21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

CIGRE US National Committee
2022 Grid of the Future Symposium

Improving Customer Power Quality Leveraging AMI Data

G. KANDAPERUMAL, M. GUIEB, J. THEODOROPOULOS, M. RAVE, C. DESJARDINE
Commonwealth Edison Company
USA

SUMMARY

Ensuring high quality power to its customers is a primary concern for utilities. With the implementation of advanced metering infrastructure (AMI), it is now possible for utilities to provide both proactive and reactive solutions to ensure high power quality and premier customer experience. When a customer receives voltages at their service that are above or below nominal service voltage, a power quality ticket is registered, and the utility must expend resources to diagnose and rectify the issue. Adverse voltage conditions may cause observable events such as flickering lights, equipment damage, and maloperation. There is also considerable field review, involving multiple personnel and vehicles, that is required to identify the cause of the voltage issue and perform corrective actions.

Commonwealth Edison (ComEd) is the electric distribution utility in northern Illinois, serving over four million customers, has spent approximately $1.2B in the conversion of conventional metering to advanced "smart" meters. These investments have presented ComEd with several benefits including service start/stop control, enabling energy efficiency programs such as peak time savings, energy theft identification, improved billing, and predicting hot socket issues in meters. The AMI network itself can support other technologies, such as smart streetlights, to offer municipalities an array of modern services, enabling smart city applications. As the industry recognizes the potential of this technology, AMI data can be used improving customer power quality through proactive and reactive addressing abnormal service voltages.

ComEd has identified the use of AMI data to reduce voltage issues experienced by the customers and improve the efficiency of the voltage correction process through a concerted, cross-functional effort. In this paper, we elaborate the proactive-reactive approach taken to a) reduce the number of customer power quality tickets registered by pre-emptively identifying equipment with improper voltage measurements, and b) to diagnose emergent customer complaints through data analytics to pinpoint the source of voltage issue and dispatch the appropriate resource; thereby, saving time, cost, and resource expenditure. We describe the use of AMI based methodology for reducing the frequency of non-outage voltage tickets and providing faster diagnosis of received tickets. We showcase that the methodology allows for an overall reduction in tickets generated and faster correction of generated tickets, providing superior customer experience and value.

KEYWORDS

Data Analytics, Power Quality, AMI Data

Gowtham.Kandaperumal@ComEd.com

1. INTRODUCTION

Advanced Metering Infrastructure (AMI) refers to the integrated system of smart meters, and associated communication and data management systems that capable of bidirectional communications between the utility and metering end points. The smart meters have high sampling rates allowing for better recording of customer consumptions while also enabling the utilities to access power quality information and implement service stop/start at the point of delivery. With its widespread adoption in North America, AMI have provided myriads of use cases from accurate billing, remote disconnection capability, diagnostic support for power quality issues, outage management, and even as endpoints for demand response use-cases.

Commonwealth Edison (ComEd) serves over four million customers in the northern Illinois region covering over 11,400 square miles of territory and has undertaken a massive effort to convert conventional meters to smart meters through an $1.2 billion investment. The primary goal of this conversion is the efficiency of smart meters in billing and service applications. Smart meters have enabled efficient transfer of electric services when a customer moves to a new address. The granularity of AMI usage data has also enabled energy efficiency programs such as peak time savings (York et al., 2019). The AMI network itself can support other technologies, such as smart streetlights, to offer municipalities an array of modern services, enabling smart city applications. AMI data analytics may become a major interest in the industry as technology evolves. Currently at ComEd, AMI data is used to identify potential theft, issue more accurate customer bills, and predict hot socket events [1]. As the industry recognizes the potential of this technology, ComEd has been exploring further avenues of application enabled by AMI.

Smart meters in the AMI network take periodic readings of voltage, current, energy at the customer service point. The customers are served by the power distribution system which is required to ensure high power quality at the point of delivery to its customers and the AMI provides the highly necessary measurement end point required to assess the power quality. A problem that utility customers sometimes encounter is the receipt f electric service at an incorrect voltage. This may stem from a variety of causes but are typically resolved using the field review process where crew is sent out to the location of the customer to diagnose potential issues in the distribution system to rectify it. There is an inherent inefficiency associated with this process due to the time and effort required to deploy crew and fleet to the area and the time required to engage in field observations, take measurements and evaluate the problem holistically. In this paper, we address the power quality issue, particularly voltage related issues in power distribution systems, and the AMI based methodology to mitigate voltage issues to improve customer power quality.

The paper is organized as follows. Section 2 introduces the AMI network at ComEd, generalized for the scope of work expounded in the paper Section 3 defines the voltage issues faced by customers and their potential causes. Section 4 elaborates the proactive and reactive methods employed using AMI voltage interval data to prevent voltage issues from occurring and to rapidly diagnose and rectify voltage issues once the customer calls in to report.

