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Power Quality Assessment of Different Load Categories

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Abstract

In this paper, a fuzzy logic based method is proposed to define and evaluate power quality indices for different categories of electricity consumers. The severity level of each power quality disturbance is first estimated according to the frequency of its identification or some other metrics including percentages of voltage imbalance, total harmonic distortion rates, and durations and varying ranges of certain types of disturbances. With the constitutions of a regional power load being analyzed, a power quality index is then computed for each category of electricity end-users based on the severities of the identified disturbances and their impacts to each particular load type. It is believed that such an index will help utilities assess power quality comprehensively so as to improve their services to meet variable requirements from different electricity customers. Some data based on site measurements are used to demonstrate the proposed method in calculating the defined power quality index.

Keywords: Power Quality Disturbance, Quality Index, Disturbance Severity, Electricity Consumer Category, Fuzzy Logic

1. Introduction

In recent years, the quality of power supplies has become a major concern of power utilities as well as electricity end-users. Up to date, extensive efforts have been engaged in this field, including assessment of impacts brought about by power quality (PQ) degrading, recognition of various disturbances occurring in transmission and distribution networks, and improvement of power supplies to meet the ever increasing customers' requirements [1]

A comprehensive investigation to identify the exact PQ problems that modern electrical networks are experiencing is a prerequisite for applying any feasible and cost-effective solutions. With the advent of novel

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technologies, more sophisticated PQ monitoring systems have been proposed, developed and deployed. Automatic disturbance recognition for PQ monitoring can be performed directly on the captured voltage/current waveforms [2]. More likely, however, transformation techniques are often employed for feature extraction. Often used approaches include Wavelet Transform, S-Transform and variable short-time Fourier Transform [3-6]. With the transformed voltage/current data, different recognition methods are applied to identify precisely the PQ disturbances. The techniques include decision tree, analytic hierarchy process, neural networks and support vector machines, to name a few [3-8].

Often encountered PQ disturbances in power systems can be grouped into seven types. They are Transients, Long-Duration Voltage Variations, Short-Duration Voltage Variations, Voltage Imbalance, Waveform Distortion, Voltage Fluctuation and Power Frequency Variations [1]. To enable efficient evaluation of PQ, it is desirable to define indices that can represent various concerns of different consumer categories to these disturbances. Traditionally, power quality is assessed in terms of reliability indices considering only the sustained interruptions, such as the system average interruption duration index (SAIDI) and the system average interruption frequency index (SAIFI) as defined in [9]. With many electric/electronic devices becoming more and more sensitive to short-duration or instantaneous PQ disturbances, substantial studies have been performed in recent years to characterize these types of PQ disturbances found in modern power grids, with well-defined indices to quantify them. In [10], a new power quality index using Ideal Analytic Hierarchy Process is presented. Another achievement of the research in this area is the indices for assessing voltage sag, a major concern of power utilities and end-users. These indices are deduced by using scaling and wavelet coefficient energy analysis [11], employing a modified power acceptability curve [12], or considering compatibility between equipment and supply [13].

Harmonics in electricity networks, as a main source of PQ problems, have captured even more attention of power industry recently. A three-phase total distortion index and a total unbalance index are proposed in [14]. In [15], the total harmonic and unbalance distortion (THUD) is defined to help utility engineers assess harmonic distortion, and in [16, 17] an index reflecting the thermal effects on three-phase induction motors due to the harmonic distortions is calculated. Studies on other types of PQ disturbances including inter-harmonics, notching and voltage fluctuation are carried out in [18, 19].

The studies addressed above are mainly focused on certain types of PQ disturbances while there is a need for a comprehensive assessment on a regional power supply. In [20], an artificial neural network (ANN) and fuzzy logic based method is proposed to integrate isolated power quality indices into a comprehensive one. A robust two-stage Newton-type numerical algorithm is proposed for the voltage and current spectra estimation [21].

In a deregulated electricity market, contracts between utility companies and consumers may include terms about the required PQ grade and penalties could be applied for non-observance of the service objective [22]. As the PQ has become a major concern of not only the power utilities but also the electricity end-users, the PQ index should also reflect customers' requirements that could be quite different with respect to a variety of load types. This paper addresses such an issue with the PQ index being determined by the severity of each identified disturbance and its impact to each type of electricity end-users. It is believed that the defined index can help power utilities evaluate comprehensively their services to different electricity consumers.

2. PQ Disturbances

PQ disturbance is regarded as any changes in voltage and/or current with respect to magnitude, frequency or waveform that interfere with normal operations of power systems and connected electrical/electronic equipment.

2.1. PQ Disturbance Types

PQ disturbances are analyzed in in this section with respect to their characteristics, causes, and potential damages. Transients, as one of the most damaging types of PQ disturbances, can be further divided into impulsive transients and oscillatory. The impulsive transients are due to electrostatic discharge, lightning and poor grounding etc., whilst the oscillatory could be caused by capacitor switching or by impulsive transients that excite the natural frequency of the power system. Instantaneous high voltage and/or current could easily damage electric/electronic devices if they are lack of appropriate protections. Voltage sag/swell is another often encountered type of PQ problems. Sag and swell are phenomena of observed voltage drop or increase for a short duration (within 50 cycles). Usually extended