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The Cognitive Power Meter using Raspberry pi

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Abstract **--A smart meter is one of the smart electronic devices that analyzes the usage of electrical energy and transfers the information to the electricity supplier for monitoring and billing. Smart meters measure the energy consumption regularly with various intervals. The smart meter is important component for displaying energy uses and useful for collecting information at any time. A smart meter is digital power meter with high communications capabilities – it is not actually smart. Load disaggregation is used to find which load is consuming more energy and disable the loads. A smart meter incorporating load disaggregation intelligence can be seen as going farther the traditional smart meter – called as cognitive power meter (c-meter).**

Keywords: ATMEGA 328, Raspberry pi 2 model B, Wi-Fi module.

I. INTRODUCTION

Smart meter is an effective automated solution for the present energy distributing and monitoring system. It will measure the readings frequently and take actions to perform the action stable. A Wi-Fi based modem is integrated with each electronic energy meter. Through Wi-Fi the meters communicate with the coordinator. The central authorized person makes use of GPRS modem to upload/analyze/download data to/from internet. A computer with a network connection at the other side, contains the database acts as the billing point for consumers. Live meter reading is fed back to utility and owner periodically. The increasing technology will sent back information to this billing point periodically and these details are upgraded in a central cloud database. All the energy backlogs, information from the Government, billing issue details and average analytical statistics will be available. The system divides the loads into two parts: critical usage loads and non-critical loads. This will make the distribution part system more smart and intelligent. More over the information about the power cuts in the areas will be intimated to the consumers in prior way. One can easily implement many addition process such as energy usage demand prediction, real time usage tariff as related to demand and supply and so on.

Appliance-level load technological models are expected to be a crucial part in future smart grid applications. Unlike direct household appliance monitoring approaches but also to make efficient, it is more flexible and easy way to mine smart meter data to generate load models at device level non-intrusively and make to all households with smart meter ownership. This analyses proposes a comprehensive and vast framework to solve the load dis-aggregation problem for residential households [5][6]. Our approach determines both the modelling of home appliances models and the solving of non-intrusive load monitoring related on sampled integer quadratic constraints programming to dis-aggregate a household power usage into the high equipped appliance level. Outline of our approach to be implemented with current smart meter infrastructure is performed based on public energy consumption datasets. All data down-sampled at the rate which is prominent with the Australia country smart meter infrastructure functionality. The results shows that our analysis is able to work and withstand with existing smart meters to generate new device level load model for numerous smart grid research and applications.

II. RESEARCH WORK

The main goal of the research project titled "Smart Metering" is to disaggregate electrical appliances in the load curve of residential buildings. For this type of research work it is divided into few parts. At first a database with measurements of individual appliances was established. Currently there are 350 measurements of individual appliances in the database. From these measurements characteristics of appliances can be extracted. With these characteristic functionalities one can make numerous models of appliances. The last part is to develop algorithms, which can disaggregate the electrical appliances. Here we can distinguish three types of algorithms. The first type are detection algorithms (find switching-on events of appliances). The second type are classification algorithms (use different parameters to classify the appliances). The final type are energy

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tracking algorithms (track the energy usage of the individual appliances).

III. A BRIEF OUTLINE OF POWER METERS EVOLUTION

The ability to withstand and control electric power GTDU has always been related to this basic element, the power meter [1]. These devices are introduced to measure and record the energy consumption in single-phase or three phase consumer units, independently of their current and voltage levels or frequency definition. Such information is traditionally used for the power system plaining, operation and for charging consumer’s use of energy. Thus, next sections present a brief overview of the energy meter evolution in the last decades.

A) Electromechanical Meter

Considering the international scenario, the electro mechanical power meters are still a widely applied technology, especially for residential consumers. Although a well-known technology, the electromechanical meter shown in Fig.1 presents several limitations due to its constructive characteristics. In general, electromechanical meters are not highly accurate and its measurement may be affected by many factors, such as: waveform distortions or imbalance, operation temperature, among others. In addition, this category of energy meter can only measure the active or average power component and basically considering unidirectional power flow, mostly for revenue purposes [15]. As depicted in Figure 1, other important limitation related to this technology is the fact that the energy measurement typically requires manual or human reading (by the utility personnel), what is certainly more susceptible to reading errors. Besides, it should be emphasized that such process represents a high operational cost for the utilities, which are basically transferred to the consumers in the energy tariffs.

