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CIGRE US National Committee
2023 Grid of the Future Symposium

Using Receptacle-Based Sensors for Utility Fire Hazard Detection Including Loose Neutrals

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SUMMARY

This paper provides an overview of a receptacle-based sensor that is capable of detecting loose neutral conditions not only within the home, but between the home and utility infrastructure. This paper reviews roughly 4400 documented cases where a loose neutral condition was detected and mitigated. The cases are based on nearly 330,000 home years of monitoring data. Further, the paper describes the performance of detection between homeowner-based infrastructure and utility infrastructure.

KEYWORDS

Loose Neutral, Fire Hazard, Utility Fire Hazard, Safety

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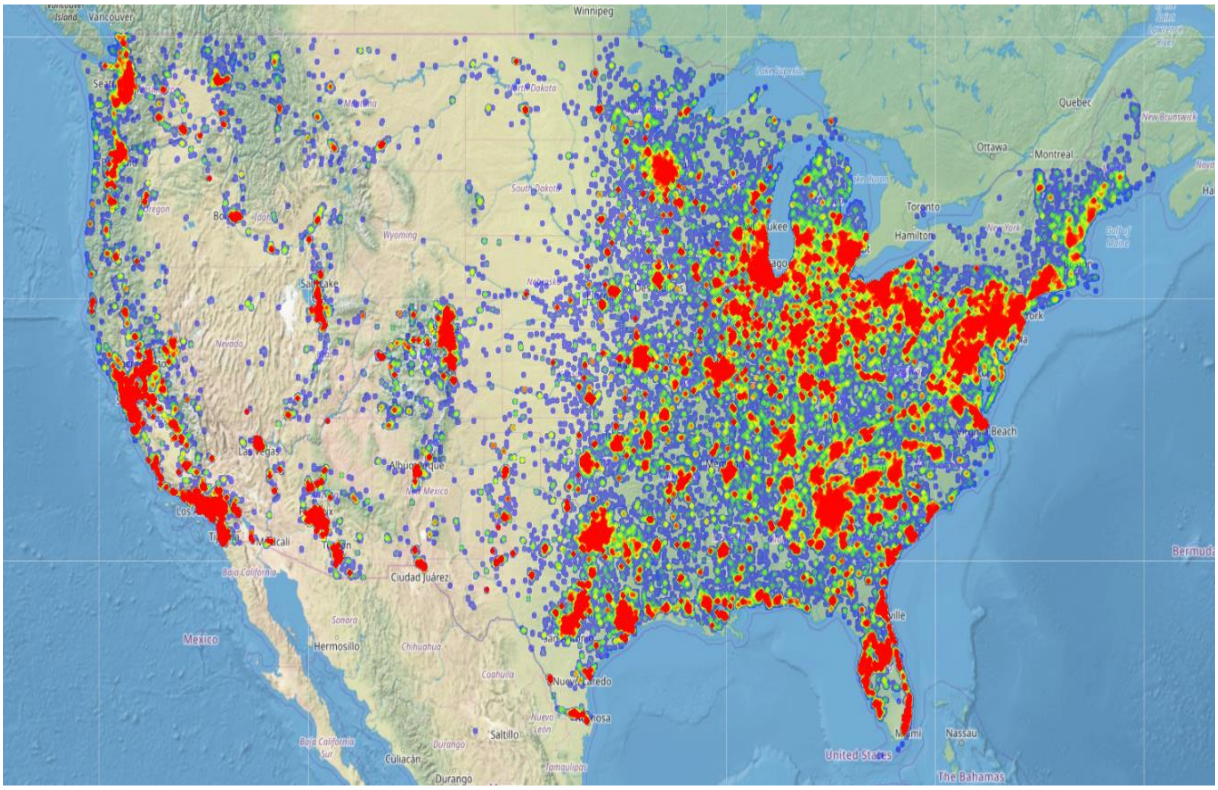
Background
A high density, smart home power quality monitor network records high-resolution voltage data. Experience with this voltage data has led to the identification, localization, and resolution of thousands of residential power quality problems across the U.S. These problems range from damaged, loose, or missing neutral connections to out-of-range base voltage. About 75 percent of these problems are classified as damaged, loose, or missing neutrals, a known hazard to life and property.

