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AUTOMATIZATION OF TAMPERING IDENTIFICATION IN INDUCTION ELECTRICAL POWER METERS

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Abstract − Technical irregularities found in electrical power meters due to tampering, which are classified as fraud, are responsible for the most part of the energy loss experienced in the sector of electrical power distribution. The cost of energy theft is shared with all consumers in the form of non-technical losses. This work suits that context, by means of combating fraud in electric power meters in order to reduce losses due to the strengthening of effective punishment of cheaters. For that is proposed a systematization model of the process for verification of irregularities in electric power meters and the respective issuance of audit reports. The proposed systematization is based on a database containing standardized irregularities which were hierarchically arranged and also from information obtained from metrological calibration audits, thus ensuring the reliability of the results. The proposed model was tested in samples of tampered power meters provided by the electrical distribution utilities in southern Brazil. A main outcome of this research is a customized software that organizes the procedures of technical audit in a legally binding basis as applied to power meters. From the results of analysis conducted on sample power meters audited, it was possible to settle the software's report.

Keywords: Electric power meter, fraud, service automation, audits.

1. INTRODUCION

Electrical power systems are basically composed by generation, transmission and distribution of energy, with it's associated components, such as: generators, transformers, loads, transmission lines, distribution lines and meters [2], [8]. The conformity of operation of these components is an essential factor for the reliability of the results of energy being generated and marketed.

The electrical distribution utilities are interested in the correct performance of an electrical power meter (EPM), because it is on it that the economic foundations of the firm are based [7]. From the analysis of the consumption profile of a particular consumer, it is possible to detect sudden changes in their energy bill. To found a tampered EPM is necessary to do a technical inspection by specialized person in the consumer installations [11].

The procedure adopted by the electrical distribution utilities, that is judicially recognized by the competent bodies is the withdrawal of EPM to be used as expert evidence in a court case. The service expert in the analysis of the EPM, execute a series of functional tests, to issue an expert report on compliance of its operation. With the production of these reports there is the strengthening of the process of punishment of cheaters and discourage of new ones. This article aims to describe a system developed for the identification of tamper in electrical power meters (EPMs), with the automation of the service of issuance of expert legal reports.

2. EPM COMPONENTS

The EPMs is the equipment to measure electrical energy through the integration of power for a given period [1]. Induction EPM is the meter in which currents in fixed coils react with the currents induced in the conducting moving element, generally a disc, which causes their movement proportional to the energy to be measured [5], [10]. The Figure 1 is the basic representation of an induction EPM and their constructive components.

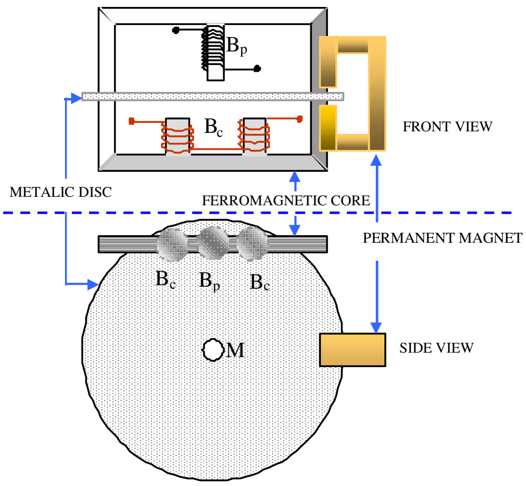

Figure 1 - Basic components of an EPM
Source: Adapted of Medeiros (1997)

According to Figure 1 the potential or voltage coil (Bp), the current coil (Bc), the laminar ferromagnetic core, the metallic disc (M), and the permanent magnet, are the basics components of the EPMs. The knowledge of these components is critical to the success of the analysis results of each EPM inspected. Besides these components, an EPM has in its structure, others parts that contribute to its operation. The operational integrity of the EPMs depends of its whole components, which can be checked through its calibration.

3. EPM CALIBRATION

EPMs and other measuring equipments have functional limitations, because of its useful life. That kind of problem can't compromise the quality of the services provided to consumers. Then, regular checks should be carried out to indicate compliance characteristics of EPMs operation.

The metrological confirmation is a set of operations required to ensure that a given inspection, measurement and testing equipment, is according with the requirements specified for its use [3]. The method used for an EPM calibration is the direct comparison between the meter under test and a calibration standard. Therefore, the errors are determined from measurements taken of the metallic disc and the cyclometer register of the EPM. For the measurement error evaluation the EPMs are calibrated according to the Table 1 parameters.

