Acceptance test of voltage quality of wind farms connected to SN network

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Abstract

His study is a description of basic quality parameters of voltage with discussing basic requirements that must be complied with by generator installations connected to electro-energetic networks. The requirements for wind power stations have been particularly included, cooperating with SN electro-energetic network SN 15 kV-20 kV.

I. Introduction

The necessity of Poland's fulfillment from accepted obligations towards EU concerning specific percentage of renewable sources in total volume of produced electric energy, caused very dynamic growth of this field of energetics. In our direct neighbourhood, distributed sources of electric energy have been created such as wind farms and bio-gas co-generators. Big part of these installations from 500 kW to 5 MW is connected to the existing electro-energetic networks of medium voltage SN 15 kV-20 kV. Considering the fact that the Operator of Distributive System is obliged to provide receivers with electric energy of parameters specified in EN-PN 50 160 standard EN-PN 50 160 each time before connecting next units to distributive network, researches and analyses of quality parameters of energy produced by these sources, shall be carried out.

II. Basic parameters of voltage with requirements for wind farms

A. Harmonics

The measure of distortion that has been commonly accepted are harmonic values. Harmonics include currents or voltages, which frequency is a total multiplicity of voltage basic frequency. Multiplicity of basic frequency specifies the so called harmonic number. By superposition of harmonic components (according to Fourier series) of different frequencies and amplitudes, an optional distorted period course is achieved. Common phase displacement of individual harmonic components decides also about form of course. Voltage or current distortions in electro-energetic networks is expressed by total distortion ratio – *THD*, which is calculated according to the following dependence:

$$\mathrm{THD}_u = \sqrt{\sum_{n=2}^{40}\left(\frac{U_{(n)}}{U_{(1)}}\right)^2}\,100\% \qquad (1)$$

The upper limit of summing up values is usually value 40, and sometimes 50. Relative distortion ratio is also defined for h harmonic - *HR,* calculated according to the following dependence:

$$HR = \frac{U_h}{U_1} \qquad (2)$$

where:
U_1 – effective value of basic harmonic,
U_h – effective value of h harmonic.

The main sources of harmonics in electro-energetic system are three groups of installations: devices with magnetic cores (e.g. transformers, engines, generators, etc.), arc devices (e.g.: discharge furnaces, discharge light sources, welding devices, etc.) and electronic and energo-electronic devices. Permissible level of harmonics in SN network is THD_U 8% value.[1]

B. Voltage fluctuations and deviations

These are voltage changes of different duration, in the range of amplitudes from 90% to 110% value of nominal voltage U_n.

With relation to a dynamics and reason of described voltage change, voltage deviation (usually fall) with constant value in time or voltage fluctuations. Voltage fluctuations defined as series of changes of effective value of envelope of time course (temporary values), where speed of voltage changes is bigger than 1% U_n *per second.*

Basic parameters of voltage fluctuations are:

1. amplitude of fluctuations – specified as a difference between adjacent effective values of voltage

$$\delta V' = U_{eks1} - U_{eks2} \qquad (3)$$

where: U_{eks1} i U_{eks2} - next extreme effective values of voltage in the moment t_1 and $t_2 = t_1 + \Delta t$

Moreover, also average frequency of amplitudes occurrence of voltage fluctuations δV is calculated in time *T* and it is number m of fluctuations amplitudes in time T per time unit and specified in the following formula:

$$f_v = \frac{m}{T} \qquad (4)$$

Frequency of voltage fluctuations amplitude is measured by a number of fluctuations per second (1/s) or relatively (1/m), (1/h).

In order to evaluate level of voltage fluctuations ratios of short-term light flickering P_{st}, defined in PN-EN 61000-3-3 are used. And long-term light flickering - P_{lt}, They characterize influence of voltage fluctuations on the process of view, including time ratio and they are modified form of energetic voltage dose P_t.