The sensors have been deployed to nearly 330,000 homes across the US. At the time of this writing, the system is growing at a rate of neary 40,000 sensors per month. The figure below shows a heat map of the sensor deployments. The deployments generally align with population density.



The sensors are primarily distributed by insurance companies to homeowner insurance policy holders. The primary motivation is to prevent electrical fires thereby reducing electrical fire claims. Historically, there have been about 50,000 fires annually because of electrical fires. These fires result in nearly 500 deaths and 1500 injuries. This costs the industry over $1.5 billion in damages annually. The average claim is about $145k.

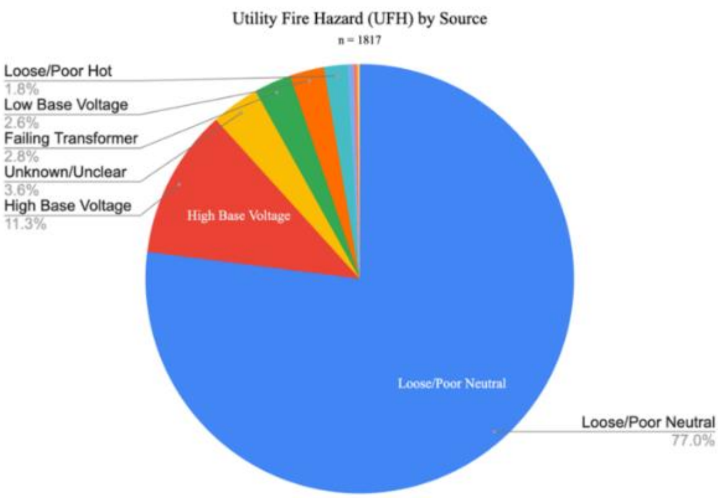
The sensor is passive monitoring device. It plugs into an ordinary receptacle within the home. The system monitors arcing by using a 30-megahertz sampling rate. A second channel measures power quality phenomenon by sampling at 30 kilohertz. The sensor employs artificial intelligence to identify known signals in the 30-megahertz data. Data is streamed back to the cloud and additional machine learning is performed to correlate data from multiple sensors.

The monitoring system has over 330,000 home-years of monitoring data. Over the systems lifespan, over 4400 documented cases have been identified and mitigated. When a single sensor identifies an issue it is flagged as an in-home event. When multiple nearby sensors detect the same event at the same time, then the event is flagged as a grid event.