2. ADVANCED METERING INFRASTRUCTURE

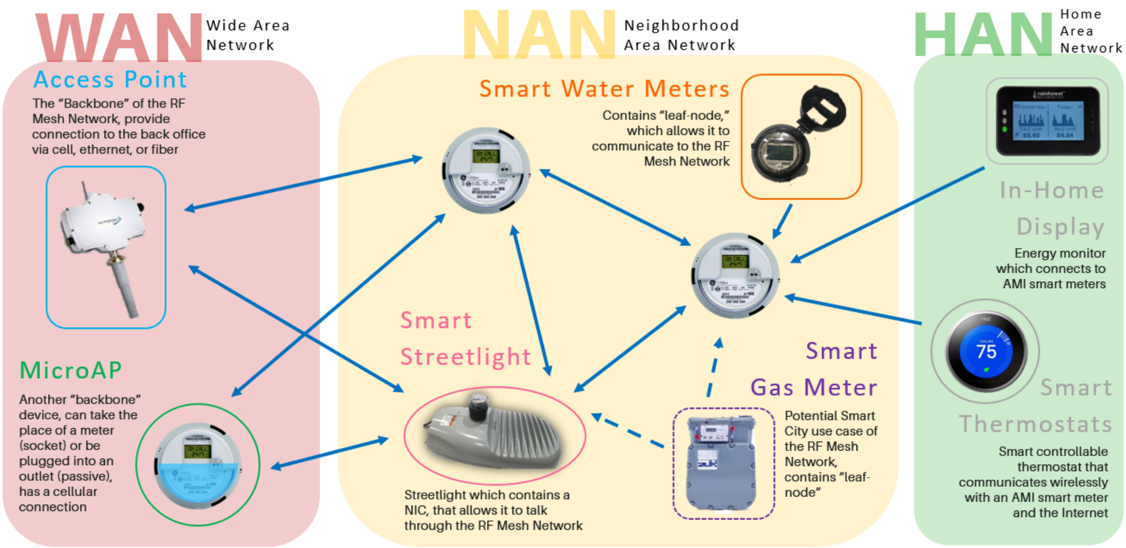

Figure 1. Architecture of AMI network

The AMI network is a mesh network which is comprised of 3 layers: the wide area network, the neighborhood area network, and the home area network. The wide area network is comprised of access points and other backbone devices. Backbone devices such as access points create the foundation of the network and allow ComEd to access the data within the smart meters via 4G cellular signal. The neighborhood area network is comprised of smart electric meters, smart water meters, smart gas meters, smart streetlights, and other potential new technologies which eventually communicate back to the access points to flow data back into the head end system. The neighborhood area network forms the mesh which communicates under the 900 MHz band. The home area network is comprised of devices that could directly communicate to the nearest smart meter via Wi-Fi. Devices include smart thermostats, smart home appliances, smart inverters, and other potential new technologies.

Some of the key features of the AMI mesh network is that it's dynamic and robust. If one node fails, there may be multiple routes for the data to reach the access points. Also, as more devices get added to the network, the more reliable and stronger the network becomes.

AMI Smart meters record 30-minute intervals for usage (kWh), generation (kWh), voltage (V) and depending on the program loaded on the meter, many types of data such as kVAR and meter temperature. AMI Smart meters also record events that can point to meter health, cybersecurity issues, outages, voltage sag/swell, and many more. ComEd schedules jobs to poll power quality reads once a week containing power factor, phase angle, and other metrics. ComEd can utilize on demand jobs to poll other data of interest as well as schedule future jobs to collect data from the smart meter that's not currently being leveraged. However, since the AMI population is large, even collecting one additional data point can translate into over 4 million extra lines of data being produced daily since the ComEd territory contains over 4 million smart meters.

Once the data from the AMI network reaches the head end system, data used for billing goes through Meter Data Management (MDM). The data goes through the VEE process to estimate values for missing intervals and validate the data received. After the VEE process, the data goes into CIMS for billing. Most data get loaded into Itron's Operations Optimizer for further review for all sorts of use cases. Nearly all the AMI data is stored in the Exelon DAP and data exploration is conducted in the data lab. The meter platform (Itron's AMM platform) also houses data for a limited time and allows the users to pull data directly from the smart meter on demand.

ComEd's AMI network produces over a quarter billion lines of data daily. Due to the volume, variety, and velocity of AMI data, it is big data and requires sophisticated tools to analyze effectively. The Exelon data lab is comprised of multiple clusters of CPUs for increased computing power. ComEd also owns multiple clusters of GPUs for training large machine learning models.

3. CUSTOMER POWER QUALITY ISSUES

Some customers experience voltage issues that are expressed physically in the form of maloperation and thermal stress in lighting and equipment. Customers usually must call in to the utility service center to record the incident and since the customer does not suffer an outage, the customer service representative registers a non-outage ticket. The typical handling of these tickets entails the use of in-house meter reading software to ping the on-demand read of the customer meter to evaluate if the issue is sustained or temporary. In case of sustained voltage issues, a crew is dispatched to the location to identify and mitigate the cause of the voltage issue. The typical voltage reading at the smart meter may show high or low voltages but may not show any definitive characteristic attesting to the cause of the voltage issue. Figure 1 below shows two voltage plots, blue line customer experiencing nominal voltage while the red line experiences high voltage. From observation, it is not apparent why the customer with high voltage experiences the issue. However, considering certain unique attributes of voltage behavior, a judgement can be made as to what the cause is, as explained in section 4 and 5 of this paper.

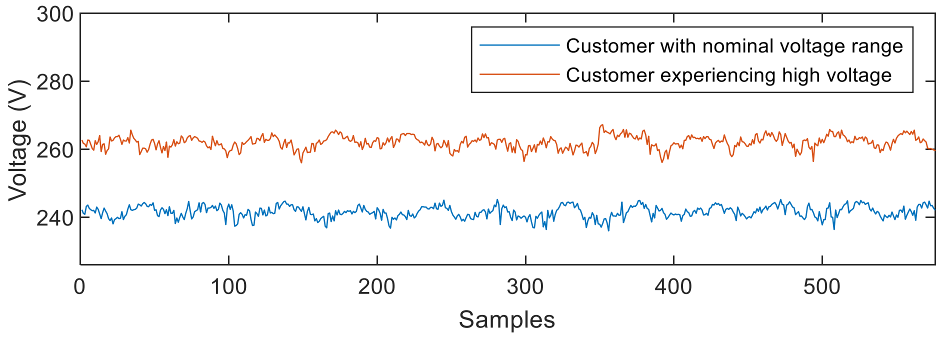

Figure 2. Voltage plots of customers with nominal and high voltage readings at the meter

Typically, the first step in identifying the cause of the voltage issue lies in the determination of the source of the voltage abnormality. The causes of the voltage issues can usually be distinguished by the number of customers affected in the feeder. The greater the extent of the voltage issues, the larger the number of customer calls registering a voltage complaint. If most of the customers in a particular feeder experience abnormal voltage values, the issue is usually at the head of the feeder – in the distribution substation due to incorrect substation bus voltage. In some instances, a misoperating distribution voltage regulator or capacitor bank can produce abnormal voltages at all customers downstream of the equipment, albeit for customers, an issue may be exacerbated by the length of the feeder section, and therefore voltage drop across the section.

