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A PROPOSAL FOR VERIFYING THE PERFORMANCE SPECIFICATIONS OF CERTAIN FUNCTIONS OF SMART METERS IN DISTRIBUTION POWER LINE NETWORKS

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Abstract

Several proposed methods for verifying the performance specifications of certain functions for power line communications and dynamic measurements of smart meters in distribution power line networks are discussed. These functions must meet the performance requirements of advanced metering infrastructure (AMI) for applications in a smart grid system.

Introduction

AMI or Smart Meter and Demand Response (DR) as well as advanced system automation are core enabling technologies for Smart Grid. New important functions have been incorporated in meters as part of AMI for applications in a smart grid system. In the current grid system, communication to the meters is either none or one way only. In distribution power line networks of a smart grid, two-way or multi-layer communications are essential requirements for power line communication (PLC). Some guides/standards have been published [1, 2], in which the power line channel specification has been given. However, they are generally applicable to PLC networks in North America, and not necessarily applicable to PLC networks in grid systems of other countries, such as in China. Nevertheless, it would still be important to verify its meter PLC function. Especially, since a new measurement function has been introduced. The meters should now have a dynamic measurement function. At present, there is not yet a proper method for verifying this function.

A proposal to verify the dynamic measurement function and PLC functions of smart meters will be presented. For the PLC function, the proposal will focus on two aspects, that is, the impedance variation and the noise disturbance in the distribution power line network [3].

Dynamic Measurement Function

The dynamic measurement function is required to facilitate interconnection and management of distributed energy resources, such as, plug-in hybrid electric vehicles, solar cell application, etc., where the current drawn will not be stable or even continuously in dynamic/transient condition. The test methods as described in IEC standards and other national/international guides/standards are for performance verification under stable/static condition. The dynamic test would verify the proper required response time, including proper selecting time to determine software compensating parameters according to meter measurement ranges or power factors.

Consider a dynamic current waveform with a sine wave envelope current signal, as shown in Figure 1.

$i = 10\sqrt{2}(0.5 + \sin(2\pi ft/10))\sin(2\pi ft)$.

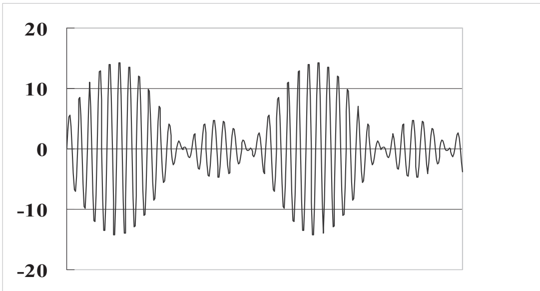

Figure 1. Dynamic test current waveform

It is basically a modulated sine wave, in which its rms value is changing from 5 A to 15 A within a short time interval (range and the time interval can be controlled). Such a current signal with a test voltage of $220\sqrt{2}\sin(2\pi ft)$ can be used to check the dynamic response of the meter. Its advantage is that the active power will be 5 A*220 V=1100 W. The current waveform contains 3 frequency components: $f, {}^{9}\!/_{10}f, {}^{11}\!/_{10}f$, in which only the component of f can produce active power. Its disadvantage is that the meter under test may always work at only one range of 20 A. To check and verify possible problems arising from not having a proper response time, or possible errors due to a change in the measurement range, a trapezoidal current waveform envelope can be used with a proper long time interval at a certain range and a linear variation between two ranges as the test waveform.

PLC Function

1. To address the PLC function that minimizes the effect for the carried signal arising from the load impedance variations/changes in the distribution power line network, an **impedance variation test** can be designed to verify the function. In [1, 2] the equivalent

load is simply a capacitor of 1 μF in series with a resistor of 1 Ω. At power frequencies, it has a relatively high equivalent impedance to allow this test to be done with the distribution power line network voltage directly applied to the meter. To achieve the same objective, it is proposed to use a standard power source with a test circuit as shown in Figure 2. The source output signals, normal voltage and basic current, are connected to the meter under test. The equivalent impedance of the load is connected in series to the current loop. Thus, at power frequencies, the loading effect to the source is practically negligible. The tuned receiver can measure the sensitivity, or the same type of meter under test can be as the receiver. The Isolation Networks minimize the impact of test frequency to the source.

2. The meter should also be subjected to a **noise disturbance** test, as shown in Figure 3. In addition to performing tests using all the noise components as per [1,2], which are basically in the form of white noise, other noise disturbance forms would need to be also considered, such as non-uniform and unstable forms. A proposal to include some tests of EMC will be further investigated. The meters are also subjected to EMC disturbances in the distribution power line networks. The EMC frequency spectrum is wide and will cover the frequency range of the carried signals. The equivalent impedance of the power line networks should include consideration that it would also be subjected to an EMC disturbance test, as shown in Figure 3. The equivalence impedance is connected in parallel to the voltage loop and the signal-to-noise ratio is measured by the receiver. Due to the wide application of new electronic products that could introduce higher levels of disturbances in the distribution power line networks than as per [1, 2], a new survey/study would be recommended.

The aforementioned two equivalent impedances, either for the load or the power line, need to be further investigated to better reflect the actual practical situation. It should provide the proper relationship between the equivalent impedance and the length of the corresponding transmission network. This data obtained from the meter would allow determination of the corresponding transmission distance, through the proposed test using either a toy brick structure or a resistor box structure simulating the equivalent impedance.

For PLC purposes, a standard text message should be incorporated as part of the PLC function which would reflect considerations of all possible cases. This standard text message could also be used to verify at any time the proper function of the communication channel.

Conclusion

New approaches for verifying the performance specifications of PLC and dynamic measurement functions of smart meters as part of AMI are proposed. Further investigations and study will be required.

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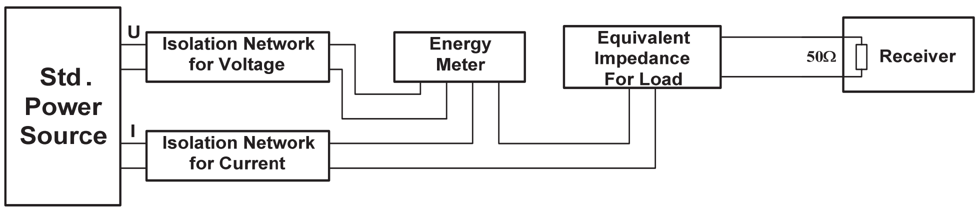

Figure 2. Impedance variation test

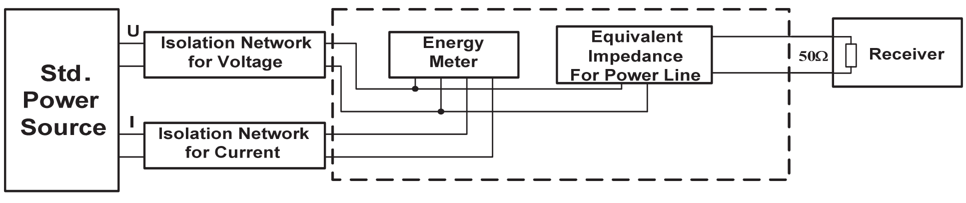

Figure 3. Noise disturbance test