Key Aspects of High Voltage Industrial Network Design

An Online Continuing Education Course for Engineers

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Key Aspects of High Voltage Industrial Network Design

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Faced with increasingly furious competition, manufacturers need to enforce highly rigorous management and their manufacturing facilities need to be highly available. Electrical networks provide the energy needed to operate production facilities. The provision of an uninterrupted power supply to loads is strived from the start of the network design, especially during the preliminary design of the single-line diagram. Reductions in electrical installation and operating costs, together with reliable uninterrupted operation, are key profitability conditions. This technical and economic optimization asks for a comprehensive preliminary assessment that includes:

- Specific requirements and constraints related to the industry type,
- Integration of the limits and constraints of the public distribution network,
- Standards and local regulations,
- Particularities of the operating staff, facilities manager, and maintenance staff.

The scope of this course is limited to the assessment involved in the design of High Voltage (HV) high-power industrial networks which have the following main characteristics:

- Total capacity in the 10 MVA range,
- Autonomous electrical energy generation,
- Power supplied by a national transmission or distribution network,
- Private Medium Voltage (MV) electrical distribution

Requirements and Main Constraints to be Met

Industrial electrical networks must provide electrical energy to all loads, at optimal investment, operating, and loss of production costs, considering:

- The requirements to be met,
- People safety,
- Safety of property,
- Power supply continuity,
- Network operating ease,
- Minimum installation expanses,
- Electrical energy optimization (cost/quality),
- Network modifications and future upgrades,
- Constraints associated to:
- The industrial production process,
- The electrical process,

- The electrical utility,
- The climate and geography of the plant location,
- Regulations and local practices.

Not all requirements can be optimally met, meaning that the network designer must endeavor to reach the best compromise.

Requirements to be Met

People Safety

Principles that must be adhered to include:

- Preventing access to energized elements (protection against direct contact),
- A system to protect against the rise in potential of metal structures (protection against indirect contact),
- Preventing on-load line disconnecting switch actions,
- Preventing grounding of live conductors
- Quick fault clearance.

Property Safety

Electrical installations should not be exposed to effects that they are not able to withstand. Hence, the selection of materials and devices is of vital importance. Two electrical phenomena need to be considered to prevent fire and limit destructive effects:

- Overcurrent (short-circuits and overloads),
- Overvoltage.

Implemented solutions need to ensure the following:

- Quick fault clearance and uninterrupted power supply to the unaffected sections of the network (discrimination),
- Supply of information on the type of initial fault, for fast servicing.

Permanent Power Supply to Loads

A permanent power supply to the loads is mandatory for the following reasons:

- People safety, e.g., lighting,
- Sustained production performance,
- Productivity,
- Operating convenience, e.g., simplified machine or workshop restart process.

Loads are grouped according to their operating requirements:

- "Normal" loads,
- "Essential" loads,
- "Sensitive" loads for which the absence of a power supply is not allowed

Network Operating Ease

To complete their tasks safely and reliably, network operators need the following:

- An electrical network that is easy to operate to act correctly in the case of a problem or a maneuver
- Adequately sized switchgear and equipment, which need minimal maintenance and are easy to fix
- Efficient methods of control and monitoring allow remote control of the network by real-time centralization in a single location of all the information relating to the state of the "electrical process", under normal and contingency conditions.

Minimum Installation Expanses

The minimum installation expenses do not mean the minimum initial cost, but the sum of three separate costs:

- Initial investment cost,
- Operating and maintenance costs,
- Cost of production losses related to the network design and protection arrangement (used protection system, selection of elements and settings).

Electrical Energy Optimization

When a plant includes electrical generators, it is mandatory to manage the energy provided by the utility and the energy generated locally. A control and monitoring system allow for optimizing the cost of plant power consumption in line with:

- The contract with the power utility (billing rates according to the time, day, and season),
- The availability of the plant generators,
- Industrial process demands

Network Modifications and Future Extensions

When designing an industrial network, it is of vital importance to make a careful evaluation of the plant's future developments, particularly when extensions are foreseeable. Modifications that are liable or due to be made in the future need to be considered:

- In sizing the main power supply elements (cables, transformers, switching elements),

- In designing the distribution network,
- In calculating the locations to be reserved for electrical rooms.

