings of up to 20%. Higher savings are attainable for locations with high daylight factors by combining bright light sensors with presence detection in open or closed loop control.

According to a study by ZVEI (German Electrical Industry Association), energy consumption for building lighting can be reduced by up to 80 % using intelligent building systems such as KNX.
Energy efficiency assessment methods do not mention the type of light control adopted, but the score is calculated using the percentage of power consumed by controlled lights in respect of the installation's total lighting consumption.

4.7.3 HVAC

The second major consumer in buildings is the heating and air conditioning. With effective management, annual energy consumption for heating and ventilation can be cut by up to 45 %.
The simplest method is individual room temperature controls that reduce room temperatures. Energy savings on heating consumption of up to 6% can be made by lowering the temperature by 1°C, depending on heating requirements and occupancy levels[9].
Temperature inside a room can be managed via temperature setpoints controlled by a timer.

A more sophisticated system is based on room temperature setpoints controlled by a presence detector. In summer time, even automatic blind control can help reduce air conditioning usage.

The possibility to control temperature in each room and manage it with different settings according to time, enables the achievement of maximum points for energy efficiency assessments.

4.7.4 Transformer

Most energy loss in dry-type transformers occurs through heat or vibration from the core. High efficiency transformers minimize these losses.
Furthermore, this should be considered the load profile for the evaluation of transformer efficiency.
It can be also advisable to select a transformer with a higher level of voltage than the nominal voltage in order to enable voltage regulation.

Moreover, 90% of transformer load losses vary directly with rises in temperature and 10% of the load losses vary inversely with temperature. The result is that every 1°C increase in operating temperature produces a 0,4% rise in load losses[10].

To keep losses low and to maintain a good life expectancy for the transformer, it is advisable to continuously monitor the temperature of the transformer's windings.

For Annex B's energy efficiency assessment method, it is necessary to consider how far the installation's transformers operate from the working point provided by the equipment manufacturer.

[8] ABB, "Energy efficiency in buildings A must, both economically and ecologically"
[10] Source: "Best Practice Manual For Transformers – Indian Renewable Energy Development Agency".

4.7.5 Wiring systems

The impact of thermal losses should be taken into consideration in the selection of cable cross-section. Switchboard location should be optimized to minimize current path. This is an effective solution covered in Annex A of the Standard with introduction of the barycenter method, and then also considered in efficiency assessment methods.

4.7.6 Power factor correction

Reduction of reactive power contributes to thermal loss reductions and better utilization of current. If the power factor drops from 1.0 to 0.9, power is used less effectively – 10% more current is required to feed the same load. Similarly, a power factor of 0.7 requires approximately 43% more current; and a power factor of 0.5 requires approximately 200% more current to feed the same load.

Any movement of the power factor closer to 1 helps to reduce power losses. And, according to the IEC 60364-8-1 Standard, this is sufficient to comply with distribution system operator requests to achieve maximum points.
To keep the power factor close to 1 individual capacitor units, banks of capacitor units or combinations of both are available.

4.7.7 Metering

Measuring is a key parameter to determine the efficiency of the system. A good monitoring system, in addition to monitoring performance, must allow comparative analysis of consumption profiles and indicate trends and data for power quality analysis.
This type of analysis requires constant data acquisition and storage, making the installation of fix meters integrated in supervision system practically essential. According to the European Parliament and Council's EU Directive 2018/844, electronic monitoring can be considered as a cost-effective alternative to inspections and can provide a payback of less than 3 years.

This was supported by a study conducted in Finland that found that use of smart metering encourages customers to increase energy efficiency by 7% [11], solely as a result of rising awareness of power usage. The addition of a load management system that avoids consumption peaks allows the user real savings on electricity costs that can reach up to 30%.

According to the energy efficiency assessment of Annex B of IEC 60364-8-1, good metering systems should enable measurement of loads according to various subdivisions: by meshes, zones and usage.

Designers should carefully consider the position of meters in the installation in order to obtain maximum points and to enable in-depth analysis of the installation's consumption.

Furthermore, the metering system is needed for the installation to achieve and verify constant performance; continuous monitoring of large loads, software able to verify installation performance daily and capable of storing historical data even for more than five years can contribute up to 16 points to the energy efficiency class assessment.

4.7.8 Harmonics

Non-linear equipment such as UPS, inverters, drives and some industrial loads generate current and voltage harmonics. These not only disturb the distribution system; they also cause malfunctions and reduce the life of equipment in the installation.

Harmonics are also responsible for overheating that contributes to thermal dissipation: the use of basic passive filters or sophisticated active filters eliminate this problem.

Total harmonic distortion measurement (on voltage or current) is required at the origin of the installation to score points for efficiency class level, according to Annex B of IEC 60364-8-1. The highest score is obtained for Total Harmonic Distortion (THD) of voltage lower than 3% or THD on current lower than 5% for all non-residential installation.

[11] "From Smart Meters to Smart Consumers", SmartRegions

4. Introduction to IEC 60364-8-1

4.7.9 Local production of energy

The availability of local production from renewable source or cogeneration does not contribute to increased efficiency of energy usage, but it does enable lower losses on utility networks and power cost reductions.

Integration of renewables is not only encouraged by electricity cost savings: a US survey indicates that 71% of organizations (commercial and industrial buildings) are planning integration of alternative power sources to increase power reliability. This is a result of the fact that 82% of respondents experienced at least one black-out in the course of 2017[12].

According to the energy efficiency assessment method proposed in Annex B of IEC 60364-8-1, local production of electrical energy from either PV, wind turbine, hydro power, geothermal or biomass, that is able to cover at least 5% of total energy plant consumption, enables the installation to obtain bonus points for energy efficiency class.
Maximum bonus points are obtainable for local generation equal to 80% or more of total plant consumption.

4.7.10 Energy storage

As renewable sources are not steady, the adoption of local battery storage can help users to increase the benefit of local generation by decreasing consumption from utilities when the cost of energy is high.

Maximum savings are obtainable when batteries are charged, when the price of energy is low, and the batteries are discharged when the price is high. Storage systems can also be used to control power factor as load shedding.

In the Standard, association of storage system and renewable energy allows additional bonus points in the energy efficiency assessment. For maximum vantage, storage systems should be dimensioned with a capacity equal to at least 10% of power installed.

4.7.11 Demand response

The possibility to modulate the power consumption according to grid power demand can result in reductions of electricity bills – subject to a contract with the utility – and an increased stability of the network, which is beneficial for all consumers.

To realize demand response, the utility should be able to alter the consumer's power consumption to manage net power demand, instead of adjusting power production. To do that, the utility can simply communicate different electricity prices to the consumer for peak consumption, or request the actuation of a peak shaving. Alternatively, the utility can request direct control in order to shed loads.

IEC 60364-8-1 Annex B takes into consideration the percentage of power that can be shed in the installation and the duration of the shedding.

[12] Source: "S&C's 2018 State of Commercial & Industrial Power Reliability Report"

5 ABB Solution

Thanks to ABB advanced solutions, it is easy to meet the requirements of the energy efficiency Standard in an easy and applicable manner. With minimum effort and complexity, the user can design, build and operate a building with maximum energy efficiency.

