# WHITE PAPER:
## *IDENTIFYING LOOSE NEUTRALS*

Contributed by Cowles Andrus May 2012

### ABSTRACT

This white paper describes what a loose neutral is, what effects it can have on electrical equipment, its causes, and some ways to easily detect if a loose neutral is the issue using PMI's power quality analyzers in conjunction with the Loose Neutral Report feature in ProVision.

Loose Neutrals are quite problematic for power utility customers and can also cause serious complications for the electric utility especially if the loose neutral is on the distribution source side of the power meter. They can cause hundreds, even thousands of dollars of damage to electrical and electronic equipment and have even been known to cause fires and/or loss of life! In extreme cases, where the loose neutral completely opens up, voltages can be close to twice what they should be. There are a number of warning signs, that if observed early, can prevent almost certain disasters that are caused when a loose neutral becomes and open neutral!

### OVERVIEW

Although a neutral is a fundamental concept to professionals in the power industry, an overview will be provided here as a foundation for the information that follows. In a three-wire, single-phase 240/120 AC system that commonly feeds a home or business, the neutral wire is intended to have the same voltage from it to the other two conductors. As shown in Figure 1, usually close to home or business there is a voltage step down transformer that reduces the voltage from the higher line voltage such as 7,200 volts on the primary down to 240 volts on the secondary windings. All normal conductors have resistance; a step down in voltage indicates a step up in current, and due to simple physics, (Power loss = I2 x R), there is more power loss. This is why all step-down power transformers are usually found close to their load. On the step down transformers, there are usually 3 wires on the secondary due to the transformer being center-tapped (a center-tapped transformer is shown in Figure 2). The center wire is referred to as neutral. At the base of the transformer, the

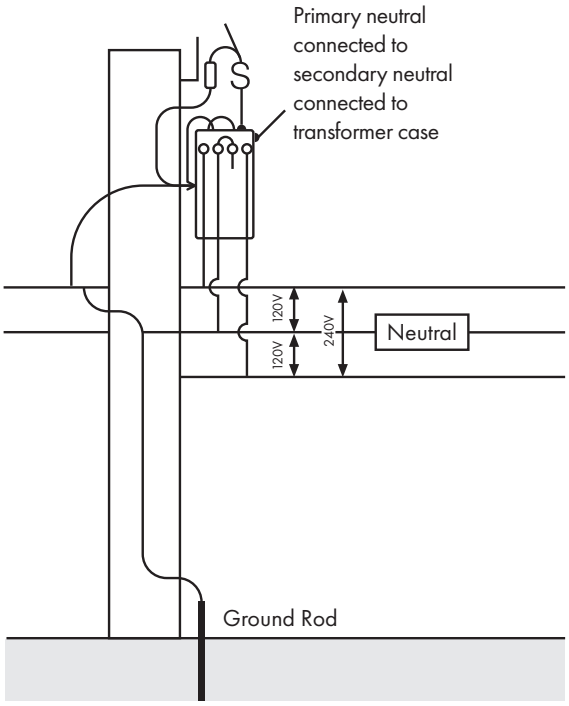


*Figure 1. Schematic*

neutral is connected to a ground rod or in many cases a ground system. Between either of the outer secondary windings to the center tap, the voltage on a normal well balanced system should measure 120 volts and 240 volts across the whole secondary winding. A 120V receptacle is shown in Figure 3. At the meter base/electrical panel another ground

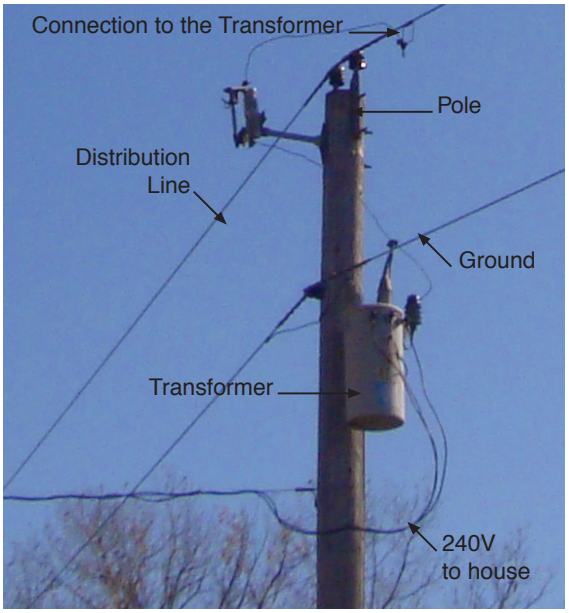


*Figure 2. Center tapped transformer*

 

