Electromagnetic compatibility (EMC)

According to IEC 61000-1-1 [148], –**Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment**.‖ The first part of the definition, –*ability ………..to function ……….in its………. environment*‖ fits well with the aforementioned definition of voltage quality. The second part of the definition, –introducing ……. disturbances ……..‖ is rather similar to our term current quality. The IEC has published a whole series of standards and technical reports on EMC, most of which are part of the IEC 61000 series.

The main set of international standards on power quality is found in the IEC documents on EMC. The IEC EMC standards consist of six parts, each of which consists of one or more sections:

Part 1: General

This part contains for the time being only one section in which the basic definitions are introduced and explained.

Part 2: Environment

This part contains a number of sections in which the various disturbance levels are quantified. It also contains a description of the environment, classification of the environment, and methods for quantifying the environment.

Part 3: Limits

This is the basis of the EMC standards where the various emission and immunity limits for equipment are given. Standards IEC 61000-3-2 and IEC 61000-3-4 give emission limits for harmonic currents; IEC 61000-3-3 and IEC 61000-3-5 give emission limits for voltage fluctuations.

Part 4: Testing and Measurement Techniques

Definition of emission and immunity limits is not enough for a standard. The standard must also define standard ways of measuring the emission and of testing the immunity of equipment. This is taken care of in part 4 of the EMC standards.

Part 5: Installation and Mitigation Guidelines

This part gives background information on how to prevent electromagnetic interference at the design and installation stage.

Part 6: Generic Standards

Emission and immunity are defined for many types of equipment in specific product standards. For those devices that are not covered by any of the product standards, the generic standards apply.

The principle of the EMC standards can best be explained by considering two devices, one which produces an electromagnetic disturbance and another that may be adversely affected by this disturbance. In EMC terms, one device (the **“emitter”**) emits an electromagnetic disturbance; the other (the **“susceptor”**) is susceptible to this disturbance. Within the EMC standards there is a clear distinction in meaning between (electromagnetic) **“disturbance”** and (electromagnetic) **“interference.”**

An electromagnetic disturbance is any unwanted signal that may lead to a degradation of the performance of a device. This degradation is referred to as electromagnetic interference. Thus the disturbance is the cause, the interference the effect.

The most obvious approach would be to test the compatibility between these two devices. If the one would adversely affect the other, there is an EMC problem, and at least one of the two needs to be improved. However, this would require testing of each possible combination of two devices, and if a combination would fail the test, it would remain unclear which device would require improvement. To provide a framework for testing and improving equipment, the concept of compatibility level is introduced. The compatibility level for an electromagnetic disturbance is a reference value used to compare equipment emission and immunity. From the compatibility level, an emission limit and an immunity limit are defined. The immunity limit is higher than or equal to the compatibility level. The emission limit, on the other hand, is lower than or equal to the compatibility level (see Fig. 1.9). Immunity limit, compatibility level, and emission limit are defined in IEC standards.

The ratio between the immunity limit and the compatibility level is called the immunity margin; the ratio between the compatibility level and the emission level is referred to as the emission margin. The value of these margins is not important in itself, as the compatibility level is just a predefined level used to fix emission and immunity limits. Of more importance for achieving EMC is the compatibility margin, the ratio between the immunity limit and the emission limit. Note that the compatibility margin is equal to the product of the emission margin and the immunity margin. The larger the compatibility margin, the smaller the risk that a disturbance from an emitter will lead to interference with a susceptor.

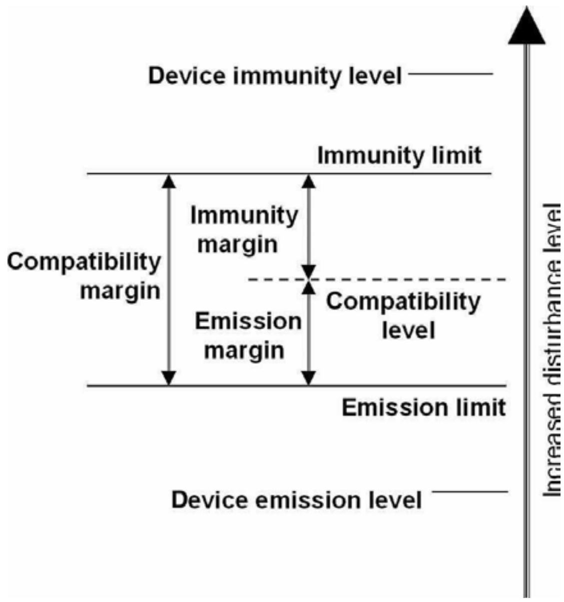

Figure 1.9 Various levels, limits, and margins used in EMC standards.

1.8.2 Voltage Fluctuation

Voltage fluctuations are systematic variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges specified by ANSI C84.1 of 0.9 to 1.1 pu.

IEC 61000-2-1 defines various types of voltage fluctuations. We will restrict our discussion here to IEC 61000-2-1 Type (d) voltage fluctuations, which are characterized as a series of random or continuous voltage fluctuations. Loads that can exhibit continuous, rapid variations in the load current magnitude can cause voltage variations that are often referred to as flicker.

The term *flicker* is derived from the impact of the voltage fluctuation on lamps such that they are perceived by the human eye to flicker. To be technically correct, voltage fluctuation is an electromagnetic phenomenon while flicker is an undesirable result of the voltage fluctuation in some loads. However, the two terms are often linked together in standards. Therefore, we will also use the common term *voltage flicker* to describe such voltage fluctuations.

