SUSTAINABLE DEVELOPMENT AND POWER QUALITY IN URBAN ELECTRICAL NETWORKS

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Urban technical networks are very important for the good town administration. However, the networks imply several risks as pollution, impact on the environment, technological errors that could affect the society etc. The role of the decision factors is to develop the network, in the same time protecting the resources. The human being is in the center of this evolution and can act both positively and negatively on these phenomena.

Keywords: Sustainable development, “urbistic” concept, EMC, power quality.

1. Introduction

In the modern, profound technological and resources consuming society, the phenomena as natural resources depletion, pollution and climatic changes were detected, leading to the appearance of sustainable development concept.

2. Sustainable development

2.1. The sustainable development concept

The concept implies the following dimensions: ecological, social, economical, political.

Applied to town administration, sustainable development concept basically fulfills the following requirements:

– does not impede future development;
– ensures equity between town inhabitants, as well as between actual and future generations;
– favors participation of all inhabitants in making decisions concerning town development.

The need to use necessity of primary or secondary energetic resources consumption had facilitated the development of transport and distribution networks. Within this context, the urban technical network referring to the water, energy, communications and transport distribution sectors has been developed.

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The development of a town depends on the land's morphology, the climate, the presence or absence of a water source, the soil's potential and the will of defending a strategic point. The urban space is characterized by two major dimensions: a visible one at the ground level including the town's entire infrastructure and a less visible one, underground. It includes different types of structures (as public, private or mixed) that have diverse properties as ensuring people and goods mobility, individual and collective housing, development of commerce, administration, services, education and sport activities, and improvement of cultural and social life of the inhabitants. The existence of all these conditions made possible the appearance of towns according with the concept of urbanism (city planning) has been defined. However, the cosmopolitanism is a process of variable time period according to the resources held by the specific land.

2.2. The URBISTIC concept

An important component of sustainable development that covers the economical, social, environmental, resources and life quality dimensions is represented by the integrating URBISTIC concept ("urbistique" in french). This concept is recent, but has major perspectives of implementation and development.

The term of URBISTIC is depicted as "the science and the art of planning and constructing new places or to systematize the existent ones". It derives from the systematization term and refers to the administration, of the energy resources. The term has been proposed by the researchers at the Center of Energetic and City Research (Le Centre de Recherches Energetiques et Municipales) (initially named CREM, after 2000 became the "Urbanistic Training Center) in Martigny, Swiss [2]. It allows central coordination of better town administration, increase of the infrastructure and urban equipments efficiency, better designing and performance of the utilities networks within the urban environment (electrical, natural gas, thermal, water, sewerage, phone and cable television networks).

Structurally speaking, the town can be regarded as a complex system with multiple inputs and outputs that can be matter, energy and information (Fig. 1). This system includes heterogeneous elements, a network of indispensable relationships and reserves. It also includes a functional aspect that implies different flows, decisions centers etc.

From the URBISTIC concept view, the management of this system has to ensure the minimization of the impact on the environment and the recovery and recycling of residual products by:

– urban exoneration by maintaining the green areas and by using performant equipments and transport systems;

– environment protection by controlling gas emissions, efficient energy usage, and by developing and exploiting the regenerating resources;
– waste recycling (ecological treatments and removal).

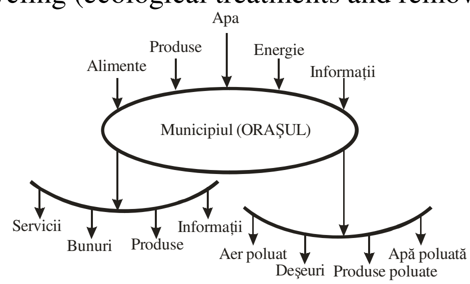

Fig. 1. Theoretical diagram of a municipal (urban space).

3. Urban technical networks for electrical power supply

3.1. The architecture of the electro energetic system

In order to be used, electrical power undergoes four stages: production, transport, delivery and usage. These highly interconnected processes result from an ensemble of equipments grouped in power stations, transmission and distribution networks, and consumers that form the electro energetic system (Fig. 2) [3]. Electrical power is transferred from the source to the consumers through electrical networks with different voltage, and their number depends on the distances between the production and the consumption centers as well as on the powers which are transported and distributed.

Power system
↓

Power plants → Transmission networks → Distribution networks → Consumers

↑
Electrical networks

Fig. 2. Diagram of the components of an electro energetic system.

3.2. Power quality in urban electrical networks

A component of URBISTIC refers to different equipments categories “living together”. In the next section we will discuss the reciprocal impact of power equipments that is quantized in the Theory of Electromagnetic Compatibility (EMC). An important component of EMC is the power quality.

