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Non-Technical Losses on Injected Distribution Energy: Case Study on Entry Meters, Installed in the Rio De Janeiro State, Brazil

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Abstract— *Commercial or non-technical losses (NTL) on injected energy (regulatory) are primarily related to their fraud and theft in the distribution sectors, and corresponded to the concessionaires installed in Brazil, about 3.46% between 2010 and 2014, or values around US$ 300 million. For the region of Rio de Janeiro, these were, between 2010 and 2013, in the order of 11%. In order to reduce the amount of fraud in the concession area of the region in a case study, the use of drilling tools, the use of magnetic fields for blocking or delaying the meter disk, changes in the terminal contacts, such as electric bridges; the inverted connections of the internal circuits, the lack of neutral, by up to 12% each.*

Keywords— ***commercial losses, electricity meters, fraud, investigation, electricity distribution networks.***

I. INTRODUCTION

Actions to combat fraud in electricity allow the recovery of concessionary revenues and play an important educational effect on the proper use of energy resources, since they deal with a situation affecting all economic classes in the various regions of the country. In this case, commercial or non-technical losses (NTL) on the injected energy (regulatory) are related to their frauds and thefts in the distribution sectors and corresponded, according to ANEEL (2015) [1], to the concessionaires installed in Brazil, about 3.46%, between 2010 and 2014, or more than US$300 million.

For the Brazilian Association of Electric Power Distributors, ABRADEE (2018) [2], the fraud was defined as the direct deviation of energy from the distribution networks to the illegal consumer. In this case, it is registered at the concessionaire, but, promoting adulterations in the electrical supply system of your home, trade and/or industry. With this action, only a portion of its total consumption is paid and has been causing annual losses, in 2018, of the order of US$2 billion [3].

The dissemination of fraud is so significant in the current times that some more popular terms are being employed by the technical community for its classification, such as those of Penin (2008) [4], which transcribed as definition of the theft of energy or NTL, the said popular "cat" and the fraud in its supply, as "rat".

In Penin (2008) [4] assessed, the irregularities caused by the action of the consumer most commonly found in the electrical distribution systems in general, were the direct connection to the secondary network; the deviation in the input extension, prior to the meter; the blocking of the movable element of the meter, by means of access by perforation in the glass lid or the base, by the introduction of objects or materials foreign to the electrical system; the forced displacement of the pointers of the meters; the inverted connections of the cables in the terminals; the opening of the test terminal; the interruption of the operation of the potential coil; the replacement and wear of gears and their teeth; the commitment of its mobile

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element; the demand pointer backlash; the opening or isolation of the calibration key; the isolation or sectioning of the connecting conductors between the measuring key and the meter; the short circuit in the secondary of current transformers; the interruption of demand timing engine power; the inversion of reversed phase sequence in reactive; and the short circuit at the inlet or outlet of the meter. Besides these, according to the author, new situations of fraud were found in the system, such as the current injection into the meter to make its measurement incorrect, with eventual burning of the internal coils.

Minguez (2007) [5], studied the main types of frauds related to electromechanical electrical energy meters by induction, EM, for having been one of the most used types by energy dealers, due to its robustness, simplicity accuracy and performance. The most evident occurrences of both internal and external to the meters were equivalent to that presented by Penin (2008) [4] assessing. Besides these, the author cited the deviation of non-measured electrical current, usually occurring in the terminal box or distribution without the use of a reverse key and, whose fraud was related to the return of voltage when the circuit was disconnected; the locking of the disc swivel from the violation of the protective case; the connection of the input and output conductors through the terminal without going through the measuring equipment; the inverted connection of one or more conductors of the input terminals to the output, or even, the inversion of the coils connections of the measuring equipment; the cheat related to the recorder rotating gears scrapings; and also the exchange thereof in order to change the rotation period; the intermittent alloy and disconnect operations of the secondary measuring circuits; and the handling of the consumption system, with return of the hands, including the disconnect of primary or secondary conductors of the measurement.

