Boston Spa Energy Efficiency Trial

Smart Meter Voltage Measurement Performance

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Contents

0 Document control

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1 Executive summary

The purpose of this report is to provide some preliminary results of performance testing carried out by Northern Powergrid on smart meters in its licence areas. The reasons for doing this are to i) understand the performance limitations related to the extraction and use of half-hourly voltage data, ii) make an initial assessment of the accuracy of the voltage measurement, and iii) assess whether the voltage accuracy assessment methodology used is a viable option for establishing a more robust assessment of the voltage accuracy measurement. This information will be used to inform the later stages of the BEET project, such as the design of the BEET algorithm. The results may also prove useful to the wider industry to inform those who are designing tools or techniques which plan to use smart meter data. The voltage measurement accuracy presented this report should be used as a “rule of thumb” only, as it is based on a very small set of smart meters from two meter manufacturers and limited tests. It is not within the scope of the BEET project to carry out large scale testing with large data sets.

For the BEET project we are interested in:

- How many smart meters deployed in the BEET trial area can we extract voltage measurements from;
- The accuracy of the smart meter voltage measurements; and
- Whether there are any limitations on the throughput i.e. how many smart meters can we extract voltage measurements from in a given time period.

This report describes some preliminary test results on the first two points. To summarise our findings:

- Of the 1228 smart meters in the BEET trial area only 64% responded to a Read Supply Status (ping) Service Request;
- We ran a trial where nine separate DCC Read Network Data Service Requests were made to extract the latest half-hour average voltage measurements. They were run at nine different half-hours. Of these 202 (16%) of the 1228 smart meters returned data for all nine requests, and 382 (31%) of these were always non-responsive;
- We identified four smart meters which were in properties located adjacent to secondary substations fitted with high-accuracy LV monitor voltage measurement equipment where the following criteria were met:
    - The voltage measurements could be accessed from the LV monitors and the smart meters at the same time;
    - The voltage measurements could be accessed during a period of low demand when the voltage drop on the circuit between the substation and the property hosting the smart meter would be at its lowest; and
    - The smart meters were averaging their voltage measurements over a time period which was clock synchronised with measurements carried out by the LV monitors where the time stamps between the LV monitors and smart meters did not deviate by more than +/-2 minutes.
- Voltage measurements were compared for 10 separate half-hour periods for each of these four smart meters. Based on this limited set of smart meters and tests, a voltage measurement accuracy of ±1% was determined.
- There are practical issues associated with applying this method globally to establish the voltage measurement accuracy, and alternative methods should be explored.

2 Introduction

In order to manage voltages on the distribution networks it is important to be able to measure or model network voltages accurately. Traditionally there was only one point on a high voltage and low voltage network where the voltage was measured, which is at the source high voltage substation where a voltage measurement is used to control the tap changer on the primary transformer (e.g. a 33/11kV transformer). Voltages on the remainder of the high voltage and low voltage network are managed, so that they remain within statutory limits, at the network design stage using a combination of network modelling and design assumptions which have been developed over several years. DNOs tend to only become aware of voltage issues when carrying out bespoke modelling as part of a network development scheme or when a customer complaint is received. The opportunity to measure and record the voltage at the point of supply to the vast majority of our customers, offered by the roll out of smart metering, provides a significant opportunity to improve the voltage management on a DNO network, if the voltage measurements sufficiently accurate. To deliver these benefits, it is important that i) the DNO can access and download the voltage data as required and ii) that the voltage measurements are sufficiently accurate.

The statutory voltage limits on the low voltage network are 230V +10% / -6%, i.e. a 14% voltage range, 253V to 216V. Network reinforcement to address high or low voltage issues on a low voltage network would be triggered if the voltage is outside this range. As indicted above this may be identified by internal modelling or via a customer complaint, but in each case a temporary high accurate voltage recorder would typically be installed to validate the issue as part of the development of any network reinforcement scheme. Reinforcement would be required if the voltage was, for example 254V, but not if it was 252V. Hence the need for reinforcement, or any other intervention works, has to be based on accurate voltage information. In this example the 2V difference between reinforcement being required or not, represents 0.8% of 230V. This illustrates the voltage accuracy required by DNOs to deliver smart meter benefits.