Timely planning will result in flexible energy management.

Network Upgrades

Electrical energy consumption increases as extensions are made to meet the requirements of new types of manufacturing and ever more powerful equipment. This makes it necessary to upgrade and/or restructure the electrical network. Better care needs to be taken in network upgrading assessment than in the assessment of new installations since extra constraints are involved. These constraints include:

- Inadequate electro-dynamic and dielectric strength of existing elements or equipment,
- Capacity to provide power to big loads (starting current, dynamic stability, etc.),
- Area and height of existing electrical rooms that cannot be modified,
- Imposed geographical location of equipment and loads.

For example, the installation of a three-phase reactor between the old installation and the power transformer increases short-circuit current capacity and therefore uses already installed equipment.

Main Constraints

Constraints Associated with the Industrial Processes

Apart from the requirements for a high level of uninterruptable power supply in specific industrial processes, those processes also impose limitations:

- Power supply and especially starting of very large motors which drive crushers, grinders, fans, pumps, and conveyor belts,
- Power supply to arc furnaces, the arc typically being unstable, which causes short but repeated unbalanced voltage drops (resulting in flicker), and can generate harmonics,
- Power supply to high-capacity electronic equipment (rectifiers, thyristors, etc.) which produce considerable voltage wave deformations (harmonics) in the network and decrease the power factor. This happens in the case of potlines, DC electric furnaces, and variable-speed devices.

Also, certain industrial processes create pollution. They produce particles (dust, gas) that are usually corrosive and can jam mechanisms or decrease the performance of electrical equipment (e.g., dielectric strength) or even cause explosions in the presence of electric arcs.

Constraints Associated with the Electrical Process

During the assessment, it is mandatory to consider different "electro-technical" requirements that all electrical networks must fulfill, especially:

- Limitation of short-circuit currents and their duration

- Starting of large motors without unacceptable voltage drops,
- Alternator stability after a disturbance has happened.

Limitations Imposed by the Electrical Power Distribution Network

Short-circuit capacity - The short-circuit strength of the upstream network supplying the private network is a decisive element when selecting:

- The structure of the private distribution network,
- The maximum load,
- Special load that is sensitive to voltage drops.

Utility grounding arrangement - The same type of grounding arrangement, as used by the utility, is typically used for the private network but it is sometimes not compatible with particular loads. In those situations, it is mandatory to make a separate system with:

- Electrical protection for phase-to-ground faults,
- Network operating method (fault tracking and/or clearing by operating staff in the case of isolated neutral systems).

Momentary voltage dips or substantial transient single-phase or multiphase voltage drops. The existence of such conditions can cause disturbances, or even production shutdowns and machine damage. These phenomena may end in:

- Operating errors and/or data loss in the industrial process computer systems, management control system as well as scientific calculation errors.
- Motor mechanical damage. This happens during momentary dips (re-energizing of motors that are still rotating), since coupling may take place with phase opposition between the mains voltage and the residual voltage created by the motor. This results in very high motor currents, i.e., 4 to 5 times the rated current, and they cause considerable electrodynamic stress.
- Overvoltage of external origin, especially lightning strokes.

Value and quality of the supply voltage:

