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Using AMR data for load estimation for distribution system analysis

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Abstract

With the development of distribution automation (DA) and other advanced applications in distribution systems, the real-time monitoring and control of distribution systems becomes possible. Now there are only a limited number of real-time measurements on the distribution systems. The load monitoring and estimation of customers can be an important source of information used by the distribution analysis applications. In recent years, an increasing number of automated meter reading (AMR) systems have been installed. AMR can provide customer consumption information and other data such as confirmations for outages and restoration. In this paper, a load estimation algorithm is discussed. The proposed algorithm makes use of the above information that AMR provides as its input. It also incorporates time series forecasting method and the use of the customer load curves to improve the accuracy of individual customer real-time load estimates. This method with the use of AMR data has excellent load estimation results. This method demonstrates how AMR data can be used for other functions besides billing.

Keywords: Power distribution systems; Load modeling; Load estimation; Automated meter reading; Time series

1. Introduction

To effectively control the power distribution system that is becoming more and more complicated, operators should have comprehensive, accurate and real-time knowledge about the system. Many distribution automation (DA) systems have been and will be installed in the distribution systems. Some of these systems can transmit real-time data back to the control center. If enough measurements can be obtained accurately, continuously and reliably, the operator or an advanced application can understand the exact status of the system and decide how to most effectively manage the system.

Transmission level loading allows for real-time values of conditions. While the distribution system does not have that feature today, one of the opportunities is to use the available AMR data to provide load models and estimations for various distribution system analysis techniques. Besides distribution state estimation as mentioned below, load estimations for individual customers can be useful for load balancing, restoration-cold load pick up and planner forecasting for upgrades for lines, transformers and other upstream power system equipment. These applications do not need exact values but estimates that provide a first-order snapshot of the distribution system as it operates day-to-day. Additional metering can be done on key locations to move from estimations and pseudo-measurements to real time data. However, as this is not practical for all the distribution system, using the AMR data is a useful initial tool.

Various constraints make it impossible to have a perfect picture of the system. First, for economical reasons, measurement instruments cannot be installed at every place where the measurements are needed, so the data are incomplete. Second, the measured data are subject to error or lost communication, so the data may be inaccurate, unreliable and delayed.

State estimation is one approach to reduce these constraints. State estimation techniques have been developed and used on the transmission level for over 30 years. Transmission system state estimation is considered to be the heart of a modern energy management system (EMS). Now it becomes possible and important to apply state estimation techniques to distribution systems as well. The distribution system state estimation can provide the real-time system states to a distribution management system (DMS) enabling operators to monitor and control the operation of the distribution systems [1–4].

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However, because of the limited number of real-time measurements in the distribution systems, the state estimator cannot acquire enough real-time measurements, so pseudo-measurements are necessary for a distribution system state estimator. One good source of the pseudo-measurements is the load estimation at the transformer node, providing the combination of several customer loads below it.

Many techniques and approaches have been investigated in load modeling and estimation in the last three decades [5–9]. Some previous algorithms make use of the transformer capacity or the customer billing information combined with coincidence factors to estimate the real-time load [5]. Others use weather information [6,7]. Miu and Wan [9] developed load estimation techniques using the limited measurements available including some meter measurements.

In recent years, an increasing number of automated meter reading (AMR) systems have been installed. AMR can provide customer consumption information and other data such as confirmations for outages and restoration. And these data can be used to simplify the load modeling algorithm and make it more accurate. AMR is the remote collection of consumption data by meters over telecommunication lines, radio, power line or other links. Meters are installed on the customers' houses. The meters transmit the data to the intermediate communication controllers at very short time intervals, and the data are routed by these controllers to a central computer [10].

In this paper, a real time load estimation algorithm is discussed. The algorithm estimates the load of a metering point. The proposed algorithm makes use of the above information that AMR provides as the input. And it also incorporates a time series method and the use of the basic customer class load curves to improve the accuracy of load estimates. With more and more utilities installing AMR equipment, one of the challenges will be to develop algorithms that use this valuable information for load modeling, monitoring and system analysis.

The next section outlines the load estimation modeling algorithm using AMR data.

2. Load estimate model

Initial development of this load modeling technique and initial test cases are outlined in [11]. This section discusses another more advanced method for load estimation. The advanced load estimation algorithm has three steps.

2.1. *Generating time-of-day customer class load curve*

Meters can transmit data to intermediate controllers at very short time interval. For some wireless systems, this is a one-way communication. There is two-way communication between the controller and the utility. So, using the on-demand reading (polling) at every constant time interval, we can estimate the average real-time power at time t:

$$P_t \approx \frac{\mathrm{kWh}_t - \mathrm{kWh}_{t-\Delta t}}{\Delta t} \quad (1)$$

where Δt is the time interval and kWh_t is the meter reading at time t.

It can be seen that with smaller time interval, P_t will closely approximate the real-time power.

Now, the real power consumption of a particular customer is obtained, and then the load curve of that customer can be generated. The curve needs to be normalized to unit kWh_t.

If the on-demand-reading is performed on one or more customer(s) for some consecutive days (like 1 week), the average value can be obtained, so the general load curve for that particular group of customer(s) is generated. It should be noted that in this step, only limited number of meters are polled, so very small time interval can be chosen (like 5 min). Using historical data, load curves can be developed for various customers that incorporate information such as time of use data, seasonal and weekly (weekday versus weekend) patterns.

2.2. *Estimate the load of an individual customer*

In order to accurately estimate the real-time load of a customer, first the load estimation algorithm needs to decide whether the customer is encountering an outage or not. AMR can provide the outage information. The algorithm needs to keep track of the outages. When an AMR system reports an outage, the algorithm puts it into the outage list, and starts the polling every short time interval. If the meter reading is increasing, then the outage is false or restored, and that outage is taken out of the list. If the lack of information is because of a communications issue instead of a power system outage, this will create some additional error in the load estimation. However, hopefully by integrating the estimate into other applications such as distribution state estimation, the analysis will show a mismatch between the load prediction and other available information.

Following is the algorithm for estimating the load of one customer at time t.

2.2.1. *Outage*

If there is an outage, then the load is zero:

$$P_t^{\mathrm{est}} = 0 \quad (2)$$

2.2.2. *No outage*

In this case, three sub-steps can be followed.

2.2.2.1. Keep historical average load data. If the power consumption data from the meters can be transmitted to the utility every T hours, then 1 day can be divided into N time intervals, where

$$N = \frac{24}{T} \quad (3)$$

We calculate the average power demand at every time interval P_i using Eq. (1).

2.2.2.2. Estimate average load at next time interval. We use the auto regressive integrated moving average (ARIMA) models to