To better understand how ABB products and solutions can be used for energy efficiency purpose, an example of typical 1.2 MW office building is used. However, this example does not reduce the generality of the solution, since ABB provides maximum flexibility to the customer. The same solutions described in the following paragraphs can be applied for any type of building and infrastructure.

5.1 ABB solutions for maximizing building energy efficiency

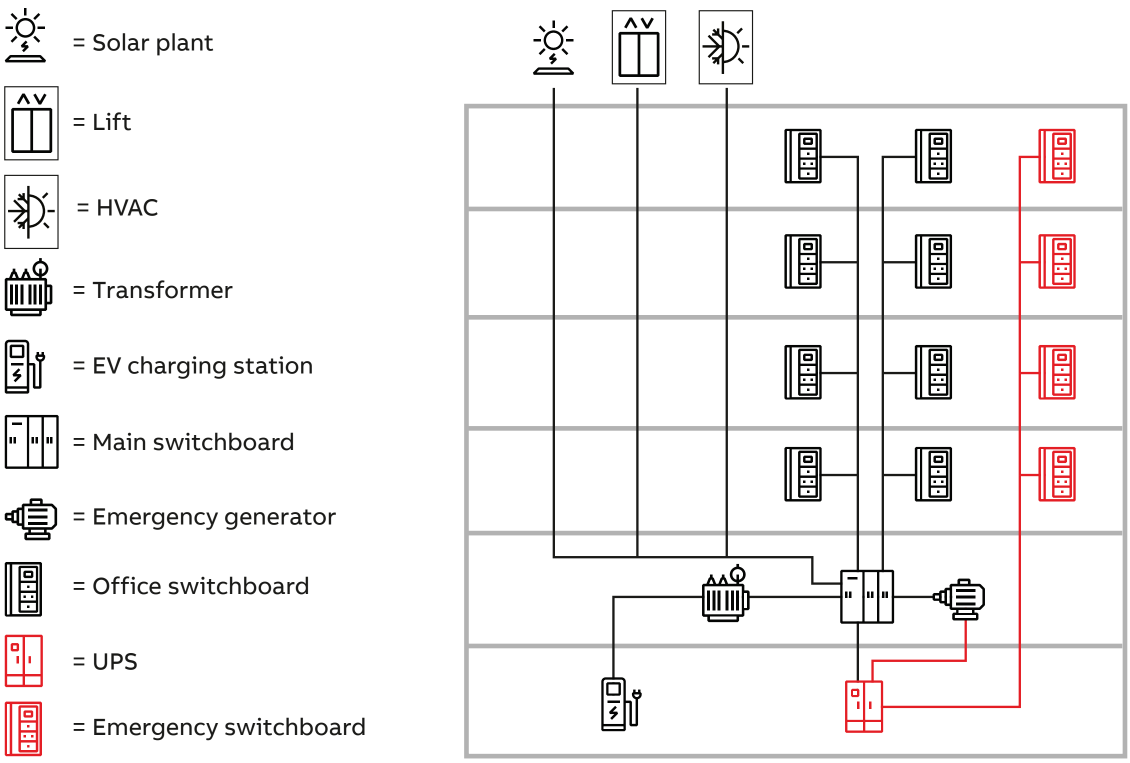
Digitalization has transformed electrical systems, allowing them to achieve maximum performance, reducing costs and development time for projects.

ABB has always been at the forefront in the development of high-efficiency products that deliver savings right from the design stage. Below we present an office building project and then the main solutions available for energy efficiency, starting from measurements to power management of the installation.

Let's consider an office building with installed power of around 1.2 MW. The structure is made up of six floors: two underground storeys hosting a car park, goods delivery area, storage area and technical rooms; a ground floor for reception, post office, conference room and canteen; and three floors for offices and meeting rooms.

The whole structure is supplied from a MV/LV substation with two MV/LV transformers working at the same time, but not in parallel; and an emergency generator to supply critical loads in case of black-out. Furthermore, a PV system is installed on the rooftop, enabling reductions to the energy bill.
A Building Management System (BMS) is foreseen to control temperature and lighting in each room, as well as for access control, fire alarm system and anti-intrusion system.

Figure 5. Block diagram power distribution of the office building



5 ABB Solution

5.2 Automation for lighting and HVAC

The main purpose of controlling lighting and heating in office buildings is to ensure maximum comfort to occupants, while also offering the possibility to optimize power consumption and measure progress.

The solution adopted for this building includes a complete building management system (BMS) that ensures the control of the heating, air conditioning, ventilation, blinds and lighting.