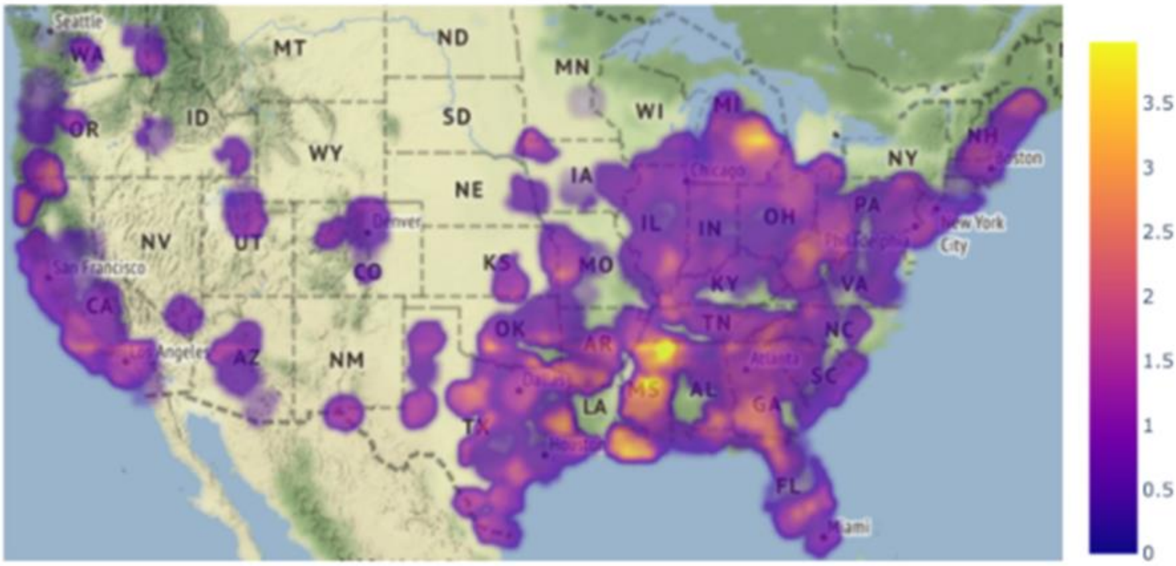
Event Definitions
For the purposes of this paper, there are two primary categories of fire hazards: electrical fire hazards (EFH), and utility fire hazards (UFH). Electrical fire hazards are defined as dangerous conditions that originate from homeowner devices, appliances, home systems, and home electrical wiring. Utility fire hazards are defined as dangerous conditions that are introduced into the home by electric utility infrastructure. EFHs occur at a rate of approximately 1 in 123 homes per year. By contrast, UFHs occur at a rate of 1 in 154 homes per year. This combined rate is roughly 1 in 68 homes per year.

Cases - EFH
There have been approximately 2285 EFHs that have been mitigated. 93% of these are the result of electrical arcing inside the home wiring. 4.6% of these are from loose neutrals inside the home wiring. A picture of a failed outlet is shown in the figure below. This was found after an electrical inspection initiated by a careful review of the sensor data. The other picture is of a failed radon pump that was identified after the sensor system alerted of a EFH.

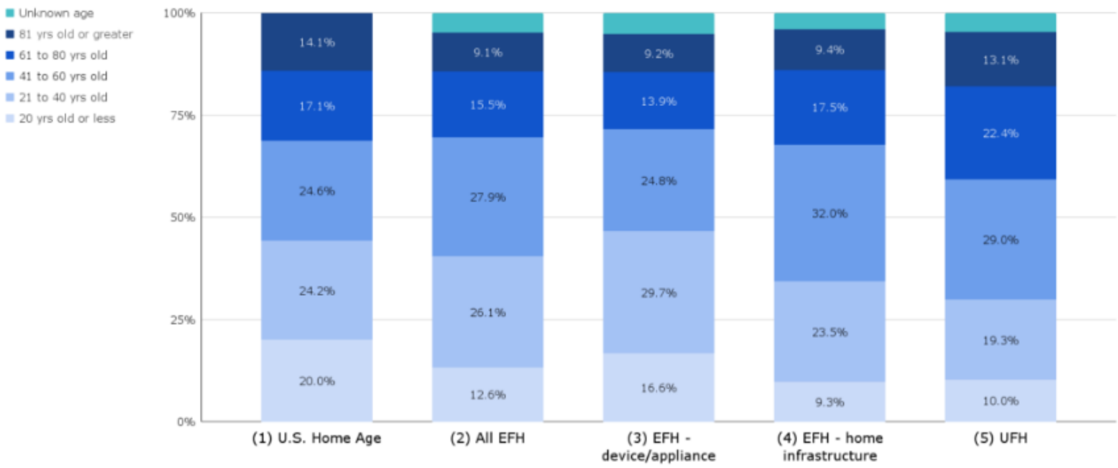
Cases - UFH
There have been approximately 1817 UFHs that have been mitigated. 77% of these are from loose neutrals on the utility side of the meter. Loose neutrals on the utility side of the meter have been attributed to the following dangers: fire, destruction of appliances, wildfire ignition, and electrocution. Consequently, these cases are typically treated with great care when found by utility operators. The graph to the right shows the other hazards the system identified.



