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Development of a Module for Measuring Electrical Variables in Power Transformers Based in IoT, to Manage and Monitoring by Telemetry Mechanism

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Abstract: This work shows the development of a module that performs measurements of electrical variables in a low voltage power transformer. These variables are sent by means of the IEEE802.11 standard, connecting to a database stored in the cloud; associating with the meter IoT concepts, this to allow a client to perform an analysis, monitoring and management of their electrical network. For the construction of this module, non-invasive current sensors connected to a three-phase meter are used and a communication card is used that allows data to be extracted from the meter and sent to the cloud database. This module, to convert a conventional electrical power transformer into a smart electrical power transformer, making it a Smart Object and thus extract information from it telemetrically in real time.

Keywords: Smart electric power measurement; IoT; testbed

1 Introduction

The infrastructure of a campus electrical network is mainly made up of locations determined by the presence of alternating current power transformers. These devices are those that can be observed characteristic references such as alternating voltage, maximum and minimum threshold, power factor, current, active energy, reactive energy, etc., which originate from the same supply network. In general, these transformers are monitored by complex systems that imply a high cost or are not monitored, and there is no local or remote management of their reference variables defined from the behavior of electrical power consumption [1,2].

To mitigate the aforementioned disadvantage, a telemetric measurement process based on IoT (Internet of Things) is offered, which provides a promising solution that is based on a module, which manages to guarantee high levels of reliability, which probably involves an increase in system performance in making decisions in less time and analysis for load increases to the infrastructure itself, among others [2,3]. The concept of IoT is specified so that there is an interrelation between computing devices and telemetry devices associated with power transformers, so that these devices have a unique ID (identification) and with the ability to deliver measurement data of its electrical references through a network in which there is an M2M (machine to machine) interaction, thereby minimizing the electrical risk to humans; this thanks to the determination of sensors and transducers, which technologically turn this kind of general basic instance into a cyber physical system, which can be part of smart grid technology systems, power plants and smart homes [4–6]. Due to the low cost of IoT-based measurement modules, a strong advantage can be established that is expected to be exploited much more when a high degree of maturity is reached and the popularization of protocols such as CoAP (Constrained Application Protocol), MQTT (Message Queue Telemetry Transport) and XMPP (Extensible Messaging and Presence Protocol), which are currently defined as standards. Due to the technological revolution around the world, smart technologies are replacing the old ones. In the energy sector, IoT technology is becoming more attractive today. It is expected that by 2023, there will be about 20 to 50 billion things that are connected to the Internet around the world [6,7].

It is to be appreciated that in a campus-type environment you can have a considerable number of transformers, which do not have an electrical energy measurement system. It is also worth mentioning that the issue of functional safety of networks that depend on the main power supply scheme is fundamental because in an environment of this kind, it can be constantly growing, which increases energy expenditure and this forces to know where the demand or capacity of the transformers can be projected and thus avoid damage to electrical equipment, affecting the entire community and increasing costs for repairs. Installing a series of measurement equipment in real time has a high economic cost and cannot be monitored by personnel outside the electricity service provider, leaving the information in the hands of third parties [6,8].

The main purpose of this work is to develop a module for measuring electrical variables in alternating current power transformers based on IoT, by means of which these can be managed and monitored by telemetry mechanisms.

2 State of the Art

In the world, intelligent electrical grids called Smart Grids are already being implemented, the electrical network is an indispensable element in society, however, not much has changed in the last 100 years [8,9].

Due to environmental changes and advances in technology, researchers are working on combining ICTs (Information and Communication Technologies) with the electrical system. Most developed countries are pioneers or applicants of Smart Grids developments, where it is sought that the networks allow bidirectional energy flows, and use communication and control methods between them, this generates improvements in environmental aspects and energy production, since efficient energy consumption has been growing rapidly throughout the world. “From 1990 to 2009, the growth rate of total consumption worldwide was 72.17%, only in 2009 consumption increased 17.3% and is expected to reach 22% in 2030” [9].

Throughout the history, electricity consumption measurements are calculated using mostly conventional analog electrical meters, and in very few parts, devices capable of doing it electronically, and that at the same time lend themselves to becoming an object of IoT. Because measurements are made only for a monthly comparison, and therefore price the consumption of users, they do not find out all the benefits that would bring control over their consumption of electricity and how they could benefit economically from measurements. If users have control over their electricity consumption, greater energy efficiency could be obtained. “According to the International Energy Agency (IEA), the world economy could be better than 18 trillion dollars by 2035 if we adapt energy efficiency as a first option” [10]; also, “world-renowned energy economists have recognized that good energy management and conservation practices can achieve up to 25% in cost reduction” [10]. However, the technology to perform efficient measurements using smart meters already exists, which carry out measurement processes in real time with the possibility of sending this information through telecommunications networks, storing this data and making it possible to use Big Data tools and thus process all the massive data supplied by the network, helping decision-making [11]. Integrating this measurement data with telecommunications networks, by integrating these measurement data with telecommunications networks, the concept of smart grids is achieved.