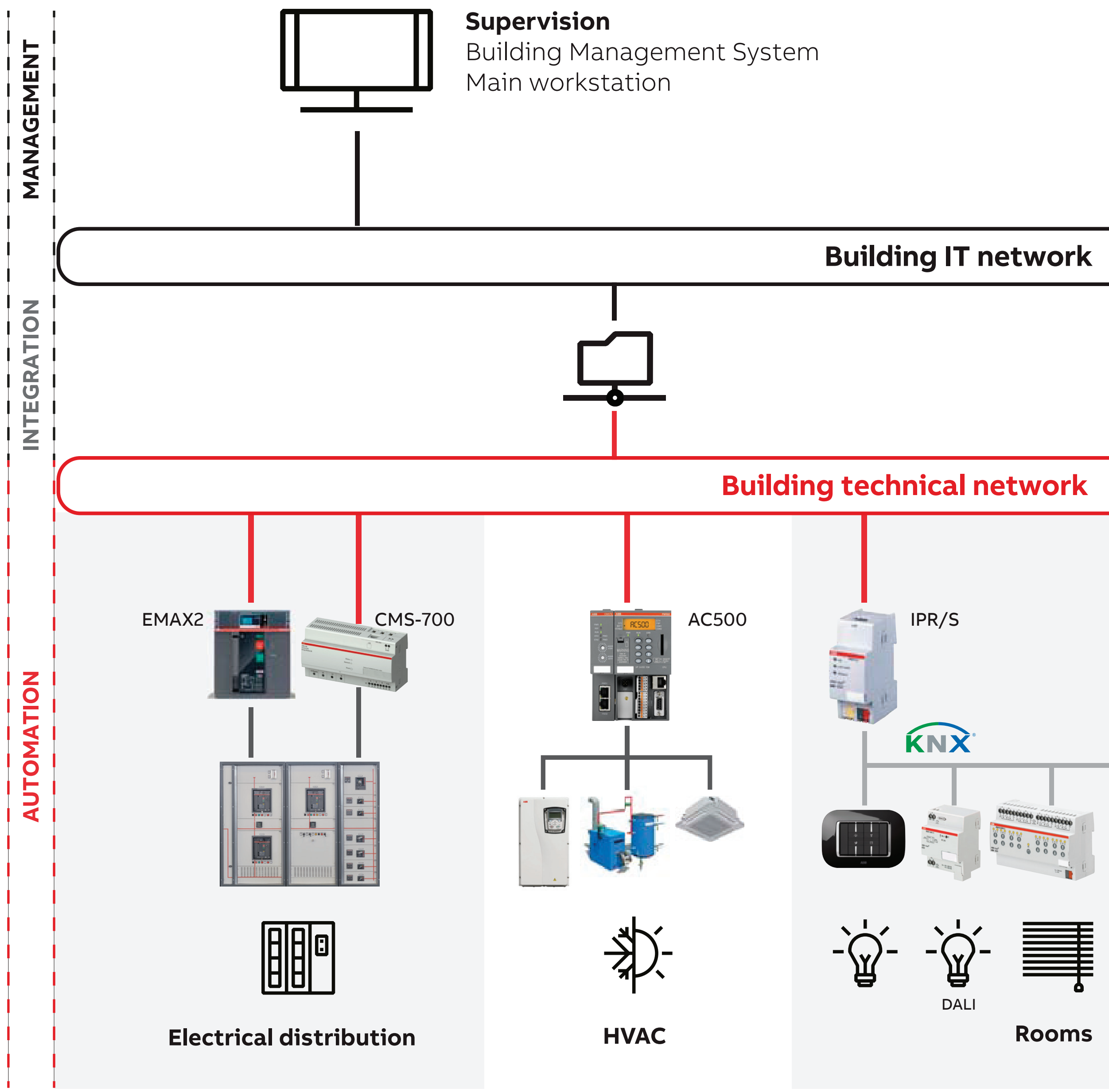
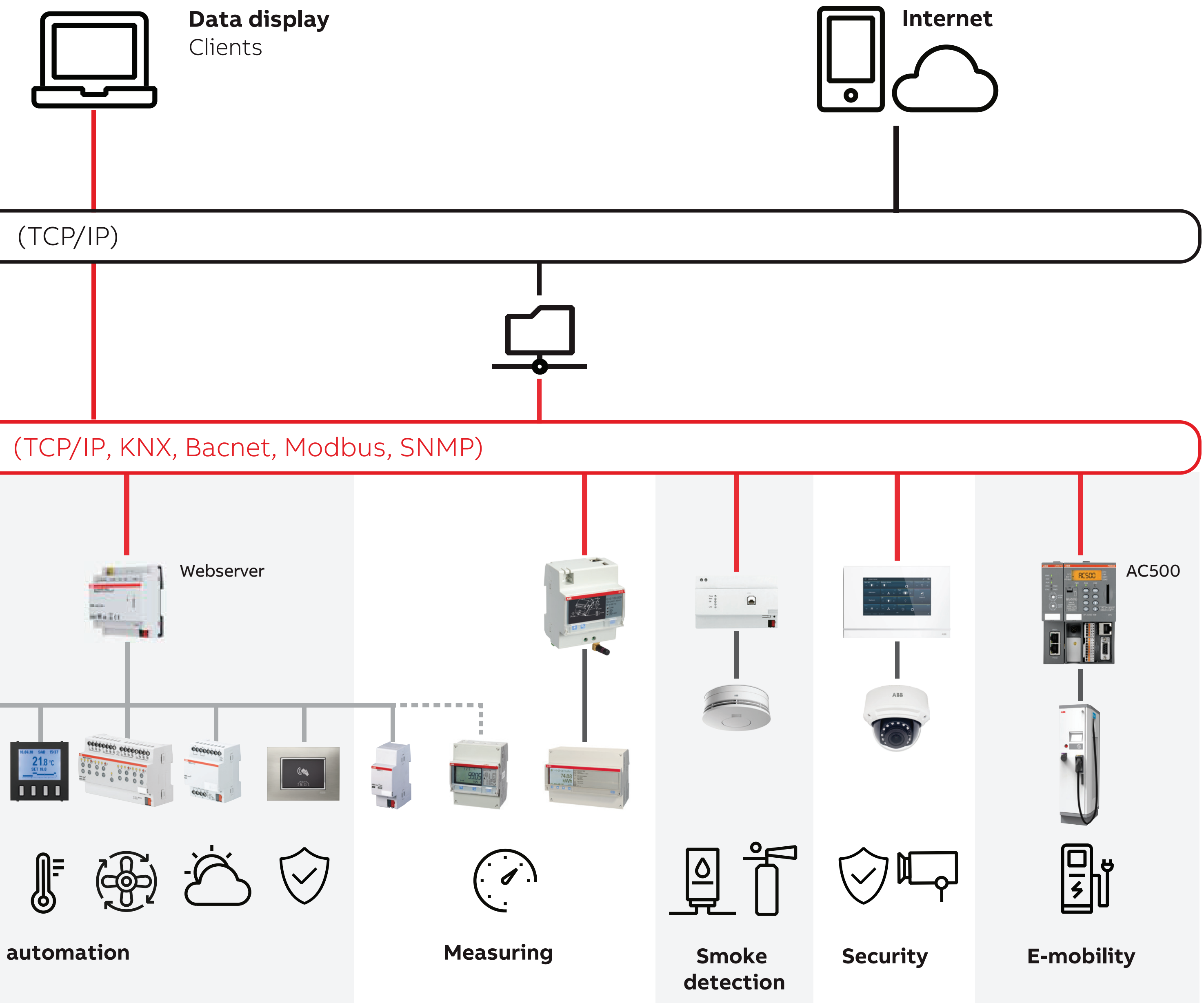


ABB i-bus® KNX interconnects all the components in the electrical installation to form a networked system, thus guaranteeing the transparency and utilization of information across the installation. In this way, building subsystems such as lighting, shutters, heating, ventilation, security and more are all interconnected and can be automated to maximize comfort and efficiency with minimal user interaction. Moreover this system allows easy reorganization of office spaces while maintaining the energy efficiency benefits.

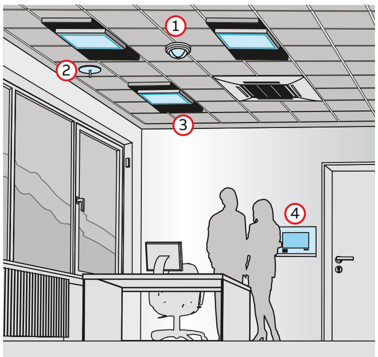
Thermostats and temperature regulators, shutter actuators, light sensors, presence and brightness detectors are installed throughout the building. They provide constant light control, adjusting the heating, air conditioning and blinds according to the brightness, the presence of people, building opening hours and site closure.
Office lighting is provided by L'ebénoïd LED panels and is controlled by a KNX management system. In addition, for the safety of occupants, the entire site is equipped with blocks of Kaufel emergency and exit lighting connected to the BMS.

For more information see:
https://new.abb.com/low-voltage/products/building-automation

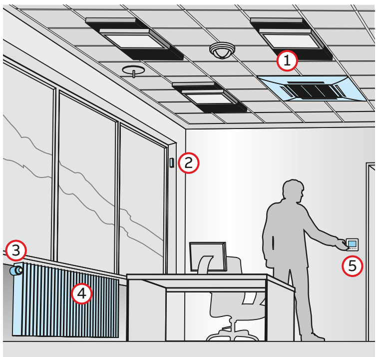


5 ABB Solution

Figure 6. Lighting (left) and HVAC (right) control



1 Presence detector
2 Light sensor
3 Lights
4 Touch display



1 Fan coil unit
2 Window contact
3 Valve drive
4 Radiator
5 Room thermostat

These building automation solutions can be applied to design efficiency measure EM06, EM08 and EM09, listed in Annex B of IEC 60364-8-2 Standard. For HVAC a control based both on rooms' temperature and time (foreseeing a shutdown out of working time) enables to reach maximum score.