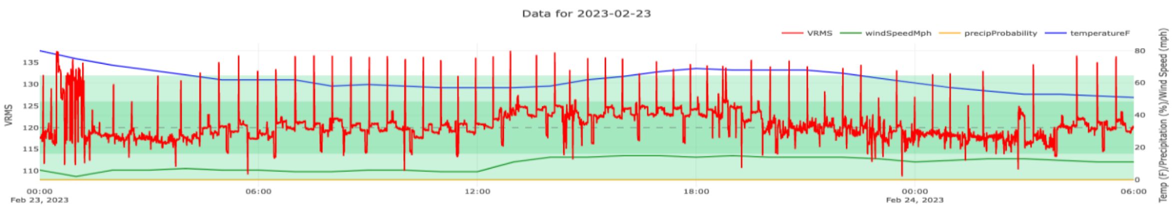
More broadly a UFH Density was computed using hazards per home year 100 home-years. The map uses a 50 mile radius around a map grid. The map extrapolates the likely loose neutral connections based on the larger data set.



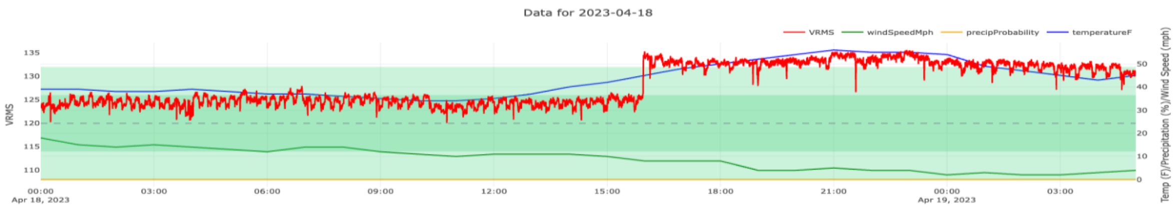
When hazards are identified, demographic data about the home is collected. In particular, the age of the home is noted. The graph below shows the correlation of event types to home age. It is interesting to note that 80% of the homes are more than 20 years old, but account for 90% of the UFHs. This suggests that older homes are more susceptible to loose neutral conditions.



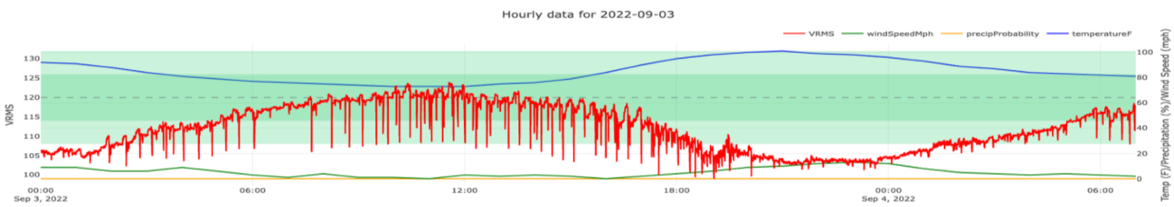
The system is recording data continuously and streaming the data back to the cloud. When the system measures an abnormal waveform, the home is flagged for additional review. The graph below shows a typical waveform for a loose neutral. When there is a loose neutral the voltage frequently exceeds 130 volts when a large load like an air conditioner or heating system turns on. The red trace shows the voltage over a 30 hour period.



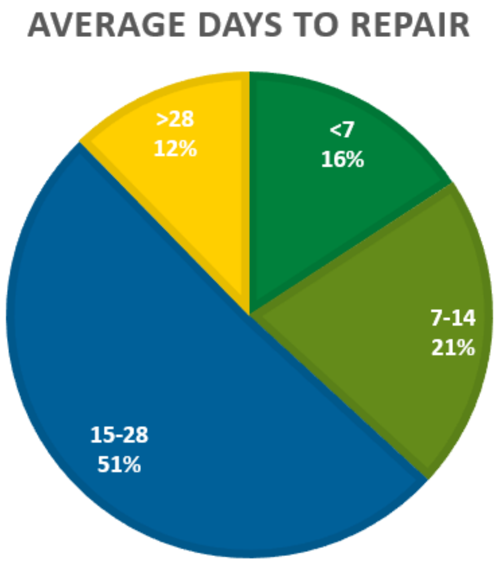
While loose neutrals are a common finding in the system, the system can also detect abhorent voltage conditions like high base voltage. The graph below shows an example of an extended high base voltage condition.

