Automatic Detection of Discontinuities in An Electrical Distribution System

Preface

Continuous, stable distribution of the electrical energy supplied to an electrical circuit is important for the proper operation of many circuit. This stability relies on the capabilities of the power-source – utility power-station, local generator or other power sources. The physical condition of the electrical distribution system in a circuit also affects the quality of the electrical-power supplied to the loads at that circuit. Usually, the electrical distribution system is composed of wiring, connectors, contactors, protection devices and a panel box. This panel box is also known as load center or fuse box.

Each of the elements of the electrical distribution system is assumed to be free of any defect when it is installed in a circuit. However, these elements are subject to degradation due to several causes. Among these causes are:

- Vibration of appliances,
- Bad contacts,
- Over-heating of cables or contacts,
- Loose connections,
- Mechanical breaks.

The method introduced in this application note enables detection of distribution faults in the electrical wiring – faults that are not detected by existing electricity monitoring devices. Deployment of this development will increase the safety and efficiency of electrical usage.

With the emerging "Internet of Things" (IoT) concepts – the ability of an appliance to detect electrical-distribution problems fully integrates with this approach.

Isra-Juk Electronics have developed several innovative technologies in the area of detecting electrical faults in an electrical system. This application note focuses on the detection of electrical failures related to discontinuities. The other developments will be covered in other application notes.

The importance of detecting and locating wiring discontinuities

Many severe electrical faults start as intermittent, rarely occurring, discontinuities of the electrical power at one or more loads. As the time interval between these occurrences becomes shorter and shorter, the distribution faults are more and more felt. As the fault becomes severe, distribution faults can lead to hazards of electrocution, electrical fires and to malfunction of electrical equipment.

Detecting the occurrence of discontinuities and providing information about their location is the goal of the development introduced here. This information can help in fixing the electrical system at an early stage of fault formation and thus prevent distribution faults from becoming severe.

Types of distribution faults

Distribution faults of the electrical distribution system can be of various durations - from sub-AC-cycle to hours and days.

Distribution faults can occur as changes in the voltage, the electrical current or both. Voltage changes can be over voltage, under voltage or other changes in the voltage pattern. The effect of distribution faults on the current in the circuit is usually seen as a sudden stop of the current and an immediate renewal of the current in the circuit.

Capabilities of existing equipment

Existing equipment detects distribution faults only when they become severe and may cause an immediate safety hazard. Fuses and circuit breakers cannot detect momentary discontinuities on the voltage or the current. The newly introduced AFCI (Arc-Fault Circuit Interrupter) detects parallel arcing, but cannot detect serial arcing. None of these devices can detect momentary separation in a wire or a contact.

The developments introduced by Isra-Juk Electronics

The development introduced by Isra-Juk Electronics is based on learning the patterns of the voltage and / or the current at a point in the electrical distribution system and analyzing changes from these patterns. A momentary change in the voltage followed by a return to the same voltage pattern is probably an indication of a momentary discontinuity in the wiring, or is an indication of a problem in the electrical power that enters the circuit. Concurrent analysis of the electrical current enables distinguishing between changes caused by activation or de-activation of an electrical load and changes caused by discontinuities in the wiring. Figure 1 depicts examples of discontinuities-waveforms that Isra-Juk's development would detect. Such discontinuities are not detected by existing equipment.

