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Using grouped smart meter data in phase identification

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ABSTRACT

Access to smart meter data will enable electricity distribution companies to have a far clearer picture of the operation of their low voltage networks. This in turn will assist in the more active management of these networks. An important current knowledge gap is knowing for certain which phase each customer is connected to. Matching the loads from the smart meter with the loads measured on different phases at the substation has the capability to fill this gap. However, in the United Kingdom at the half hourly level only the loads from groups of meters will be available to the network operators. Therefore, a method is described for using this grouped data to assist with determining each customer's phase when the phase of most meters is correctly known. The method is analysed using the load readings from a data set of 96 smart meters. It successfully ranks the mixed phase groups very highly compared with the single phase groups.

1. Introduction

The very large size of low voltage networks means that increasing the amount of their active management has the potential to deliver significant benefits. For example, in the United Kingdom the low voltage network comprises 48% of the combined length of the country's electricity distribution and transmission networks (EurElectric, 2013). Of all the energy supplied by the UK's electricity distribution networks (that is 132 kV and below), 4% is lost on the low voltage network, while only 3% is lost on the rest of the network put together (Sohn Associates, 2009). Unfortunately, the size of the low voltage network also means that the costs of the collection of detailed information about, for example, the average hourly current in each cable, has been prohibitive. This means that the knowledge of the power flows on the low voltage network is very poor when compared to the higher voltage networks. This has been a barrier to the more active management of low voltage networks. However, it is hoped that the completion of the roll out of the UK's smart meter programme to domestic customers in 2025 will address this. This will come from providing the Distribution Network Operators (DNOs) such as Northern Powergrid, with the half hourly customer loads in real time. While the cost of collecting phase information in the past has been prohibitive, smart meters potentially offer a minimal cost solution. However, in the UK only the load values from groups of smart meters will be available at the half hourly level for network analysis (DECC, 2012). This paper investigates how the DNOs can use this grouped smart meter data to assist in determining which phase each customer is connected to.

The paper's structure is: The background on phasing and methods for phase detection are reviewed in Section 2. Following this, the data used in the research is described. Section 4 discusses the availability of readings from individual smart meters in the UK before Section 5 introduces a novel approach for using load readings from groups of smart meters. It then goes on to analyse the performance of this approach using data from 96 smart meters. The final sections discuss the implications of the research and summarise the findings.

2. Background on phasing

Any low voltage network that supplies more than a few customers is composed of three live phases (labelled red, yellow and blue) and a neutral phase. A normal domestic customer is connected between one of the live phases and the neutral phase (see Fig. 1). It is beneficial to have approximately equal loads on each phase, not just at the substation but throughout the network as this reduces voltage problems and losses through reducing the sizes of the neutral and largest phase currents – the consequence on the losses of different levels of imbalance are discussed in (Pezeshki and Wolfs, 2012; Strbac et al., 2014). Combining the knowledge of what phase a customer is connected to together with smart meter load readings will enable the performance of the low voltage networks to be modelled in much better detail.

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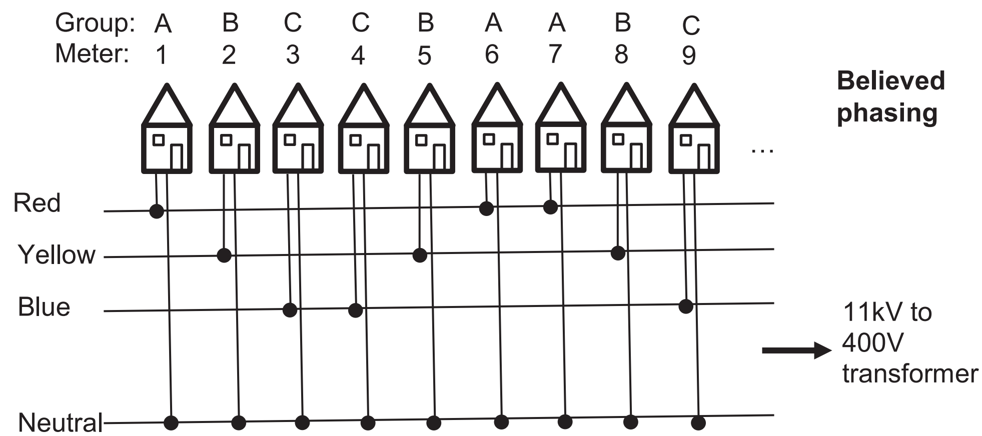