The main purpose of an electricity meter is to measure energy and there are no requirements in the GB Smart Meter Equipment Technical Specification (SMETS), the Measuring Instrument Directive (MID) 2014/32/EU nor in the relevant British or International standards relating to the accuracy of voltage measurements.

Electricity Meter manufacturers, via BEAMA, have provided DNOs confirmation that, despite there being no voltage required accuracy requirements, it would be reasonable to expect an accuracy in the region of +/-2%. This view was also confirmed to BEIS in 2017.

More recently DNOs have been working with BEIS and BEAMA to better understand the voltage accuracy delivered in practice from the SMET1 and SMETS2 meters installed as part of the roll out. Several options are currently being discussed including:

1. Introduce a SEC mandated voltage accuracy requirement;
2. Introduce a SEC mandated requiring manufacturers (possibly via suppliers) to report on the voltage accuracy of installed and future) meters;
3. Invite manufacturers to voluntarily report on the voltage accuracy of installed and future meters;
4. Test meters in an independent test lab;
5. Include meter testing as part of SMDA testing; and

6. DNO testing of specific meters in customers premises against high accuracy voltage recorders.

An option considered, but not thought to be viable, was to analyse measurements from smart meters installed in customers' premises together with information from high-accuracy instrumentation installed in secondary substations to form a view of the voltage accuracy.

We have therefore taken the opportunity, as part of the Boston Spa Energy Efficiency (BEET) project, to undertake such analysis and consider whether this would be a viable means of forming a view of the accuracy of voltage measurements obtained from smart electricity meters.

This report describes some performance and voltage measurement accuracy tests carried out on smart meters which will be used to i) assess whether the this approach for assessing the observed voltage measurement accuracy is valid and ii) to inform the design of the 'BEET-Box', which it is proposed to use to manage network voltages in the Boston Spa network.

During November and December 2020, a series of tests involving issuing Service Requests 7.4 'Read Supply Status' to check the energisation status of a meters and Service Requests 4.10 'Read Network Data' to read the voltage profile logs were carried out on 1228 smart meters in the trial area, to determine the responsiveness of these meters. Voltage measurements have been retrieved from four smart meters which are located adjacent to secondary substation where high-accuracy voltage measurement equipment is also installed. These measurements have been used to help determine whether this methodology is a viable means of establishing a view of smart meter voltage measurement accuracy.

3 Retrieving voltage data

Read Supply Status (Ping) Service Request

During November and December 2020 test "ping" requests[1] were sent to the 1228 smart meters in the trial area. 64% of these responded. NPg's Siemens EIP smart meter gateway was set with a timeout of 45 minutes, and a response was received from the DCC for all the 1228 ping requests (irrespective of the response from the smart meter).

Read Network Data (Voltage measurement data) Service Request

We ran nine sets of tests, spread over two days, where we tested the performance of the DCC Read Network Data service request to extract the contents of the voltage profile log within each of the 1228 smart meters which contains the latest voltage measurements. The success and failure rates are shown in Table 1. We further grouped these results to understand from how many smart meters we could consistently retrieve voltage measurements, as shown in Table 2. These tests showed that we could only retrieve voltage measurements consistently for all nine service requests issued, from 202 (16%) of the 1228 smart meters, and only 390 (31%) of the 1228 smart meters responded at least 50% of the time. There were 382 (31%) smart meters that were always non-responsive. Of these 382 we received an N12 (Failure to deliver command to device) on 265 occasions, and on a further 43 occasions received an N13 (Failure to

[1] This is a Service Request 7.4 – Read Supply Status

receive response from device); these failures are being investigated by the DCC and Arqiva who are currently working with Scottish Power Energy Networks to establish root causes.

