Appliances Can Detect Voltage Drop Issues on the Wiring in an Electrical Set-up

Preface

In an ideal electrical set-up, all of the electrical energy supplied at the entry point will reach their loads. As no electrical circuit is ideal, some of the voltage supplied will reduce due to the wiring and connectors that conduct the electrical energy from the entry of the circuit, to the loads. **This voltage drop introduces issues of safety and efficiency.** Modern electrical distribution systems control several parameters of the distribution such as power factor and harmonics. However, the voltage-drop is not controlled by these systems.

Bearing in mind that "You cannot control what you do not measure" raises the need for an in-system voltage-drop measurement. A novel, patented development from Isra-Juk Electronics Ltd. introduces a solution for measuring voltage-drop in an electrical set-up during the normal usage. The purpose of this application note is to describe this method and how to use it.

The method introduced here enables appliances to detect voltage-drop problems in the electricity supplied to them. As it becomes a machine task instead of a human task – it can be performed continually and for long periods of time. **This technology will enable detection of glowing connections on the wiring.** This will increase the safety and efficiency of the electrical usage.

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

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

Voltage drop Definition

The term "voltage drop" in this application note refers to the voltage that drops due to the wiring, connectors and contacts that conduct electrical power from the entry point of the set-up to an electrical load.

The term "voltage drop" sometime refers to a fall in the power supplied to a circuit from utilities or from local sources, in which there is a step-down in the amplitude of the voltage that enters the circuit. To avoid confusion, it is now common to call such a supply change in the name "Voltage Sag" in American English and "Voltage Dip" in British English.

Electricity regulations worldwide also use the term "Voltage Drop" when referring to the voltage that is wasted on the wiring system in a circuit between the entry point (known as panel-box or load-center) and the actual loads.

Misleading voltage drop metering, using volt-metering comparison

A simple method for measuring voltage-drop at a point close to an electrical load is to measure the voltage at that point with a voltmeter when the electrical load is inactive, and then activate the load and measure the voltage at that point again. According to this method, the voltage drop value is obtained by dividing the difference between the two values, by the voltage measured with no load connected. This method is misleading because it does not take into account the phase offset of the voltage at the load, which is significant when the load is inductive or capacitive. The measuring with just a voltmeter will show lower voltage drop values than the values that will be obtained by using the method introduced by Isra-Juk. This means that it may happen that the lower voltage drop values shown will hide an actual electrical problem of voltage drop on the wiring.

Some professional testing tools measure voltage drop by loading the wiring with a known, resistive load for a short time and computing the voltage drop percentage as the result of dividing the delta of the voltage readouts by the unloaded voltage value. As mentioned above, this method is misleading.

The importance of in-system measuring of voltage drop

Existing protection devices used in electrical installations are not aware of the voltage drop on the line to the load. These devices, like the fuse and the circuit breaker monitor the current that flows through them. They physically cannot be aware of the voltages across the wiring and the loads in the circuit.

As stated above, this voltage drop introduces issues of safety and efficiency. Safety issues result from heating of wiring and connectors. Excessive resistance causes them to dissipate power and increase their temperature and as a result, isolation of wiring melts and electrical fires ignite.

Excessive voltage drop on wiring is also an efficiency issue. The voltage that drops on the wiring was planned to reach the load. As the load receives a lower voltage that it was planned to, it works less efficiently.

Voltage drop in regulations

There are regulations about voltage drop in many countries. Here are several examples:

In the US: National Electrical Code (NEC) Articles 210-19(a) FPN No. 4 and 215-2(d) FPN No. 2 state in part, "...and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5%"

IN EUROPE: IEC 364 states: “the nominal maximum acceptable voltage drop specified by the IEE Regulations is 2.5% of the system voltage”.

IN BRITAIN: BS 7671, section 525 provides the requirements for voltage drop – to not exceed 4 % of the nominal voltage of the supply.

Present Effect of Regulations

The regulations are taken care of when setting the wiring in a circuit. These requirements are taken into account during the **design** of an electrical network. Compliance with the regulations is not tested during its active life, in which the wiring is in use. This can be tens of years later.

There are lots of "voltage-drop calculators" used during the wiring design phase to determine required wire gauge.

