Electric Power Systems Research 151 (2017) 59–67

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Valuation of measurement data for low voltage network expansion planning

M. Nijhuis[a,*], M. Gibescu[a], J.F.G. Cobben[a,b]

[a] Electrical Energy Systems, Eindhoven University of Technology, Den Dolech 2, Eindhoven, The Netherlands
[b] Liander N.V., Utrechtseweg 86, Arnhem, The Netherlands

ARTICLE INFO

Article history:
Received 15 August 2016
Received in revised form 5 April 2017
Accepted 13 May 2017

Keywords:
Advanced meter infrastructure
Distribution networks
Power system monitoring
Power system planning

ABSTRACT

The introduction of electric vehicles and photovoltaics is changing the residential electricity consumption. Distribution network operators (DNO) are investing in an advanced metering infrastructure (AMI) to enable cost reduction through smart grid applications. The DNO also benefits from the additional measurement data the AMI gives for the network planning process. The availability of AMI data can be limited by the cost of communication and by privacy concerns. To determine the social welfare of an AMI, the economic gains should be estimated. For the planning of the low voltage (LV) network, a method for determining the value of an AMI still needs to be developed. Therefore, a planning methodology which allows various levels of measurement data availability has been developed. By applying this approach the value of different levels of AMI from an LV-network planning perspective can be determined. To illustrated the application of this approach a case study for the LV-network of a Dutch DNO is performed. The results show that an increase in measurement data can lead to €49-254 lower LV-network reinforcement costs. A detailed analysis of the results shows that already 50% of the possible cost reduction can be achieved if only 65% of the households have AMI data available.

1. Introduction

With the electrification of heating and transportation loads and the introduction of distributed generation, the residential energy use is changing. The loading of the low voltage (LV) network can increase due to additional loads like heart pumps. Bi-directional power flows become possible through rooftop PV [1]. On the local level, the pace of and extent to which these developments take place can vary. Errors in the spatial load forecasting can have a significant effect on the required investments in the LV-network [2]. Currently, in most LV-networks, almost no measurement data is available, which generates uncertainty about the current loading of the LV-network [3]. This makes an adequate planning of the LV-network more complicated. The introduction of an advanced metering infrastructure (AMI) can, however, present the distribution network operator (DNO) with an unprecedented amount of data about the residential load.

The AMI data can be used for a multitude of applications [4], from demand response to automating the meter reading process and more accurate LV-network expansion planning [5]. AMI data offers many opportunities for real time operation of the distribution network [6–8], however for the planning of the LV-network the available opportunities are not well documented. AMI data can be used to improve the load modelling [9] and load models based on AMI data can be implemented in the network planning process [10]. The question of how much value these measurements give to the DNO remains open. Privacy concerns about the use of AMI data require anonymisation. Depending on the implemented AMI communication infrastructure a limited read-out frequency and/or measurement frequency of the AMI data may be required [11]. This limits the DNO in the amount of information which can be extracted from the AMI measurements or requires additional communication infrastructure investments [12].

To be able to make adequate choices about the extent of the implementation of an AMI, the benefits of the AMI data should be assessed. The valuation of the AMI data from a demand response perspective has already been performed [13]. The assessment of the automation of a business process like the surveying of conventional electricity meters can easily be assessed from the expenses of the DNO. The use of AMI data to accurately assess transformer loading has also been studied [14], as well as the creation of load forecasts based on AMI data [15]. The usefulness of the additional measurements to increase observability from an operational perspective,

* Corresponding author.
E-mail addresses: m.nijhuis@tue.nl (M. Nijhuis), m.gibescu@tue.nl (M. Gibescu), j.f.g.cobben@tue.nl (J.F.G. Cobben).

http://dx.doi.org/10.1016/j.epsr.2017.05.017

e.g. in state estimation, is a common research topic [16], however, the data requirements from a long-term planning perspective are different. Preliminary research in using AMI data for the long-term network planning problem has been conducted [17]. The valuation of AMI data for the planning and reinforcement of LV-networks has not been covered. It is, therefore, hard to give an adequate estimation of the value of AMI data from an LV-network expansion planning perspective. This estimate is needed when determining the required characteristics of an AMI. From the point of view of generation adequacy studies into the value of additional measurement data have already been performed [18,19], however for the LV-network expansion planning the effects of the additional measurement data still need to be quantified. A uniform network planning methodology which incorporates different types of LV-measurement data is therefore needed to assess the value of AMI measurements for the LV-network planning process. Like standard network planning approaches, the methodology to provide a valuation for the AMI data from a network planning perspective should compute the LV-network cost, however, unlike the currently applied approaches, the methodology for the valuation should be able to handle load data with different levels of uncertainty in a similar way.

This paper proposes an LV-network expansion planning approach capable of handling these different levels of load uncertainty. How this approach subsequently can be applied to determine the value of AMI data from a network planning perspective is also shown in this paper. In Section 2 the effect of measurement data on the planning of the LV-network is discussed. In Section 3, the different levels of LV-measurement data availability are discussed, in combination with the methodology for incorporating this data in the LV-network expansion planning process. In Section 4, the application of this methodology is presented through a case study for the largest DNO in the Netherlands. Conclusions on the value of AMI data from a network expansion planning perspective are shown in Section 5.