The design chosen by consultant whit more than 80% of lightings automatically controlled via occupancy sensors or timers, enables the satisfaction of requirements to get maximum score according to EM09.

Table 5. HVAC control

Type of HVAC control	Points for industrial building	Points for commercial building	Points for infrastructure
No consideration	0	0	0
Temperature control	1	1	1
Temperature control at room level	4	4	4
Time and temperature control at room level	6	6	6

Table 6. Lighting control

% of the consumption of lighting automatically controlled	Points for industrial building	Points for commercial building	Points for infrastructure
< 10	0	0	0
≥ 10 % and 50%	1	3	2
≥ 50 %	2	6	4

Other ABB solutions to achieve the 60364-8-1 objectives for HVAC
Automation controller has predefined automation modules for a holistic Heating, Ventilation and Air Conditioning (HVAC) automation solution from Central HVAC to room automation that meets the Energy Efficiency Objectives.

Automation Modules include, for example, schedule, set point calculation, heat curve calculation, data logging and device monitoring. Custom automation modules can also be created using a graphical Logic editor. The Controller has an automatic generated web-based user interface to monitor and manage the KNX System.

For more information see:
https://new.abb.com/low-voltage/products/building-automation/product-range/abb-i-bus-knx/products/heating-ventilation-and-air-conditioning

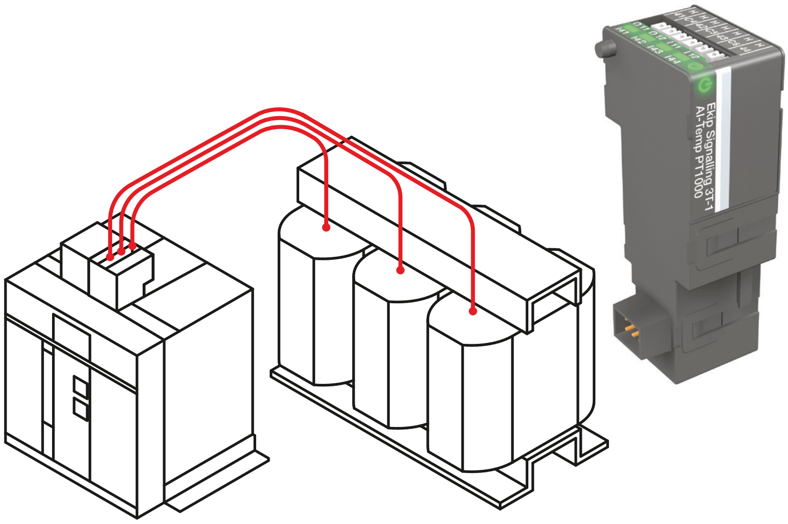
5.3 Transformer's winding monitoring

Environmental conditions affect overall plant performance and device functionalities. Continuous monitoring systems are required in all applications where electric devices such as motors or transformers could work under overload conditions for a short time.

In the event of the temperature of a transformer's windings exceeding a certain value, the supervision system must alert the office tenant, who can then decide to actuate an emergency procedure to mitigate and prevent further circuit overheating. To monitor and collect transformer winding data in this project, three thermo-resistance PT1000 are directly connected to the module Ekip Signalling 3T can be mounted either on Emax 2 and on Tmax XT low voltage circuit-breakers.

The temperature data collected are then sent from the breaker to the supervision system via a selected communication protocol.

Temperature data collected are then sent from breaker to supervision system via selected communication protocol.



5.4 Efficient UPS

UPS are essential in all buildings and infrastructures, but they are also power consumers. Traditional UPS have an average efficiency from 92% to 95% and it becomes worst when load is low. ABB offers an Uninterruptible Power Supply (UPS) DPA 250 S4 with the highest energy efficiency on the market, which enables reduction of power losses of more than 30%, thanks to an efficiency per module of 97.6% – and system level efficiency of 97.4%.

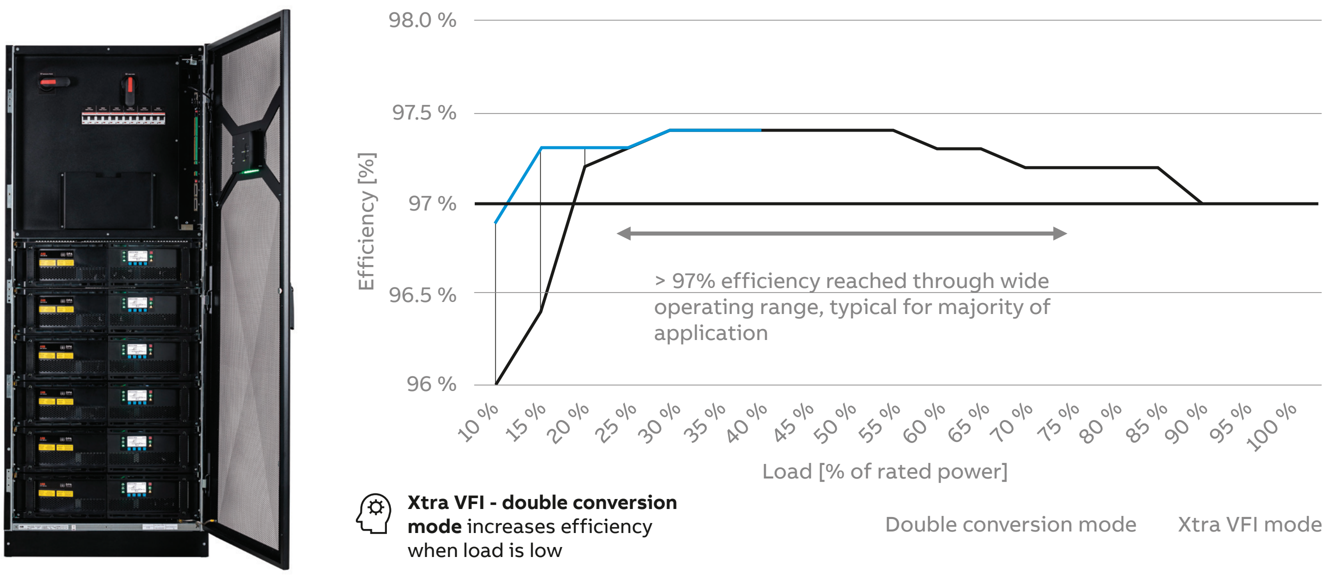
Under low load conditions, the unique Xtra VFI mode switches the UPS to “lean-power” operation by optimizing the number of modules used to feed the load.

All DPA models can perform the measurements of output power, battery capacity, input voltage, battery autonomy, input frequency, output voltage and output current. Based on the measured values, the UPS can also produce alarms in case of values above or below set limits. All this information is available locally, on the DPA display, as well as remotely using the Modbus communication protocol.

For more information see:
https://new.abb.com/ups/systems/three-phase-ups/dpa-250-s4

Considering an existing building with an old UPS system with 92% or 95% efficiency, it could be convenient to substitute it with a new more efficient UPS, as the ratio of power consumption of the old vs the new machine would result in up to four points according to efficiency measure II05.