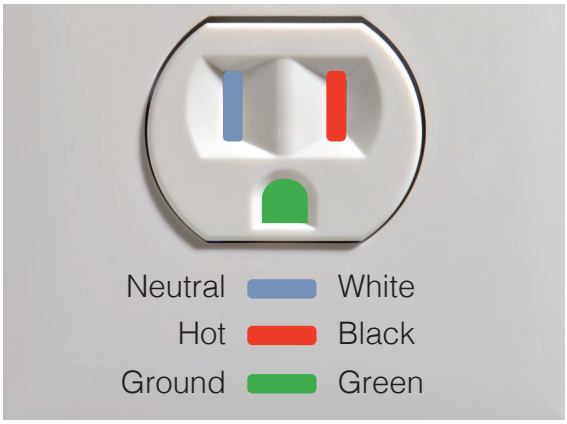


*Figure 3. 120V receptacle*

is attached to the neutral. Some grounds are better than others, so a good low resistive neutral is needed between the meter base and the center tap of the power transformer.

## LOOSE NEUTRAL DEFINED

If, at anytime, for any reason, the neutral connection or wire becomes compromised or resistive this is referred to as a Loose Neutral. Sometimes during installation the connections are not tightened properly or the conductor becomes exposed to weather allowing oxidation to make the contact more resistive.. If the conductor does become resistive, for whatever reason, when current flows, heat is generated and usually causes this oxidation reaction to increase, making the loose neutral connection even more resistive. Sometimes, due to human error, the insulation is not stripped back enough for a good contact. During underground installations, the neutral can be nicked, for instance by a backhoe or sharp rock, which allows the wire to be exposed to the elements and eventually corrode to the point that resistance increases. The severity of a Loose Neutral can change with the season due to natural variations in humidity and soil conditions throughout the course of the year. These are just a few of the most common reasons for loose neutrals.

One clear indication that a loose neutral exists is when a customer complains that their lights appear brighter when a heavy load is pulled from one leg of the system. This effect can come and go to some degree depending whether or not the load of a 240 volt device, such as an electric range or strip heater is on line. In such a case, a heavy load across the 240 volt leg can help balance out the load and reduce the effect. Sometimes a defect in a voltage regulator can cause the lights to become bright, or in extreme situations can cause the lights to burn out altogether and can therefore be confused with a loose neutral. If some light appears to get brighter and some dimmer at the same time, this is a sure sign that a loose neutral is looming somewhere in the system! A good solid neutral is important at all times. The issue of not having a solid neutral is more apparent when the load impedance between the 120 volt lines to the neutral is not balanced from one voltage leg to the other.

A typical symptom of a loose neutral condition is for one voltage leg fall in voltage, and the other leg rise in voltage, with the sum of the two voltages remaining close to twice the nominal voltage. For example, if the voltages start at 119 volts on the first leg and 121 volts on the second leg, then a move down to 105 on the first leg and a move up to 135 volts on the second leg, a loose neutral is a likely cause– one leg went down as the other leg went up, and the sum is close to twice the nominal (240 volts). This happens especially when the load is not balanced, and the neutral is disconnected. The more extreme the imbalance, the more extreme the voltage changes from the nominal voltage. If this condition is met for long enough, the Loose Neutral report is triggered.

## NEUTRAL REPORT IN PROVISION

PMI's data analysis software, Provision, provides a Loose Neutral report that is designed specifically for the purpose of detecting typical symptoms that may indicate that a loose neutral has occurred. The Loose Neutral report is intended for single phase services, with voltage channels one and two connected from line to neutral. All PMI's power quality analyzers have at least 2 input voltage input channels or more are capable of working with the Neutral Report.