In cases where meters only belonging to a particular transformer shows issues, it can indicate a potential equipment issue such as a transformer with incorrect primary tap setting or one with an internal fault. The primary tap setting is used to finetune the secondary voltage served to the customer. Depending on the length of the feeder, location of voltage compensation, and size of the load, the primary tap is adjusted between its five positions, +/-5%, +-2.5% and 0, to provide the adequate voltage within nominal range to the customer. However, there may arise situations due to mechanical and thermal stress of transformers causing an internal fault in the windings of the transformer, permanently altering its turns-ratio. The fault in the primary windings reduces the primary turns and consequently boosts the voltage at the secondary. In addition to these common modes of failures, other causes are listed in Table 1.

Table 1. Common causes of voltage issues in power distribution systems

System Side Causes	Customer Side Causes
Transformer with incorrect tap setting	Installation of new loads
Transformer overload	Non-linear loads and harmonics
Internal faults in Transformers	Large load changes such as induction loads startups
Capacitor bank switching	Faults in customer owned secondary
Voltage Optimization	

4. PROACTIVE METHODS TO REDUCE VOLTAGE ISSUES

Predictive Approach

A distribution transformer delivers a constant voltage transformation. When energized, the transformer has a fixed number of turns in the high voltage (HV) winding and low voltage (LV) winding resulting in a constant turns ratio. An abrupt step increase or spikes in the transformer secondary voltage measured by a smart meter remaining at the increased voltage level never returning to the previous lower voltage level is a potential indicator of imminent transformer failure. A step increase or spike in the transformer secondary voltage is potentially the result of shorted turns in the HV winding which effectively decreases the total number of turns in the HV winding. Decreasing the number of turns in the HV winding while the number of turns in the LV winding remains unchanged decreases the overall HV winding/LV winding turns ratio resulting in an increase in the secondary voltage assuming the primary voltage remains constant.

However, an abrupt step increase or spike in the transformer secondary voltage measured by a smart meter may be the result of other causes than shorted turns in the transformer HV winding. Another potential cause of an abrupt step increase or spike in the transformer secondary voltage is a change in position of the subject transformer de-energized tap changer (DETC) position. Another potential cause is a sudden increase in the source voltage as the result of capacitor bank operation, upstream transformer issue, upstream voltage regulator issue, or other issues. It is critical to evaluate whether an abrupt step increase or spike in the transformer secondary voltage is isolated to one transformer or also appears in other single-phase transformers served by the same primary phase or in other three phase transformers on the same feeder before concluding the abrupt step increase or spike in the transformer secondary voltage is the result of shorted turns in the transformer HV winding.

Figure 3 below shows a single phase, overhead, 15 kVA, 7200/12470Y – 120/240 V transformer secondary voltage trend with the smart meter identifying an abrupt step increase in the secondary voltage of approximately 8.3% never returning to the previous nominal secondary voltage trend.

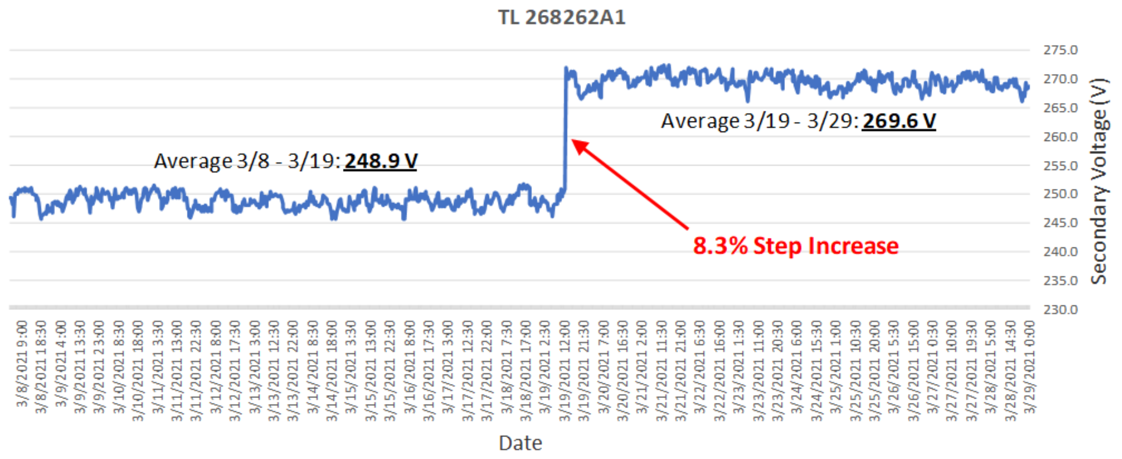

Figure 3. Single Phase Transformer Secondary Voltage Trend with Abrupt Increase

When comparing the transformer secondary voltage trend with the abrupt step increase to another single-phase transformer served by the same primary phase of the same feeder geographically adjacent to the suspect transformer, Figure 4 reveals the abrupt step increase is unique to the suspect transformer and likely not an upstream source voltage issue.