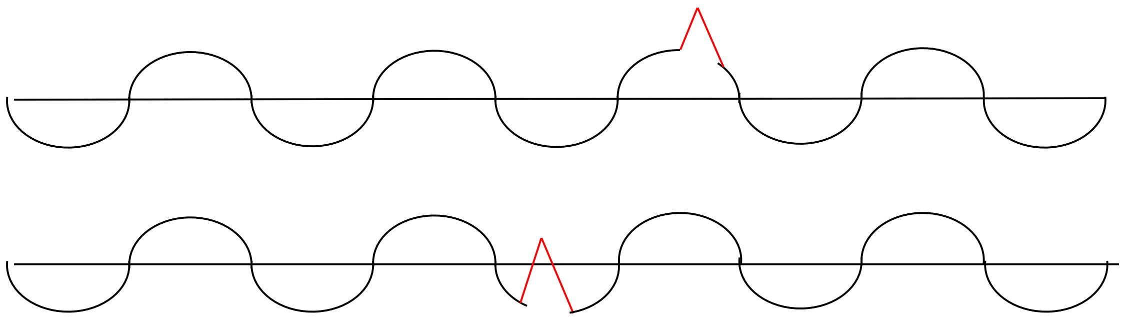

Figure 1: Examples of electrical discontinuities

The waveforms at figure 1 are examples of voltage-deviations in an AC system. While the upper waveform can be detected by sensing an over-voltage indication, the lower waveform cannot be detected by over- or under-voltage detection methods because it is inside the acceptable values. The lower waveform will be detected by the development introduced here – by learning the voltage-pattern and detecting deviations from that pattern.

Preferably, the processing required to detect these electrical faults will be performed by sensing-units that will be included in appliances. Another way of use is by portable devices – for professional use of electricians, for example.

The importance of gathering time-information about distribution faults

For enabling better fault location, it is important to have information about the time in which an electrical distribution fault occurred at a sensing unit. Analysis of this time-domain information that will be gathered from appliances and other loads in the system will help in locating the place of the distribution fault. Simultaneous occurrence of distribution faults at all sensing units in a facility indicates a distribution fault in the common part of the power line. Occurrence of a distribution fault in a single sensing unit will usually indicate a fault in the branch of the wiring that is specific to that sensing unit. Identical time-of-fault information from all sensing devices in a system will indicate a failure at a point common to all sensing units. Different indications at different locations will indicate occurrence of several discontinuity events. Therefore, the information provided by the sensing unit that will detect the fault, will include time related information. To simplify time synchronization, the timing information will indicate the time elapsed since the discontinuity occurred. Thus, the sensing unit does not need to receive time-of-day information from any control system. This enables the sensing unit to work as a stand-alone unit, in addition to its ability to work as part of a connected system.

Description of the discontinuity logic

The discontinuity logic finds occurrences of discontinuity in the voltage at the point where the voltage is sensed.

Reading discontinuity values

The value read from the continuity sensors indicates the time that elapsed since a power-discontinuity occurred at each of the discontinuity sensors. This enables backwards-analysis of the events at the facility that led to the discontinuity.

The preferred monitoring method is done by collecting continuity-values from the sensors at the facility to a central control-unit. In a simple implementation, analysis is done by a person that notices the restarting that occurs. In an automated system, analysis is done by software.

Analysis of reading

Analysis of the continuity readings is based on the values present at the monitoring unit.

Several scenarios are possible:

Common discontinuity – all sensors restart: This means that there is a continuity problem in the common part of the electrical wiring at the facility.

Partial discontinuity – some sensors restart: This means that there is a continuity problem in the part of the electrical wiring that is common to the sensors that has discontinuity issues.

Single discontinuity – one sensor restarts: This means that there is a continuity problem in the electrical wiring specific to the sensor that reports occurrence of discontinuity.

The basic idea is to set a counter in each sensing device – that will restart every time when there are AC-power discontinues on that sensing data. A counting-restart at one sensing unit, while other keep counting – indicates continuity-problems on the conduction of power to that unit.

An example of counter-restarting that helps in analyzing discontinuity events is depicted in the flowing drawing:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
0 1 2 3 4 0 1 2 3 0 1 2 3 4 0 1 2 3 4 5 6 0 1 2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 2: Example of counting results

The digits are counting results gathered over time from several sensing units
- To a central monitoring unit.

The numbers in red – indicate counting-restart – which means
Problems of continuity on the wiring to the sensing unit.

Availability

The Embedded-Electrician™ is a digital IP block that can detect electrical fault conditions not detectable by existing electricity monitoring equipment. The worldwide patented Embedded-Electrician™ IP is now available as a VHDL design. To license this block please contact Isra-Juk Electronics.

Ways of use

The technology introduced here can be used in many configurations:

- Inside appliances,
- In home-control systems,
- In professional equipment for electricians,
- In industrial equipment and more.

Revision Info

Version number	Date	Changes	Comments
0.1	05-Nov-14	Initial Draft	
0.2	17-Nov-14	File name corrected	
0.3	26-Feb-17	Updated figures, added text	

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