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Intelligent three-phase current balancing technique for single-phase load based on smart metering

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ABSTRACT

This paper studies the problem of current balancing in a three-phase, low-voltage distribution network. We assume that the network has an automatic metering system that communicates using the power line carrier technique. Each meter reports the customer's energy consumption and local current/voltage data to the central station at specified intervals. To maximize the efficiency of the grid, we wish to minimize the unbalanced current in the neutral phase. After framing this problem as a quadratic assignment problem, we use the "ant colony optimization" method to assign each customer to a phase. We confirm the effectiveness of the proposed method on an ensemble of simulated networks. Besides triggering point of high current relay is also decisive and should be consider in software commands output.

1. Introduction

Automatic meter reading (AMR) systems are used by energy suppliers in many countries. An AMR system records the customer's energy consumption [1], and can transmit this information to the supplier through various long-distance communication techniques. Wireless and power line carrier (PLC) communications are both good solutions, but the latter is more economical [2–4]. The PLC technique transmits data by modulating the low-voltage side of the power line on a specific carrier frequency; every user connected to the power line in the same phase therefore acts as a data node. Once a PLC AMR system is established in a network, all users are connected to each other via the power line. Because such systems provides a great deal of information, new "smart metering" systems that do more than just meter reading are being introduced. Smart metering allows the energy supplier to acquire more data and transmit commands to individual nodes in the network.

This paper presents an intelligent method to enhance grid balance in three-phase, low-voltage distribution networks. Specifically, the proposed method collects statistics on the network and uses an optimization approach to construct the new network model. A numerical simulation of a test case is also used to confirm the method.

2. Three-phase unbalance

Loads using three-phase power sources sometimes lose one of the three phases from the power distribution system. This condition is known as "single-phasing". External causes of this problem might be a downed line or a blown pole top fuse on the utility system. End users may also lose a single phase if overload conditions cause one of their fuses to blow, or if there is an equipment failure within their facility.

Unbalance of a three-phase system is less extreme than a complete loss of phase, but may have similar consequences. On new installations, careful attention is given to balancing the loads on each phase. However, an unbalance may occur later as single-phase loads are added to these systems. Thermal overloads, magnetic breakers, and other such devices will not detect this gradual unbalance, and therefore do not provide adequate protection.

The voltage unbalance in a three-phase system is defined as the maximum deviation from the average of the three voltages divided by the average of the three voltages. Naturally, the same definition can be applied to currents if this is more convenient. Expressed as a percentage, the voltage unbalance is given by the following equation:

$$\text{Voltage unbalance} = \frac{100 \times \text{Maximum deviation from average voltage}}{\text{Average voltage}} \quad (1)$$

Phase voltage unbalance causes three-phase motors to run at temperatures greater than their published ratings. The excess heat is due mainly to negative-sequence currents attempting to turn the

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