Figure 7. DPA 250 S4 with related operational efficiency



>97% efficiency reached across a wide operating range, typical for the majority of applications

5 ABB Solution

Table 7. Efficiency of fixed installed current using equipment consuming more than 5% of the installation's total energy consumption (kWh)

R_{EC}	Points for industrial building	Points for commercial building	Points for infrastructure
< 12	0	0	0
≥ 1.05 % and < 1.2	2	2	2
< 1.05	4	4	4

5.5 Power factor correction

To avoid power quality problems, capacitor banks for power factor compensation has been integrated in the low voltage distribution system. The benefits of using ABB's LV capacitor and filter solutions include:

- Compliance with the strictest power quality regulations on reactive power and harmonics
- Reducing and/or eliminating utility penalties for a low power factor and/or high harmonic content
- Off-loading and reduction of power losses in cables and transformers
- Reducing production downtime and/or commercial system downtime
- Increasing system efficiency and reduction of CO^2 emissions

Figure 8. Capacitor bank unit

To speed up project design, engineers choose a preassembled capacitor unit ready for installation with protection devices, supplied by ABB.

The PMOD power module has a standard range from 220V to 690V and ratings starting from 6.25 kvar up to 100 kvar in a single module (option with detuning reactor included up to 50 kvar), reaching up to 400 kvar (without reactors) or 300 kvar (with detuning reactors) per cubicle. The System Pro E power, innovative ABB main distribution switchboard solution, is coupled with the capacitor bank unit, for a perfect integrated solution.

For more information see:
https://new.abb.com/high-voltage/capacitors/lv/power-factor-correction-solutions/thyristor-switched-capacitor-banks

http://search-ext.abb.com/library/Download.aspx?DocumentID=9AKK107045A2189&LanguageCode=en&DocumentPartId=&Action=Launch

Annex B foresees some additional points for installations with high power factors, and low harmonic content, for more details, see tables below.

Table 8. Power factor

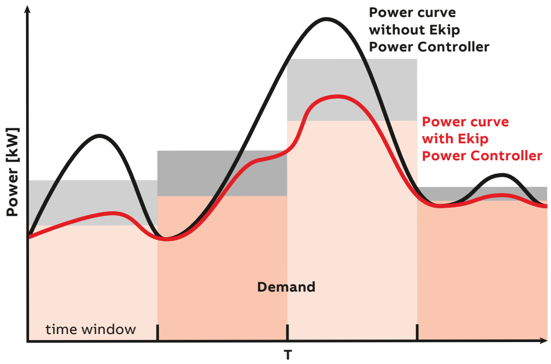
Value of the power factor	Points for industrial building	Points for commercial building	Points for infrastructure
< 0.85 or no measurement	0	0	0
≥ 0.85 and < 0.90	1	1	1
≥ 0.90 and < 0.93	2	2	2
≥ 0.93 and < 0.95	4	3	4
≥ 0.95	6	4	6

5.6 Demand management

The use of an energy management system to optimize energy consumption considering the status of the loads, the energy produced locally, and the charging status of the batteries is one of the active measures promoted by the IEC 60364-8-1.
In the past these controlling functions were obtainable only through automation systems requiring the implementation of complex architectures, long programming processes and high costs.
Nowadays Ekip Power Controller enables engineers to quickly design peak shaving functions by managing different loads and generators.
This solution, embedded in ABB low voltage circuit-breakers, offers designers a flexible solution.

A patented power controller algorithm uses consumption forecasts to allow listed loads to be controlled remotely via the relevant switching device (circuit-breaker, switch-disconnector, contactor...) or to control circuits according to priorities set by users. Ekip Power Controllers can be synchronized with utilities and can adapt power demand according to energy tariffs for maximum power cost savings.

Figure 9. Power consumption with and without Power Controller



The Emax2 circuit-breaker with Ekip Power Controller is also recognised by LEED© (Leadership in Energy and Environmental Design), a rating system for green buildings.
In this building project, the Ekip Power Controller has been applied for partializing the HVAC system and for the EV charging stations when the load demand reaches the maximum power limit set.
The implementation of this logic to control the air conditioning and EV charging of the office building leads to annual savings of approximately €11000.

For more information see:
https://new.abb.com/low-voltage/products/circuit-breakers/emax2/benefits/ekip-power-controller

With the ability to control more than 50% of installed loads, it is possible to increase the Efficiency of Electrical Installation (EM07) score.

Table 9. Energy management system

R_i	Points for industrial building	Points for commercial building	Points for infrastructure
< 50 %	0	0	0
≥ 50 % and < 70 %	3	3	2
≥ 70 % and < 83 %	6	6	4
≥ 83 % and < 90 %	10	10	6
≥ 90 %	12	12	8

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5.7 Measures and monitoring

To control power consumption and the power quality analysis of all services in the installation, engineers decided to use measuring functions and a network analyzer embedded in the ABB circuit-breaker trip units, MCCBs and ACBs, TruONE automatic transfer Switch and SlimLine XRG switch-disconnector fuse.

This solution simplifies the switchboard design, as there is no need to reserve space for sensors and power meters in the switchboard. High measurement accuracy is ensured thanks to the possibility to choose trip units with measurement modules with Class 1 accuracy for power and energy measurements, according to the IEC61557-12 Standard for main distribution boards and critical loads.

For more information see:
Tmax XT: https://new.abb.com/low-voltage/products/circuit-breakers/xt
Emax 2: https://new.abb.com/low-voltage/products/circuit-breakers/emax2
TruOne ATS: https://new.abb.com/low-voltage/launches/truone-ats
SlimLine XRG: https://new.abb.com/low-voltage/products/fusegear/slimline-xr-gold

Full connectivity of the monitoring system is ensured by the availability of several native communication protocols.

The most relevant ones are IEC61850, Modbus TCP, Modbus RT, Ethernet IP, Profibus, ProfiNet and DeviceNet, allowing easy integration into any BMS without the use of converters, helping simplify architecture and reduce installation costs.

For measurement of small terminal loads, the CMS-700 (Circuit Monitoring System) has been adopted, enabling in this way a detailed analysis of the installation.

Accurate measurements enable the addition of many more points for the energy efficiency score.

- Annual monitoring of meshes for comparison with total power consumption enables up to 6 points (II01)
- Annual monitoring of usages for comparison with total power consumption enables up to 2 points (EM02 – EM05)
- Presence of continuous monitoring for systems consuming over 10% of total installation power consumption, including automatic warnings in case of variance of consumption, can bring up to 5 points (MA05)

For more information see:
https://new.abb.com/low-voltage/products/system-pro-m/measurement-products-for-din-rail/circuit-monitoring-systems/cms-700

Other ABB Solutions to achieve the 60364-8-1 objectives
ABB offers a full range of metering devices:
ABB Energy Meters with 1% and 0,5% accuracy in accordance with IEC 62053-21 or 62053-22 are useful for billing applications.
ABB M4M Network Analyzers are used for energy usage analysis and power monitoring with 0,5% accuracy in accordance to IEC 61557-12.

