Development and assessment of a load decomposition method applied at the distribution level

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Abstract: The properties of a load decomposition method based on measured current and voltage waveforms and used for obtaining the load composition at distribution level are studied. To improve the precision of the results a generalised nonlinear load model is used which takes into account the harmonic interaction between voltage and current. Several tests have been carried out in laboratory and field environments. Results show that it is possible to obtain information about loads when these are grouped according to their electrical behaviour.

1 Introduction

Load composition data are of great interest to utilities as this information can be used in static as well as dynamic studies. It can be useful in those activities related to the planning stages of the electric utility (load forecasting and load research activities) as well as operational stages (power flow and dynamic simulation programs) [1]. Nowadays, these data are obtained through load research studies, classified as either intrusive and nonintrusive [2]. The information obtained by these methods, especially the intrusive ones, can be very detailed and reliable but there is the need to process the data to obtain the load composition, not being able to have it online.

This study is motivated by the desire to obtain the maximum available information about the load composition in real time and at the distribution level. After reviewing the bibliography, two different approaches could be used: the first is related to the dynamic behaviour of load when it is submitted to a voltage drop; the second is based on the decomposition of the total current absorbed by the individual electrical loads.

The voltage drop method has already been studied for the determination of load characteristics in field tests [3], where the tests were performed by introducing a sudden voltage reduction on the secondary side and recording the real and reactive power demand of various feeders. Finally, the behaviour was correlated to an exponential load model. This approach has the inconvenience of being able to reduce the voltage at a feeder as needed, which was not possible for us.

The decomposition method, which uses the load current waveform for the determination of load composition, was thought to be a better approach. It is also a passive method, not needing to modify the electrical magnitudes at the point of measurement, in contrast to the first method. Besides, the measurement of the current absorbed by loads along an electrical period also uses more data than the voltage drop method, which only uses measurements of active and reactive power; so it is expected to obtain better results.

In [4] the decomposition method is used for estimating the load composition of an industrial plant with a demand of about 300 kW. In that paper the model used for the nonlinear loads did not take into account the harmonic interaction between voltage and current, sacrificing precision for simplicity [5].

Here we study the limits of resolution of the decomposition method under laboratory conditions, taking into account the harmonic interaction in nonlinear loads. To do so, a nonlinear load model that stores the harmonic influence between harmonic currents and harmonic voltages has been developed. In laboratory tests, typical loads found in commercial and residential sectors have been modelled and software to solve the optimisation problem has been implemented using the models from the laboratory tests. Finally, several tests in laboratory and real environments have been made for identifying the load composition.

2 Nonlinear load models

The load model used in [4] makes the assumption that small distortions in the shape of the input voltage do not affect the current waveform significantly. Each load was modelled by measuring, under a given voltage, amplitudes and phases for each current harmonic through the 30th. To model the behaviour under different voltage amplitudes, the load current harmonics were calculated by interpolating between the currents measured under six different voltages.

If greater precision is required, a better model is needed and two possible alternatives were studied: physically based models of nonlinear loads and black-box type models derived from direct measurements of these loads. Both kinds of model have advantages and drawbacks. In both cases the test system used in the laboratory to obtain the current absorbed by the loads under different voltage waveforms can be seen in Fig. 1. In this system the voltage waveform with the desired harmonic content was generated by software developed for running in a PC. This software downloaded the waveforms to the power source, an ELGAR SW5250 power arbitrary waveform generator,

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