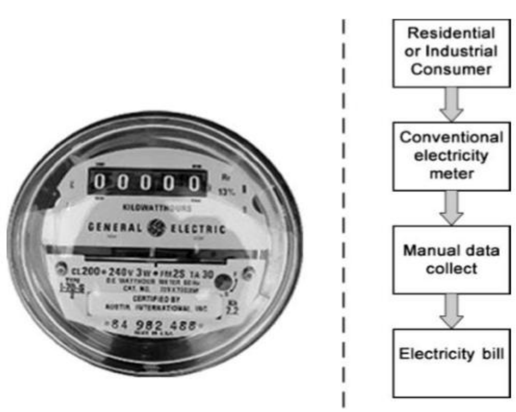

Fig.1 The conventional electromechanical metering system

B) Electronic Power Meters

Considering the evolution of electronic and microelectronic devices in the last decades, several solutions have arisen for the problems related to the electromechanical meter. Thus, the first electronic meters were developed, as shown in Fig. 2, and the main goals were associated to the improvement of measurement accuracy and the reduction of operational measuring costs.

Fig 2. Electronic power meters

The main features of the AMR/AMI systems are :

- Electronic meters: perform energy measurements and provide communication between consumer and utility.
- Management system: is composed of a data concentrator and signal processing unit.
- Communication infrastructure: Establish the means of communication for the data transmission between the network elements.

C) “Smart “Measurement Of The Electric Power

With the dissemination of the electrical smart grids, AMI has being known as Smart Metering System (SMS)[2], as illustrated in Fig.3. This new concept has been developed in a fast way during the last years and it has been driven by the technological progress and by the need to obtain data that cannot be provided by the traditional metering systems. In this scenario, the smart meter is considered a pillar of the smart grid evolution. A smart meter is an electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing as

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shown in fig.3. Smart meters are used to record energy consumption hourly or more frequently, and report at least daily. Smart meters make us two-way communication between the meter and the central host system. Such advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) and it enables two-way communication between the meter and the supplier in a state. Communications from the meter through network may be wireless, or via fixed wired connections such as power line carrier communication (PLC). Wireless communication are in common use include cellular communications (which can be expensive), Wi-Fi (readily available), wireless ad networks over Wi-Fi, wireless mesh networks, low power long range wireless (LORA), Zig Bee (low power, low data rate), and Wi-SUN (Smart Utility Network).

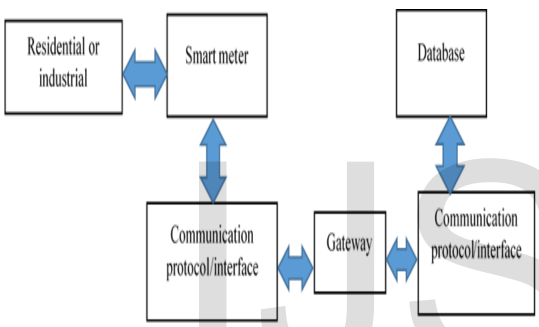

Fig 3. Smart Metering System (bidirectional communication between utility and consumer point).

D) Cognitive Energy Meters

As previously mentioned, the SMS technology has undoubtedly brought several evolutions to the electricity metering systems[4], but the "smart" term requires consolidation to identify the meter class required to develop the future power system. The ability to read apparent power in four quadrants, locally or remotely, is not enough to be considered a smart meter. Thus, several ways of adding more intelligence to the meters have been presented. One of the keys to the smart meter evolution is certainly the load disaggregation capability. This functionality can be obtained using the method called Non-Intrusive Load Monitoring (NILM) initially proposed by Hart[5], which makes use of a pattern recognition method to identify appliances power signature, simply using the metering point at the Point of Common Coupling (PCC). Other method of load monitoring is called Intrusive Load Monitoring (ILM) or distributed monitoring, which is based on sensors distribution at measuring points as electrical sockets or appliances. The ILM is said intrusive because has the need to install measuring devices at each point of interest.

Between the ILM and NILM, the NILM has attracted more interest because it is more practical for residential applications mainly due to the advantages of using only one measuring instrument and connection. The simplest NILM method involves identifying the changing of the load power state, that is, when the load changes the power consumption or it is on or off. This method has several advantages because it enables to create representative models of a residence using state machine concept. Such models can be used for data analysis through several techniques found in literature. Although these models are simple and they do not show high accuracy in relation to the individual consumption of appliances with complex power signatures, like a LCD television. In this sense, state machine models discard significant information that can be used for analysis. For the accuracy detection and exact monitoring, it is necessary to consider that the loads have variations over the time. The NILM technique [6] analyzes the power grid in order to detect events that characterize the load power signature. This procedure can be seen in Fig.4 and it is represented by six states. Briefly, first the voltage and current data are collected. Next, this data is processed to detect appliances that are operating. After that, an algorithm is executed to identify which appliance (load) is consuming energy according to the power values over the time (appliance power signature). Finally, the appliance consumption is evaluated.