The *Loose Neutral Report* setup screen is shown in Figure 4. The Loose Neutral logic uses three pa-

  

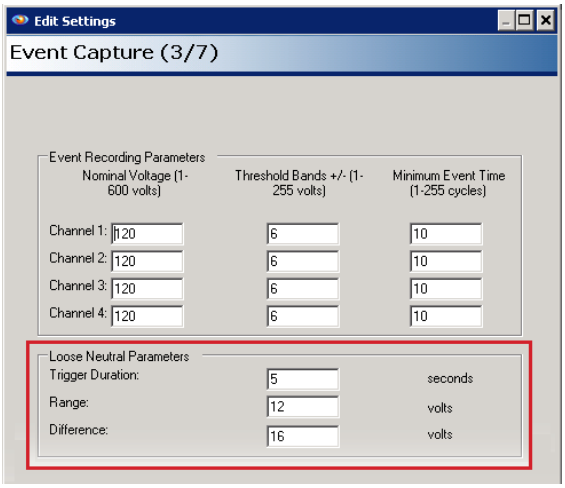


*Figure 4. Loose Neutral Report Setup Screen*

rameters: duration, range, and difference. These parameters are used to judge whether one voltage leg has risen, and one fallen, while the sum remained the same. The difference is a voltage that specifies the minimum difference between the two legs. For example, if the difference is 16 volts, then there must be at least a 16 volt separation between the two legs. The range is a voltage that specifies how close the sum of the two voltages must be to twice the nominal. For example, a range of 12 volts means that the sum of the two legs must be within 12 volts of twice the nominal voltage.

Both the range and the difference conditions must be met for at least the number of seconds specified by the duration. If the duration is set to 5 seconds, then the difference and range conditions must be met for 5 consecutive seconds before a loose neutral is declared. One second average voltages are used. The nominal voltage is the nominal determined during the two minute countdown by the Abnormal Voltage record type, and is typically 120 volts in a single-phase hookup. As an example, assume the difference parameter is 16 volts, and the range 12 volts, with a duration of 5 seconds. The two line voltages are 119 and 121 volts. Then one leg moves to 128 volts, and the other to 110 volts. The difference between the two legs is 18 volts, which meets the difference threshold. The sum of the two voltages is 238 volts, which is within the required 12 volts (specified by the range value) of twice the nominal (240 volts). If these voltages persist for 5 seconds in a row, then a Loose Neutral record will be triggered.

If the device has more than two voltage input channels, it would be necessary to set it to only use two of the input channels. Only a two-channel PQ recorder, or a recorder set to use two channels, can record a Loose Neutral.

The date and time of the loose neutral triggering is recorded, along with the voltage on the two channels. Only the first occurrence of a Loose Neutral is recorded; if the conditions are met again, nothing further happens. The Loose Neutral report shows whether the neutral may have a bad connection, not the exact times the connection was made and broken. Figure 5 shows an example of a Loose Neutral report.

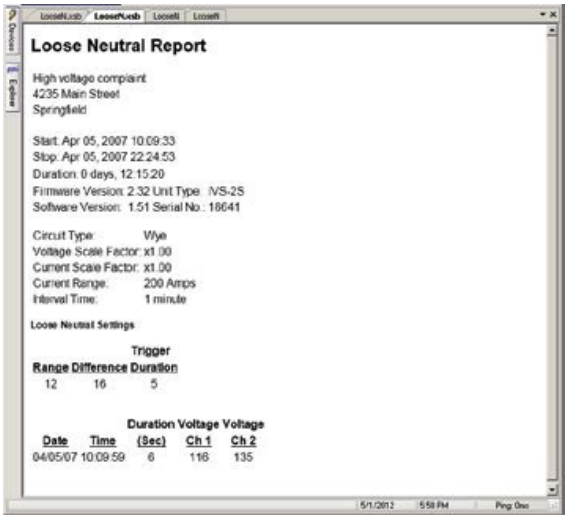


*Figure 5. Loose Neutral Report*

Figure 6 shows the RMS Voltage and Current stripchart. The beginning and ends of the graph (indicated with arrows) show possible loose neutral conditions – the average voltage (green trace) rises on one leg, and falls in the other. The one-cycle min and max graphs (dark green and red) rise and fall on both legs during the same minute interval, further indicating possible bad connections.