Also, for Minguez (2007) [5] the main indications of manipulation or violation, in this case, of the outside of the meters were related to the disruption or adulteration of its seal; the cutting, breaking and melting with glue marks different from the original or from the manufacturer, with characterization of the pierce-type screw removal; the cutting or machining mark of this, which have been chopped, without thread, or with other damage marks; the perforation or cutting of the main lid, indicating its movement of the site; the protection box perforations; and, the changes by cutting, punching, chipping, among other features access to the terminals from the ruler and the meter cover. By the analysis of 3,400 EM of the concession region it was found that the 5 most common types of fraud in the region of analysis, up to 2007, were the violation of the meter cover, by perforation, with 29.85% of the cases; followed by the violation of the lid, by 23.12%; of perforated box, with 9.11%; of the bored base, in 7.97% of the cases and the perforated post, with 7.17%.

The numbers of the violation were also verified by Ortega (2008) [6], when he reported that the concessionaire had in the research period about 3,790,000 of customers at low voltage in 31 municipalities of the state of Rio de Janeiro and was being considered as the 3rd national distributor with a greater number of commercial losses, as a consequence of fraud, mainly in its energy meters, because of defective equipment and clandestine connections.

II. MATERIALS AND METHODS

The analysis of the main manufacturers and the types of meters were carried out from a data collection with the concessionaire, being then made available in a spreadsheet to obtain statistics of the number of events, by manufacturer and type of meter and for comparison with the data published by other authors conducted in about 10 years, in order to visualize the persistence of the problem and if there was any statistical evolution.

The types of fraud were also raised by each manufacturer inspected. Additionally, in this study, the main meters were identified in operation at the concessionaire, in order to subsidize the information with respect to the most practiced fraud methods in the sector, and these were coded.

Types of meters installed in the distribution network of the concessionaire. They were codified by the non-interest of exposing their manufacturers, who can also be considered victims of this whole process of commercial losses of energy dealers, especially in case study.

ME 1, was a power input meter, electronic type, monophasic, class B, represented in 1.62% of the park. It consists of a cyclometric dial, with a maximum rated current, Inmax, of 15/100 A; operates in the voltage range from 120 to 240 V and in the frequency of 60 Hz. It has as an additional feature an LED system that indicates whether there is reverse flow of electric current, that is, an anti-theft system.

ME 2, is represented in the concession park with 6.80% units. It is an electronic meter for the measurement of active and reactive energy with a high degree of precision and can be operated in single-phase, biphasic and three-phase connections. An advantage of the meter is in the form of its data storage, independent, and of the active energy totalizations (kWh) in direct flow, active energy in reverse flow, reactive energy (kVARh) inductive and capacitive. Also, two modes of operation related to the totalization of active energy, the ratchet mode and the unidirectional are possible. For data transmission there is an infrared communication output, with device that allows the electronic reading of the registers, the safety data and the current state, from a microprocessed system. The data can be transmitted by auxiliary terminals from an OBIS identification standard port: IEC 62056-61 [7]. The IrDA port can be read at a distance of up to 250 mm and provides important information such as the safety, registers, identification and state of the meter. In its manufacture, security features were worked in the registry and configuration data, by storing them in non-volatile memory, in addition to others. Operates in the temperature and humidity range, regular in Brazil, having a maximum weight of 1.2 kg. The active energy (kWh) of this meter is of direct and reverse type, independent, in the type ratchet or direct and reverse, added to the same record, in the one-way model. It has the accuracy classes B (1%), can work in the operating voltage between 96 and 288 V dc and in the frequencies of 50 and 60 Hz. The model complies with the technical recommendations of the standards ABNT NBR 14519 [8] and NBR 14520 [9], IEC 61036:1996 (with addendum 1:2000) [9], degree of protection IP52 (IEC 60529:1989) [10].

The equipment ME 3, is represented in about 4.85% of the park with electronic meters. As specified by the manufacturer, the electronic single-phase meter has a display for the active energy measurement kWh. As main advantages, it presents a better class of precision, when compared to the single-phase electromechanical meters; operates with low consumption, low starting current and a fraud detection system by means of a reverse active power indication on the LED, from a pulse emitter. The meters are supplied in the following configurations: 120 V 15/100 A, 60 Hz; 240 V 15/100 A, 60 Hz and 120 to 240 V, 15/100 A and 60 Hz. This electronic meter meets the standards ABNT NBR 14519 [8], NBR 14520 [11], NBR 14521 [12], NBR 14522 [13]; IEC IEC 62052-11 [14], IEC 62053-21 [15]; INMETRO RTM 431/2007 [16], and is commanded by a dedicated chip that carries out the product of the instantaneous current and voltage signals, acquired by an analog-to-digital converter that totals the power with its transformation to the energy consumed. As its register is unidirectional, the value of the reverse kWh is added to the direct kWh. It is able to record the active energy in both flow directions (direct or reverse energy), totaling its modules in a single register. In addition, it has LEDs as indicative of reverse consumption, besides indicating phase and neutral currents with different directions or amplitudes when lighting the red light, with the possibility of the accusation of these two conditions of fraud.

