Scottish and Southern Energy Power Distribution	TVV Appendix 2.2	
	UoS State Estimation	
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University of Strathclyde

Thames Valley Vision LCNF Project

Southern Electric Power Distribution (SEPD) Low Carbon Network Fund Bids

Project #6: Assessment of LV network measurements and state estimation

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Introduction

UK national energy policy set in the context of legally binding targets for emissions reduction is changing the way electricity is used and generated in the UK. These changes are expected to accelerate as many of the emission reduction policies indicate the need for high carbon energy vectors such as transport and heating to migrate to electrical supply via low carbon electricity generation.

The implication for electricity network operators is for a very different operating environment: new loads such as heat pumps and EVs, new consumer behaviours, increasing penetration of micro generation are just some of the expected developments.

This new operating environment will require new approaches and technologies which are commonly being described collectively as the Smart Grid.

There is a growing acknowledgement of the value of active distribution networks for enabling increased connection of renewable distributed generation and for minimising infrastructure

upgrades. Reducing and manipulating the use of electricity is also deemed to be essential for balancing future networks where generation sources will be increasingly intermittent and non dispatchable. Technology such as active network management and demand side management are therefore significant areas of research for active distribution networks.

The value of ANM is being demonstrated at MV level with recent field deployments. However, major changes are also expected for the operation of the LV network and monitoring with active control throughout the distribution network is expected to be a key part of future planning and operating philosophies.

For active control of the network it is essential to have accurate visibility of the state of the network.

Observability and State Estimation

Previous operating requirements have meant a low visibility of the distribution network has been sufficient whilst also being economically attractive. SCADA systems generally operate to the 33kV level providing measurements of voltage and power flow but seldom extend into 11kV circuits and almost never to LV network level.

With the absence of network measurements added to the absence of consumer load measurement, historical and sample load profiles is the only data available for network planning and operations.

In order to develop appropriate planning and operation methodologies for LCN/smart grid futures and to move towards active control across the distribution network, improved visibility of the network and improved understanding of the future load profiles is necessary.

ANM schemes at the MV level depend on measurements of the sections of network in question. As measuring every bus and feeder in the network is economically unfeasible, methods of accurately estimating the state of the distribution network are expected to underlie any widespread active control of the distribution network.

State Estimation (SE) techniques for electricity networks are widely used at the transmission level, however, Distribution State Estimation (DSE) is currently in its infancy compared to the SE techniques deployed in transmission systems.

SE techniques aim to achieve an accurate representation of the system using the available real measurements and "pseudo measurements". At transmission level the relative coverage of real time measurements is much higher, however there is still a requirement to use historical, a priori, load profiles to produce pseudo-measurements for state estimation.

Unlike transmission SE which mostly focuses on improving measurement accuracy and bad data detection, DSE is mostly aimed at filling the gap caused by measurement insufficiency to enable further developments of active control or active network management techniques.

A key concept is the observability of the system. Monticelli and Wu (Monticelli, 1985) define this as: 'A power network is observable if the set of measurements makes the state estimation possible'. It is

clear then that when considering DSE, the accuracy of the solution will be dependent on the location, types and number of measurements.

Key questions to be answered in the development of reliable distribution state estimation solutions are therefore:

- What is the balance between real and pseudo measurements that achieves sufficient accuracy at reasonable cost?
- What kind of data is required to define accurate pseudo measurements?
- What are the trade-offs between measurement and estimation in terms of cost and precision?

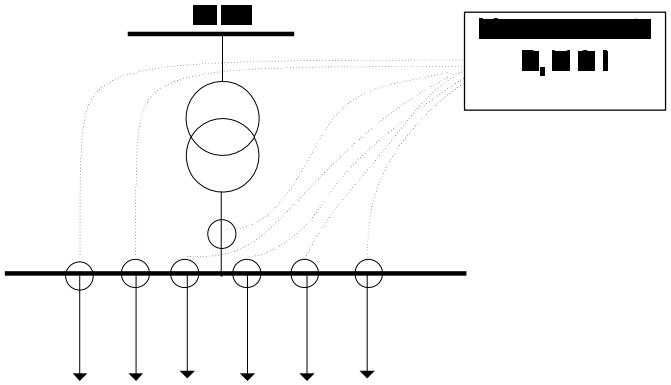
Recent attention on DSE has investigated the use of Transmission SE approaches and proposed methods of optimising the measurement location and placement on distribution networks. These efforts are working from the starting position of minimal real measurements and inaccurate pseudo measurements and have been simulated on generic distribution network models. Research is ongoing in pseudo-measurement modelling as providing a better initial "guess" in the form of accurate pseudo measurements will result in better DSE results.

Value of TVV Bracknell monitoring proposal

The proposed monitoring implementation in the TVV project will provide a high level of LV and MV network monitoring which is unprecedented on the distribution network.

The LV network connected to the largest primary substation in the Bracknell area (in terms of number of feeders, load, etc.) will be fully monitored:

- All 11kV customer loads will be measured
- All secondary substation load (3 phases) will be measured (LV side)
- All individual LV feeder loads will be measured at the connection point in the secondary s/s
- Max and Min P, V and I will be measured at the above locations.



Monitoring example secondary substation fed from Bracknell primary

There are clear benefits in providing updated profiles for 11kV customers and load profiles on the LV feeders - i.e. improved pseudo measurements. The viability of DSE is an issue with far reaching consequences in terms of the architecture, measurement, control possibilities and costs of future distribution systems and a serious attempt at answering the related questions and making any case for estimation rather than measurement can only be made with the credibility building approach of over-instrumenting trial sites in a demonstration project.

In addition, starting from a network position of full observability down to the LV feeder level from a large primary substation provides an excellent case study for developing and testing DSE techniques. Proposed methodologies to optimise the minimum level of measurement required can be tested against the actual state of the network.

By measuring every 11kV customer and LV feeder a broad representation of feeder loadings and customer types can be obtained. The resulting profiles can be used to inform the calculation of pseudo-measurements around the rest of the network.

The value of network and customer loading data may prove highly beneficial for establishing the case for DSE but also in understanding dynamic of distribution system loading and the possibilities for active network management and demand contribution. High quality and extensive data sets will be required to establish, in any conclusive way, the case for adoption of these new technologies.

The more system states that can be measured and the more different locations (e.g. load terminals, substation and transformer level, feeder level) the higher the value of the resulting data analysis in relation to customer load demand, the role of novel technological solutions and the case for state estimation. Understanding in the academic and industrial community is not sufficient in the trade-offs between more and less measurement points in the anticipated architectures of rolled out state estimation in distribution networks. Neither does either observability analysis or statistical analysis of the number of measurements yield a clear result for a measurement strategy in a trial such as that proposed. 'Over-instrumentation' in this case has value and will add to the learning from the project.

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