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Photovoltaic farm impact on parameters of power quality and the current legislation

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ABSTRACT

Over the last decade, as a result of a pro-ecological policy of the EU, there has been a rapid development of renewable energy. Unfortunately, legislation, which should ensure the safety of the expanding and developing power system, cannot keep up with the technological development. There is a need for serious and insightful analysis on the impact of distributed generation on the power system. The article shows possible adverse effects of the source on the power network parameters while meeting the conditions contained in the applicable standards and regulations. On the example of the chosen photovoltaic farm, there has been shown a negative impact of the source on the power quality parameters, based on the methodology of research in accordance with the applicable standards and based on the analysis of the results. The paper presents possible problems and risks associated with the described issue that may arise in the future with the further development of renewable energy sources.

1. Introduction

Connecting of the distributed energy resources to the power system is related to the three main aspects: commercial, continuity of supply and power quality. The commercial aspect determines conditions for connection to the power network, failure removal, settlement methods, information flow and complaint modes. The aspect of supply continuity is connected to the time and number of power outages. The third aspect is power quality specifying technical acceptable parameters that will provide correct work of a power system.

The problem of quality of power produced by renewable energy sources has been analysed for many years. Studies on power quality produced by a renewable energy source (e.g. small photovoltaic source) can be found already in a publication from 1998 (Oliva et al., 1998). These studies were continued in following years (Oliva and Balda, 2003). A small number of articles, however, relies on real measurements. There are works concerning power quality from photovoltaic farm based on simulations, e.g. (Infield et al. 2004) where authors described problem of power quality coming from many inverters paying attention to the fact that if several inverters are connected, their negative impact on quality may decrease and showing that with the reduction of inverter load power, current distortion can increase. Another example can be (Enslin and Heskes, 2004) where the article's remark was returned to the problem of the quality of electricity in the case of a distribution network in which a significant number of inverters have been installed. The modelled network with inverters was used for analyses. Resonance phenomena that may negatively affect the network's operation have been shown.

In most of papers, relating to this topic, there are presented analysis concerning wind farms (Kocatepe et al., 2009). Importance of power quality problem is pointed and there are works carried out on a wind farm models (Mutlu et al., 2009) which could be used to analyse power produced by this sources (Rodway et al., 2013; Patsalidesa et al., 2016, 2015). Measurements of the quality can be also used to monitor (Yang and Tian, 2015) and control wind turbine (Boutoubata et al., 2013; Cardosoa et al., 2016). Studies on solar energy (IEA-PVPS T14-08:2017; IEAPVPS T14-02:2014) indicate that farm can have an impact on the power system and also on power quality parameters. This paper presents an analysis of power produced by the almost 2 MW photovoltaic farm, with particular emphasis on its impact on harmonics in the current generation. This problem, though widely analysed, may not be noticeable (IEAPVPS T14-02:2014). However, as writes in his letter (Li, 2017), with a large number of installed inverters it may be a problem which also confirmed our measurements (especially in the case of low power plant generation).

Documents allowing to assess the impact of the power plant on the system are relevant standards and regulations. The main document which concerns parameters of power quality is PN-EN50160 standard

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“Voltage characteristics of electricity supplied by public electricity networks” (EN50160:2010). Parameters described in the standard are frequency, voltage level and its variations. This standard concerns low voltage < 1 kV, medium voltage < 35 kV and after update in 2010 also high voltage networks (up to 150 kV). Parameters of energy supplied to the consumer are clearly specified, the problem shows up when we think about energy generated and supplied to the energy system. This problem wasn't as much substantial before raising development of renewable energy sources and energy market release which caused the emergence of new non-state energy producers.

As the appearance of more and more new sources of electricity, there is noticed the need to analyse the impact of these sources on the parameters of power quality at the point of connection (POC). In a letter (Li, 2017) there was presented unstable operation of photovoltaic farm attached to the network. The occurrence of significant distortion of current and voltage was shown, at the same time not registering the external cause that could cause such work of the farm. However, attention was drawn to the fact that grid codes should be adapted to the new type of power quality disturbances. To analyse the source in terms of its impact on the system, there must be analysed parameters of voltage (frequency, supply voltage variations, flicker severity, unbalance, asymmetry, harmonics) and current (asymmetry, harmonics) (Sikorski, 2015).