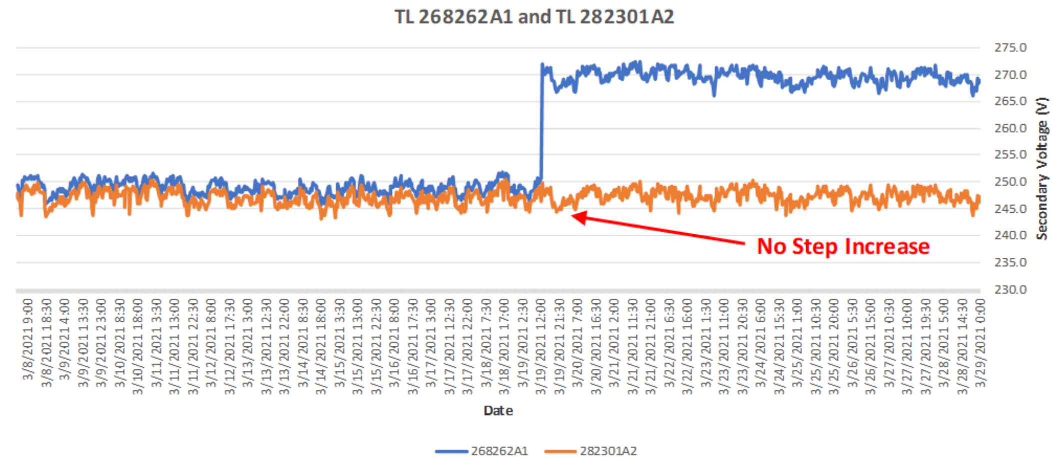

Figure 4. Comparing Single Phase Transformer Secondary Voltage Trends Served by the Same Phase

The suspect transformer was removed from service and investigated in more detail.

A transformer turns ratio (TTR) was performed with a handheld test device with failing results:

- TTR calculated value 30.00 (7200/240)
- Acceptable test values 29.85 – 30.15 (industry acceptance criteria ±0.5% of calculated value)
- Suspect transformer tested TTR value 27.65 (-7.8% deviation from calculated value failing industry acceptance criteria)

A winding megger at 1000 VDC was performed with a handheld test device with passing results:

- HV winding to ground ≈ 150 MΩ (acceptance criteria minimum 8.2 MΩ)
- LV winding to ground ≈ 100 MΩ (acceptance criteria minimum 1.2 MΩ)
- HV winding to LV winding ≈ 100 MΩ (acceptance criteria minimum 1.2 MΩ)

Dissolved Gas-in-Oil Analysis (DGA) testing showed 1690 ppm concentration of acetylene which is indicative of significant arcing under oil. The complete DGA results:

Table 2. Results of the DGA test

Dissolved Gas	**Concentration (ppm)**	**Dissolved Gas**	**Concentration (ppm)**
Hydrogen	580	Carbon dioxide	580
Oxygen	500	Ethylene	560
Methane	350	Ethane	68
Carbon Monoxide	730	Acetylene	1690

Oil quality testing showed acceptable dielectric strength and water content results:

- Dielectric strength – 39 kV
- Water content – 11 ppm

The core & coil assembly was removed from the tank and revealed obvious HV winding damage.

Figure 4. Images from forensic analysis of transformer failure. Starting from left going clockwise. 1) Exterior of failed transformer 2) Observed damage on exterior of insulation 3) View of the HV winding damage 4) Magnified view of HV winding damage

Proactive Filtering of Equipment

Historically as a large utility company power quality has typically been addressed in a reactive method. Traditionally customers called in with a complaint and the appropriate parties would be dispatched to assess and implement the solution. Without the initiation from the customer there were limited avenues to proactively correct these power quality issues. Prior to AMI meter usage the proactive approach involved installing recording meters on select problem areas to assess if there were any issues that could be remediated. While issues were found and remediated with this method, due to the size of the distribution system it was very difficult to find many of the issues which are now identified through AMI meter data.

Currently with the databases and applications available through AMI data records and instantaneous voltage readings we created an algorithm to identify meters which experience high / low voltage. The power grid is transient in nature and voltages can shift depending on loading, switching, capacitor bank operation and many other common occurrences. To filter out some of these issues we only wanted analyze meters which exhibited voltages 7% above or below nominal at any point in the day for 4 consecutive days. Before creating the database these issues would be stored in, we pulled 8 meters which fit these criteria and investigated to find the root cause in each case. From the initial 8 we found high station voltage, 4 distribution transformers with incorrect primary tap setting, a failing neutral, one failed meter voltage sensor and a 12kV/4kV step down transformer with the incorrect turns ratio that had to be replaced. From this pilot since we were able to find a multitude of issues and correct voltage for a variety of issues, we have committed to expand the program and enhance the algorithm.

Based on the data available through the smart meter and basic math functions run on that information 17 filterable characteristics were assigned for each meter experiencing the high/low voltage. Meters are ranked based on number of days in a row the high/low voltage occurred and the severity of the voltage fluctuation. Additionally, since we identified that these issues were occurring at transformer, feeder and even station level the algorithm which initially only was a list of service points was further correlated to the respective transformer and feeders. This allowed for easy identification of issues at the station, feeder, and transformer level in addition to individual meters which were experiencing a voltage concern. For example, if multiple feeders from the same station were appearing in the repository all with high voltage, we could quickly determine that there may be an issue at the station causing the issues. Likewise, if 100% of the meters from a specific transformer are exhibiting high voltage and no other meters on that same feeder have high voltage there is likely an issue with only that individual transformer. The following flow chart was created based on the results as they were identified through the initiative to allow for further testing of different filters to identify specific issues. Since this algorithm has only been utilized since the end of summer 2021 the focus has been high voltage issues since low voltage is typically a byproduct of high loading which occurs in the summer.