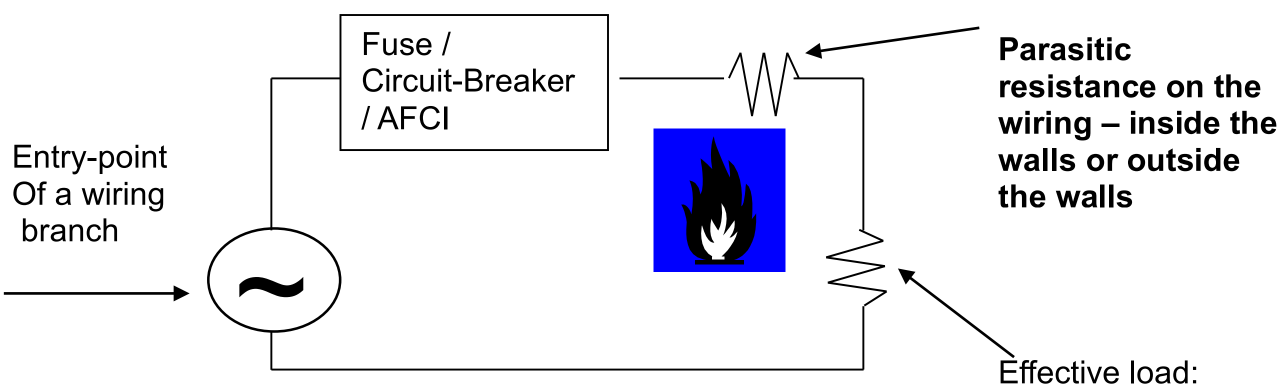
Note: the ± 10 % swing allowed for the utilities hides the wiring voltage drop. Merely checking the voltage at the appliance-input is not enough.

Some test tools designed for use by professional electricians perform a voltage drop measurement when connected to a wall outlet and activated. These test tools load the electrical system with a known resistive load and measure the voltage drop that occurs when this load is connected. But these tools are not planned to be continually connected and functioning.

Technical explanation of real-time voltage-drop measurement

Figure 1 depicts a schematic of a branch in wiring of an electrical facility:

Voltage on the effective load is reduced by the voltage-divider
Formed by the parasitic-load being in series with the effective load



Parasitic resistance is caused by corrosion, micro-arcing and carbonization of contacts.
This condition – excessive voltage drop on the wiring -cannot be detected by fuses, circuit-breakers or AFCI's.
It leads to the fault known as a "glowing connection".

Figure 1: **Schematic of a branch in a wiring of an electrical facility**

In an ideal electrical system, the voltage at the entry to the facility will be identical to the voltage at the load. But, as the wiring and conductors between the entry point and the load has a non-zero resistance – Rp, the momentary voltage at the load will be therefore:

(1) Vload = Vin(t) – Rp(t)*I(t)

Where:

Vin(t) is the voltage at the input to the branch, at time t,

Rp(t) is the parasitic resistance of the wiring and connectors, at time t,

I(t) is the current in the circuit, at time t, not necessarily in phase with the input voltage

Vload(t) is the voltage across the load, at time t,

When I(t) is 0 – then Vload = Vin(t). This enables a sensing unit located close to the load, or even inside the load, to learn the input voltage. When the load starts consuming power – the voltage at the load will differ from the input voltage. The difference between the input voltage and the voltage at the load – is the voltage-drop on the wiring and contacts. This is depicted in figure 2. The sensing-unit introduced here – reconstructs the expected Vin and computes the voltage-drop percentage. This ratio is defined by the following formula:

(2) Voltage-Drop = ∑ (| (Vin(t) – Vload(t)) |) / ∑ (| (Vin(t)|)

The Voltage-Drop is computed for each AC cycle.