During the last decade, numerous research works have been developed and significant progress has been made in the use of Internet of Things (IoT) technology in relation to electrical infrastructure. It can be mentioned that this is considered a support technology that can be associated with an intelligent measurement system [12]. In the energy sector, many studies have been conducted to ameliorate the energy crisis by adopting renewable energy sources. At the same time, the researchers show that many IoT-based devices are already designed in the electrical energy saving and management sector [4,13,14].

There is already a defined relationship between measurement devices and smart sensors, which were integrated into the electrical network, under the concept of Smart Object. Therefore, this allows the vision of having an intelligent network for control and management, such as Smart Grid [15–17]. Consequently, new technologies, especially telecommunications, make available information regarding production and consumption, which is determined in efficiency and reliability gains [18].

Within campus-type architectures, measurement devices can be provided that allow knowing and controlling energy consumption. The information obtained is useful when what is observed by the behavior of electricity consumption can be captured and processed as information, which should be directed to a management and control center that can make the data collected available through an information and visualization system for both consumers and suppliers [4,13,14,19–21].

An energy information acquisition system associated with the telemetry processes of a meter under the concept of IoT, determines a range of additional capabilities that are achieved through real-time monitoring of Smart Objects and the collection of information. This provides, in addition to the basic data to the relevant systems, other considerations that strengthen the concept of analysis, which makes this type of mechanism more timely, complete, and accurate [19–22].

In the IoT field, the network infrastructure is mainly short-range, which is now widely used for mobile reading of main meters that are particularly difficult to read, and for remote reading of household divisional meters [20–24].

The main objectives of a communication infrastructure are represented by the possibility of access to the data for users, developers and the accessibility of the node not only intended for data related to itself [25]. Another important parameter with respect to network infrastructures refers to their degree of maturity, in fact, the use of consolidated infrastructures allows technological solutions available on the market [20,21,24,26,27].

It can be seen that electrical measurements are evolving rapidly with the new concept of Smart Grids, this makes the developed module an aid to the transition from conventional to smart grids as different authors have been proposing [20,21].

3 Methodology and Materials

3.1 Methodology

The methodology for carrying out the project is divided into the following phases:

Phase I: Requirements analysis: The structure of the electrical system in the campus-type environment must be clear to install the appropriate equipment, for this, data is requested from the area in charge.

Phase II: Logical and physical design of the solutions: According to the data provided by the campus-type environment, the solution with the greatest positive impact on the electricity grid is sought, which allows easy data collection for timely decision-making. The purchase of the equipment is carried out.

Phase III: Development of the solution model-testbed: The data is recorded wirelessly in a storage infrastructure using the IEEE 802.11 network, the data is processed using software mechanisms that allow visualization to offer a type of analysis that may be required through a web service.

Phase IV: Test and optimization of the resulting model: Preliminary tests are carried out on a distribution board in a low-power household electrical network and results are taken which are used to optimize the prototype of the final model.

Phase V: Implementation and testing of the resulting model: The prototype is installed and tests are carried out on the implemented model using an experimental field process at the transformer sites, which are in the aforementioned environment, in which simultaneous samples are taken in order to determine and guarantee the functionalities of the model.

Phase VI: Monitoring and observation of the results of the system to be measured: Observation and monitoring actions are carried out from the design tests in reference to its operation with the electrical network that the analyzed campus has, samples are taken of the results obtained from functional tests of the equipment.

Systems are typically developed and continue to be tested in the development environment that is determined for their application for a certain period of time, often called the development life cycle of the test process, which can be composed of a group of phases to be defined, in which the due limits for the collection of results are specified [8]. The approach highlights that the development of a prototype for the acquisition of electrical variables is carried out by means of telemetry mechanisms that are supported in IoT, for this reason it is considered to carry out experimental practices with the Testbed (Test bench) arranged for the case. The methodology consists of the development of procedures that are carried out by first identifying large actions and progressively descending to their details, that is, experimental and systemic. This can be seen in Fig. 1.