The above diagram shows the breakdown of different analysis applied to the meters which are identified through the algorithm. Station and feeder level issues are prioritized to be addressed first since they affect the most customers, however since stations are already closely monitored there are not as many investigations at this level. High Station voltage is typically a symptom of improper settings of station voltage relay or a physical equipment issue. An example of high station voltage due to improper relay settings occurred when switching took place at the station and the station transformer was briefly taken out of service and the 90-relay reverted to a previous setpoint. In this scenario voltage was operating within allowable parameters but was trending on the high side of the voltage band. A long-standing issue which was identified through the station analysis portion was that on specific stations which have a unique voltage 11.95kV p-p the station relays were using 12.0kV as their nominal setpoint. This rounding would not make a huge impact on its own however, there are transformers with 11.85kV ratio on the system which even at the normally programmed setpoints could experience high voltage. As a result, the station nominal voltage was adjusted down to 11.85kV along with the bandcenter calculations for all the stations affected which remedied a multitude of customers which were constantly on the border of high voltage. The last type of station issue commonly identified was with stations that have separate transformers and regulators instead of a LTC (load tap changer) transformer. In these instances, a single regulator can get physically stuck, unable to tap itself down until there is intervention by a technician. Although they represent a small number of instances the station level issues have mitigated high voltage for the largest number of customers.

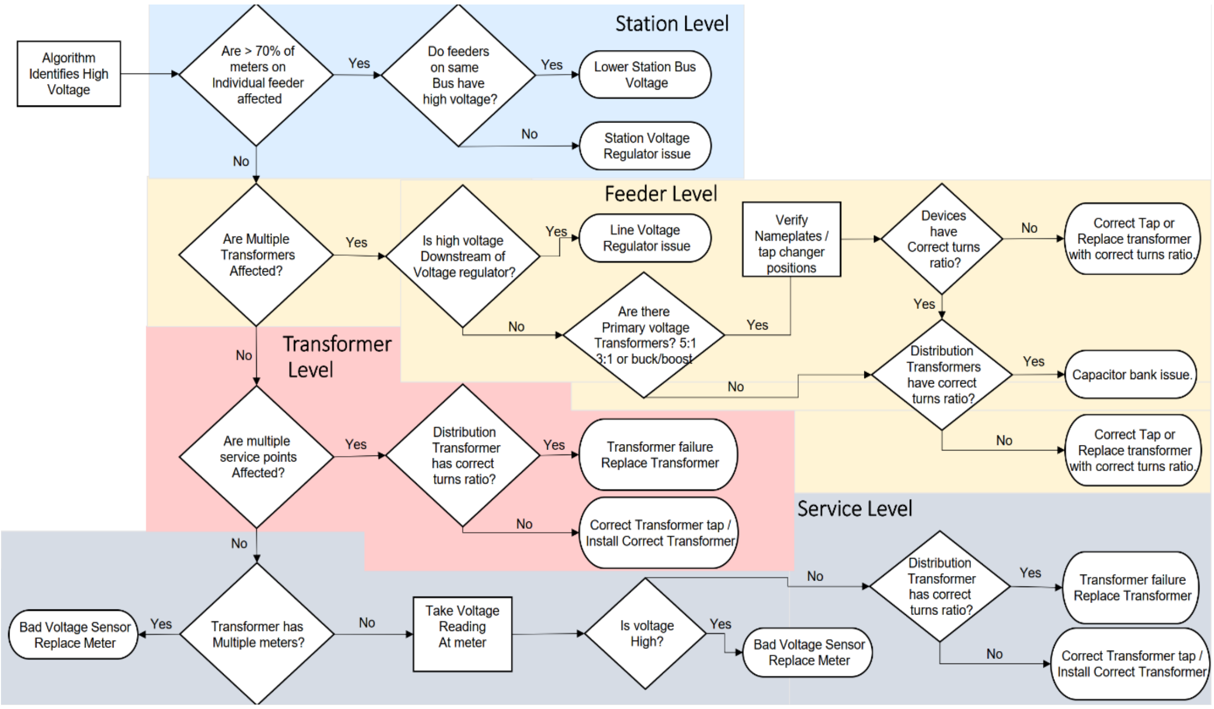

Figure 5. Flowchart of Voltage Issues

Feeder level issues affect only a single feeder from a station but can still affect many customers depending on how severe the issue is. The algorithm is designed to show what percentage of a feeder is experiencing high voltage and then based on user analysis is how the root cause can be determined. The most common issues identified are distribution regulators and capacitor banks which have faulted. Capacitor banks have built-in safety which automatically opens them up if voltage goes above a certain threshold, however if there is a physical issue with the switches or control cables, they will be unable to operate. Typically, with capacitor banks the elevated voltage is exclusive to a single phase which failed to operate thus causing high voltage or complete failure and all three primary phases to have elevated voltages. The other subset of voltage issues identified at a feeder level are primary voltage regulation transformers being incorrectly adjusted. Due to the different primary operating voltages in Chicago transformers in the same geographic area must be set for different primary voltages. These large transformers which transform from 12kV to 4kV were identified with incorrect primary tap position due to all downstream transformers having elevated voltage signatures. Many of these devices have been set in an unideal position for long periods of time with no customer complaints, so without the AMI data they may have sat in the wrong position until a complaint came in.

The next two levels for transformer and individual service points have many commonalities since some transformers only have a single meter associated with them. At the transformer level, if there are no other transformers experiencing the same voltage issue on the feeder it allows for quick determination of the root cause. The typical data signatures associated with transformer issues are 5% elevated voltage for incorrect tap changer position or greater than 7% for internal transformer faults. The other common transformer level issue identified is transformers with the incorrect ratio being installed in the wrong primary voltage area. If the transformer has the correct ratio / tap position but is exhibiting the high voltage those are replaced. Lastly for individual service points with issues, if only 1 meter off a shared transformer is exhibiting high voltage, we have found that that is due to a damaged voltage sensor. For this reason, voltage must be confirmed in the field for transformers with only a single meter so that the determination between a damaged transformer and damaged meter can be made.