2. Power quality parameters and their requirements

Renewable energy sources technologies are constantly developing and their use is becoming more common. Because of their continues development, law regulations cannot keep up with the specific requirements of these sources. There is a lack of regulations clarifying the requirements for some of the quality parameters of produced renewable energy. There is no standard that would apply directly to the quality of energy produced by renewable sources, and therefore the energy producers must meet a number of often disparate requirements contained in the numerous documents, dedicated to other devices.

In the further parts, power quality requirements described in standards and other documents obligatory in Poland are compared.

2.1. Frequency

The reason for the frequency change is mainly a permanent or a temporary lack of balance of active power produced by the system and subscribed demand. This situation may occur during very large fluctuations of the power generated by large photovoltaic or wind farms or in the case of very high loads with insufficient generation. Documents that should be considered for meeting law conditions are: previously mentioned standard EN 50160, the Regulation of the Minister of Economy on the detailed conditions of operation of the power system from 4th May 2007 and Instructions of traffic and operation in distribution networks (IRiESD). The differences in the requirements for this parameter relate only to the period of measurement used in the study (see Table 1). Standard requires maintaining frequency between specific values during 99.5% of the year and 100% of the time. Regulation of the Polish Minister of Economy and instructions of operation in distributed networks (IRiESD) require maintaining frequency between the same values but only during week.

Table 1
Requirements of the LV and MV frequency.

Document	Required range
EN 50160	50 Hz ± 1% (49.5–50.5 Hz) during 99.5% of the year 50 Hz + 4%/−6% (47 H–52 Hz) during 100% of time
Regulation of the Minister of Economy from 4th May 2007 IRiESD	50 Hz ± 1% (49.5H–50.5 Hz) during 99.5% of the week 50 Hz + 4%/−6% (47–52 Hz) during 100% of week

2.2. Supply voltage variations

The level of the supply voltage on the network is affected by many factors, including process of generation, transmission and distribution of energy. To the operation of the distribution networks the biggest impact have variable load, switching operations and short circuits. Also renewable sources change the voltage value. According to the applicable standards the relative voltage change caused by these sources should not exceed 3.3% (IEC 61000-3-3:2013; IEC 61000-3-11:2017).

Referring, however, to the applicable regulations in other countries (Belgium, Germany), it is assumed there that voltage changes caused by operation of production units will not cause a voltage exceeding 3% (VDE-AR-N 4105:2011–8).

Acceptable levels of voltage changes caused by the operation of the sources are determined by the several documents:

- Regulation of the Minister of Economy of 4 May 2007,
- Instructions of traffic and operation in distribution networks (IRiESD),
- Instructions of traffic and operation in transmission (TNC),
- EN 61000-2-2 on electromagnetic compatibility in general,
- EN 50160 with voltage characteristics of electricity supplied by public electricity networks,
- EN 61000-3-3 for equipment with rated current up to 16 A,
- EN 61000-3-11 for equipment with rated voltage current < 75 A,
- VDE-AR-N-4105 on conditions for connection of LV micro-generation network.

Each of these documents defines different limit values as it is shown in Tables 2 and 3.

Differences occur in required range of changes and in period of measurement. The first difference is that EN 50160 differentiates the requirements depending on the level of the supply voltage. For the slow voltage changes there are little differences between analysed documents. The situation is different for fast voltage changes. Regulation of the Minister of Economy of 4 May 2007 doesn't define any restrictions and the restrictions given by EN 50160 and IRiESD are different (see Table 3). The most restrictive are requirements defined by IRiESD defined for LV network (there is a lack of guidelines for MV network).

2.3. Flicker severity

As a result of disturbances that occur in the network, supply voltage varies over time. The appropriate frequency and severity of these fluctuations can cause flickering of the light sources.

Requirements for the installation are based on P_{lt} value where:

$$P_{lt} = \sqrt[3]{\frac{\sum_{i=1}^{n} P_{st(i)}^{3}}{n}} \quad (1)$$

where: P_{lt} – long term flicker value for the group receivers with different work cycles, P_{st} – short term flicker value, counted as the square root of the weighted levels sum, determined with the probability distribution.

Requirements for the installation are based on measurement of long (Table 4) and short (Table 5) term flicker.

EN 50160 standard defines the requirements only of long term flicker. In IRiESD, requirements concerning long term flicker are more stringent and requirements for short term flicker are added. It should be noticed that special requirements apply to wind farms. For them, the instructions of the traffic distribution very tighten requirements of the flicker.