Aspects of metrology and statement of conformity in the asset management of electric power utilities

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Abstract. This paper presents the main concepts of Metrology and how they can impact activities related to the management of assets of an electric power utility, such as transformers and transmission lines. Examples of decision making related to predictive maintenance, which involve tests and measurements of critical parameters, are shown. The lack of observation of certain metrological concepts or requirements can seriously compromise the correct conformity assessment and decision making.

1. Introduction

Asset Management has the benefits, among others, of improving efficiency and reducing costs and losses. The ISO 55000 series of standards provide requirements and guidance for implementing and maintaining an effective asset management system. In the case of electricity transmission and generation companies, asset management involves the operation and maintenance (O&M) of large equipment, such as generators, transformers and reactors, with preventive and predictive actions. In maintenance, decision-making includes evaluating data after carrying out tests, the results of which must have quality and reliability, providing equally reliable decisions. This scenario becomes even more challenging as the useful life of the equipment park advances, so maintenance is of paramount importance to guarantee the supply of electricity and even to avoid catastrophic failures.

To obtain reliable results in tests and measurements, one must obey, among other points, the requirements of Metrology: the use of inadequate or uncalibrated test instruments, the underestimation of the measurement uncertainty and the disregard of risks and their occurrence probabilities, among other inappropriate practices, can compromise the correct decision-making.

This paper presents some situations in which Metrology requirements must be used to guarantee the reliability of the asset management system of an electric power concessionaire. Section 2 presents the main assets of an electric utility company, and how to manage them through predictive maintenance. Section 3 describes the main concepts of metrology and conformity assessment to understand this work. Section 4 presents two examples of how metrology can help guarantee the reliability of decision-making based on test and measurement results associated with predictive maintenance and asset management at the concessionaire. Finally, Section 5 presents some conclusions.

2. Asset management in the electric system

In the model of the Brazilian electrical system, the assets of a company providing transmission services or electricity generation are composed of large equipments, such as generators, transformers and reactors, and transmission lines. The Allowed Annual Revenue (RAP) is the remuneration that transmission companies receive for making assets available to the National Electric System Operator and providing the public transmission service to users. The RAP is defined when the service is granted. Monthly, the transmission company receives an amount corresponding to 1 (one) twelfth of the RAP for services provided, minus the value of penalties calculated on the assessment of the quality of the service provided [1].

It can be seen in this model that to maximize the revenue earned, equipment and lines must be kept available most of the time. This availability must be accompanied by quality and reliability. In this scenario, the importance of adopting predictive maintenance becomes evident, to the detriment of preventive maintenance as a way of optimizing the availability of assets. In predictive maintenance, also called condition-based maintenance, each asset is monitored individually, through the monitoring and measurement of various parameters and magnitudes, and in this way, it is possible to obtain the data and information necessary to assess the operating condition. actual asset. With this more reliable evaluation, it is possible to plan more efficiently the shutdown or unavailability of the asset for maintenance, minimizing the number of failures or breakdowns. Depending on the type of equipment or asset monitored, several predictive techniques can be used, such as: vibration analysis, thermography, ultrasound and analysis of insulating or lubricating oils [2],[3].

In the case of high voltage network equipment or assets, the parameters to be monitored for predictive maintenance purposes are defined by the Brazilian Regulatory Agency through a specific resolution. Mandatory inspections are the thermography of the substation and its components, every six months, and the analysis of the insulating oil of the equipment, with the physical-chemical analysis being carried out every twenty-four months and the analysis of dissolved gases every six months [4]. Thermographic inspections at substations and their equipment and lines are carried out by infrared cameras-type instruments, as shown in Figure 1. Its use allows, from the thermal image of the location that needs to be evaluated, together with a temperature scale, to analyze whether there is overheating at some points.

Figure 1. Infrared camera.

Electrical equipment at substations is insulated with oil, which acts as an electrical insulator and as a heat exchange fluid, which ensures proper operation of the equipment. Their physicochemical properties ensure that they can be used for that purpose and that the equipment operates safely. Through physical-chemical analysis, it is possible to assess whether the oil of certain equipment still has its properties under appropriate conditions. The analysis of gases dissolved in the oil makes it possible to identify defects inside this equipment.

3. Metrology and conformity assessment

Measurements carried out in inspections, tests and monitoring associated with predictive maintenance must produce data and information with adequate quality and reliability, to enable equally reliable decision-making. To ensure this reliability, Metrology requirements must be observed and obeyed.