The ME 4, is represented by 9.31% of the park, with 3 models of electronic energy meters, being 1 monophasic and the other 2 three-phase. The electronic single-phase active energy meter is recommended for direct energy measurement in the charging of consumers in group "B". It has the ability to register with good accuracy small loads from 6 W, however, does not have sensitivity in relation to the empty gear. On its front face, it features a 5-digit panel that informs the recorded data of the active energy. This, operates in the voltage of 90 to 280 V dc, in 60 Hz, in nominal current of 15 A and maximum continuous of 100 A, being the starting, less than 0.4% of the nominal. The insulation voltages of 4 kV dc, at 60 Hz, 1 min; the impulse of 1.2/50 – 6 kV; and operates at temperatures between-10 to 85 ^{o}C.

The ME 5, with 21.12% of the electric park of the concessionaire, has as one of the products of the same manufacturer the two-way polyphasic electronic meter, multi-functional, for the application of measurement to 2 elements, 3 wires; or 3 elements, 4 wires, which assists in identifying irregularities in the installation, combating commercial losses and recovering revenue from the concessionaire. The equipment shows on the LCD the energy and the active demand; the energies, reactive inductive and capacitive; and the instantaneous values of current, voltage and power factor and meets the recommendations of the standards: IECs 62052-11 [14], 62053-21 [15], 62053-23 [17]; NBRs 14519 [8], 14520 [11], 14522 [13] and INMETRO RTM 431 [16]. The meter has some characteristics such as the event log, the closing of the main lid promoted by chemical fusion, which increases its protection against fraud and greater resistance to mechanical shocks and ultraviolet rays, in addition to other features.

The other three meters installed are electromechanical, with most of their characteristics are similar to those already presented, as the ME 6, with participation in 9.93% of the concessionaire's electric park, the ME 7, with 15.16% and the ME 8 models, with 22.12% of the total installed in park.

III. RESULTS AND DISCUSSION

Table 1, shows the manufacturers and their types of meters with the percentage of frauds observed during the period.

Table 1. Models and types of electrical, electronic (E) and electromechanical (EM) meters and percentage of fraud observed in the concession Park analyzed.

Meters/damage	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6	ME 7	ME 8
Type of meter	E	E	E	E	E	EM	EM	EM
Percentage in park	**1.62**	**6.8**	**4.85**	**9.31**	**21.12**	**9.93**	**15.16**	**22.12**
Damaged meter	19.9	8.95	9.39	15.76	15.42	4.83	9.61	11.53
Disc locked	14.85	5.43	7.68	8.53	8.2	8.75	16.03	14.11
Potential circuit	0.46	34.4	1.54	15.61	27.65	8.17	4.42	3.68
Bridge between the terminals	13.81	2.69	9.38	17.73	5.83	5.66	5.8	19.77
Register	24.54	8.16	7.74	14.83	13.83	7.78	4.98	11.13
Lack of neutral	8.34	1.63	13.02	16.6	11.54	5.38	5.72	16.54
Inverted connection	11.98	4.86	6.08	11.98	11.63	9.2	17.53	16.32
Overall failures	**93.88**	**66.12**	**54.83**	**99.04**	**94.1**	**49.77**	**64.09**	**92.48**
Total Failures/Park	**1.52**	**4.50**	**2.66**	**9.22**	**19.87**	**4.94**	**9.72**	**20.46**

From the inspection carried out by the laboratory, was verified the main types of frauds listed in the sequence, for some of the meters assessed.

ME 1. In 2013, the product was homologated by CEEE-D and, since then, an average of 50,000 units per year has been acquired. However, with the time of operation in the network, a failure rate was verified in 2,623 meters manufactured between the years 2013 and 2014 that made it inoperable, always breaking the internal power supply.