Service Request issued	Success rate	Failure rate
26/11/2020 11:00 - 11:30	35%	65%
26/11/2020 11:30 – 12:00	35%	65%
26/11/2020 12:00 – 12:30	35%	65%
26/11/2020 12:30 – 13:00	36%	64%
26/11/2020 13:00 – 13:30	36%	64%
01/12/2020 10:00 – 10:30	36%	64%
01/12/2020 10:30 – 11:00	37%	63%
01/12/2020 11:00 – 11:30	37%	63%
01/12/2020 11:30 – 12:00	35%	65%

Table 1 – Voltage measurement request response rate

Number of occasions when the Service Request was successful	Number of meters with that number of successes	Percentage of meters with that number of successes
0	382	31%
1	203	17%
2	92	7%
3	72	6%
4	89	7%
5	77	6%
6	34	3%
7	36	3%
8	41	3%
9	202	16%

Table 2 – Consistency rate for retrieving voltage measurements

4 Voltage measurement accuracy

There are a number of secondary substations in NPg's licence areas where high-accuracy substation LV monitors are deployed. These can measure the busbar voltage on each of the three phases over a 10-minute averaging period and have a measurement accuracy better than 0.1%. We have identified four of these substations where adjacent domestic properties have a SMETS2 smart meter deployed and we know, from records, the phase that the single-phase smart meter is connected to. By comparing the voltage measurements from the high-accuracy monitors and the smart meter, the hypothesis is that we can calculate an accuracy value for smart meter voltage measurements. The time periods when the voltage measurements have been chosen were when there was low demand on the network and therefore minimal voltage drop on the low voltage circuit between the substation and the property where the smart meter is located. These time periods are typically between 3am and 6am.

The smart meters are configured as standard with a 30-minute voltage averaging period, although they can be changed to a 10-minute averaging period. In order to obtain comparable data we average three of the 10-minute average measurements from the substation LV monitors.

Due to the length of the averaging period increases or reductions in the network voltage which might occur due to large demand being switched on for only a few minutes, might not necessarily be evident in the voltage measurements.

For this work it was assumed that the voltage measurement accuracy of smart meters is unaffected by the demand. We are aware that the accuracy of the smart meter energy measurements can vary with the demand, particularly at low demand levels which is when our measurements were taken, and that further work in this area may be required.

The substation LV monitor voltage measurements are clock synchronised to the hour, and for each subsequent ten-minute period after that. Only one of the four smart meters is clock synchronised to the hour and half-hour. The other three smart meters (all made by the same manufacturer) are not clock synchronised but these have been chosen as their measurement time stamp is within two minutes of when the substation LV monitor records a measurement.

One of the smart meters correctly records voltage measurements to four significant figures; the other three meters only appeared to record the voltage measurement to three significant figures. The SMETS requires all electricity meters to record voltages to four significant figures, so it appears that three of the four smart meters analysed may not be compliant with the Smart Energy Code. This will be raised with the DCC. Because these three meters appear not to be compliant with the SEC it is not clear whether the fourth significant figure (which is not recorded) is simply truncated or whether the third significant figure has been properly rounded. Assuming that the third significant figure is properly rounded, then reporting to three significant figures means the smart meter does not record to a precision greater than 1V, which means all measurements have a minimum error of ±0.5V or ±0.22% (based on a 230V nominal voltage). If the fourth significant figure is simply truncated, the inherent error could be twice this value.

SMETS2 meters from two other manufacturers are also installed in our licence areas, but so far we have been unable to identify suitable sites where these are co-located with substation LV monitors.

The results for the measurements are shown in Appendix A. A summary of the measured errors is given in Table 3.