Voltage drop on wiring - consumption

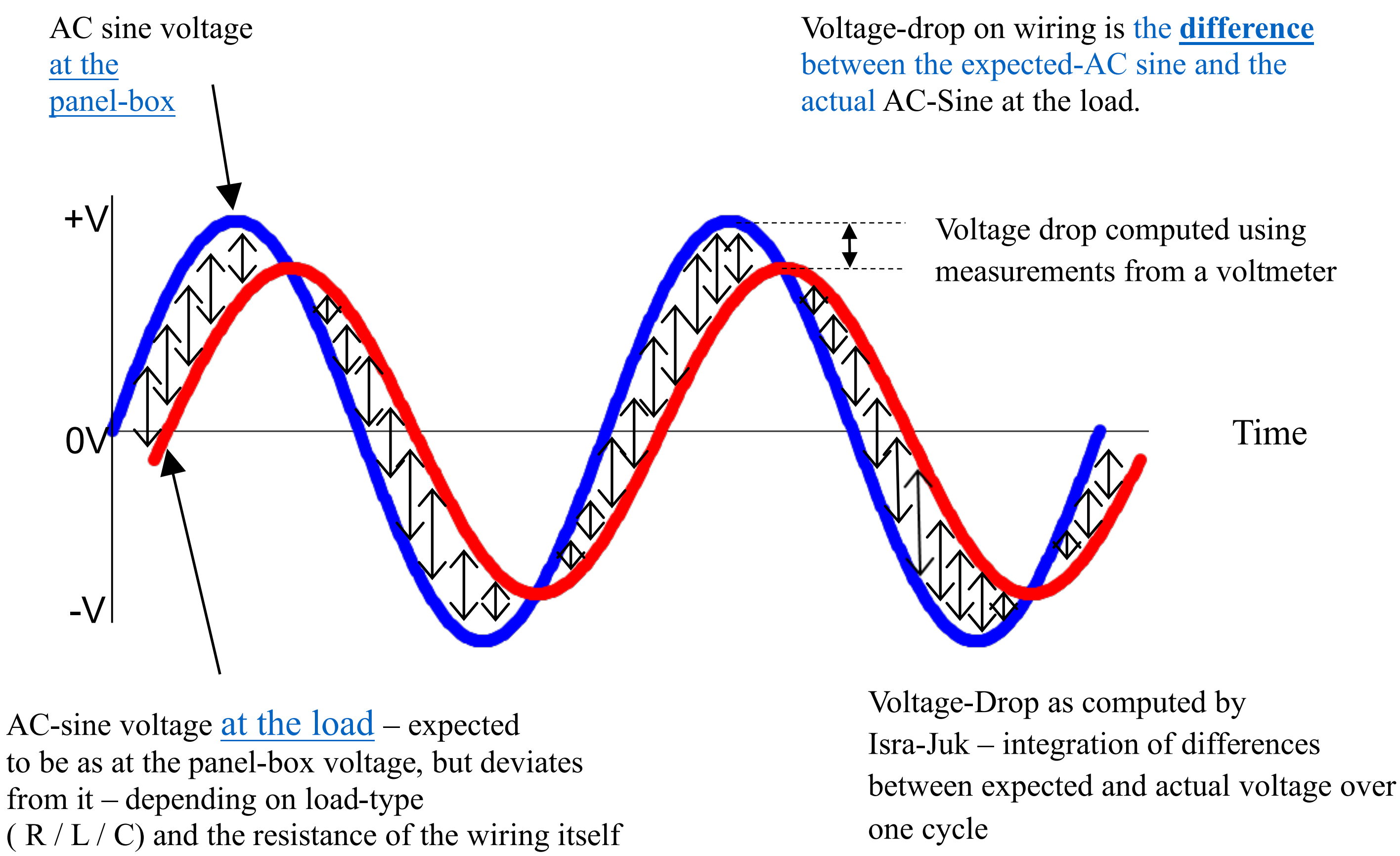


Figure 2: **Vin vs. Vload waveform in an electrical facility**

The AC sine voltage at the load is expected to be as it is at the panel-box. Actually the voltage at the load deviates from the voltage at the panel box depending on network-type (R / L / C) and the resistance of the wiring itself.
Figure 2 may seem similar to Cosine-Phi power-factor waveforms. However, in Cosine-Phi waveforms – the phase difference is between the voltage and the current at a specific point in the electrical circuit. This is due to the capacitive / inductive behavior of the load. However, figure 2 depicts two voltage waveforms. The light-blue waveform relates to the voltage at the entry-point of an electrical facility. The dark-blue waveform relates to the voltage present at the load. With a purely-resistive load – there is no phase-difference between the two waveforms.