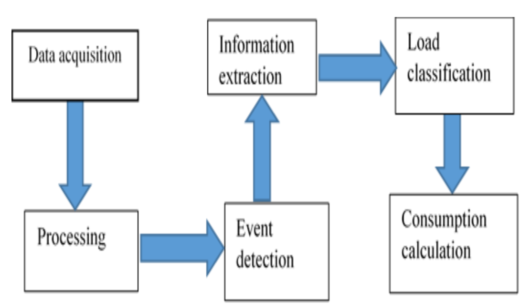

Fig 4. Stages of the Non-Intrusive Load Monitoring (NILM) process

Therefore, the NILM technique can be considered as an effective tool for collecting load information and can also encourage other applications [7]. From this point of view, the concept of smart meter is redefined and it is called cognitive meter. With this cognitive meters concept and implementation, it is possible to take relevant information about the electric energy consumption of each type of load for metering.

IV. COMPONENTS FOR POWER METERING

A) Raspberry Pi 2 Model B

The raspberry pi is a progression of little single board PCs as shown in fig.5, create in the unified kingdom by the raspberry pi establishment to advance the instructing of fundamental PCs science in school in creating nations the first model turn out to be more prominent at that point expected offering outside its objective market as apply autonomy .

OPERATING SYSTEM	**OPERATING SYSTEM ANDROID THINGS LINUX WINDOWS 10**
System-On-Chip Used	Broad com Bcm2837
Cpu	1.2GHZ 64/32-Bit Quad core Arm
Memory	1GB RAM
Storage	Micro SDHC Slot
Graphics	Broadcom Video core
Power	1.5 W To Max 6.7 W

Fig.5 features of raspberry pi

B) Wi-Fi Module

The Esp is a minimal effort Wi-Fi microchip with full TCP/IP stock and microcontroller capacity created by Shanghai based Chinese produce. This little module permits microcontroller/raspberry pi to interface with a Wi-Fi system and make basic TCP/IP associations utilizing Hayes style orders [12].

The superior microchip 8-bit AVR RISC based microcontroller incorporates 32 KB ISP memory with read while compose capacities, 1 KB EEPROM 2 KB SRAM 23 broadly useful information yield lines, 32 useful working registers, some adaptable clock/counters with look at modes, interior and outer intrudes on, serial programmable USART, a byte started to wire serial communication interface, SPI serial port, 8 channel 10 bit A/D converter. By executing intense guidelines in a solitary clock cycle, the gadget accomplishes through puts moving towards 1 MIPS for every MHZ adjusting power utilization and handling speed.

V. ALGORITHM DEVELOPMENT

The main part of the paper consists of the development of dis-aggregation algorithms. With these algorithms the electrical appliances should be detected in the load profile of residential buildings. The quality of the algorithms should be verified. There are several criteria for defining the quality of developed algorithms. On the one hand the algorithms should yield a high detection rate. One should analyze the quality of an algorithm is testing them on real signals. For this the already performed measurements in residential buildings are used. This method has a severe disadvantage: for showing a measure of error and success rate one needs to have detailed information on the switching cycles of each and every appliance in the household during the energy measurement. This information is not always available as autonomous operating appliances (e.g. refrigerators, heat pumps)[10] do not keep record of their cycles. Additionally the documentation effort for the measurement would rise to an undesirable level. For this reason a test system was developed. This system consists of three components and it is shown. The first part of the test system is the test set generator which generates well defined and well described test sets. The advantage is that the switching cycles of appliances included in the test set are known. This way the measured events can be compared to the events in the test generator set. Another element of the test system is the reference algorithm. For this the well-known algorithm of Hart was implemented. The detection rate and the error rate of the newly developed algorithms are compared to those of the reference algorithm. This way it is possible to judge the quality of the new algorithms.

VI. TEST SET GENERATOR

For the development of the test set generator, a simple model for the external grid and the appliances in the house is used [14]. Using this type of model, signal characteristics of energy consumption can be identified. The basic idea of the test set generator is

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to superpose the measured individual appliances at different times.