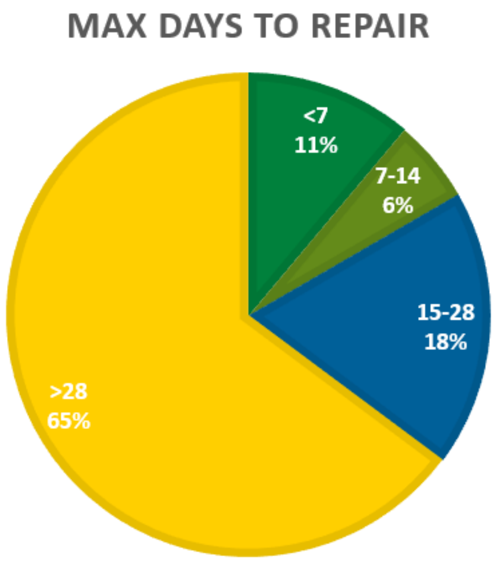


A few cases have been identified where the transformer appears to be overloaded or failing. The graph below shows the voltage as the red trace, while the temperature is the blue trace. Notice that the voltage and temperature have an inverse relationship.



Since the system is continuously monitoring the voltage. It is possible to detect when the event has been resolved. By noting the start and end time of the event, it is possible to identify typical repair times. The graphs below show the average and max days to repair. It is notable that a majority of the time the it takes more than 28 days to repair.



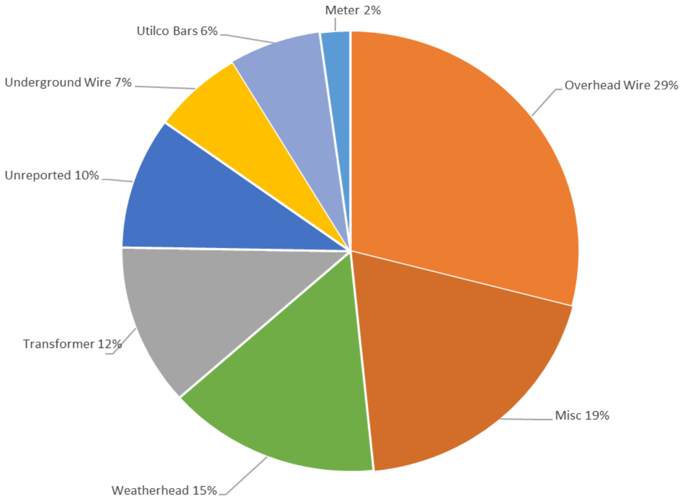


Opportunity for Improvement

Presently, when the system detects an event, the operations team notifies the homeowner to the dangerous condition. The homeowner, in turn, contacts the utility. The utility may send a repair technician to identify the problem. This utility often sends multiple repair technicians to the home before the issue is resolved. This may be the root cause of the lengthy repair times.

Loose Neutral Analysis

Over 100 loose neutral cases were evaluated in cooperation with an electric utility. The utility provided information about the location of the loose neutral. The graph below shows the location of the loose neutrals. Unsurprisingly, many of the loose neutral locations coincided with exposure to weather conditions for example, overhead wire, weatherhead, and transformers contributed to 56% of all cases.



Conclusions

The system identifies dangerous electrical conditions with a very low false alarm rate (less than 0.01%). The accuracy for identifying loose neutral conditions is 99%. Even though the detection is accurate and efficient, the repair times are still lengthy. It appears the typical cause for loose neutral conditions is largely age and related exposure to the elements.

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