REAL TIME PURCHASE AND SETTLEMENT OF DISTRIBUTION LOSSES

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ABSTRACT

This paper describes a methodology to purchase distribution losses real time from the power market. The real time hourly loss is calculated with a loss function. A method for evaluation of the loss function using billing data and energy data from AMR and conventional kWh-meters is described. This methodology is applied for Fortum Distribution Finland networks of 613 000 customers and several other Finnish utilities.

INTRODUCTION

The power distribution network is a large energy consumer itself. About three to five percent of the total energy is lost in the distribution network. The major share of the loss energy is heating conductors, transformers, meters and instruments without kWh-metering. Furthermore there are non-technical losses like stealth as well as administrative losses caused by data processing errors.

It is impossible to directly measure the loss energy because of the size and complexity of the distribution network where the loss energy is spread all over. The traditional approach to loss estimation is to use the network data from conductors, lines, sub-stations etc. The modern network information systems (NIS) can estimate the loss energy [1], but the lack of load data is a big source of errors, and there is no feedback to the metered load data in the estimation.

The demand for more accurate loss energy estimation comes from two directions: Firstly the development of the energy efficiency of the distribution network requires accurate loss estimation to measure the real achievement of energy saving. Secondly, the de-regulated power market requires the distribution operators to be neutral to competing suppliers. The purchase and settlement of the distribution losses must treat all the energy suppliers equally. To be able to report sales accurately the purchased loss energy must be equal to losses consumed in the network. If the purchased loss energy is too much, the balancing supplier earns extra money at the cost of distribution customers. If the purchased loss is too little, the balancing supplier loses money.

The distribution network operator purchases the loss energy from the power market. The loss energy must be defined on hourly level to achieve market price and handle the energy in the balance settlement in the power market [2]. While the price of the energy becomes higher and more volatile, the interest for more accurate loss estimates grows.

THE DEFINITION OF LOSS ENERGY

The loss energy is all the energy that is fed to the distribution network but not delivered to the customer load points and energy meters. The customer load points include also the distribution company’s own metered energy use:

\[
\text{Loss energy} = \text{Input energy} - \sum \text{Loadpoint energy}
\]

The input energy (feeders and generation) is hourly measured and data is easily accessible. Normally, the largest customer loads are hourly metered. However there are a large number of customer loads that are monthly metered or conventionally metered in uneven time periods ranging from one to few years.

An automated meter reading system (AMR) connected to every load point would be an ideal solution to obtain load point energy. However, because of the cost optimisation, the AMR systems usually do not cover all the load points, and conventional meters are used at least for metering minor loads.

When calculating the loss energy, it is critical that the algorithm calculating the total of the load point energy can use all the energy information from the network. Otherwise the missing data is cumulated into the loss energy, and the accuracy of the loss energy worsens.

The comprehensive source for load point energy data is the distribution operator’s customer information database, billing data and the meter reading database.
OVERVIEW OF THE METHOD

In the Nordic power market energy purchases are done real-time, and the hourly balance between the suppliers is settled every working day. The final settlement between the suppliers is eventually made in 14 days. To achieve metered loss data in such time window would require a complete hourly reading from all load points. Such a complete hourly metering system with high reliability would be very expensive and therefore the optimal solution is to use the loss function estimating the hourly loss energy.

The loss function calculates the hourly loss energy from the hourly network input energy:

\[
\text{Hourly loss energy} = \text{Loss function(hourly input energy)}
\]

The network input energy is hourly metered and available for the daily balance settlement. Thus also the hourly loss energy is always available for the balance settlement after the computation of loss function.

The loss function is estimated from the loss percent (loss%). The loss% is calculated from the loss energy from the loss analysis and input energy of the network:

\[
\text{loss\%} = 100 \times \frac{\text{annual loss energy}}{\text{annual input energy}}
\]

The time period of the calculation of loss% depends on the meter reading practices. There must be majority of the meter reading data collected from the load points.

The hourly loss purchasing consists of the following phases (Fig 1):
1. Initially estimate the loss% and loss function.
2. Calculate the input and loss forecasts.
3. Daily make the hourly loss calculation with loss function and input energy for the loss supplier and balance settlement.
4. Periodically collect energy and load point data to re-calculate the loss% and make the final settlement of the loss energy.
5. Update the loss% and the loss function and go to phase 2.

\[P_L(t) = P_0 + k \times P(t)^2\]

The idle loss power \(P_0\) is the total of transformer idle loss power in the network.

The coefficient \(k\) is calculated so that the loss function results to the loss% over the period \(T\) that is usually one calendar year or multiple years:

\[k = \frac{0.01 \times \text{loss\%} \times \sum_{t \in T} P(t) - \sum_{t \in T} P_0}{\sum_{t \in T} P(t)^2}\]

Example of hourly input and loss is shown in Fig 2.
The loss energy must be forecasted one or two years ahead for price hedging. The network input profile is forecasted first, and the loss profile forecast is then evaluated using the loss function.