Difficulty ratio of fluctuations is assigned to time *t* and specified by the following formula:

$$P_t = \frac{k}{\Theta} \int_{t-\Theta}^{t} dt \int_{0}^{35} g^2(f_u) G(f_u, t) dt \qquad (5)$$

where: $G(f_u, t)$ - frequency of process spectrum of voltage changes in time *t*,

Θ - average interval, including sight effect of differentiation memory (300 s),

k – ratio selected so that P_t=1 value matched the level of occurring bad sight feeling during light flickering.

The basic reason of voltage changes of described nature, is time variation, mainly of passive power of receivers generally named current variation receivers. The examples of such receivers can be wind generators, where variation of generated voltage is mainly caused by wind fluctuation.[3] During the acceptance process of wind farms, requirements are met when the above ratios in the point of contact with electro-energetic network do not exceed value P_{Lt} = 0,35 and P_{St} = 0,45.[2]

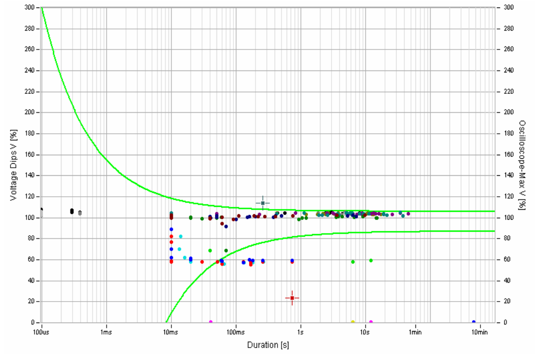
C. *Power supply dip and short breaks*

Dips are defined as short-term reduction of effective value of voltage in the range between 10% and 90% of nominal voltage. U_n, with duration from 10ms to 1 min (sometimes 3 min are taken). After a given time the effective value of voltage comes back to previous state. Also, a relative amplitude of dip is defined $AU_n[\%]$ (residual voltage), as minimum difference of effective value during dip and nominal voltage, expressed in percent.

Reducing value of effective voltage below 10% in time range described above is taken as short-term power supply break.

The reason of occurring dips and short breaks in power supply are mainly short circuit in electro-energetic system, causing the flow of big currents, finally significant voltage drops in electro-energetic network. Relative amplitude of created dip or break depends on place of short circuit occurrence in respect of power supply sources. The closer short circuit to power supply source, the bigger voltage drop is observed. Duration of such an occurrence is determined by speed of protective devices. Many short circuits in transfer lines is eliminated in the time from 100 to 500ms. In case of generator installations of wind farms, there is a requirements of mounting additional installations, very sensible additional protections, adjusted to cooperation with electro-energetic network e.g. CZIP 1E.

The results of dips (short breaks) depend on their amplitude and duration, and also on receivers connected to electro-energetic network, and more specifically from characteristics of their sensitivity represented by means of CBEMA or ITIC curve. The exemplary characteristics of tolerance of energy quality in the form of CBEMA curve is presented on picture 1, registered in connection point of wind farm of 1,5 MW.



Pict. 1. CBEMA curve of voltage tolerance.

D. *Frequency variation*

Frequency of basic component of voltage in electro-energetic network is one of the basic values connected with electric energy quality. Quality parameters concerning voltage frequency include voltage frequency deviations and voltage frequency fluctuations. Voltage frequency deviation is expressed by the following dependancies:

$$\Delta f = f - f_N \qquad (6)$$

where:

f – real frequency voltage basic component of electro-energetic network.

f_N – voltage nominal frequency of electro-energetic network,

Δf – voltage frequency deviation of electro-energetic network.

Frequency fluctuations are specified by fluctuation amplitude and frequency of their occurrence according to the following dependency:

$$\delta f = f_{eks1} - f_{eks2} \qquad (7)$$

where :

f_{eks1}, f_{eks2} – adjoining extreme values of frequency changing in time with relatively high speed (e.g..: 0,2Hz per second).

4. CONCLUSIONS

With relation to a growing number of productive units and their variety not only in terms of power, construction, characteristics of exploitation the owners of distributive networks must pay special attention to continual network's monitoring with respect to meeting voltage quality parameters. However, in spite of ecological effect resulting from connecting "green" sources of energy these units can be and very often are sources of electric energy quality parameters disturbances. It results from their particular motor characteristics.

LITERATURE

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