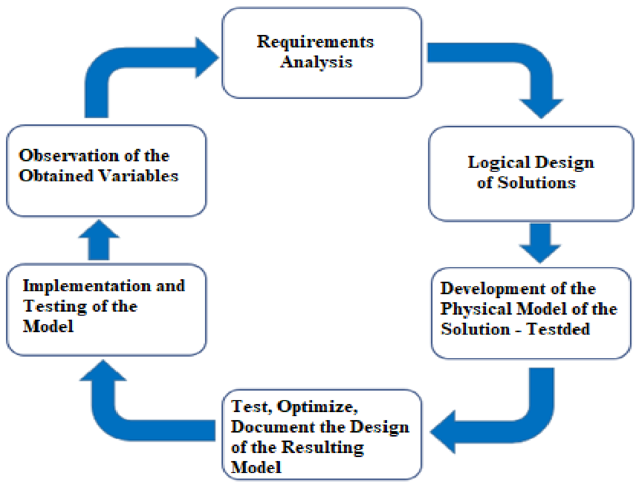

Figure 1: Top-down design methodology life cycle

3.2 Materials and Procedures for Development

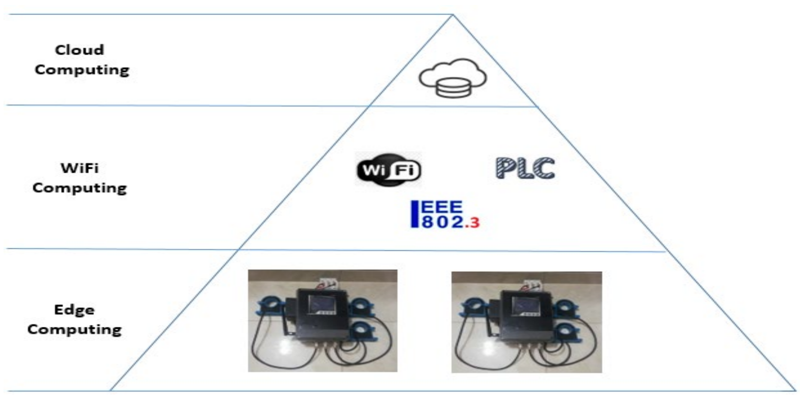

Figure 2: Layered model of the measurement process about the concept of IoT

In this part, the elements that were discussed for the implementation of the development obtained are determined and the crucial technical requirements are justified to associate them with the scheme that was modeled and left in the proposed solution and in this way conceive the proposed system. Most of the references taken about the elements used are based on the typical requirements that these systems must have and that they must meet in accordance with the theoretical, functional and industrial standards that are currently used in power measurements based on IoT; the applications that were added to the development process are limited to the field of online monitoring of electrical parameters of power transformers, this can be seen in Fig. 2.

3.2.1 The Materials Mentioned Below are Those Used for the Implementation of the Measurement Module Development

- Three-phase meter with MODBUS RTU communication module.
- MODBUS RTU to TCP/IP converter.
- Development board with IEEE802.11 module.
- Non-invasive current sensors.

Tab. 1 shows the characteristics of the meter arranged for the measurement module.

Table 1: Technical references of the measurement module [28]

Technical Parameters		
Voltage	**Measuring Range**	380 V / 100 V
	Energy Consumption	<1 VA
Electric Current	**Measuring Range**	5 A / 1 A
	Energy Consumption	<1 VA
Frequency	**Measuring Range**	45 Hz–65 Hz
Measure Class	**Active Energy**	0,5 S
	Reactive Energy	1 S
Work Temperature	–10°C–55°C	

3.2.2 Communication and Connections Arranged for the Proposed System

- Communication with typical systems currently applied for on-line electrical measurements using the RS485 interface, 2-wire full duplex (with Modbus protocol).
- Communication with typical external current sensors via portable multi-conductor flexible cables composed of two soft copper conductors with individual thermoplastic polyvinyl chloride insulation (PVC).
- The meter communication with the IEEE802.11 system is done using a MODBUS RTU to TCP/IP converter, using such a converter in slave mode.
- Communication with the database is done through a development card that has an IEEE802.11 module and is configured in Server mode, this is in charge of interrogating the meter and sending the data received to the database through the Internet.
- The MQTT protocol is used to load the information to the database.
- The database is managed through a high-performance unrelated system (NoSQL).

3.2.3 Acquisition of Data

For local recording of all electrical power parameter data, a three-phase meter with RS-485 communication was used, connected to voltage and current signals, the data obtained is passed as a reference to a database system, in which they can be operated for their proper deployment in the information system.