Of this lot, 1,200 meters were installed in the consumer for a period of less than 4 months, being then withdrawn for analysis. The result of this, showed that approximately 60% of them were with the capacitor damaged; 30% had Zener diode burnt; 15%, there were breakdowns in the varistor; 15% were with the resistor open. Additionally, in some meters, more than one defective component was detected. Problems related to the capacitor of the meter source were also verified by Eletrobras [17].

ME 2. This model has been presenting the following vulnerabilities: a) easy handling to lift the back cover and have access to the internal area of the meter (usually disconnects the circuit of potential); b) ease of internal access by using a drill to reach potential circuit conductors and electronic circuits (Fig. 1).

ME 3. This model has been presenting the following vulnerabilities: a) hole in the lid for the locking of the consumption recorder; b) coil imantation, the magnetic field generator device is placed on the disc brake; c) ease of access to the terminals, promoting wiring bridges to the circuit breaker; d) ease of decoupling the disc; and e) ease of internal access for partial or total scraping of the recorder disk.

Fig. 1. Illustrative image of the ME 2, highlighting the region of easy access of the internal electronic circuit, with the use of drill.

ME 4. This model has been presenting the following vulnerabilities: a) meter with an average duration of 2 years according to the climate (problems of the capacitor, probably due to the high temperatures recorded in Rio de Janeiro); b) use of a drill to reach the electronic circuit (Fig. 2 a and b); c) indirect and direct measurement, with access through the battery compartment to reach the electronic circuit, since the drum compartment has a fragile lid (Fig. 2. c).

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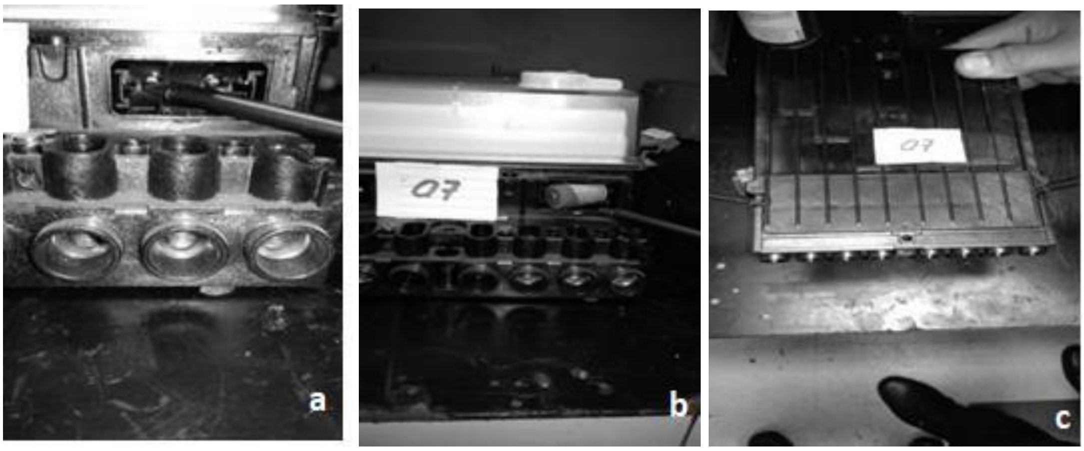

Fig. 2. Illustrative images of the common types of fraud in the ME 4, such as: in (a) and (b) the ease of by drill; and (c) access of the internal electronic circuit through the battery compartment.

ME 5. The models in reference presented the following vulnerabilities: A – easy access to the internal area of the meter, mainly with drill, to reach the conductors of the potential circuit to disconnect it, problem this, solved by changing the internal configuration of drivers; B - access by the optical port; C - coil imantation; D - inner compartment with design that allowed remote control device housing; E - ease of damage to the display by using laser lanterns; F - ease of opening for feed sectioning and/or potential circuit inversion; G - execution of external cabling exchange in the terminals; and H - change of the asset by the reactive (function 03 by function 24) using the optical sensor with the aid of a notebook and specific program.

In Fig. 3, there are four examples of common frauds found in this type of meter installed in the park of the energy concessionaire, being: i) in Fig. 3 A, the perforation of the cradle of the post with drill to reach the potential circuit; (ii) in Fig. 3 B, the ease of access by the optical port; (iii) in Fig. 3 C, internal compartment allowing the installation of a remote fraud control; and in Fig. 3 D, a meter taken from a consumer containing the remote control of fraud.

