A testing method proposal to improve the reliability of lifetime tests applied on electricity meters

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Resumo: Medidores de eletricidade são equipamentos responsáveis pela função de faturamento, por isso são considerados elementos críticos de um smart grid e são projetados para ter alta confiabilidade e longa vida útil em condições normais de operação. Existem padrões estabelecidos que descrevem os testes de vida acelerada e que estimam as características de vida de um produto. Neste sentido, este artigo apresenta um estudo sobre a aplicação destes testes, destacando os principais elementos que os influenciam. O estudo conclui com uma proposta para um modelo de teste de vida acelerado que visa melhorar a confiabilidade, adicionando evidências, aos testes executados.

Palavras-chaves: Medidor de energia elétrica; Teste de vida útil de medidores de energia; confiabilidade de teste.

Abstract: Electricity meters are devices responsible for the billing function, so they are considered critical elements of a smart grid and are designed to have high reliability and long service life under normal operating conditions. There are established standards that describe accelerated life tests and the life characteristics of a product. In this sense, this article presents a study on the application of these tests, highlighting the main elements that influence them. The study concludes with a proposal for an accelerated life test model that aims to improve the reliability, adding evidence, to the tests performed.

Keywords: Electricity meter; Electricity meters accelerated life testing; Testing reliability.

1. INTRODUCTION

Accelerated life testing (ADT) consists in experiments which are applied in an equipment some levels of stress with the objective to exceed the normal and established parameters, forcing the product to present failures sooner than if it was in normal conditions of operation. The applied stress is the acceleration factor (AF) that the product will be submitted.

A lifetime reliability test aims to estimate equipment's life through analysis of failures during the tests [1]. Accelerated life testing has emerged with the need to evaluate the reliability of devices and systems. Electronic energy meters are equipment that are subjected to lifetime tests, the main accelerating agents are: temperature, humidity, voltage and current. Some other agents such as vibration and dust are ignored during the accelerated life test because they do not significantly influence the lifetime of the equipment [2].

The life expectancy of an equipment can be estimated in several manners, among the main methods are the tests of high and low temperature, mechanical shock, high humidity, high voltages, among others. [3].

The exigency of lifetime estimative in electronic energy meters is becoming highly present in the Brazilian market. With the objective to study the equipment characteristics and behavior along its lifetime, the accelerated life test is used by most of the energy distributors in Brazil to evaluate the electronic energy meters [2]. The Brazilian regulation ABNT NBR 16078:2012 says that this test simulates 13 years.

This study is the result of theoretical and practical researches carried out by engineers of Eletra Energy Solutions, an electronic energy meter manufacturer, during accelerated life testing methods applied to electronic energy meters. The objective of this article is to point out possible failures in currently lifetime tests and propose a test procedure that eliminate uncertainty variables, extinguish unwanted or unforeseen correlations between accelerator factors, and also add evidences of parallel tests which increases the test reliability.

2. AGENTS OF LIFETIME TESTS IN ELECTRONIC ENERGY METERS

Many agents determine the results of the accelerated life tests in electronic energy meters. Several mathematic models describe the relationship between an equipment and an agent. The mathematic basis that defines a degradation process needs the following information [4]:

a) A function of parameter change according to its objective.
b) A function that defines the percentage between the change of a parameter and a determined level of an acceleration agent.

Models that take into account more than one acceleration agent are notoriously more complex when compared to models that evaluate agents individually [3]. Evidences of the correlation between the group interference and the agents are usually obtained by empirical methods. [1]. The most suitable model to the accelerated life test, as shown in the Brazilian regulation ABNT NBR 16078:2012, is the Peck model, which its main objective is to model either humidity and stress temperature. The Peck model is expressed by the equation (1):

$$AF = \left(\frac{RHu}{RHs}\right)^{-n} e^{\frac{Ea}{k}\left(\frac{1}{Tu} - \frac{1}{Ts}\right)} \tag{1}$$

Where RH_u and RHs are the percentage of relative humidity under normal conditions and stressed conditions, respectively; n is the characteristic constant of the humidity agent; T_u and T_s are the absolute temperature in Kelvin (K) under normal conditions of use and stressed conditions of use; E_a is the activation energy in eletron-volts; k is the *Boltzman* constant.