Figure 10. Protocols available and related modules

Protocol	Ekip Com Module	Ekip Com Redundant Module
Modbus RTU	Ekip Com Modbus RS-485	Ekip Com R Modbus RS-485
Modbus TCP	Ekip Com Modbus TCP	Ekip Com R Modbus TCP
Profibus-DP	Ekip Com Profibus	Ekip Com R Profibus
Profinet	Ekip Com Profinet	Ekip Com R Profinet
EtherNet/IP™	Ekip Com EtherNet/IP™	Ekip Com R EtherNet/IP™
DeviceNet™	Ekip Com DeviceNet™	Ekip Com R DeviceNet™
IEC61850	Ekip Com IEC61850	Ekip Com R IEC61850

Table 10. Determination of energy consumption: coverage

K_1	Points for industrial building	Points for commercial building	Points for infrastructure
< 50 %	0	0	0
≥ 50 % and < 65 %	1	1	1
≥ 65 % and < 75 %	2	2	2
≥ 75 % and < 83 %	4	4	4
≥ 83 % and < 90 %	6	5	6
≥ 90 %	7	6	7

Table 11. Usages

K_U	Points for industrial building	Points for commercial building	Points for infrastructure
< 80 %	0	0	0
≥ 80 %	1	1	1
≥ 80 % and determine for each zone	2	2	2

Table 12. Measurement by usages

R_{MU}	Points for industrial building	Points for commercial building	Points for infrastructure
< 50 %	0	0	0
≥ 50 % and < 70 %	1	2	1
≥ 70 % and < 83 %	2	4	2
≥ 83 % and < 90 %	3	5	3
≥ 90 %	4	6	4

Table 13. Presence of monitoring for large en- ergy using systems

Presence of continuos monitoring	Points for industrial building	Points for commercial building	Points for infrastructure
NO	0	0	0
YES	5	5	5

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5.8 Energy and Asset management

Continuous supervision is mandatory for compliance with IEC 60364-8-1: designers should specify communications suitable for supervision system such Building Management System or SCADA. Customized solutions that require long and explosive programming can result in unnecessary complexity and long pay-back periods. Additionally, any extension or modification of the existing system requires further complex customization.
To speed up the project, designers decided to adopt a cloud-based system, requiring no programming and ensuring high flexibility.

The chosen solution is the ABB Ability™ EDCS (Electrical Distribution Control System) platform, suitable for small- and medium-sized industries and commercial buildings. It has been developed to meet the needs of end users, operators, consultants and panel builders, and allows plant monitoring, collecting and analysing data from each connected device.

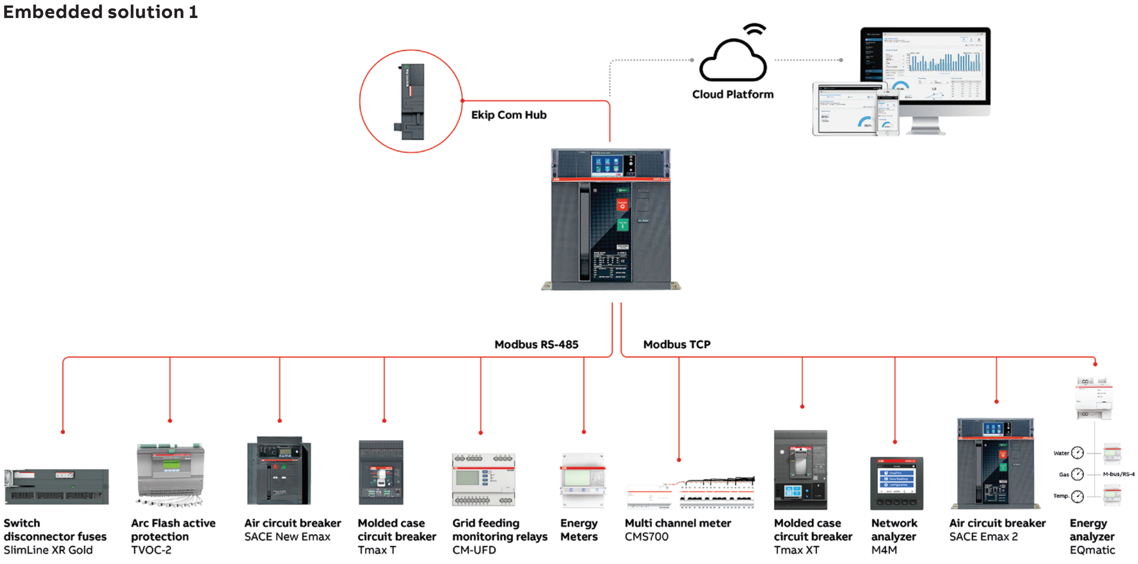
All this is achieved by means of a communication module integrated into an ACB and a MCCB or provided as a separate module. This allows communication between equipment installed in the electrical switchboard and the collection of digital or analogue data, such as temperature, humidity and water consumption.

Commissioning requires no additional programming as it is based on an auto-configuring procedure. Within a few minutes all data are available on any device with an Internet connection.

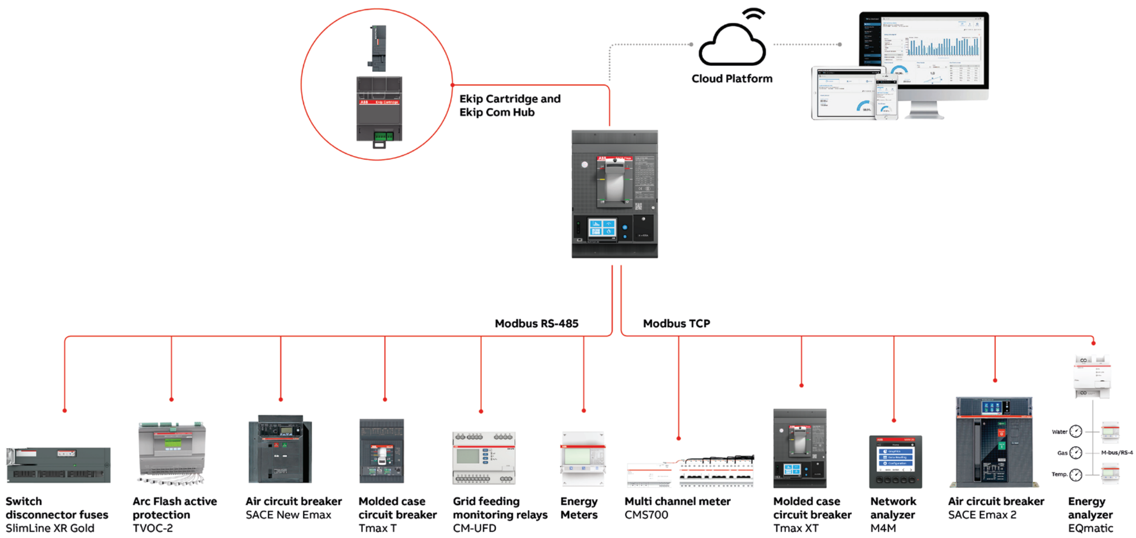
Energy management can be easily implemented as ABB Ability™ EDCS integrates a Power Controller function.