Voltage drop problems are felt in 100V-110V systems much more that in 220V-240V. This is because in the 110V systems – the current in a branch is double than the current in the 220V systems for the same power. P = V * I, So when V is halved, I must be doubled for the same P. Since the power dissipated by a resistor is I^2 * R, doubled I will mean *4 power dissipation on a resistor for the same R. Hence, if a resistor of R ohms ignites an electrical-fire on a 220V network, a resistor of R / 4 ohms will ignite an electrical-fire on a 110V network. As degradation of contacts causes their resistance to increase over time – on a 110V network the contacts reach the resistance required for electrical-fire ignition – long before it happens on a 220V network. This 110V / 220V difference explains why electrical fires are more common in 110V networks.

Advantages of real-time voltage-drop measurement

The method introduced here is the only way to continuously determine voltage drop thru regular network usage. The measurement is performed automatically, without a need for human intervention. Thus, formation of fire conditions can be detected long before an electrical fire actually exists.

This method also enables the detection of energy-waste on the wiring. Voltage-drop on the wiring – means waste of energy, as the electrical energy that heats the wiring – was planned to be used for other purposes. Waste of a few percent of the energy – when accumulated over many cycles of operation of the appliances – sums-up to a significant amount of lost energy.

This technology can help electricians, firemen and home-owners with locating faults in the wiring. It will minimize the cases in which people find themselves smelling the smell of an electrical fire, but cannot locate it.

Information obtained from voltage drop analysis – stand-alone appliance

The following information can be obtained by a sensing unit that implements this technology, without connection to any other sensing device:

a) Voltage drop at the present and previous AC cycles,
b) Resistance of the wiring – obtained by computing:
(3) Resistance of the wiring = momentary-voltage-drop / momentary current

Constant resistance of the wiring over time – indicates a good wiring condition. Increase in wiring-resistance when the load starts drawing electrical current – is, in many cases, **an indication of a glowing-connection**. This is because the copper, of which most wiring and contacts are made, has a positive thermal-resistance coefficient. This means that the resistance of the wiring increases with the rise of its temperature.

Information obtained from voltage drop analysis – Connected appliances

With connected appliances several working modes are available:

- Centralized control: The voltage-drop information from all sensing units in the facility will be collected by a central control-unit. Sensing units will have minimal processing capabilities.
- Distributed control: All sensing units will receive the data from other devices and perform the analysis of the data gathered.

Interchange of information between the devices in the facility - enables distinguishing between issues of voltage-drop on the wiring at specific locations – and changes in the voltage supplied by the utility. This will reduce the occurrence of false alarms.

Long-Term Voltage drop Analysis

Many appliances in a modern house are connected using fixed wiring, for periods of years. The wiring through which these appliances are connected is never, or rarely, checked. Examples of this are a refrigerator, dishwasher, washing machine and clothes dryer. When they are installed their electrical connection is hidden within them, and never checked.

The following graph illustrates typical voltage-drop problem development over time. The voltage drop on the wiring increases gradually, very slowly for many years. But when a specific point in the wiring becomes more and more resistive, the power it dissipates grows, and a danger of electrical fire arises. Existing protection devices like circuit-breakers detect the problem when the wiring isolation melts and short-circuit is formed. According to official American publications, this happens about 80 mSec before electrical fires actually ignites. The newly introduced AFCI devices, according to the same sources, ought to detect melting of the wiring isolation 200 mSec before ignition of electrical fires. A "smell of electrical fire" is known to many of those who live in wooden houses – as many US residents to. It is also known to electricians and firemen.

Deployment of this development in home-automation systems will enable continuous electrical-inspection of the electrical system. This will help in reducing damages due to electrical faults and long-term energy-waste of voltage that drops on the conducting part of an electrical facility.

Availability

The in-system voltage drop-measurement method introduced in this application note is patented worldwide.

Isra-Juk now offers code of a VHDL block that implements the voltage drop measurement. This block receives voltage and current measurements and computes the voltage drop on the monitored line. The code is technology independent so it can be used in an FPGA or an ASIC.

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
0.2	02-Nov-14	Initial Draft
0.3	08-Jun-16	Added explanation about Misleading voltage-drop metering using volt-metering comparison. Updated figure 2.
0.4	16-Feb-17	Updated figure 2, new layout
0.5	22-Feb-17	Updated figure 1

Contact Information

Web: www.isra-juk.com

E-mail: isra-juk@zahav.net.il

Isra-Juk Electronics Ltd.
48 Hanesi'im st.
4955052 Petach-Tikva
Israel