3.2.4 Synchronization and Data Updates

Unix Timestamp was used for automatic time update and synchronization, referenced in the built-in RTC real time clock and NTP time server (Network Time Protocol). This can be seen in Fig. 3, which presents the general architecture of the measurement system.

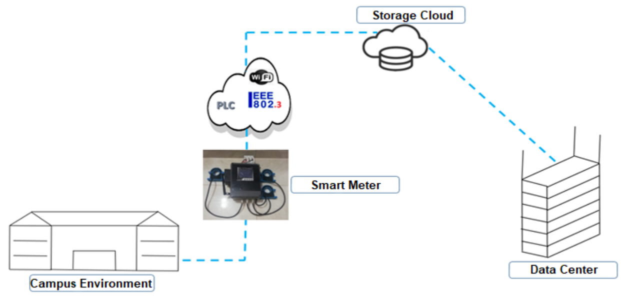

Figure 3: General architecture of the measurement system

3.2.5 Reliability, Security and Data Protection

One of the crucial aspects with respect to the system is the continuity of the process of recording and filing the measured parameters, since the communication available is unilateral between the measurement unit and the database and to make any modification in the device configuration it must be physically accessed. The basic registration of remote system parameters in the database, control and collection of related information is done through an IEEE802.11 connection supported in IPSec (Internet Protocol Security). The composition by blocks of the data handling scheme is found in Fig. 4 [20].

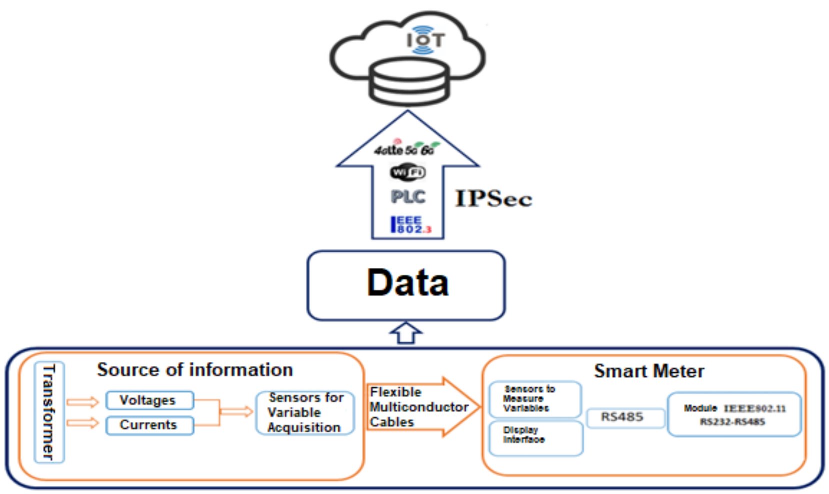

Figure 4: Block structure of the measurement and data handling concept

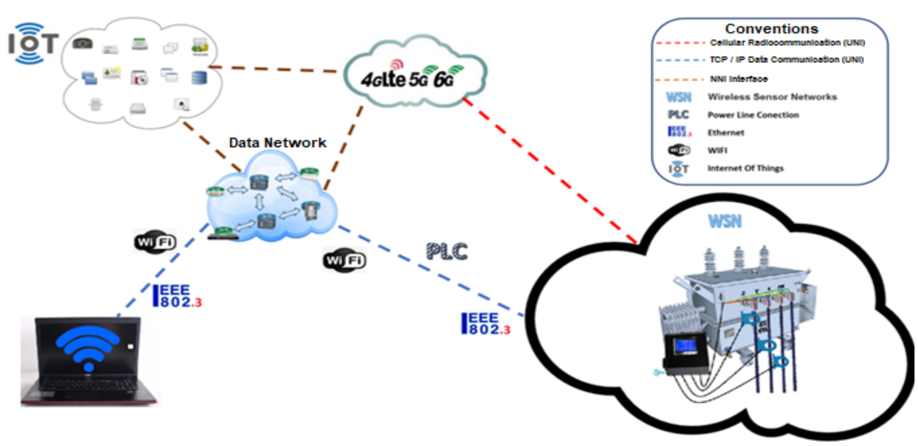

Figure 5: Schematic connection model of the measuring module

4 Results of the Development Process

The goal defined in this development is in charge of acquiring data with a measurement solution arranged in a node that was attached to a power transformer, which was achieved using the proper concepts related to power management and electrical loads for consumption. This section presents the results obtained after an operating procedure, together with the results of the field tests of the measurement sensors that were in the device that became a Smart Object [5,16].