The long-time forecasting of the loss profile is done by creating a long time load model for the network input load. The elements of the input load model are monthly 24 hour load profiles for working day, Saturday and Sunday. The temperature correlation is calculated for each hour from the load and temperature history. Finally the load model is evaluated using long time temperature statistics to get the hourly loss load forecast (Fig 3).

The total of load point loads is calculated by summing the columns of the load grid. The data is meter readings or energy consumptions between dates. For each load point the metered energy is transferred to daily loads and put into the calculation. Transferring energy data of longer periods to daily loads requires estimation of the load curves in order to split the meter reading interval to daily energy [3]. The best result is achieved by applying profile that is calculated from the difference between the input load and the hourly metered loads. For the hourly metered loads the load profile is estimated directly from their metered data.

Outside the reading intervals the load is estimated using the annual energy estimate (AEE) for each load point. The AEE is usually calculated by the invoicing system from meter readings and billing history.

The accuracy of the loss% estimation depends on the length of the analysis. The longer the analysis period is, the more accurate the loss% is because the error caused by the asynchronous kWh-meter reading intervals is limited by the average reading interval at the both ends of the analysis period.
An example of the 6 years analysis of loss% from the load grid is shown in Fig. 5. In this network case the loss% is quite stable varying around the 4% value.

The loss% for the 2006...2008 period is the average of the curve in Fig 5.

**The Data Quality Control**

The calculation result of the loss% is very sensitive to errors in the source data. Cross checking is needed to ensure that there is enough data from all load points and the data is correct.

The backbone of the loss% analysis data is the uniquely coded list of all delivery load points of the network, the dates when they were connected to the network and the dates disconnected from the network. An annual energy estimate is also imported from the billing system with the load point information.

The energy data from the billing system must include the load point, start date, end date and energy for each metered interval. There will be several records of energy data for each load point.

The data quality control includes finding load points where energy data is missing and comparing energy to the annual energy estimate. Also bad and unrealistic data is checked by computing statistic from the load data and checking extreme values.

After the quality of data is carefully checked, the loss table will be populated and the loss energy calculated.

While the load data is transferred to the load grid, the data is marked estimated or metered. Each cell of the load grid is marked as "metered" if the value of the cell is result of metered energy or "estimated" when the value of the cell is estimated from the annual energy estimate.

**THE FINAL SETTLEMENT OF THE LOSS ENERGY**

Depending on the business practices the calculation of losses with the loss function may be sufficient if the loss% from the analysis is almost the same as the loss% used in loss function.

If the loss% varies a lot, it is relevant to settle the final loss energy. The real time purchased loss energy is then compared with the new loss calculation and the final settlement is funding or re-funding between the distribution operator and the loss energy supplier.

**THE FORTUM DISTRIBUTION CASE**

Fortum Distribution network in Finland has 613 000 customers, and the network is divided to eight distribution areas. The areas are geographically in different locations and have different characteristics and features in terms of size, outdoor temperature and customer behaviour. The largest area is about 150 000 customers and the smallest 32 000 customers.

The data flow of the process is shown in Fig 7.

The hourly network input data for each area was retrieved from the Fortum Distribution energy management system (EMS). Also, the hourly outdoor temperature for the input load modeling was retrieved for each area.

The load data for each load point was retrieved from the Fortum distribution’s customer information and billing system (CIS) for each area:
The load point data:
- load point id
- connection date
- disconnection date
- annual energy estimate
- customer category

The load data for each metered load:
- load point id
- start date
- end date
- energy
- supplier

The hourly metered data was retrieved from the meter reading database.

For area “LS” of 158000 customers, total annual input 2285 GWh, max demand 501 MW, loss\% = 4.05 % and loss function:

\[ P_{L,LS} = 2,290 \, MW + (0.0001138 \, MW^{-1}) \times P^2_{LS} \]

The input load and loss energy was forecasted for 2011 for each area.

The hourly loss energy is calculated with these loss functions daily in the Fortum’s energy management system. The procurement of the loss energy is done monthly with the supplier. The final settlement will be done after the next loss\% analysis.

Until the end of 2013 most of the conventional kWh-meters will be replaced with AMR meters. Then the final settlement of loss energy can be scheduled monthly or annually.

**CONCLUSIONS**

The procedure of purchase and settlement of loss energy with loss function presented in this paper are used in several utilities in Finland. The required accuracy for loss energy has been achieved.

The advantage of this method takes benefit from all meter readings, and the AMR can be fully utilised to improve the accuracy of the loss energy estimation and purchasing process.

**REFERENCES**