ERROR / %	**Substation / SMETS2 Meter**			
	Station Road Manufacturer A Meter 1	East Ardsley Manufacturer B	Outwood Vicarage Manufacturer A Meter 2	Doncaster Road Manufacturer A Meter 3
MIN	0.1%	-0.2%	-0.8%	0.4%
MEAN	0.3%	0.0%	-0.2%	0.3%
MAX	0.7%	0.2%	0.4%	0.1%
STANDARD DEVIATION	0.18%	0.14%	0.36%	0.09%

Table 3 – Summary of measured errors

Considering all the errors reported for every half-hour period (40 in total) the mean error is 0.08% and the standard deviation is 0.30%. Based on a three sigma[2] rule of thumb, and the limited set of testing carried out, a voltage measurement accuracy for the four meters assessed of ±1% would seem reasonable.

[2] For a normal distribution, three standard deviations (or three sigma) means that statistically 99.73% of measurements lie within the range.

5 Conclusion

The work shows that there are still issues communicating with smart meters and accessing data from them. These issues are being addressed by industry forums and processes.

The analysis shows that it is possible to use high-accuracy substation monitoring to form a view of the accuracy of smart meter voltage accuracy measurements. In this analysis only four smart meters were installed at an appropriate place on the network, one being from one manufacturer and the other three from a second manufacturer. From this sample of four meters a voltage measurement accuracy of +/-1% is observed, however this is based on a very small sample of four meters, three of which seem not to be complaint with the SEC requirements.

There are a number of practical issues that have been identified by this project which mean that this method is unlikely to be a viable means of establishing the accuracy of all versions of smart meters from all manufacturers. Factors influencing this view include:

- Only those meters electrically close to a substation are appropriate candidates;
- Only a limited number of secondary substations are fitted with high accuracy metering;
- As meters installed by suppliers via their meter operators, there may be no or a limited number of some manufacturers' meters installed electrically close to suitable substations;
- Issues related to time synchronisation of the smart meters provide a further constraint;
- Voltage measurement can only be taken at times of light load; the voltage accuracy may be different at different load levels;
- There are still practical difficulties communicating with smart meters and downloading the required data sets;
- The assessment would need to be carried out on a statistically robust number of each type of meter from each manufacturer;
- The phase to which the meter is connected may need to be verified on site as phase connectivity records may not always be reliable; and
- The process for assessing voltage measurement accuracy would need to be an enduring process as new meter models (and possibly firmware versions) are deployed.

Hence other means of determining the voltage measurement accuracy as set out in section one should be explored and implemented by industry.

6 Appendix A – Voltage measurement accuracy results

Station Road Substation

Manufacturer A Meter 1

SMETS2 time stamp	SMET2 voltage [V]	Substation LV Monitor Timestamp	Substation LV Monitor voltage [V]	Substation LV Monitor half-hourly average	Error between SMETS2 and LV Monitor [V]	Error between SMETS2 and LV Monitor [%]
		2020-09-06 04:20	246.8			
		2020-09-06 04:30	247			
2020-09-06 04:38:34	247	2020-09-06 04:40	247.6	247.1	0.1	0.1%
		2020-09-06 04:50	248.1			
		2020-09-06 05:00	247.1			
2020-09-06 05:08:34	247	2020-09-06 05:10	247	247.4	0.4	0.2%
		2020-09-06 05:20	247.1			
		2020-09-06 05:30	247.3			
2020-09-06 05:38:34	247	2020-09-06 05:40	247.7	247.4	0.4	0.2%
		2020-09-06 05:50	247.1			
		2020-09-06 06:00	246.5			
2020-09-06 06:08:34	247	2020-09-06 06:10	248.3	247.3	0.3	0.1%
		2020-09-06 06:20	247.3			
		2020-09-06 06:30	247.4			
2020-09-06 06:38:34	247	2020-09-06 06:40	247.9	247.5	0.5	0.2%
		2020-09-08 03:20	246.9			
		2020-09-08 03:30	247			
2020-09-08 03:38:34	246	2020-09-08 03:40	246.7	246.9	0.9	0.4%
		2020-09-08 03:50	247			
		2020-09-08 04:00	246.9			
2020-09-08 04:08:34	246	2020-09-08 04:10	246.8	246.9	0.9	0.4%
		2020-09-08 04:20	246.9			
		2020-09-08 04:30	247.2			
2020-09-08 04:38:34	246	2020-09-08 04:40	247	247.0	1.0	0.4%
		2020-09-08 04:50	247.5			
		2020-09-08 05:00	247.6			
2020-09-08 05:08:34	246	2020-09-08 05:10	247.6	247.6	1.6	0.7%
		2020-09-08 05:20	247.8			
		2020-09-08 05:30	247.2			
2020-09-08 05:38:34	247	2020-09-08 05:40	246.7	247.2	0.2	0.1%
					MIN	0.1%
					MEAN	0.3%
					MAX	0.7%
					STD DEV	0.18%