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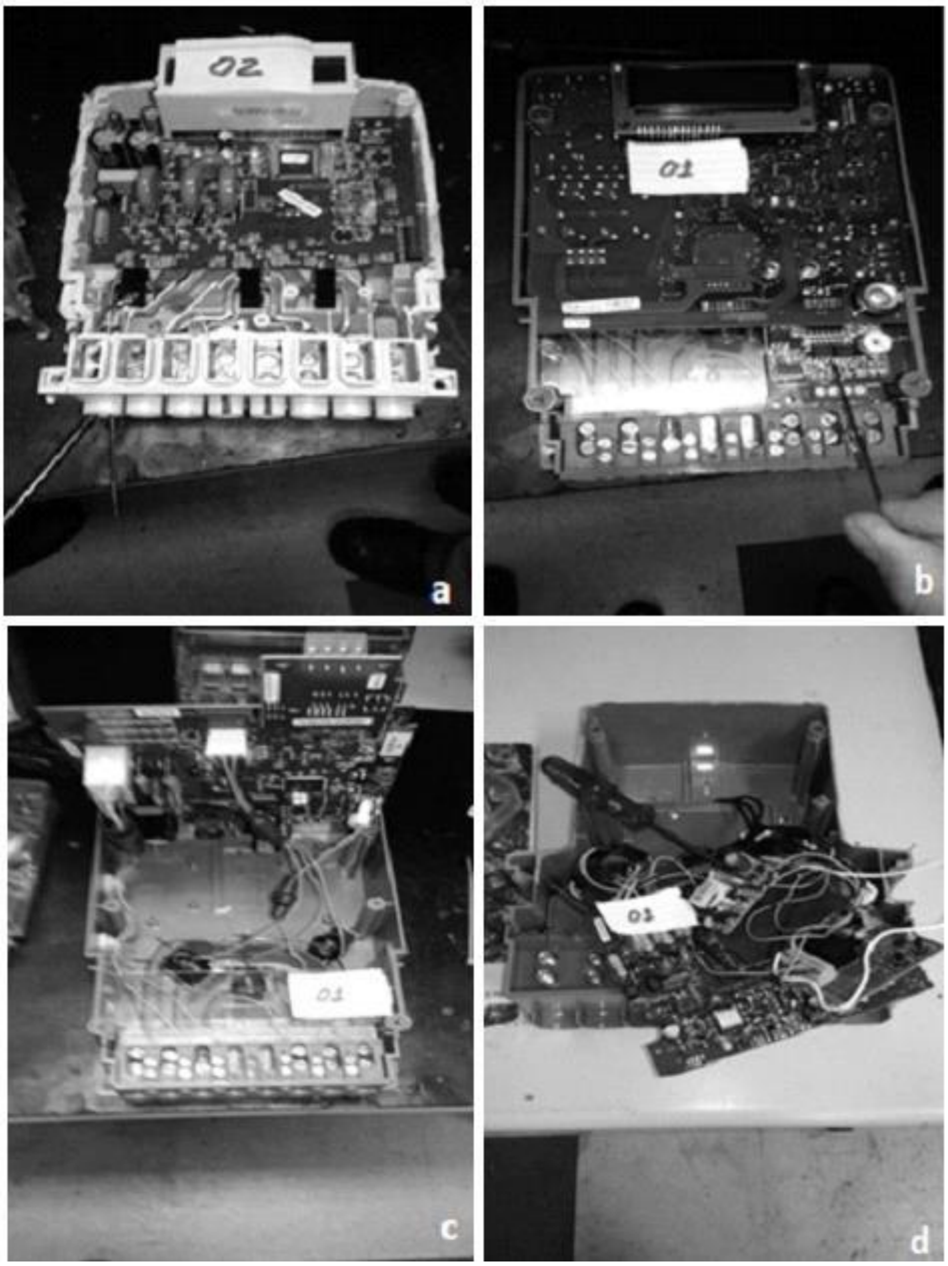

Fig. 3. Illustrative images of the main types of fraud in the ME 5 meter, installed in the concessionaire park, being: a) the perforation of the cradle of the post with drill to reach the circuit of potential; b) the ease of access by the optical port; c) internal compartment that allows the installation of a remote fraud control; and, D) a meter taken from a consumer containing the remote control of fraud.