An example of a voltage waveform which produces flicker is shown in Fig. 1.10. This is caused by an arc furnace, one of the most common causes of voltage fluctuations on utility transmission and distribution systems. The flicker signal is defined by its rms magnitude expressed as a percent of the fundamental. Voltage flicker is measured with respect to the sensitivity of the human eye. Typically, magnitudes as low as 0.5 percent can result in perceptible lamp flicker if the frequencies are in the range of 6 to 8 Hz.

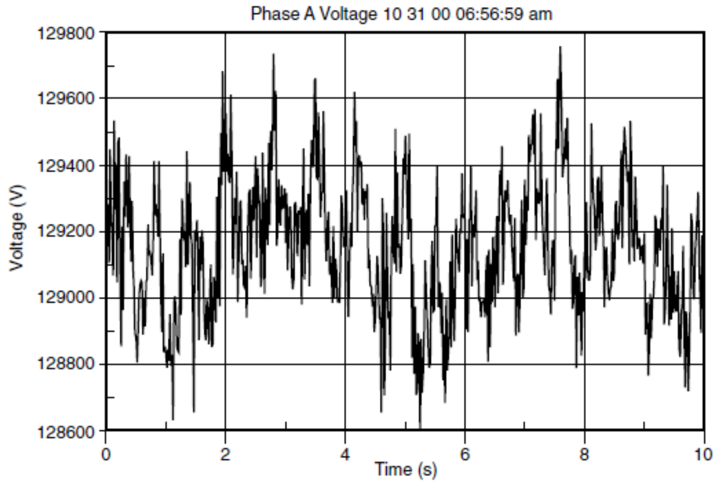

Figure 1.10 Example of voltage fluctuations caused by arc furnace operation

1.8.3 Power Frequency Variations

Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g., 50 or 60 Hz).

The power system frequency is directly related to the rotational speed of the generators supplying the system. There are slight variations in frequency as the dynamic balance between load and generation changes. The size of the frequency shift and its duration depend on the load characteristics and the response of the generation control system to load changes. Figure 1.11 illustrates frequency variations for a 24-h period on a typical 13-kV substation bus.

Frequency variations that go outside of accepted limits for normal steady-state operation of the power system can be caused by faults on the bulk power transmission system, a large block of load being disconnected, or a large source of generation going off-line.

On modern interconnected power systems, significant frequency variations are rare. Frequency variations of consequence are much more likely to occur for loads that are supplied by a generator isolated from the utility system. In such cases, governor response to abrupt load changes may not be adequate to regulate within the narrow bandwidth required by frequency sensitive equipment.

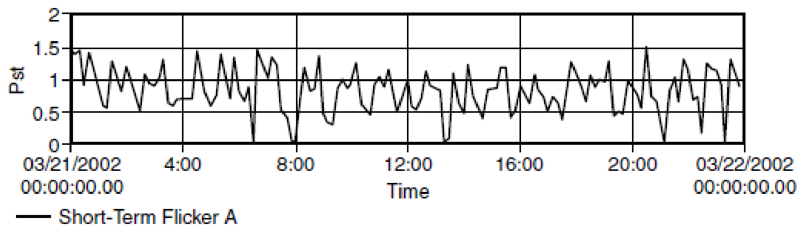

Figure 1.11 Flicker (Pst) at 161-kV substation bus measured according to IEC Standard 61000-4-15

1.8.4 Voltage Imbalance

Voltage imbalance (also called *voltage unbalance*) is sometimes defined as the maximum deviation from the average of the three-phase voltages or currents, divided by the average of the three-phase voltages or currents, expressed in percent.

Imbalance is more rigorously defined in the standards using symmetrical components. The ratio of either the negative- or zero sequence component to the positive-sequence component can be used to specify the percent unbalance. The most recent standards11 specify that the negative-sequence method be used. Figure 1.12 shows an example of these two ratios for a 1-week trend of imbalance on a residential feeder.

The primary source of voltage unbalances of less than 2 percent is single-phase loads on a three-phase circuit. Voltage unbalance can also be the result of blown fuses in one phase of a three-phase capacitor bank. Severe voltage unbalance (greater than 5 percent) can result from single-phasing conditions.

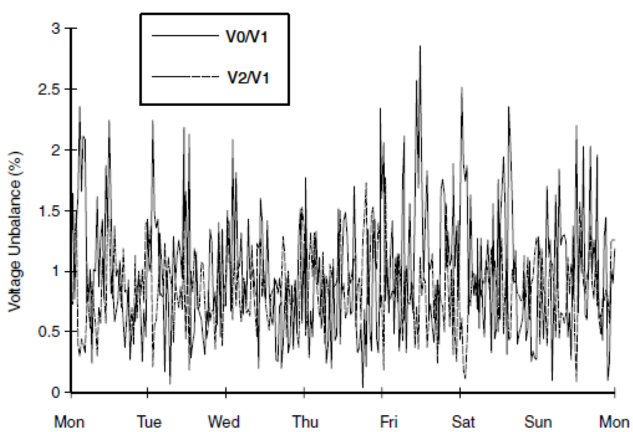

Figure 1.12 Voltage unbalance trend for a residential feeder

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