Table 1. Generalization of the EPM calibration

	CALIBRATION POINT		
	1	2	3
NOMINAL CURRENT	100%	100%	10%
NOMINAL VOLTAGE	100%	100%	100%
POWER FACTOR	1 resistive	0,5 inductive	1 resistive
ACCURACY	Percentage		
MEASURING SYSTEM	Single phase, two-phase or three-phase		
CONSTANT OF MEASUREMENT	Absolute value		
FREQUENCY	60Hz		

To estimate the measurement uncertainty, the contributions listed in Table 2 were considered. The calculation is performed in accordance with [16] and automatically by the software developed.

Table 2. Uncertainty contributions for the energy measurement

Uncertainty contribution	Unit	Type
Standard deviation of measurements of EPM under test	%	A
Resolution of calibration standard (CS)	%	B
Approval criteria for certification of CS	%	B
Standard accuracy	%	B
Coefficient of variation of temperature of the CS	%/ºC	B
Factor of safety for stability of measures	%	B

The time required for the calibration process of an EPM is approximately 20 minutes, based on a sample of at least 4 readings per calibration point, and a time integration of the energy of 1 minute. For the proposed methodology the calibration results are indicators to the presence or absence of measurement errors, which therefore can justify tampering cases of EPMs.

4. EPM TAMPER

The fraud is characterized when the consumer deliberately tries to deceive the utility [14]. Other definition, proposed by [12] define electricity fraud as a dishonest or illegal use of electricity equipment or service with the intention to avoid billing charge. The frauds imposed to the EPMs are the principal cause of the revenue losses by the electrical distribution utilities [9].

For more than a hundred years electromechanical EPMs are used to register the energy commercialization revenues. Along this period a large number of tampering methods have been devised. According with [13], all forms of tamper, without exception, are known and are detectable. Tampering the terminal seals is by far the most common method of meter violation, because the terminal seals are easy to reach. The terminals are located immediately below the meter itself. Once the terminals were broken, it is simple to tamper the EPMs [9].

A usual tamper, according to [15], occur when voltage coil or control wires are shorted or opened, this would divert the current reading in the meter. In this case the current going to the meter would be zero. The effect on the meter is immediate and obvious: with zero-current, the power and energy readings become zero, or the accumulated consumption becomes stationary [15]. In the same way, tamper in the shaft or metallic disc by its obstruction is common [9], [15].

One way to recover the losses of revenues caused by EPM tampered is the realization of technical inspection by a legal expert which identifies the EPMs irregularities. For that, the standardization and the knowledge of the types of irregularities provide speed and reliability in the results related in the legal reports.

5. STANDARDIZED IRREGULARITIES

The structuring of the irregularities database that characterize fraud in an EPM is the initial stage of the project developed in partnership with the electrical distribution utilities, in order to systematize the description of EPMs performance. The database was designed from theoretical research and from a study group with experts in EPMs.

A qualitative forecasting applied to the developed methodology was made through study groups with experts in electrical energy measurement. For qualitative forecasting methods the required information is mainly based on subjective judgments and experience of experts in the subject [6]. The study groups consisted of engineers and technicians, from electrical distribution utilities, technical consultants of EPM manufacturers, and by engineers who act as experts in legal actions involving energy theft.

The qualitative forecasting consist of four groups, working on focused sessions, and each group with the participation of five experts (at least one from each category above). In the focused sessions, the groups sought to know the types of irregularities from the analysis on different aspects of 6 tampered EPMs. Each group evaluated one EPM at a time, recording the irregularities identified. The Figure 2 illustrates this process.

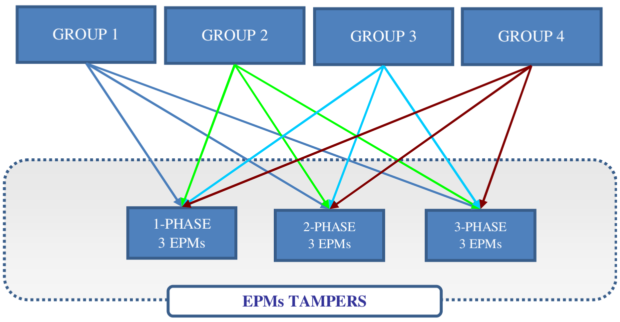

Figure 2. Qualitative techniques of forecasting to identifications tamper in the EPMs

Among the EPMs in this qualitative forecasting, 3 of them were single phase, 3 two-phase and 3 three-phase. Furthermore, the EPMs are from 4 different brands manufactured between the years of 1975 to 2004.