ME 6. This model has presented the following vulnerabilities: a) glass-topped meter; b) coil imantation- the magnetic field generator device is placed on the disc brake; c) ease of access to the terminals, promoting wiring bridges to the circuit breaker; d) ease of decoupling the disc; e) ease of internal access to the partial or total scraping of the recorder disc from the post and the misalignment of the screw ruler; and f) ease of opening the potential coil. Fig. 4 shows the main access facilities inside the device.

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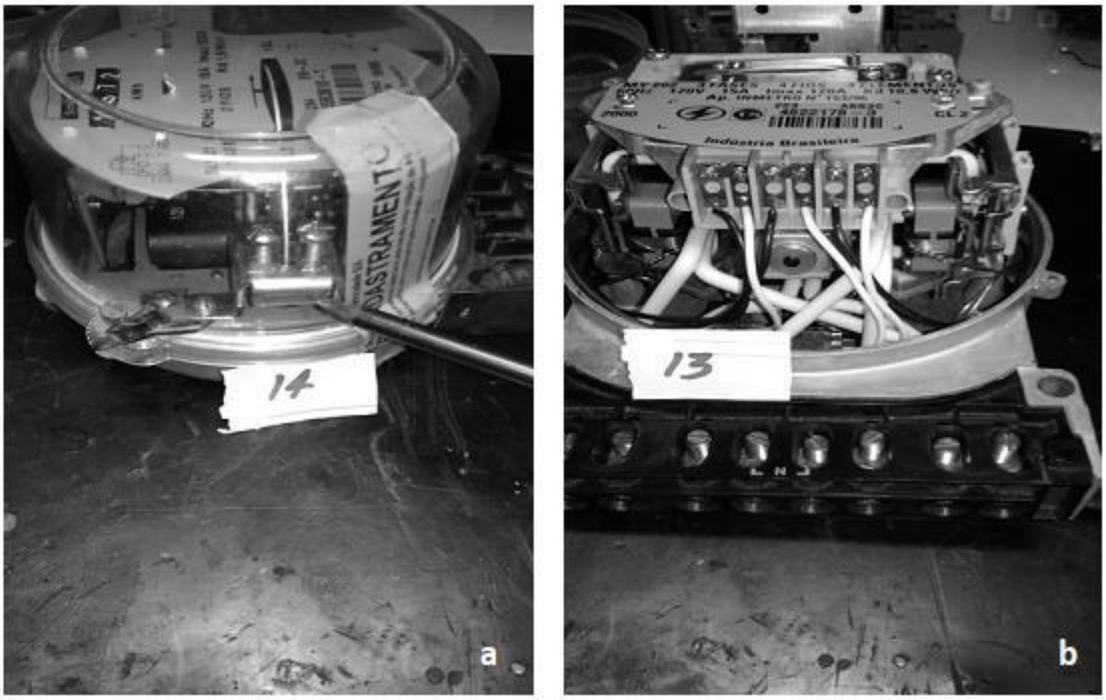

Fig. 4. Illustrative images of the ME 6, highlighting in (a) and (b) the glass lid and the ease of connecting a bridge in the posts.

ME 7. This model (Fig. 5), has been presenting the following vulnerabilities: a) meter with glass top (Fig. 5 a); b) vulnerability also to the imantation of the coil; the magnetic field generator device is placed on the disc brake; c) ease of access to the terminals, promoting wiring bridges to the circuit breaker (Fig. 5 b); d) ease of decoupling the disc; e) ease of internal access to the partial or total scraping of the register disk; and f) ease of internal access by removing screws from the terminals, with decentralization of the screws fixing ruler (Fig. 5 c).