Table 3. Voltage issues identified and their causes

Level of issue	Number of instances
Station Level	**26**
Capacitor Bank Issue	1
High Station Voltage	17
Voltage Optimization Settings	1
Voltage Regulator Issue	7
Feeder Level	**36**
Capacitor Bank Issue	15
High Station Voltage	1
Incorrect Primary Tap	13
VO Feeder	1
Voltage Optimization Settings	1
Voltage Regulator Issue	5
Transformer Level	**131**
Failed Transformer Windings	32
Incorrect Primary Tap	70
Incorrect Transformer	24
Neutral Issue	3
Voltage Drop / Connections	2
Meter Level	**30**
Failed Meter	25
Incorrect Meter	2
Voltage Drop / Connections	2

Table 3 outlines issues identified by their respective level and contrasts the number of issues identified and resolved along with the total number of meters that had their voltages corrected. There are more issues identified in this chart vs. the flow chart above because many of these issues are the specific root causes which would fall under the umbrella of the terms outlined in the flow chart. We can see below that high station voltage was the leading cause of high voltage at the station level with 17 instances identified. At the feeder level, capacitor bank issues and incorrect primary tap of step-down transformers were the most common root causes. At transformer level incorrect primary tap is the leading culprit for high voltage issues in addition to a sizeable number of failed transformers which were unable to be picked up by the other algorithm due to the timeframe of the occurrence. Lastly at the meter level 25 failed meter voltage sensors were the cause of the algorithm seeing high voltage and flagging the meters.

Overall, the proactive approach enabled by AMI data analysis is greatly assisting with improving power quality for the consumers on our distribution system. As technology gets more advanced the parameters which electronics require are becoming narrower as to the acceptable voltage ranges. Resolving these voltage parameters proactively allows us as a utility to provide optimal quality and premier customer service for our customers.

REACTIVE APPROACH

The proactive portion of this work elaborated in the previous section describes the methodology that in addition to the overall reduction in the non-outage voltage tickets, provided a trove of analyzable data to create diagnostic tools to evaluate the cause of the voltage issue, prescribe the appropriate corrective action and dispatch the appropriate resource to handle the issue. The diagnostic tool is reactive as the voltage issue is evaluated after a customer calls in with a voltage issue and a ticket has been created.

From Table 2, the AMI data for the voltage tickets that we fixed was obtained and the AMI voltage interval data of meters pertaining to the identified voltage issue were analyzed to reveal data signatures that can be used to identify if a similar issue is present in the ticket to be analyzed. The flowchart below shows the process to create the diagnostic tool. The data signatures observed in the data analysis of the AMI voltage data for each cause is used to evaluate current tickets for similar behavior, and thereby improving operational efficiency and the correct allocation of resources to mitigate the issue.

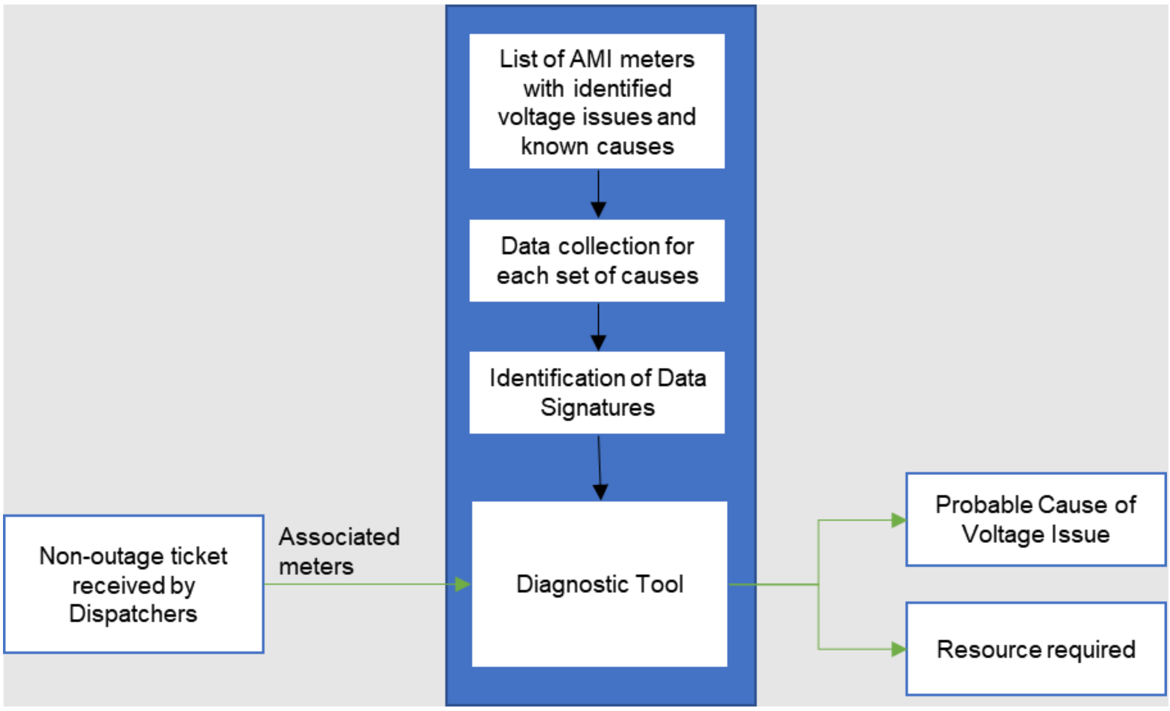

Figure 6. Flowchart of the Reactive Approach using the Diagnostic Tool

The causes for which the data signatures were analyzed and validated are:

1. Feeder level issues
2. Transformer level issues
   2.1 Transformer with incorrect primary tap setting
   2.2 Transformer with potential internal fault in the primary windings

Each of the causes have a unique data signature that can be used to verify if the meter associated with a non-outage ticket exhibits the same voltage behavior.