To measure target systems that reflect the consumption of aspects such as electrical power and what it represents, currently forms, methodologies and models are used that through technologies and other mechanisms, they materialize such actions in a direct or indirect way, or through methods that may or may not be invasive, and due to the structural arrangement nowadays commercial products have the possibility of extracting their data, using protocol concepts with industrial type determinations, which make them a closed concept to potentially manage them; which implies going straight to the implicit and explicit recognition of consumption processes, where it is necessary to know how a mechanism proposed in this way can be composed and at the same time determined as an IoT object; This seeks the possibility of measuring the reference conditions of its operation, which are of interest to the objective of construction of such object. The way in which this is done is by considering a measurement mechanism that physically takes this process in a direct way and extracts these variables for storage and subsequent processing.

The implementation peculiarities used within this development, as already mentioned, are determined by the electric power measurement processes, defined in principle on main circuit transformers of a campus; The aforementioned was specified by modeling the measurement concept, using for this a voltmeter, which can be managed by associating it to a network interface, which makes it a Smart Object that can be tracked with the use of such interface by means of a management system, what is represented in the possibility that said composite object becomes by the management of convergence, pervasiveness and ubiquity, in a characteristic element of IoT [29].

The data acquisition system obtained through the model was used to monitor transformer installations connected to the electrical network of an infrastructure campus. The operation of this gives the possibility of extracting thirteen (13) functional behavioral variables [29].

From this, the data obtained from the voltage and current signals in phase A, B and C are presented below, which were developed during an approximate period of time of two (2) h, however, the model can be in continuous operation for the time to be determined, but in this case, samples were taken every 5 s in the period considered; For the management process, the information was graphed in periods of 15 min for an easy global reading of the data, which the user of the management system may vary, this implies being able to have advantages and dynamic analysis tools. This can be seen in the voltage and current measurements of each phase as shown in Fig. 6. The tables attached to the graph define the peak values of the voltages and currents per phase, showing their value, date, and time in the one that was presented.

	Max	Date	Hour
Va (Vac)	122	30/06/2020	01:00:00 p. m.
Vb (Vac)	122	30/06/2020	12:30:03 p. m.
Vc (Vac)	123	30/06/2020	01:00:00 p. m.

	Max	Date	Hour
Ia (A)	59	30/06/2020	12:45:04 p. m.
Ib (A)	55,9	30/06/2020	01:00:00 p. m.
Ic (A)	60,9	30/06/2020	01:00:00 p. m.

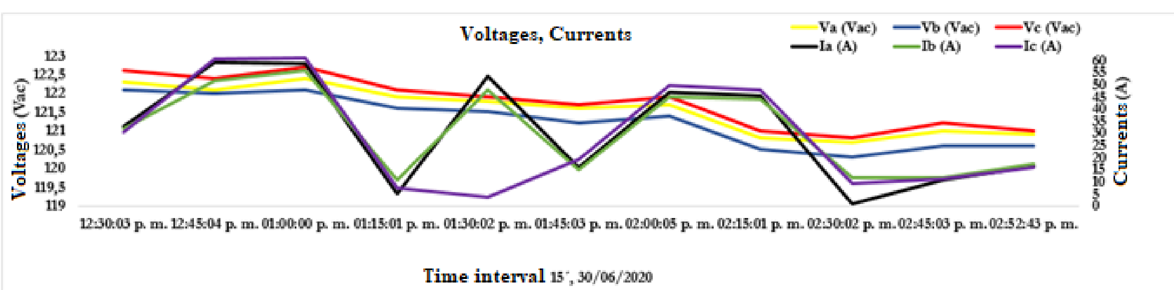

Figure 6: Voltage and current signals from the measured campus transformer

Similarly, active power measurements were obtained per phase during the same sampling process, which can be seen in Fig. 7. The table attached to the graph defines the peak values of the active power per phase, showing their value, date and time when they were presented.

	Max	Date	Hour
Pa (W)	7191	30/06/2020	12:45:04 p. m.
Pb (W)	1697	30/06/2020	01:00:00 p. m.
Pc (W)	6083	30/06/2020	01:00:00 p. m.