All the irregularities identified by the groups were recorded on standardized forms. After each group has recorded the results for each EPM, these results were discussed with the whole group of specialists. By the end of the discussion, the standardized nomenclature and the technical evidence of each irregularity was agreed unanimously by the experts.

6. IRREGULARITIES DATABASE

The format of the database follows techniques of software development based on SQL (*Structured Query Language*). The registration of the types of irregularities was conducted in a standardized way and in accordance with [4].

Structurally, the database was willing to irregularities in levels (Figure 3) that branch as the level of detail of the irregularity. The four entries of the first level of this hierarchy are the seals of the EPM, the general verification, the components located outside the EPM and the components located inside the EPM. By selecting, for example, the components located outside the MEE will be displayed to the user sub-levels as the terminal block, the bridge of potential, and the EPM cover.

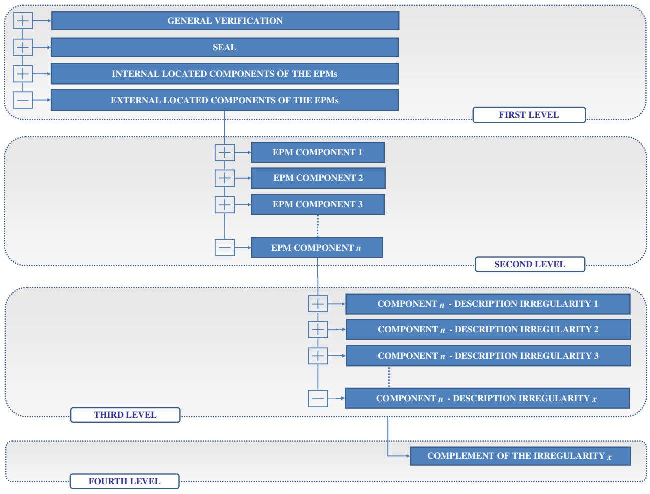

Figure 3. The format of the database irregularities

Therefore, according to Figure 3, beyond the primary level, are displayed to the users more three levels: one for a specific description of the related component, one for description of the possible irregularities associated with that component, and finally, a level with a complementary text to the selected description.

Operationally, the selection of an irregularity is performed by clicking with the mouse on the description. Therefore, it's possible to cross the information from the database (stored irregularities) with the characteristics of the EPM under analysis (irregularities identified). For the audit reports, only the information related to the EPM under analysis is presented to the decision of the expert or user of the system.

7. PROPOSED METHODOLOGY

This work adopted a methodology that allows the use of technical subsidies for analysis of the EPM operational compliance. As basic steps are the EPM information data registration, its metrological verification and its functional inspection. The recommendations of [4] were used as reference to define the limits for approval of the measurement results obtained for each EPM. These equipments have a class of accuracy that in most cases are around 2%. All EPMs have their measurement circuits submitted to technical inspections.

The EPM with disapproval in their measurement errors shows strong evidence of technical irregularities on it. The functional inspection, based on measurement errors must describe features, associated with images, which characterizes the EPM operation conformity. With this, it aims to show the conformity operation of an EPM, reporting the facts and the conclusions about them in the final report.

8. RESULTS

For the four primary irregularities levels and the sample of 570 EPMs analyzed, there are 137 different types of irregularities that could be possible to occur in EPM with the intention to stop, contribution to stop or change the accounting of energy consumption.

For the second level of the proposed structure 20 components were standardized. For each component of an EPM were registered from 2 to 28 types of irregularities, and for each irregularity, was associated with a complementary text that explains their impact on the accounting of the energy indicated by the EPM. The Figure 4 illustrates part of that structure.

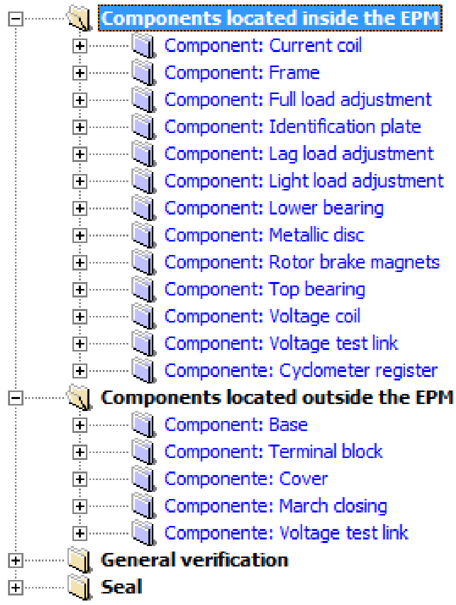

Figure 4. Partial representation of the selection structure of irregularities in the database

To facilitate the understanding of the impact of the irregularities on the measurement process, the fourth and final level of the structural hierarchy was dedicated. To this, complementary texts were standardized to describe the irregularities. For the 570 worked samples the component that showed the largest number of citations on the irregularities was the metallic disc (Figure 5).