Fig. 1. Believed phasing according to the network records. Smart meters are allocated to groups based on proximity and their believed phase. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

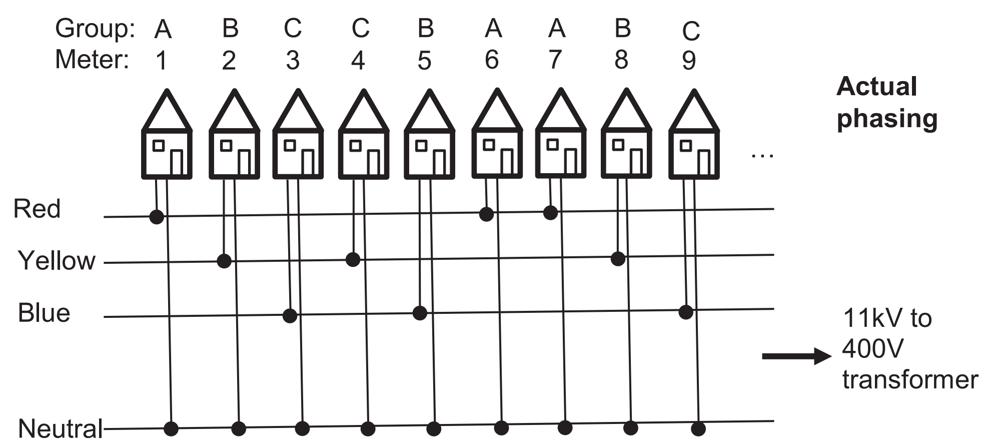

Fig. 2. Actual phasing. Meters 4 and 5 are on different phases to those they are believed to be on in Fig. 1, and so groups B and C now contain a mixture of meters connected to the yellow and blue phases. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Hence where problems are occurring or are likely to occur can be highlighted, thus allowing remedial actions to be taken, e.g. determining which phase to connect new loads or generation to.

For cable networks, once the joint connecting the customer to the mains cable has been made and sealed, it is then not possible to visibly determine the phase the customer is connected to. In the UK, although the phase has normally been recorded at the time the joint was made, there is a universal belief that these records are not totally accurate, and that a percentage of the phases are incorrectly recorded (see Figs. 1 and 2). However, although knowing the correct phase provides benefits, these benefits are usually not sufficient to justify the expenditure needed to directly measure all the customer phases on a network by visiting their connection point. Consequently, there is interest in lower cost ways of determining the phase each meter is on. In some countries communications to the smart meter use the power line, and this can allow the smart meter's phase to be determined (Arya and Mitra, 2013), but this is not the case in many countries, e.g. the United Kingdom communicates the readings via the mobile phone network.

Several approaches have been suggested for how the voltages and loads measured by the smart meters can be used to infer the phase of each meter. The methods fall into 3 classes depending on whether they are based around the reactive powers, the voltages or the currents at the smart meters. The first class is based on linking the phase angle at each customer and the reactive power element of their load (Fan et al., 2012) but it needs a detailed network model and grouping smart meters together would thus seem to be a problem. The second class involves comparing voltage time series at a smart meter with those at other smart meters and with the voltage time series of the substation phases (Arya and Mitra, 2013; Arya et al., 2014; Seal and McGranaghan, 2011; Short, 2013). Differences between the approaches in this class are whether step changes in the substation voltages are the feature to be matched to or whether the smart meter time series are clustered together first and then matched to a substation phase. This clustering of smart meters first can also allow connectivity problems to be identified, i.e. highlighting meters that are not connected to the substations they are modelled as being connected to (Arya and Mitra, 2013). Although using voltage time series has been the preferred direction recently, it is more dependent on the network model in that the voltages will vary down a circuit in line with the loads along it. When smart meters are grouped together this complicates this changing pattern. Also it is not clear how the approach would perform on the reasonably balanced UK urban cable networks, e.g. the examples illustrating its performance in (Short, 2013) are for single phase-taps. Therefore, we chose to work with the third class which uses the fact that customer power measurements should approximately sum to the total of the corresponding phase power measurements at the substation (Arya et al., 2011).

2.1. Summing smart meter power measurements

The main criticisms of the summation based approach are that:

- It is reliant on knowing which 11 kV to 400 V substation each meter is connected to.