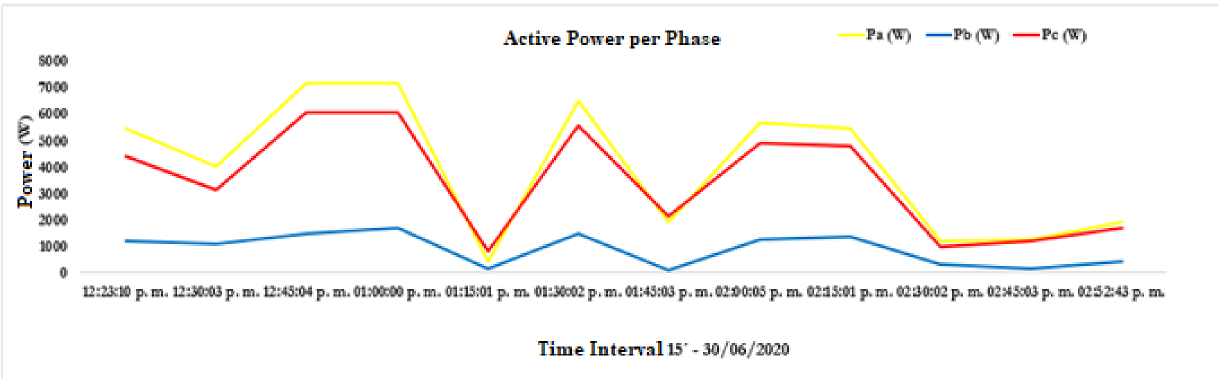

Figure 7: Active power per phase of the measured campus transformer

The management of electrical indicators, which are mainly referred to the support taken from an electric power supplier, in which support is provided and the management of these parameters in the conversion of energy and the generation of electricity, as is the case of the total powers that can be seen in Fig. 8. The table attached to the graph defines the peak values of total powers (active, reactive and apparent) showing its value, date and time in which it was presented.

	Max	Date	Hour
P (W)	651,00	30/06/2020	02:15:01 p. m.
Q (VAr)	2036,00	30/06/2020	01:00:00 p. m.
S (VA)	2131,24	30/06/2020	01:00:00 p. m.

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0,233

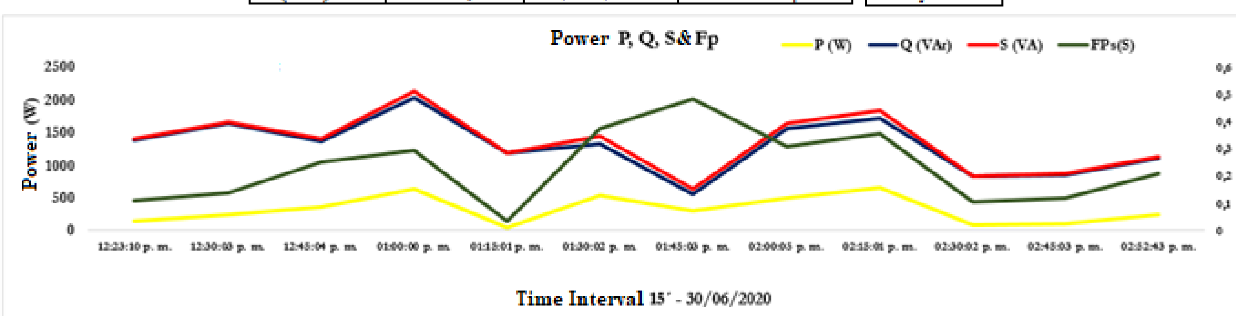

Figure 8: Total power P, Q, S (phase A, B and C) of the measured campus transformer

In the case of an implicit electrical power system in an ICT GNS environment, the behavior is determined by the electricity consumed, which is destined for support processes in terms of services deployed on platforms that are supported such as luminaires, support for power networks and telecommunications systems, where all of which is determined about networking environments, where the concept of IoT begins to spread, that is, the resource that is typified is low voltage electricity, in particular for ICT environments and similar systems such as campus-type network architectures, as well as those environments of industrial consumption medium and large scale energy [27].

In the market there are different types of electricity grid meters, which have prices that differ according to the elements and needs of the customers, however, the developed module has the advantage of converting a conventional transformer into an smart transformer at a low cost, allowing the measurement time rate to be adjusted to the client's requirements, the measured electrical variables can be acquired remotely with the IEEE802.11 standard or done locally with the IEEE802.3 standard and thus make graphs or analysis in a simple way through software. The developed module does not have its own database in the cloud, which means that it is necessary to resort to the payment of a database rental service, the operating price in a database for a month with a rate of 5-second measurement is $ 0.75, however, this module is intended to work in conjunction with other measurement modules at other points on the network, causing the database price to vary according to the number of modules installed and the measurement rate [30].