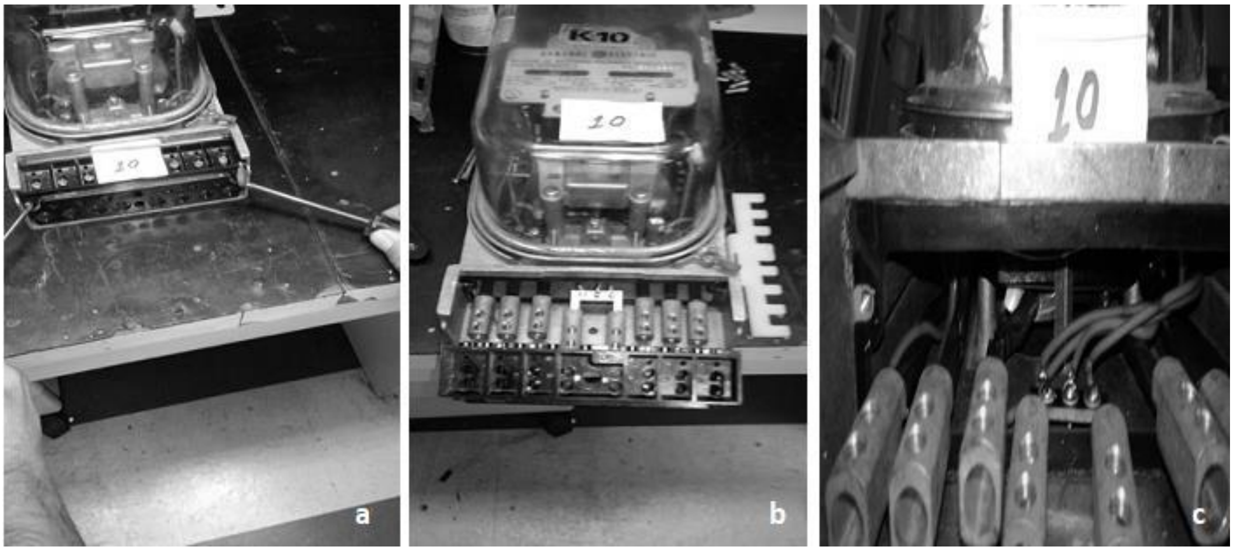

Fig. 5. Illustrative images of the ME 7: (a) the glass cover; (b) ease of connection of a bridge in the terminals; and (c) ease of access to the inside of the meter by removing the screws on the terminals.

ME 8. This type has been presenting the following vulnerabilities: a) hole in the meter cover to access the internal mechanisms; b) total locking of the meter disc; c) possible imantation of the coil with the magnetic field devices available on the market, which are placed to brake the disc; d) Bridge on the terminals on the meter and this for the circuit breaker; e) decoupling of the disc; and f) partial or total scraping of the recorder disc, as illustrated in Fig. 6.

Fig. 6. Illustrative image of one of the common types of fraud in the ME 8, as the change in internal gear, with scraping of the disc.

General considerations. The typologies of fraud were repetitive and depended on the characteristics of the meters, electromechanical and electronic. Also, according to the survey and data analysis was used all type of tool for the damage in the measuring equipment, among others not cited as the use of the hair dryer for the melting of the liquid crystal of the viewfinder, the use of laser for short circuit the electronic seals, the use of drills for access to the discs and the locking of the meters and to reach electronic/mechanical circuits and damage them.

From the revised technical papers of the literature, it could be considered that a large part of the Brazilian energy concessionaires, mainly due to fraud, has been working with innovations and updates of its consumer databases in order to facilitate the automated procedures via geo-referenced identification and analysis software, the type of meter, the profile of consumers and the forms of fraud that stood out most in the area. Also, it was verified a tendency of the use of electronic meters, with the additional deployment of software and algorithms analysis of possible frauds, robberies, cyber-attacks and failures between supply and demand of energy, since even the smart grids are subject to these attacks via external machines. Internal changes in the meters in order to sensor any external interventions such as the application of impact and vibration tools, opening of the lid, perforation by the terminals, opacity of the displays, among others, are also being researched [19-24].

IV. CONCLUSION

In this investigation, were observed the main types of fraud in energy input meters, electronic and electromechanical, in the region of Rio de Janeiro, Brazil, by the consumers of one of the local concessionaires and that represented in the first semester of 2018, NTL of the order of 11% of financial losses. For this purpose, were observed experimentally and by technical and visual inspection, the uses of drilling tools, the magnetic field generators for the blockade or the delay of the meter disk, the changes in the contacts in the terminals, such as the electric bridges; the inverted connections of the internal circuits, the lack of neutral, up to 12%, each. Also, not considered in the statistical data of this research, the uses of hair dryers were observed, in order to cause overheating of the internal electronic circuit, damage by impacts, vibrations, among others technics not identified.

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