As is already known, the power quality term has been intensively used after 1980. The term takes into account the influence of a great number of electromagnetic disturbances that can occur into power system (especially for medium and low voltage) [6]. At this moment there are several terms employed in the electrical power supplier – consumer relationship such as: power quality, voltage quality, current quality, quality of power supply and quality of consumption.

Power quality refers to notions and terms as:

- electromagnetic compatibility that is the ability of a device, equipment or system to properly function in its electromagnetic environment and without producing intolerable electromagnetic disturbances that could affect the surrounding;
- level of electromagnetic compatibility that is the maximum specified level of electromagnetic disturbances expected to be applied to a device, equipment or system that functions in specific conditions.

In analyzing the electromagnetic compatibility issues, CEI standards operate with two important notions:

- emission that is the level of electromagnetic pollution produced by an equipment;
- immunity that is the capacity of an equipment to be unaffected by electromagnetic pollution.

The level of electromagnetic compatibility can be overcome with low probability (5%) in practice. To evaluate the impact of users' tasks on the network, a level of planned electromagnetic disturbances is set, lower than the compatibility levels (Fig. 3).

The influences on the devices' functionality induced by the system network disturbances have determined the creation of three classes of electromagnetic media:

- class 1 – protected networks with compatibility levels lower than the public ones (devices for the industrial laboratories, some equipments for automation and protection, some computers etc);
- class 2 – generally referring to common coupling points (CCP) and internal coupling points (ICP). The levels of compatibility of this class are identical to those of the public networks;
- class 3 – refers only to ICP from the industry. The levels of compatibility are superior to those of class 2 for specific disturbances.

Because this ensemble of parameters varies aleatory with the time, its description requires a statistical approach.

The equipments are tested at the test immunity level that is greater than the compatibility level. Thus the risk (*R*) of an equipment to be affected by the disturbances *d* is defined as the area under the intersection of the two curves representing *p(d)* and *P(d)* functions:

$$R = \int_{0}^{\infty} p(d) \cdot P(d) \cdot \delta d \qquad (1)$$

Therefore the disturbances sources can be defined by a probabilistic repartition $p(d)$ in which d is the disturbance and $p(d)$ is the density of probability of the disturbance and $P(d)$ is the equipment's probability of susceptibility, from Fig. 3.

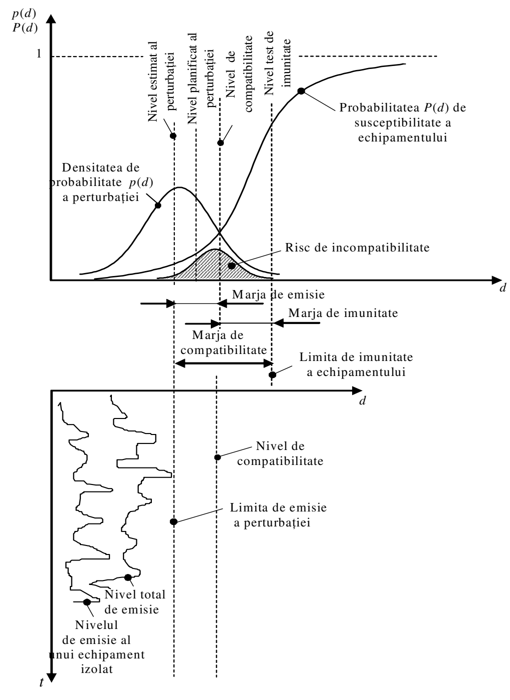

Fig.3. Graphic illustration of EMC principles [8].

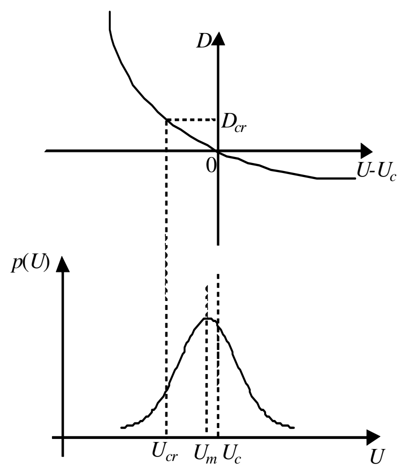

Fig. 4. Correlation between damages and aleatory voltage variation of the supply bars [8].

As a general rule, in the disturbing electrical equipment, the planned level of the perturbation has to be lower than the compatibility level that is imposed by standards. However, in practice, the estimated level has to be lower or equal to the compatibility level.

The levels of emission and immunity vary with time and on the device used, especially considering that the usage conditions differ from the test conditions. The momentary levels of the environmental disturbances vary with the modifications on the configuration of the media, on the lines' load etc. The compatibility level has to be considered as a specified value established to ensure coordination between the disturbance and the disturbed equipments within a network.