5 Conclusions

- This study described the design and implementation of an electrical measurement module, applicable to low-power networks and supported by an architecture over TCP/IP, manageable through a cloud database, with which it was possible to extrapolate the processes of convergence, pervasiveness and ubiquity through the concept of IoT and the use of the appropriate interfaces.
- The goal achieved is to make electrical management through a process of adaptation of the observed systems, taking advantage of the advantages offered by the devices through their interfaces and the generation of their OId's (Object Identification) and thus putting into practice working methods based on IoT.
- With the association of the measurement interface to the transformer, it was possible to achieve the resolution of the uncertainty state, and allowed to develop a functional concept of Smart Object, which was solved simply with the determination of configuration processes, readings of electrical parameters, extraction of the related values and interpretation of energy consumption, which can be applied using the appropriate network standards (ISO, TCP/IP and standards) and electrical handling of the case.
- It was possible to treat everything that is defined as a functional electrical power generation device, in which an adequate telemetry process for electrical administration has not been established.
- Once the measured factors are obtained, it is considered that they are compared with the historical reference data that is considered in an analysis of this kind. Finally, in measured and selected factors, it is proposed to carry out the due continuous monitoring, through a distributed and convergence model, which must be carried out cyclically, thereby ensuring adequate monitoring of the environment to be observed.
- Having an intelligent power transformer is a great advantage because the information of the measured variables can be accessed from anywhere in the world and at any time.
- The technical sheet of any device can be generated and viewed at any time, since it is possible to record all the changes generated in the variables, maintenance, events, or loads associated with it.
- As the work developed is a single module for measuring electrical variables, for future instances, it is expected to determine the measurement processes of the electrical network with the provision of multiple modules that converge in a data acquisition system.
- Fort the continuation of this development, another type of additional backup communication should be taken into account in case of loss of signal from the IEEE801.11 networks, which does so automatically without the need to go to the equipment and connect to it through the alternate network as the IEEE802.3 standards.
- The development of this this work let obtaining of a module that can turn any device, that in this case was power transformer, in a smart object of IoT, because is possible take measurements of referential parameters, like electrical variables of consumption, and take this information for store in a cloud database, with the purpose to perform an analysis with technologies like Big Data, monitoring and management of its electrical behavior.

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References

[1] V. Aubel and Poland E. Poll, "Smart metering in the Netherlands: What, how, and why," *Electrical Power and Energy Systems*, vol. 109, pp. 719–725, 2019.

[2] K. A. Ogudo, D. Muwawa, J. Nestor, O. I. Khalaf and H. D. Kasmaei, "A device performance and data analytics concept for smartphones' IoT services and machine-type communication in cellular networks." *Symmetry*, pp. 11, 2019.

[3] N. Erraissi, M. Raoufi, N. Aarich, M. Akhsassi and A. Bennouna, "Implementation of a low-cost data acquisition system for 'PROPRE.MA' project," *Measurement*, vol. 117, pp. 21–40, 2018.

[4] R. R. Singh, S. M. Yash, S. C. Shubham, V. Indragandhi and V. Subramaniyaswamy, "IoT embedded cloud–based intelligent power quality monitoring system for industrial drive application," *Future Generation Computer Systems*, vol. 112, pp. 884–898, 2020.

[5] A. Dawood, I. Osamah, O. I. Khalaf and G. M. Abdulsahib, "An adaptive intelligent alarm system for wireless sensor network," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 15, no. 1, pp. 142 – 147, 2019.

[6] O. I. Khalaf, G. M. Abdulsahib and M. Sadik, "A modified algorithm for improving lifetime WSN," *Journal of Engineering and Applied Sciences*, vol. 13, pp. 9277–9282, 2018.

[7] M. S. Hossain, M. Rahman, M. T. Sarker, M. E. Haque and A. Jahid, "A smart IoT based system for monitoring and controlling the sub-station equipment," *Internet of Things*, vol. 7, 100085, 2019.

[8] S. Muralidhara, N. Hegde and P. M. Rekha, "An Internet of Things–based smart energy meter for monitoring device–level consumption of energy," *Computers and Electrical Engineering,* vol. 87, 106772, 2020.

[9] J. Su, Y. Chen, Z. Sheng and L. Sun, "Bit query based M-ary tree protocol for RFID tags identification," in *IEEE Global Communications Conf.*, Singapore, pp. 1–7, 2017.

[10] K. Natarajan, "Some strategies for electrical energy conservation and management in industries," *Energy Engineering*, vol. 112, no. 6, pp. 33–45, 2015.

[11] M. Kunicki, S. Borucki, D. Zmarzły, D. Zmarzły and J. Frymus, "Data acquisition system for on-line temperature monitoring in power Transformers," *Measurement*, vol. 161, 107909, 2020.