East Ardsley Substation

Manufacturer B

SMETS2 time stamp	SMET2 voltage [V]	LV Monitor Timestamp	LV Monitor voltage [V]	LV Monitor half-hourly average	Error between SMETS2 and LV Monitor [V]	Error between SMETS2 and LV Monitor [%]
		2020-07-11 05:10	245.2			
		2020-07-11 05:20	244.9			
2020-07-11 05:30:00	245.3	2020-07-11 05:30	245.2	245.1	-0.2	-0.1%
		2020-07-11 05:40	244.9			
		2020-07-11 05:50	244.6			
2020-07-11 06:00:00	245.1	2020-07-11 06:00	244.5	244.7	-0.4	-0.2%
		2020-07-11 06:10	243.9			
		2020-07-11 06:20	243.7			
2020-07-11 06:30:00	243.9	2020-07-11 06:30	243	243.5	-0.4	-0.2%
		2020-07-12 04:10	242.2			
		2020-07-12 04:20	243			
2020-07-12 04:00:00	242.6	2020-07-12 04:30	243.8	243.0	0.4	0.2%
		2020-07-12 04:40	244.4			
		2020-07-12 04:50	244.6			
2020-07-12 05:00:00	244.6	2020-07-12 05:00	244.7	244.6	0.0	0.0%
		2020-07-12 05:10	244.2			
		2020-07-12 05:20	244.5			
2020-07-12 05:30:00	244.8	2020-07-12 05:30	244.3	244.3	-0.5	-0.2%
		2020-07-12 05:40	244.5			
		2020-07-12 05:50	244.2			
2020-07-12 06:00:00	244.7	2020-07-12 06:00	243.9	244.2	-0.5	-0.2%
		2020-07-13 04:00	243.5			
		2020-07-13 04:10	243.4			
		2020-07-13 04:20	243.4			
2020-07-13 04:30:00	243.4	2020-07-13 04:30	244.2	243.7	0.3	0.1%
		2020-07-13 04:40	244.6			
		2020-07-13 04:50	244.3			
2020-07-13 05:00:00	244.3	2020-07-13 05:00	244	244.3	0.0	0.0%
		2020-07-13 05:10	244.2			
		2020-07-13 05:20	244.4			
2020-07-13 05:30:00	244.2	2020-07-13 05:30	244.6	244.4	0.2	0.1%
		2020-07-13 05:40	244.3			
		2020-07-13 05:50	244			
2020-07-13 06:00:00	244.2	2020-07-13 06:00	244.3	244.2	0.0	0.0%
					MIN	-0.2%
					MEAN	0.0%
					MAX	0.2%
					STD DEV	0.14%