Figure 11. Examples of cloud communication architectures

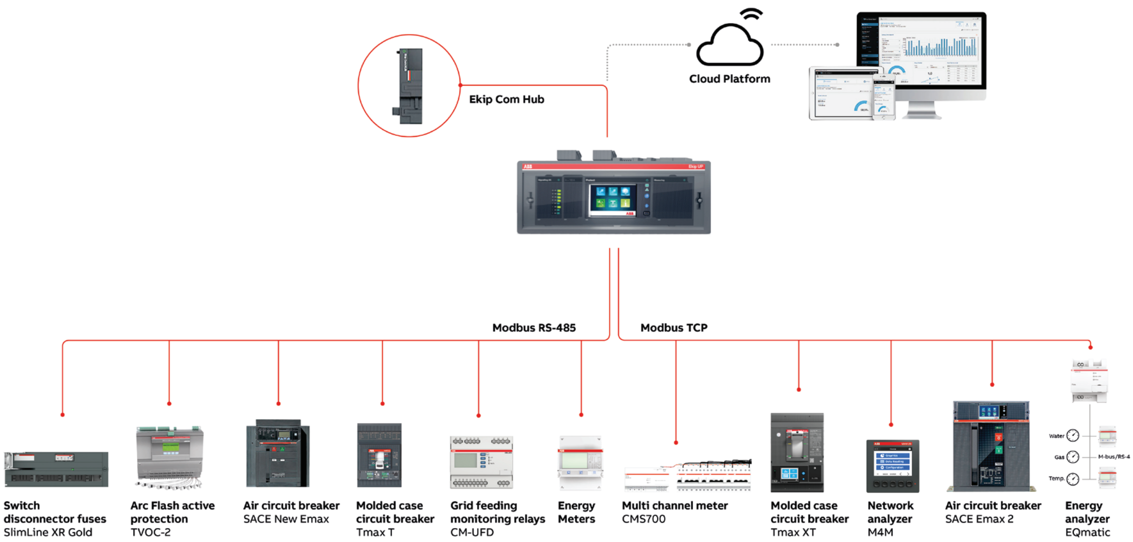
Embedded solution 1



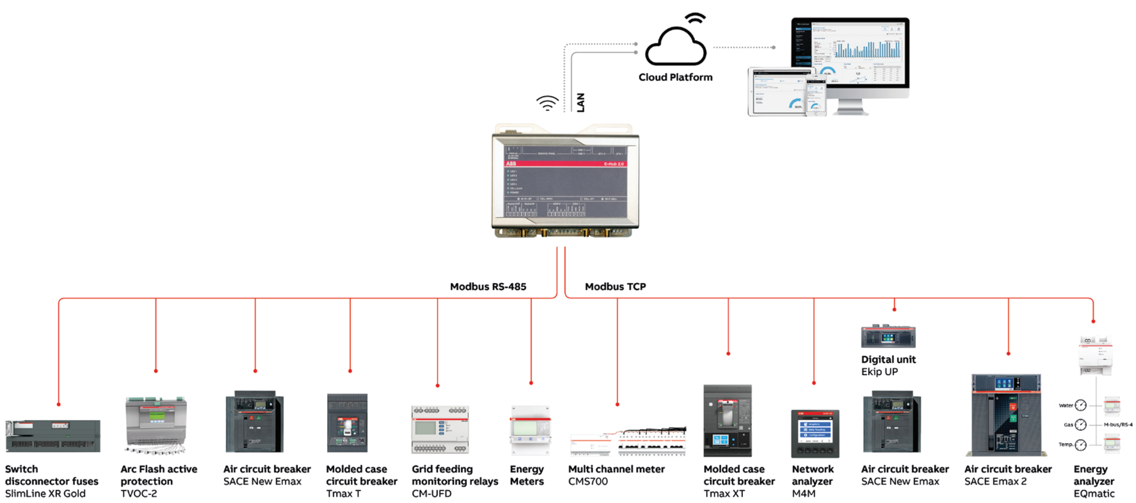
Embedded solution 2



Upgrade solution



External solution



5 ABB Solution

ABB Ability™ EDCS enables the supervision of entire electrical system starting from MV relay, along the low voltage distribution with ACBs, MCCBs and MCBs.

Scheduled automatic reports and analysis improve the use of assets and enable energy managers to take the right business decisions.

Furthermore, the new algorithm allows building managers to benefit the predictive maintenance, reducing associated maintenance costs bu up to 30%. For this project, ABB Ability™ EDCS substitutes the electrical module of the Building Management System.

For more information see:
https://new.abb.com/low-voltage/launches/abb-ability-edcs

Alternative web-server ABB Solutions to achieve the 60364-8-1 objectives
The CMS-700 and the ABB EQmatic energy analyzer are two proven energy monitoring solutions that can scale down functionalities to suit any customer requirements for measurements, monitoring and reporting. Specifically, the former is a compact AC and DC multichannel branch monitoring system, while the latter is a new range of compact, web-based DIN rail devices for energy management and sub-metering applications, able to monitor, display and analyze data from ABB and third-party meters.

The components are simple to install, arranging clearly inside control and distribution cabinets. They can both work as standalone webserver platforms and it is possible to integrate them into the Electrical Distribution Control System (EDCS) via the ABB AbilityTM cloud.

These fully scalable solutions belong to ABB's "Give your buildings a new dimension" program, that supports the digital transformation of public, commercial and industrial buildings and their power technologies.
ABB plug-and-play solutions make it simple to set up the network and cloud connectivity in a new installation or to upgrade existing facilities.

For more information see:
http://search.abb.com/library/Download.aspx?DocumentID=1SDC007270B0201&LanguageCode=en&DocumentPartId=&Action=Launch

Below a summary of available measurements for product families

Family	Device	Status	Current	Voltages	Power	Energy	Power Factor	Power Quality	Maintenance & Diagnositc	Analog or Puls / Digital Inputs
MCCBs	Tmax XT	•	•	•	•	•	•	•	•	•
ACBs	Emax 2	•	•	•	•	•	•	•	•	•
Digital Units	Ekip UP	•	•	•	•	•	•	•		•
Switches & Fusegear	TruOne	•	•	•	•	•	•	•	•	•
	Slimline XRG	•	•	•	•	•	•		•	
Submetering	EQ Meters		•	•	•	•	•			
Power Meters	M4M		•	•	•	•	•	•		
Branch Monitoring	CMS-700		•	•	•	•				

For efficiency analysis it is important not only to acquire data, but also to store them. With ABB Ability™ EDCS, data can be stored for 5 years or more, bringing a value of 8 points for determination of the electrical energy efficiency class, according to efficiency measure MA03 in Annex B.

Table 15. Data Management

Data stored	Points for industrial building	Points for commercial building	Points for infrastructure
< 1 year of history	0	0	0
> 1 year and < 5 years	4	4	4
> 5 years	10	8	8

5.9 Interface Protection System (IPS)

The integration of local renewable power sources allows CO2 emissions reduction and reduction of electricity bills.