Metrology is the science of measurement and its applications, encompassing all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application. Measurement presupposes a description of the quantity that is compatible with the intended use of a measurement result, under a measurement procedure, and with a calibrated measurement system that operates in accordance with the specified measurement procedure, including the measurement conditions. A calibration is an operation that establishes, under specified conditions, in a first step, a relationship between the measurement values and uncertainties provided by standards and the corresponding indications with the associated uncertainties; in a second step, it uses this information to establish a relationship in order to obtain a measurement result from an indication. This relationship between measurement results and standards is called traceability [5]. Every instrument, device or measurement system must be previously calibrated before being put into operation, and the results of this calibration must be critically analyzed, under penalty of not guaranteeing the reliability of the measurements produced. An important feature of measuring instruments is the maximum permissible error, or error limit, which corresponds to the extreme value of the measurement error. Instrument manufacturers often mistakenly refer to this term as “precision”, “accuracy” or other terms.

A measurement result shall be expressed by a single measured value and a measurement uncertainty. Measurement uncertainty is a non-negative parameter that characterizes the dispersion of values attributed to a measurand, based on the information used. The word uncertainty means doubt, and so, in the broadest sense, measurement uncertainty means doubt about the validity of a measurement result. Uncertainty illustrates the quality of the measurement: the lower the uncertainty, the higher its quality. Care must be taken not to confuse measurement uncertainty with measurement error – they are complementary but distinct [6]. The latter is related to the difference between the measured value of a quantity and a reference value, or the standard used. Reference [7] establishes general rules for evaluating and expressing measurement uncertainty applicable to various types of measurements. In this assessment, sources of uncertainty must be identified and quantified. Some sources of uncertainty can be inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions, finite instrument resolution or mobility threshold, and inaccurate values of measurement standards and reference materials.

The conformity assessment of any object, when treated systemically, makes use of a set of quality management techniques, with a view to providing confidence that the object submitted to assessment meets the requirements established in a standard or technical regulation. Key to conformity assessment is the concept of “decision rules”. These rules give a prescription for meeting or failing a specification limit, considering the acceptable level of probability of making a wrong decision. In the decision rules, it should be described how the measurement uncertainty is considered when declaring compliance with the specified requirement. The use of guard banding can be important. Guard banding is a technique used to reduce the risk of encountering an incorrect conformity decision, such as false acceptance - Claiming a result is in tolerance when it is out of tolerance or false rejection - claiming a result is out of tolerance when it is in tolerance [8].

4. Decision-making in asset management

This section presents and discusses some situations where decision-making is necessary in the evaluation of test and measurement results related to predictive maintenance of assets of electric power utilities.

In thermographic inspections, the temperature measured on the surface of a given component of the electrical system (equipment, connection, etc.) is compared to a reference temperature, and the difference between them will determine what type of intervention will be applied to that component - for example no intervention, urgent or emergency maintenance. The limits that determine the types of intervention can have differences as small as 2°C or 3°C [9]. The infrared cameras used in Brazil usually have a maximum permissible error of ±2 °C or ±2% of the measured value (whichever is greater). It can be noticed, in this situation, that, simply taking the maximum permissible error of the infrared camera as the measurement uncertainty, the difference between the measured temperature and the reference temperature can vary by up to 4 °C, compromising the reliability of the evaluation of the type of intervention. The situation can be even more dramatic if the instruments have not been calibrated, or if the error reported in the respective calibration certificates is not corrected. As the difference between the limits is quite narrow, the lack of calibration or error correction can lead to situations of false need of non-intervention or urgent maintenance, which can lead to losses due to uncorrected defects that evolve into failures or expenses with unnecessary immediate maintenance. This situation can also occur when the measured value is close to one of the decision-making thresholds. Figure 2 shows this scenario, where the top bar represents the measurement performed by the infrared camera instrument, where measurement uncertainty is 2 °C, the bottom bar represents the decision limits and T_1 and T_2 the temperatures associated with these limits. The width of zone 2 and consequently the separation between zones 1 and 3 is only 3 °C.

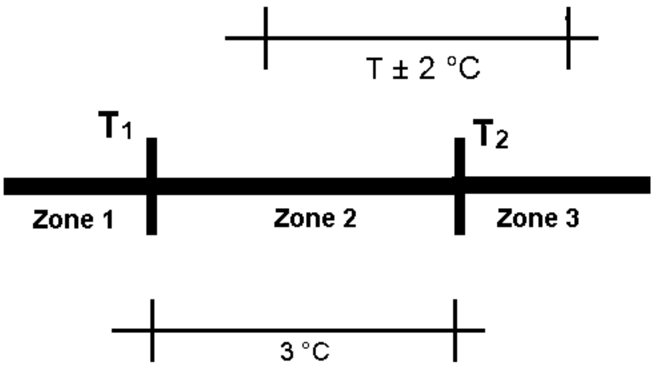

Figure 2. Evaluation of a measurement performed with an infrared camera-type instrument.