[12] L. W. R. Junior, F. A. Borges, A. F. D. S. Veloso and J. JRodrigues, "Low voltage smart for monitoring of power quality disturbances applied in smart grid," *Measurement*, vol. 147, 106890, 2019.

[13] D. B. Avancini, J. J. Rodrigues, S. G. Martins, R. A. Rabêlo, J. Al-Muhtadi *et al.,* "Energy meters evolution in smart grids: A review," *Journal of Cleaner Production*, vol. 217, pp. 702–715, 2019.

[14] O'Driscoll, Eoin and G. E. O'Donnell, "Industrial power and energy metering a-state-of-art review," *Journal of Cleaner Production*, vol. 41, pp. 53–64, 2013.

[15] E. C. Bravo, J. C. García and W. A. Morales, Metodología para la evaluación de proyectos Smart Grid en Colombia, Cali: Programa Editorial Universidad del Valle, 2018.

[16] Khalaf, O. Ibrahim and B. M. Sabbar, "An overview on wireless sensor networks and finding optimal location of nodes," *Periodicals of Engineering and Natural Sciences*, vol. 7, no. 3, pp. 1096–1101, 2019.

[17] Khalaf, O. Ibrahim and G. M. Abdulsahib, "Frequency estimation by the method of minimum mean squared error and *P*–value distributed in the wireless sensor network," *Journal of Information Science and Engineering*, vol. 35, no. 5, pp. 1099–1112, 2019.

[18] F. Al-Turjman and M. Abujubbeh, "IoT–enabled smart grid via SM: An overview," *Future Generation Computer Systems*, vol. 96, pp. 579–590, 2019.

[19] O. I. Khalaf, G. M. Abdulsahib and B. M. Sabbar ,"Optimization of wireless sensor network coverage using the

bee algorithm," *Journal of Information Science and Engineering*, vol. 36, no. 2, pp. 377–386, 2020.

[20] O. I. Khalaf, G. M. Abdulsahib, H. D. Kasmaei and K. A. Ogudo, "A new algorithm on application of blockchain technology in live stream video transmissions and telecommunications," *International Journal of e–Collaboration*, vol. 16, no. 1, pp. 16–32, 2020.

[21] O. I. Khalaf, G. M. Abdulsahib, H. D. Kasmaei and K. A. Ogudo, "A new algorithm on application of blockchain technology in live stream video transmissions and telecommunications," *International Journal of e–Collaboration*, vol. 16, no. 1, 2020.

[22] H. Yao, X. Wang, L. S. Wu, D. Jiang, T. Luo *et al.,* "Prediction method for smart meter life based on Big Data," *Procedia Engineering*, vol. 211, pp. 1111–1114, 2018.

[23] F. Vélez Varela, Proceso de gestión tecnológica aplicada a la evaluación del impacto ambiental de la infraestructura de las TIC, bienes, redes y servicios usando como modelo de referencia una red LAN, Cali: Universidad Libre Seccional Cali, 2018.

[24] O. I. Khalaf, G. M. Abdulsahib and B. M. Sabbar, "Optimization of wireless sensor network coverage using the Bee Algorithm," *Journal of Information Science and Engineering*, vol. 36, no. 2, pp. 377–386, 2020.

[25] M. H. Liang, Y. F. He, L. J. Chen and S. F. Du "Greenhouse environment dynamic monitoring system based on WiFi," *IFAC PapersOnLine*, vol. 51, no. 17, pp. 736–740, 2018.

[26] F. Abate, M. Carratù, C. Liguori and V. Paciello , "A low cost smart power meter for IoT," *Measurement,* vol. 136, pp. 59–66, 2019.

[27] Ortiz, J. Hamilton, F. V. Varela and B. T. Ahmed. "Energy consumption model for green computing," *Mobile Computing*, London, Intech Open, pp. 1–14, 2020.

[28] J. Su, D. Hong, J. Tang and H. Chen, "An efficient anti-collision algorithm based on improved collision detection scheme," *IEICE Transactions* on *Communications*, vol. E99-B, no. 2, pp. 465–469, 2016.

[29] C. Inteligente, "Parte I Antecedentes y Marco Conceptual del Análisis, Evaluación y Recomendaciones para la Implementación de Redes Inteligentes en Colombia," *Smart Grids Colombia Vision*, vol. 2030, no. 81, 2016.

[30] Abdulsahib, G. Muttashar and O. I. Khalaf, "Comparison and evaluation of cloud processing models in loud–based networks," *International Journal of Simulation–Systems, Science & Technology*, vol. 19, no. 5, 2018.