2. Use of measurement data in LV-network expansion planning

The use of additional measurement data in LV-network planning reduces the uncertainty about the current loading of the LV-network. This reduction in uncertainty can lead to better investment decisions and thus to lower LV-network cost. If more measurement data is available the number of possible loading states of the LV-network reduces. This results in a tighter probability distribution of the load, which reduces the uncertainty and allows for more efficient investment decisions. Assume the loading of the network is normally distributed with mean μ and standard deviation σ. The network can be planned for the 98th percentile value of the peak load, or roughly the value of $\mu + 2\sigma$. This is illustrated in Fig. 1a where a normal distribution of the loading and the ideal planning level are shown. In this illustration, the network loading can be seen as the level of the peak load in the network. Where the distribution of this loading comes from the uncertainty about the actual level of peak load as there are no measurements available. A reduction of uncertainty would result in a lower variance, so $\sigma_{new} < \sigma_{old}$. The mean of the new probability density function can also change. Through the reduction of uncertainty, the mean of the probability density function moves closer to the actual value of the loading. Two situations are likely to occur $\mu_{new} + 2\sigma_{new} < \mu_{old} + 2\sigma_{old}$ or $\mu_{new} + 2\sigma_{new} > \mu_{old} + 2\sigma_{old}$. Both situations are shown in Fig. 1b and c, respectively.

$$\mu_{new} + 2\sigma_{new} < \mu_{old} + 2\sigma_{old}$$

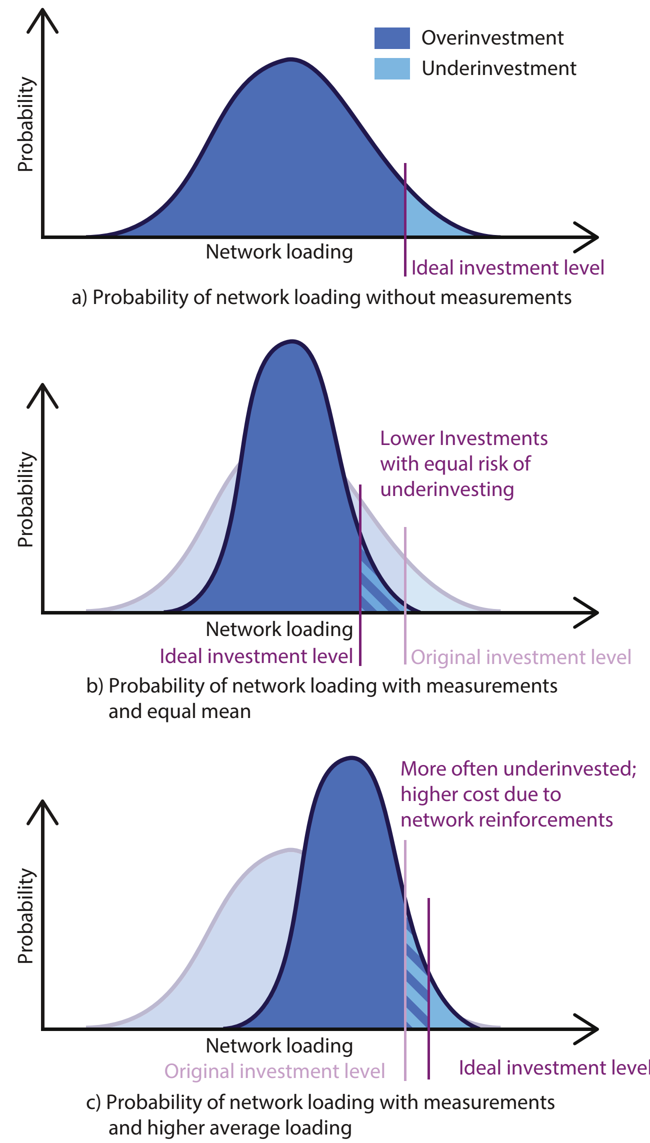

Fig. 1. Value of measurement data in the LV-planning process.

If the network is still planned with the same level of risk, the 98th percentile value of the peak load, the network investments will decrease. The value of the 98th percentile of the load is lower thus a less strong and cheaper network can be constructed with the same expected chance of overloading. This difference is the cost saving for the DNO from a network planning perspective.

$$\mu_{new} + 2\sigma_{new} > \mu_{old} + 2\sigma_{old}$$

If the network is still planned with the same 98th percentile value of the load, the DNO will construct a stronger and more expensive network. However, as the old network was planned with a percentile value for the risk which turned out to be lower than the 98*th* percentile, more cases in which the network has to be reinforced at a later stage will occur (more than the planned 2% of the cases). In the long run, this reduction in the need for future reinforcements of the network generates a lower total investment cost for the DNO, as unforeseen reinforcements can assumed to be suboptimal.