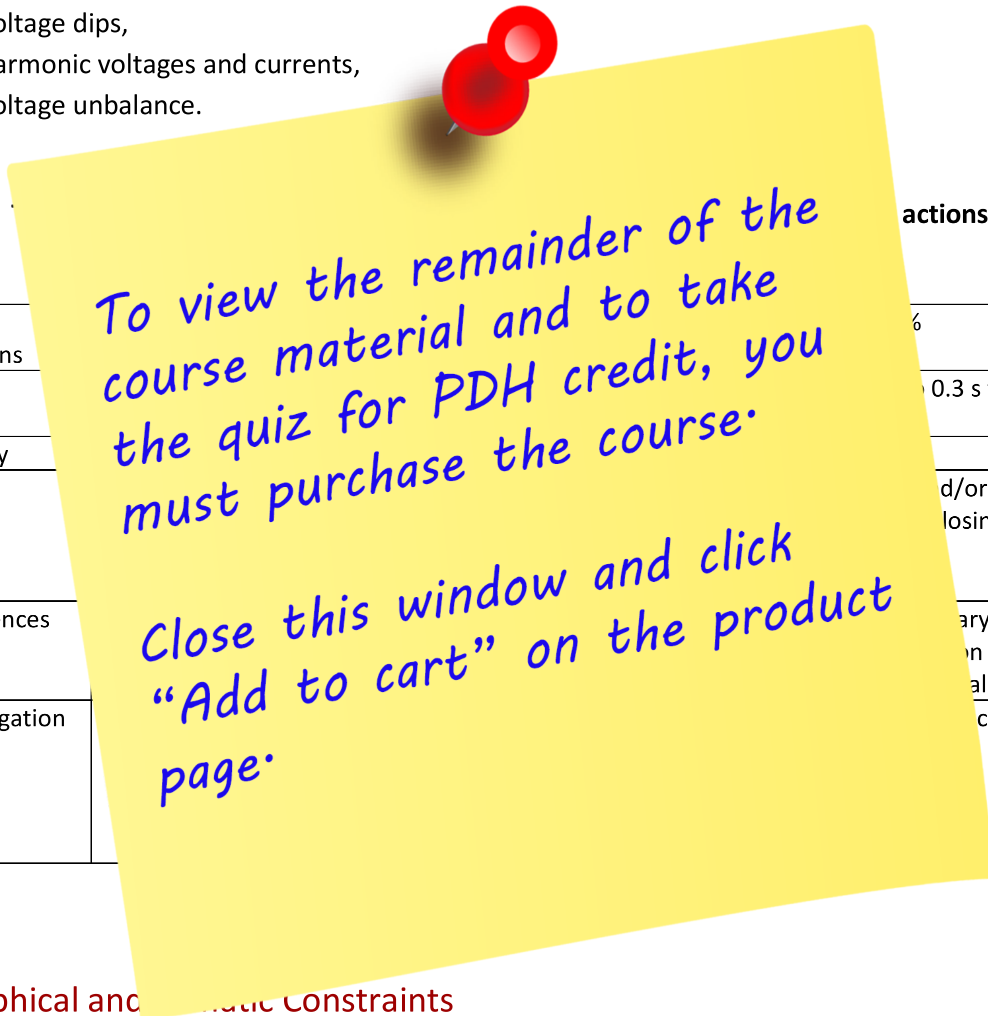
- The value of the supply voltage affects to a certain extent the level of private network voltages. If the power supply is in High Voltage (HV) range, it may be beneficial to use that voltage level for the plant's main electrical distribution system,
- Supply voltage quality.

Different voltage fluctuations may affect or even stop production equipment operation. Table 1 presents these faults, causes and consequences, as well as the main mitigation actions.

Notes:

Regarding supply voltage quality, frequency fluctuations must be within ±2% and harmonic voltages must be less than 3%. Power quality analyzers are used for these measurements. These devices measure:

- RMS voltage and current,
- Active and reactive power,
- Short and long power outages,
- Voltage dips,
- Harmonic voltages and currents,
- Voltage unbalance.



[illegible] actions

Voltage fluctuations	[illegible]	%
Duration	[illegible]	0.3 s to 10 to 30
Periodicity	[illegible]	
Causes	[illegible]	d/or slow HV losing system
Consequences	[illegible]	ary n of power all loads
Main mitigation actions	[illegible]	circuit

Geographical and [illegible] Constraints

To find the best equipment specifications according to the different installation types, it is mandatory to know the following:

- Maximum and average daily temperatures,
- Relative humidity rate at maximum temperature,
- Maximum wind speed,
- Presence of frost, ice, sand-bearing winds,
- Environment (corrosive atmosphere or explosion risk),