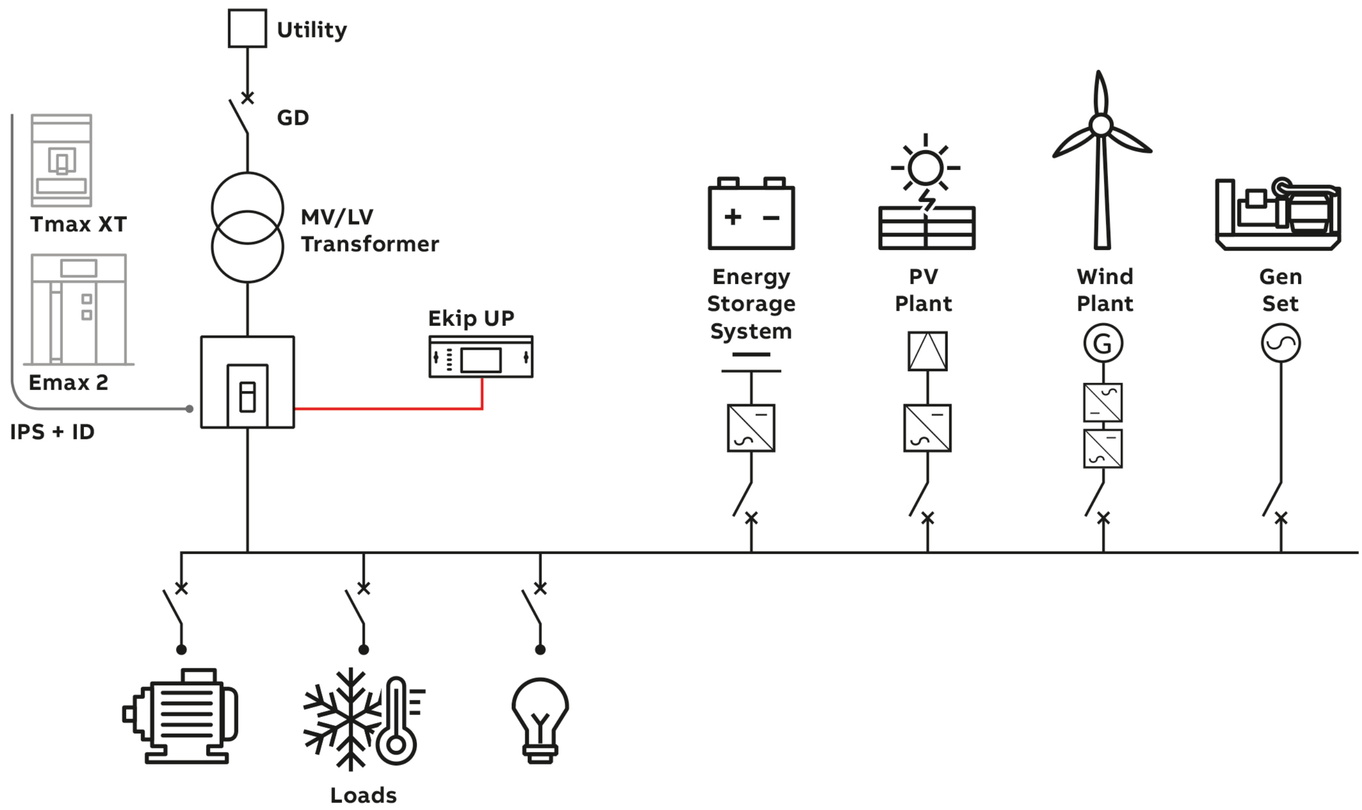
Logic control should comply to Standards and local utility should guarantee safe production and a safe connection with the public distribution network.

Engineers can comply with Standards by using the IPS algorithm embedded in the Ekip trip units. The algorithm is based on voltage and frequency and can command the disconnection of local generation from the main grid in the event that parameters go out of range.

IPS also provides an automatic reclosing function that reconnects the local generation to the main grid according to synchro check conditions and switching logics.

Ekip trip units with IPS were chosen due to the ease of their installation and because they perform interface protections with every possible switching device, also ensuring reclosing operation.
Furthermore, Ekip trip units can be supplied with measuring and network analyzer functions; the wide range of communication protocols makes its integration easy into a supervision system or into the ABB Ability™ EDCS ™ cloud monitoring system.

For more information see:
https://new.abb.com/low-voltage/products/circuit-breakers/ekip-up



5 ABB Solution

The integration of renewable power sources enables additional bonuses, if the power generated is higher than 5% of the installation's power consumption.

5.10 Energy storage

To further maximize electricity bill savings, designers can choose to associate a battery system to photovoltaic generation. ABB offers a line of string inverters with integrated energy storage to meet the needs of modern smart homes and commercial buildings.

ABB's new REACT 2 energy storage solution includes a high-voltage Li-ion battery with a long life and a storage capacity of up to 12 kWh. The modular solution can grow with the needs of any household from 4 kWh to 12 kWh and significantly reduce electricity charges thanks to an achievable energy self-reliance of up to 90 percent.
This new line, available in power ratings of 3.6 and 5.0 kW, has one of the industry's highest energy efficiency rates, providing up to 10% more energy than lower voltage battery systems.

For more information see:
https://new.abb.com/power-converters-inverters/solar/photovoltaic-energy-storage/react-2

In storage systems batteries are charged and discharged, therefore current flows in two directions. ABB can offer suitable bidirectional devices for protection from overloads and short-circuits, as well as disconnecting up to 1500V DC. On the AC side, malfunctions caused by high harmonic content can lead to unwanted trips on normal currents and for this reason ABB offers a range of products with a suitable level of immunity from high harmonics.

The wide range of ABB protection products can cover all the applications from residential to industrial.

For more information see:
http://search.abb.com/library/Download.aspx?DocumentID=9AKK106713A3398&LanguageCode=en&DocumentPartId=&Action=Launch

Adoption of battery storage with capacity of more than 1% of te installation power consumption qualify for extra bonus points.

5.11 EV charging stations

Despite not being mentioned in IEC 60364-8-1, EV charging stations are now required in most of the buildings under development or under renovation in Europe. This trend is not driven by the Energy Performance of Buildings Directive.

The number of electric plug-in vehicles sold increased from 1 million in September 2015 to 5 million in December 2018. By 2030, forecasts indicate electric vehicles will reach a 30% market share. This growth should be sustained by progressive reductions in battery costs, with Tesla predicting that this should reach 100$/kW in 2020.

EV infrastructure will play a significant role in the future of distributed energy resources and smart grid development. Having a partner on the leading edge of this trend helped designers find the solution needed for the modern office building. ABB can offer a total solution from compact, high quality AC wall boxes to reliable DC fast charging stations with robust connectivity.

ABB has years of experience in creating, installing and maintaining charging infrastructure, including several nationwide charger networks

For more information see:
https://new.abb.com/ev-charging/

5.12 Summary of case study solutions

Calculation of the energy efficiency class of a low voltage electrical installation according to IEC 60364-8-1, includes aspects not considered in this chapter. It also depends on the layout of the installation.

We concentrated on simple and effective solutions obtainable by using ABB's intelligent distribution solutions.

If we calculate the energy efficiency score contribution due exclusively to the ABB advanced intelligent solutions applied to the reference case, we can obtain following table:

Efficiency Measure	Installation Score	Maximum score possible
II01	6	6
II05	4	4
EM02	2	2
EM05	2	6
EM06	10	12
EM07	3	12
EM08	6	6
EM09	6	6
MA03	8	8
MA05	5	5
PM01	4	4
BS01	1	5
Total	**57**	**76**

The presented case study is only an example to show the impact of ABB intelligent distribution solutions on the efficiency of a low voltage electrical system.

The attainable class is different plant by plant, but ABB can help designers and energy managers to consider the specific requirements of each installation to find the right solution.

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