Figure 7 shows a zoomed in view, of voltage only. The characteristic rise on one leg, and drop in the other is clear.

  

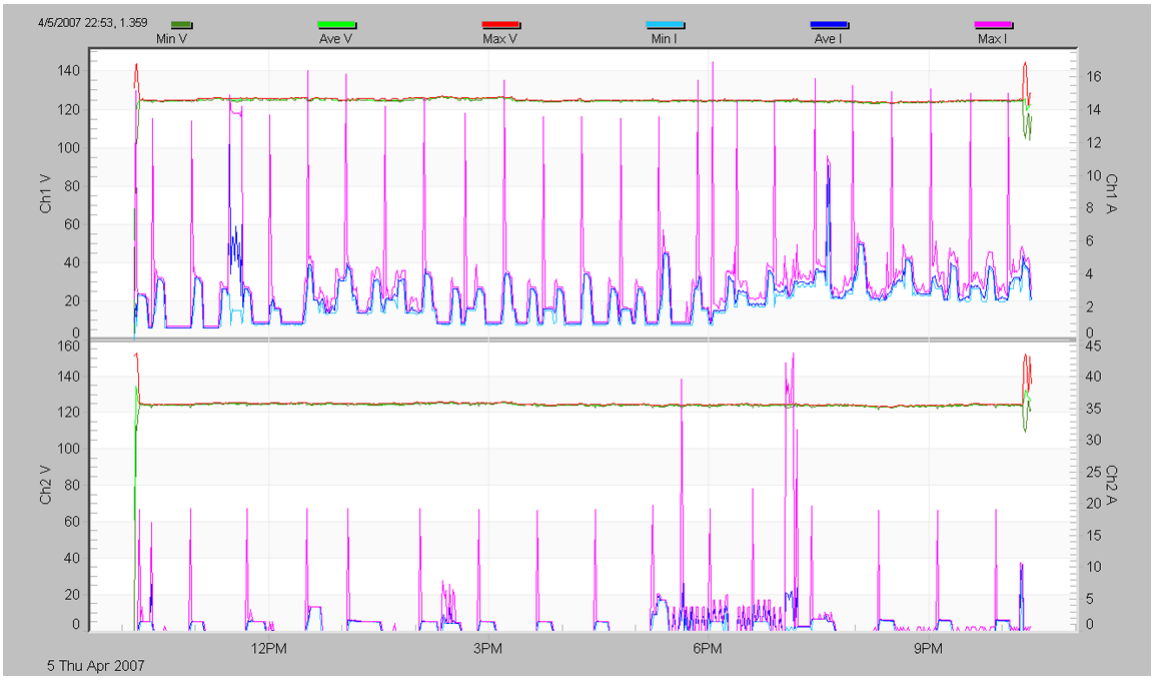


*Figure 6. RMS voltage and current stripchart*

## CONCLUSION

Loose Neutrals can cause higher and lower than normal voltages and can sometimes damage electrical and electronic equipment when load imbalances are large. Loose Neutrals need to be detected and repaired quickly to minimized property damage.

Changes in light intensity can be a warning sign of a loose neutral. Light intensity changes can also be caused by other electrical issues, such as a power line regulator or changes in large loads in a small amount of time. PMI's Provision Loose Neutral Report is an excellent way of verifying and identifying loose neutral connection so the loose or open neutrals can be repaired as soon as possible.

When one voltage leg increases in voltage at the same time the other leg decreases in voltage while the sum stays close to twice the nominal voltage, this is a sure sign of a loose or open neutral connection. Provision's Loose Neutral Report is especially designed to trigger on a loose neutral condition and clearly point out and record the voltage changes from each leg to neutral, and leg to leg allowing the operator to be able analyze the extent of the loose neutral condition.

Cowles Andrus, III
Communications Specialist
candrus@powermonitors.com
http://www.powermonitors.com
(800) 296-4120

*Figure 7. Loose Neutral Graph (zoomed in)*