In the physical chemical analysis of the insulating oil used in high voltage equipment, one of the measured parameters is the dielectric strength, or breakdown voltage, which is the maximum voltage that the oil can withstand before presenting insulation failures and endangering the integrity of the equipment [10]. In certain tests, the measurement uncertainty can be quite significant, compromising the quality of the oil evaluation. In a given test of an oil whose minimum dielectric strength must be 40 kV, the measured value was 44.3 kV with an uncertainty of 8.5 kV. Considering that the probability distribution is normal (Gaussian), and that the uncertainty coverage probability is approximately 95%, it can be concluded, with reasonable confidence, that the insulating oil has the required minimum dielectric strength with approximately 84% probability. This situation is shown in Figure 3. In an asset management system, this 16% probability that the dielectric strength of the oil is below the minimum value can be carefully analyzed, considering for example the maximum acceptable risk for the condition of the oil, which can be a function of the revenue associated with the equipment. Using the concept of guard banding in this situation, the minimum dielectric strength to obtain a 5% maximum probability of false assessment of the insulating oil should be 47.0 kV.

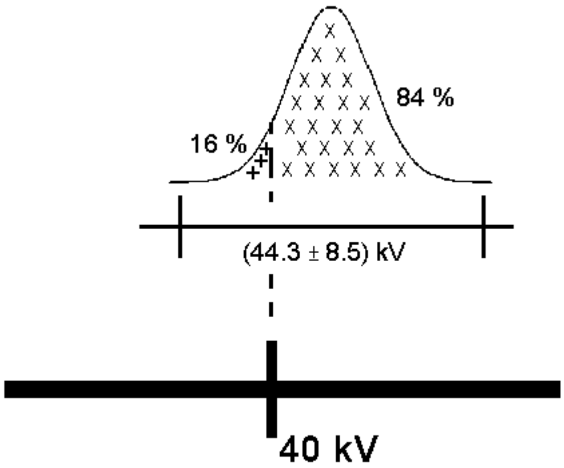

Figure 3. Evaluation of a test result for determining the dielectric strength of insulating oil.

In analysis of dissolved gases in the insulated oil, one of the gases whose concentration is evaluated is acetylene, because its formation is indicative of the degradation of the mineral oil due to electrical and/or thermal defects in the equipment [11]. In a given test, two true replicas (samples from the same equipment collected separately) analyzed independently, showed acetylene gas contents of 1.292 ppm and 1.514 ppm. However, expression of results in whole numbers is recommended. So, according to the rounding rules, one of the samples would be rounded to 1 ppm and the other to 2 ppm of acetylene, and the diagnosis of the same equipment would be differentiated, in each specific case. Thus, if a more conservative and prudent evaluation criterion is used, the decision is made to adopt the value of 2 ppm, which will result in preventive and brief inspection actions of the equipment or request for additional electrical tests for a more detailed evaluation of its condition.

5. Conclusion

This article presented how Metrology concepts and definitions should be observed in the management of assets of an electric power utility, with the objective of subsidizing the decision-making associated with the predictive maintenance of equipment and other components of the electric system, which involves different types of measurement. Situations were shown where the characteristics of a measuring instrument do not allow an adequate decision to be taken, where the limits are very narrow, and where the non-use of measurement uncertainty and probability of false acceptance can compromise the quality of the evaluation of a critical test.

References

[1] Jesus L 2008 *Evaluation of The Variable Portion to Determine the Quality of the Transmission Service in Brazil According to Reliability Concepts* (Rio de Janeiro: Federal University of Rio de Janeiro)

[2] Holanda S 2016 *Application of Predictive Maintenance by Analysis of Vibrations in Urban Train Equipment with Proposed Maintenance Plan* (Recife: Federal University of Pernambuco)

[3] Coandă P, Avram M and Constantin V 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **997** 012039

[4] Brazilian Electricity Regulatory Agency (ANEEL) *Resolution 906/2020*

[5] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML 2012 *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)*

[6] Cohen E 1996 *Modeling Complex Data for Creating Information* ed Dubois J and Gershon N (Berlin, Heidelberg: Springer) pp 55-64

[7] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML 2008 *Guide to the Expression of*

Uncertainty in Measurement (GUM 1995 with minor corrections)
[8] EURACHEM/CITAC 2021 *Use of uncertainty information in compliance assessment*
[9] Fidali M 2015 *Meas Automation Monit* **61** 245248
[10] Ghani S, Abu Bakar N, Chairul I, Khiar M and Ab Aziz N 2020 *Journal Adv Res in Fluid Mech Thermal Sci* **63** 107116
[11] U-Khan I, Wang Z, Cotton I and S. Northcote 2007 *IEEE Elect Ins Magaz* **23** 514