- **Feeder Level Issue**

The ability to distinguish between feeder and transformer level issues requires additional transformers to be included in the analysis to see if abnormal voltages are present in all transformers reviewed. A feeder level issue can be attributed to either incorrect bus voltage at the substation, misoperating equipment upstream of the transformers such as capacitor banks or voltage regulators. By comparing the two transformers, a judgement can be made if the issue is transformer level or feeder level. The diagnostics algorithm compares the voltages of meters in two neighboring transformers and finds the mismatch. In the following figure, the average voltages in meters belonging to two meters are plotted over time. For this example, we have considered 4 meters, 3 belonging to transformer 1 (XFMR1) and 1 belonging to transformer 2 (XFMR2). We use transformer 2 as our reference in judging if all transformers exhibit similar voltage excursions. The Fig. 2(a) shows the feeder level issue where all meters exhibit the same voltage profile but exceeds the nominal voltage threshold of +5.8%.

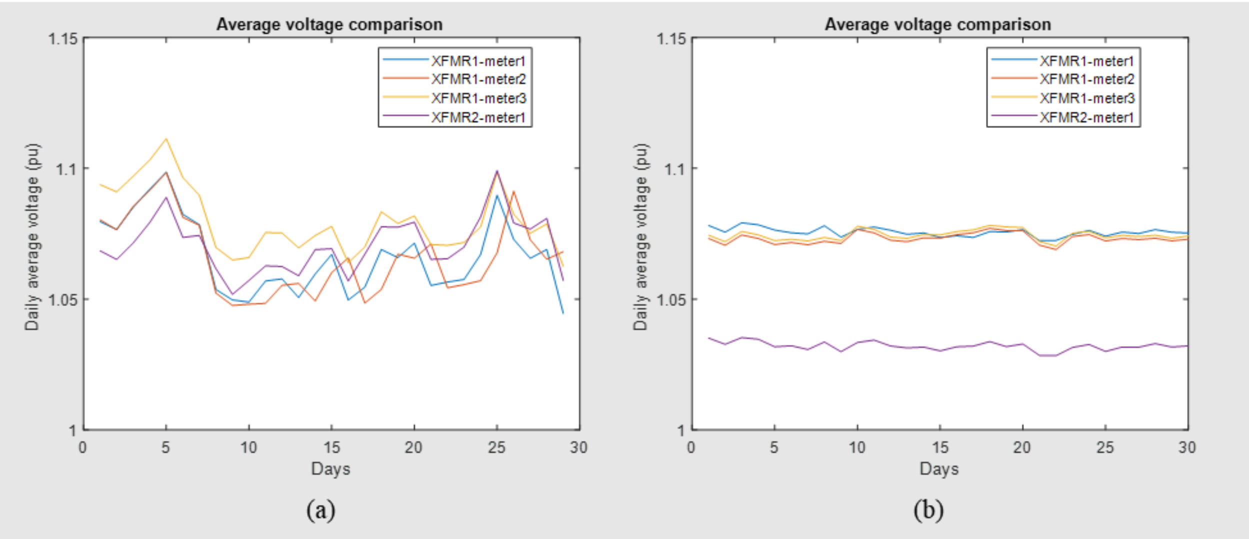

Figure 7. Comparison of Voltages recorded by meters experience feeder level and transformer level voltage issues

However, if the voltage issue is localized at a single transformer as seen in Fig. 2(b), there are two possible causes – Transformer in incorrect primary tap setting, or the transformer has an internal fault in the primary winding, effectively increasing the turns ratio and expressing a higher than nominal secondary voltage.

- **Transformer Level Issue**

Three other signatures are used to make this distinction between incorrect tap setting and as explained in the following section.

(a) Overvoltage events: For transformers with incorrect taps, overvoltage events are observed intermittently with voltages returning to nominal level periodically. For transformer internal fault, the overvoltage is sustained as seen in Figure 5.

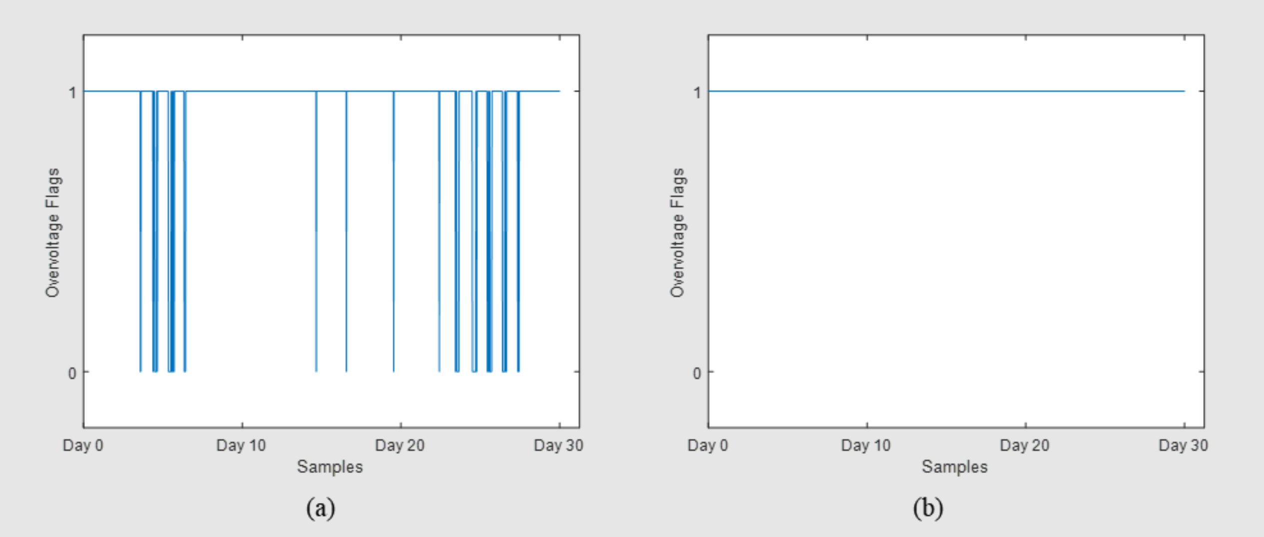

Figure 8. Intermittency of voltage events

(b) Histogram of voltage difference from nominal voltage: Figure 7 shows the difference in the histograms of voltage deviation observed in meters connected to transformers with incorrect taps and in meters connected to transformers with internal faults. For transformers with internal faults, the overvoltage was observed to be significantly higher in transformers with internal faults (>10%) than in transformers with incorrect primary taps (>6%).