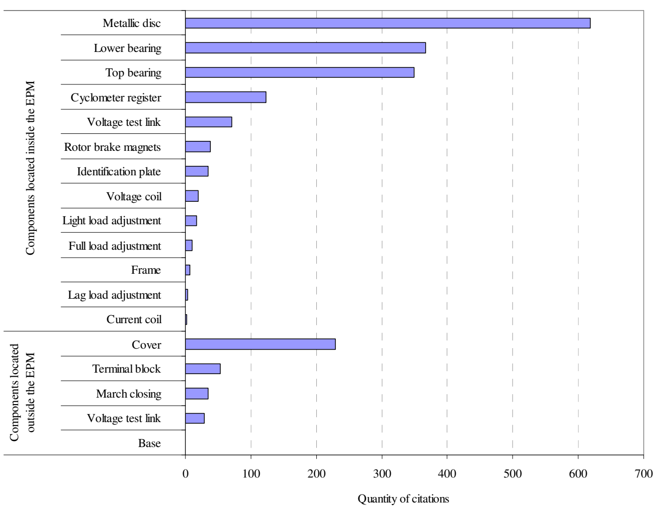

Figure 5. Quantification of irregularities standardized citations

The average reduction in the accounting of energy consumption for the types of metallic disc irregularities varies from 15% to 100%. An 100% error indicates that the component is totally inoperative and could be locked, or uncoupled from the circuit or its shaft. The Figure 6 and the Figure 7 represents the metallic disc tampered.

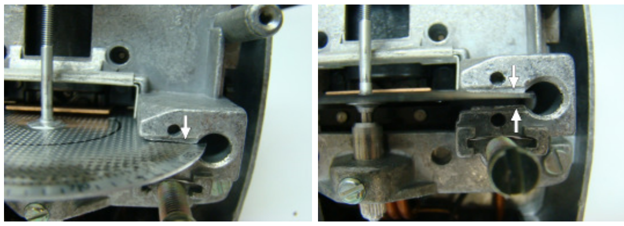

Figure 6. Metallic disc scraping in the permanent magnet

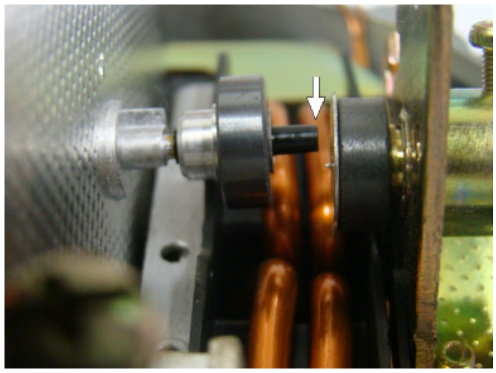

Figure 7. Metallic disc uncoupled from its shaft

The Figure 8 represents the results for the EPM type T8L, historically installed in rural, residential, commercial and industrial consumers. For that EPM, the fraud was realized principally in the metallic disc with errors ranging from approximately 5% to 100%, for each calibration point.

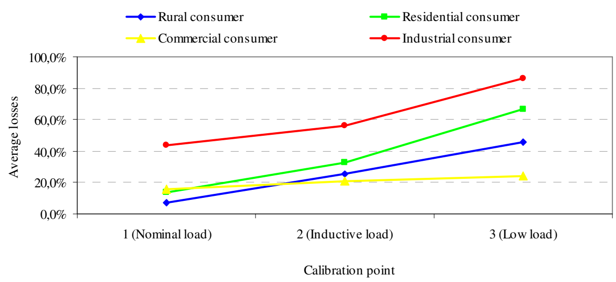

Figure 8. Average energy loss for EPM T8L tampered

9. CONCLUSIONS

The automation of irregularities recognition that characterizes fraud has been validated. This process is a tool in strengthening the combat of energy theft.

The research for database structure, using qualitative forecasting techniques, was consistent with the results recorded from samples of EPMs tampered of the electrical distribution utilities. The reliability associated with the service expertise and reduced time needed to issue an expert legal report are results of the developed system implementation.

In this context, the reduction of interpretations variations in the identification of different kinds of irregularities with the aid of a standardized database was achieved. With the systematization process, the production of large amounts of the audits reports is possible and these can be strengthening the process used for punishing the fraudsters.

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