3. METHODOLOGY

The test method proposed in this paper consists in to accomplish tests combined with agents that influence in the meter aging. Aging the equipment the same time period, but with different setups. In this proposal, the chosen agents were temperature and humidity. The method consists in two steps:

- **Isolated agents test:** In this step, the test must be accomplished with the individual influence of each agent.
- **Correlation test between agents:** In this step the tests are applied considering all the involved agents, but attenuating one of them.

The testing method can be divided in two types: complete and optimized.

- **Complete:** The tests are applied with variation of agents with all the severity degree combinations.

- **Optimized:** Tests are applied with the severity degree combinations that better define the meter lifetime characteristics in the most optimized way, aiming in a shorter time and greatest benefit.

Once that the post-test data collect has been made, it is mandatory that all the tests present equal results, once that the acceleration time is the same for all. Any discrepant result points to the existence of some failure in the test procedure, whether at the proposed mathematic model or at the proof sampling or even so to the bad definition of agents and their respective severities.

The tables 1 and 2 describe the procedures to optimized and complete tests, considering tests with the isolated agent and with multiple agents.

Table 1. Optimized test

Isolated Agent	**Degrees of severity**	
	Temperature	**Humidity**
Test 1	High	Normal Conditions
Test 2	Normal Conditions	High
Test 3	High	High
Multiple Agents	**Degrees of severity**	
	Temperature	**Humidity**
Test 4	High	Attenuated
Test 5	Attenuated	High

Table 2. Complete Test

Isolated Agent	**Degrees of severity**	
	Temperature	**Humidity**
Test 1	Attenuated	Normal Conditions
Test 2	High	Normal Conditions
Test 3	Variant	Normal Conditions
Test 4	Normal Conditions	Attenuated
Test 5	Normal Conditions	High
Test 6	Normal Conditions	Variant
Multiple Agents	**Degrees of severity**	
	Temperature	**Humidity**
Test 7	High	Attenuated
Test 8	Attenuated	High
Test 9	Attenuated	Attenuated

From this new test methodology it is possible to accomplish a more concise analysis of the tests procedure, once that the results will present information about the isolated influence of the agents, the interrelation between agents and most importantly, they will eliminate fake positives or negatives resulting from one single incorrect test setup [5]. In the accelerated degradation test the more of the degradation data, the higher accuracy of the accelerated function it is obtained [1]. Therefore, applying the electronic meters to different accelerating factors in different ADT tests will improve the prediction of the meter during its lifetime. The ability to calculate the acceleration factor is critical to the development of an efficient test plan adequately reflecting the field level stress conditions [6]. The Acceleration Factor (AF) relationship with reliability function can be calculated by the equation (2).

$$R_{Field} = R_{Test}\left(\frac{t}{AF}\right) \qquad (2)$$

Through the combination of multiple R_{Test}, we can improve the estimation of the ADT reliability of smart meters. The figure 1 illustrates the relationship between the accelerating factor (AF) and the meter reliability.

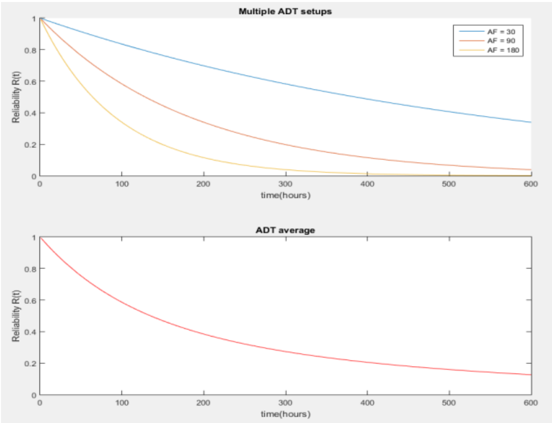

Figure 1. Graphs to illustrate the relationship between the acceleration factor and the reliability for different setup of acceleration life testing (ADT).

4. CONCLUSION

The test method proposed in this paper is a test procedure that has the potential to improve the accelerated life tests reliability in electronic energy meters as it is defined by the Brazilian regulation ABNT NBR 6078:2012. From this new method it is possible to evaluate more precisely the data about the lifetime of the equipment, through the realization of tests variation that intensifies the evaluation of isolated agents in extreme conditions.

The combination of isolated tests application of high severity degree in a specific agent contributes with the tests currently applied, where it is evaluated more than one agent in group. As future work for this research, will be made tests procedures in meters to evaluate the impact in the lifetime analysis using the proposed methodology in comparison with the methods currently applied.

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