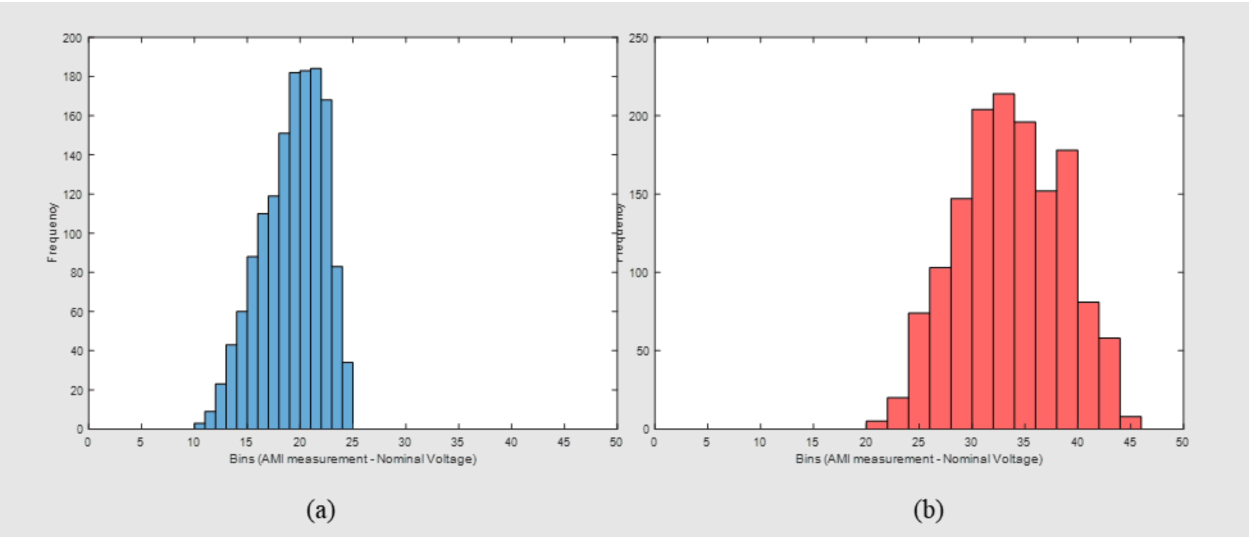

Figure 9. Histogram of voltage deviation

Based on the diagnosis of the tickets, a judgement is made to deploy the appropriate resource to mitigate the issue in an expedited manner following utility standard practice.

Supplemental Efforts utilizing AMI to improve power quality

Because ComEd's AMI meter population is over 4 million large, quality control processes are needed to ensure that the AMI meter population is healthy. AMI Operations has various processes to identify damaged/malfunctioning meters. We screen the entire communicating AMI meter population for critical events that point to damaged/malfunctioning meters and issue change meter orders daily. We also screen the entire communicating AMI meter population for irregularities such as consistently incorrect time as well as abnormal voltage/temperature measurements and issue change meter orders on a regular basis. These processes in place help ensure that the AMI meter population is healthy and recording quality data.

During the summer, RF signal quality weakens, making it harder for the AMI smart meter to communicate back to the network. To remediate this issue, AMI screens the entire meter population for areas with potential low RF signal quality. ComEd uses AMI RSSI data along with various data streams such as events in the event log, missed scheduled jobs, estimated bills, and onsite field comments that may point to low RF signal quality. Once an area of low signal quality is identified, a work order is created to strengthen the network to prepare for summer by installing additional backbone devices. Strengthening AMI network communication increases its reliability and helps ensure a steady stream of data from the AMI network.

AMI Smart Meter Data Analytics is also investigating meters who report back abnormal phase angles. From the results of field investigations, most meters that were investigated had a bad fuse or blown fuse; cable faults; issues with upstream transformer; or incorrect wiring. Mitigating these premises with meters that report back abnormal phase angles ensures that we accurately bill the customer, and that the customer is receiving quality electric service. This effort also helps categorize different power quality complaints to determine whether the issue is isolated at the customer's premise or a symptom of a larger distribution line issue.

4 CONCLUSIONS

In this paper, a multi-step AMI driven approach to improving customer voltage quality is presented. The methodology improves customer power quality by employing proactive and reactive methods to reduce the number of customer tickets and to effectively handle voltage tickets. The proactive approach uses AMI data to tag equipment exhibiting abnormal voltage behavior. The tagged equipment is field reviewed and if an issue is found, is repaired, or replaced to reduce the number of customer tickets generated. The data from equipment confirmed of known voltage issues is used to extract data signatures that can diagnose customer tickets for faster mitigation. Some processes elaborated in this paper are currently being tested as part of a pilot program in ComEd. As part of future work, updated algorithms for the methodology presented will be tested and validated to improve performance.

BIBLIOGRAPHY

[1] Bao, Z., & Li, Z. (2016, July). Identifying hot socket problem in smart meters. In 2016 IEEE Power and Energy Society General Meeting (PESGM) (pp. 1-5). IEEE.

[2] Wang, Y., Chen, Q., Hong, T., & Kang, C. (2018). Review of smart meter data analytics: Applications, methodologies, and challenges. IEEE Transactions on Smart Grid, 10(3), 3125-3148.

[3] Bakar, N. A., Abu-Siada, A., & Islam, S. (2014). A review of dissolved gas analysis measurement and interpretation techniques. IEEE Electrical Insulation Magazine, 30(3), 39-49.