Outwood Vicarage Substation

Manufacturer A Meter 2

SMETS2 time stamp	SMET2 voltage [V]	Substation LV Monitor Timestamp	Substation LV Monitor voltage [V]	Substation LV Monitor half-hourly average	Error between SMETS2 and LV Monitor [V]	Error between SMETS2 and LV Monitor [%]
		2020-07-10 04:20	251			
		2020-07-10 04:30	252.3			
2020-07-10 04:38:01	251	2020-07-10 04:40	252.6	252.0	1.0	0.4%
		2020-07-10 04:50	252.6			
		2020-07-10 05:00	251.9			
2020-07-10 05:08:01	253	2020-07-10 05:10	251.8	252.1	-0.9	-0.4%
		2020-07-10 05:20	251.9			
		2020-07-10 05:30	252.2			
2020-07-10 05:38:01	252	2020-07-10 05:40	251.9	252.0	0.0	0.0%
		2020-07-10 05:50	250.9			
		2020-07-10 06:00	250.5			
2020-07-10 06:08:01	252	2020-07-10 06:10	249.1	250.2	-1.8	-0.8%
		2020-07-11 03:50	250.2			
		2020-07-11 04:00	250.5			
2020-07-11 04:08:01	250	2020-07-11 04:10	250.7	250.5	0.5	0.2%
		2020-07-11 04:20	251.7			
		2020-07-11 04:30	252.7			
2020-07-11 04:38:01	252	2020-07-11 04:40	252.4	252.3	0.3	0.1%
		2020-07-11 04:50	252.3			
		2020-07-11 05:00	252.1			
2020-07-11 05:08:01	253	2020-07-11 05:10	251.5	252.0	-1.0	-0.4%
		2020-07-11 05:20	251.5			
		2020-07-11 05:30	251.9			
2020-07-11 05:38:01	252	2020-07-11 05:40	251.5	251.6	-0.4	-0.2%
		2020-07-11 05:50	251.1			
		2020-07-11 06:00	250.6			
2020-07-11 06:08:01	252	2020-07-11 06:10	250.1	250.6	-1.4	-0.6%
					MIN	-0.8%
					MEAN	-0.2%
					MAX	0.4%
					STD DEV	0.36%

Doncaster Road Substation

Manufacturer A Meter 3

SMETS2 time stamp	SMET2 voltage [V]	Substation LV Monitor Timestamp	Substation LV Monitor voltage [V]	Substation LV Monitor half-hourly average	Error between SMETS2 and LV Monitor [V]	Error between SMETS2 and LV Monitor [%]
		10/07/2020 03:50				
		10/07/2020 04:00				
2020-07-10 04:12:49	247	10/07/2020 04:10	247.9	248.0	1.0	0.4%
		10/07/2020 04:20	247.6			
		10/07/2020 04:30	247.7			
2020-07-10 04:42:49	247	10/07/2020 04:40	247.7	247.7	0.7	0.3%
		10/07/2020 04:50	247.5			
		10/07/2020 05:00	247.2			
2020-07-10 05:12:49	247	10/07/2020 05:10	247.1	247.3	0.3	0.1%
		10/07/2020 05:20	247.4			
		10/07/2020 05:30	247.5			
2020-07-10 05:42:49	247	10/07/2020 05:40	247.5	247.5	0.5	0.2%
		10/07/2020 05:50	247.1			
		10/07/2020 06:00	246.6			
2020-07-10 06:12:49	246	10/07/2020 06:10	245.6	246.4	0.4	0.2%
		11/07/2020 03:50	246.8			
		11/07/2020 04:00	245.5			
2020-07-11 04:12:49	245	11/07/2020 04:10	245.4	245.9	0.9	0.4%
		11/07/2020 04:20	245.5			
		11/07/2020 04:30	245.6			
2020-07-11 04:42:49	245	11/07/2020 04:40	245.5	245.5	0.5	0.2%
		11/07/2020 04:50	245.3			
		11/07/2020 05:00	245.9			
2020-07-11 05:12:49	245	11/07/2020 05:10	245.8	245.7	0.7	0.3%
		11/07/2020 05:20	245.9			
		11/07/2020 05:30	245.7			
2020-07-11 05:42:49	245	11/07/2020 05:40	245.4	245.7	0.7	0.3%
		11/07/2020 05:50	245			
		11/07/2020 06:00	244.5			
2020-07-11 06:12:49	244	11/07/2020 06:10	244	244.5	0.5	0.2%
					MIN	0.1%
					MEAN	0.3%
					MAX	0.4%
					STD DEV	0.09%