Generally, if a the network has nominal load and all the consumers inject at the level of their individual allocated limits, the total level of the disturbance in the power network equals the planning level. The sum of the disturbances from different sources (that differs on the type of disturbances) uses rules indicated by international settlements.

The user is responsible for maintaining the limits of emissions generated in CCP under the limits specified by the "provider" of power energy [9]. The provider is responsible of the general control of disturbances' level under normal conditions of working in accordance with the international settlements [10]. Thus is essential that the user and the provider cooperate to establish the optimal method ensuring emissions reduction.

Table 1 shows the variation limits recommended for different electrical dimensions in accordance with EN 50160.

Table 1

EN 50160 standards: characteristics of power quality in JT and MT

Indicator	**EN 50160 stipulations**
Frequency	50 Hz ± 1%; 95 %in a week; 50 Hz +4/-6%; 100% in a week
Variation of the voltage amplitude	±10% x U_c (contracted voltage); 95% in a week
Voltage rapid variations (sudden)	Generally limited to 4% x U_c; in very exceptional cases is 6% x U_c
Voltage rapid variations (flicker)	$P_{lt} \leq 1\%$; 95 % in a week
Voltage sags	Most of the gaps have a duration less than 1s with the amplitude lower than 60%
Short time interruptions	From less than 100 to several hundreds in year; 70% from the interruptions have a duration less than 1s
Long time interruptions	From 10 to 50 in a year
Temporary overvoltage	$1,7 \cdot U_c$
Transitory overvoltage	Present
Unbalance	2%; 95% in a week
Harmonics	Limit to harmonic up to 25^{th} degree and distortion factor ≤ 8%; 95 % in a week
Interharmonics	Under study
Remote control signals	Limited according to Meister's curve; 99% in a day

The deviations of the electric power quality parameters from the accepted values can induce damages by reducing the planned production or by reducing the life span of the consumer's devices and equipments [11]. For example, the deviations from the nominal value of the supplying voltage can induce important damages to the power energy receivers by insulations overstressing if the amplitude exceeds the nominal value and supply interruptions if the voltage has gaps or is discontinued. In terms of the period and the amplitude of voltage sags, the modern equipments that have numeric control production can determine equipment disconnection and products rebooting under processing. Restarting these equipments requires supplemental material and energy consumptions.

When calculating the damages induced by the variations of power energy quality indicators is taken into account the contracted values for which damages are considered zero. In Fig. 4 the relationship between the damages *D* and the aleatory voltage variation *U* in the supplying bars is analyzed. Considering the correlation $D = f(U)$ with the shape indicated in Fig. 4 and if the voltage in the supplying bars can be defined by the probability density $p(U)$ with the U_m as the medial value (generally U_m differs from the contracted value U_c), the probability density of the damages occurring with variations of the supplying voltage $p(D)$ can be calculated.

In practice, the relationship between damages *D* and the quality indicator (for the case under study is voltage amplitude on the supply bars *U*) can be expressed as a grade two polynomial:

$$D = a \cdot \Delta U + b \cdot (\Delta U)^2 = a \cdot (U - U_c) + b \cdot (U - U_c)^2 \tag{2}$$

The fact that a value U_{cr} which is the minimal voltage admitted because the damages exceeds the allowable value corresponds to a value D_{cr} of the critical damages (maximum allowed) is emphasized in Fig. 4. The determination of the U_{cr} value is very important to establish the variation range of the voltage in the bars and the conditions that have to be used for each consumer.

Usually, the variation of the voltage in the supply bars can be defined by a normal repartition law (Gauss):

$$p(U) = \frac{1}{\sigma_U \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{(U - U_m)}{2 \cdot \sigma_U^2}}, \quad p(\Delta U) = \frac{1}{\sigma_U \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{(\Delta U - \Delta U_m)}{2 \cdot \sigma_U^2}} \tag{3}$$

In many cases, lowering the quality indicators of the power energy below a specific limit (value U_{cr} in Fig. 4) induces productions rejects that mathematically speaking lead to constant damages independently on the value of the quality indicator.

4. Conslusions

URBISTIC is a modern concept for administration of the utilities urban networks. It is a component of sustainable development. This paper describes the electromagnetic compatibility relationship of different equipments within the urban infrastructure. In this case, electromagnetic compatibility is translated in effects on the power energy quality. The deviations of the quality parameters for power energy in the supply bars of the consumers generally lead to damages that can be analytically determined in specific cases for various receptors. The compatibility level, accepted internationally, serves as a reference value for functioning without disturbances, particularly for power energy public supply systems to which the consumers' equipments are connected.

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