Modeling of the external Grid Adding the measured individual current profiles of appliances for generating superposition will result in errors which was shown by measurements. One reason is that the mains voltage $v_L(t)$ is not constant due to the resistance of the grid lines. By switching on more and more devices z_L the voltage drop across the internal resistance z_S increases. This has direct impact on the energy consumption of each appliance in usage. When switching ON the second appliance, the energy usage efficiency of the first appliance decreases. So the instantaneous power is calculated as follows

$$P(t) = v_L(t) \cdot i(t) \quad P(t) = v_s(t) \cdot z_L / (z_L + z_S) \tag{1}$$

Secondly the measurement of the single appliance was carried out at many different times. This means that the mains frequency may be different for each measurement. To show the on and off behavior of the appliances, a real voltage source was constructed. At this particular point the superposition is not calculated using the apparent power because of the different supply voltages and frequency in the measurements of the individual appliance. It will be calculated by adding the admittances of the individual appliances. Using a nominal voltage, the apparent power will be calculated from these admittances. The grid can be modeled as an ideal voltage source with a voltage $V_S(t)$ connected to an admittance $Y_{(s)}$ (internal resistance of the grid). The different appliances can be modeled as

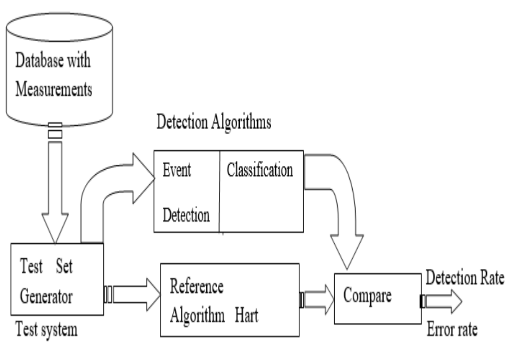

Fig. 8. Test System to analyze the developed Algorithms

Admittances (Y^1) to (Y^M) (M number of appliances). Together they form the admittance $Y_{(L)}$

$$Y_{(L)} = \sum_{m=1}^{M} Y(m) \tag{2}$$

While dealing with the non linear loads distortions in the current are likely to be observed. These distortions are called harmonics. By means of the Fourier transformation all periodic signals can be represented as a sum of individual harmonic functions. Thus the current i(t) is modeled as a complex current consisting of the superposition of different harmonic currents. In the following we use only the positive spectral components because of the symmetry of the spectrum. Furthermore, the number of necessary harmonics should be limited to N. Analyses of the measurements show that with the first seven harmonics a good approximation of the current waveform is achieved. This means that the current can be calculated as

$$i(t) = i_o + i_n e^{j\omega t} e^{j\varphi i}{}_n \tag{3}$$

The component i_o represents the constant component (dc) of the current. i_1 is the first harmonic of the distorted current. It is the part of the fundamental wave. The components i_2 to i_N are the higher harmonics of the current. N is the N-th harmonic. The $\varphi_{in}$the phase angles of the harmonics. ω is the angular frequency of the fundamental wave and is calculated by $\omega = 2\pi f$. The n-th angular frequency is a multiple of the fundamental frequency. The mains voltage may be influenced by distortions as well. Fortunately these distortions are negligible. This is also verified by the measurements analyzed in-house. So at this point the voltage of the appliances is modeled analogously to the current in equation (3) as

$$V_l(t) = V_1 e^{j\omega t} e^{j\varphi i} \tag{4}$$

VII. IMPLEMENTATION

Smart meters not only meant for automatic billing purpose but also for displaying the energy consumption details at where ever in any place. The vitality meter perusing is get past the beat sensors and every usage is incorporated with the raspberry pi and LCD display will show the numerical data. The transmitted and got pins (Rx and Tx) transmitted the information to the raspberry pi circuit and with the assistance of Wi-Fi module the perusing is transmitted to the web database. The consumed energy is analyzed by various procedures and cost per unit is described for regular intervals of time and can be checked by the consumers about the energy usage.

Though, there are numerous innovations emerged in the concept of smart metering and having various improvements. Among several commercial smart meters around the globe, the authors identified the following additional features [16]:

• Power quality monitoring, especially for fault detection and voltage quality analysis.

• Different time events recording, especially for fraud detection, energy price time changing, violation of maximum contracted power, etc.

• Demand control with capability to limit the load power at the measurement point.

• Programmable acquisition sampling rate.

• Data storage in memory.

• Calendar-based electricity bill calculated in the smart meter.

• Two-way communication for remote reading or for pre-payment systems, credit purchase, software upgrade, etc.

• Micro generation support

• Immunity to phase inversion.

• Automatic low voltage

Administrative losses are those losses which are given by unknown connections and missing meters in the system. The third kind of loss is illegal use of electricity which is done in several ways like energy tampering in smart meters are checked and proper indication will be alerted to utility also on LT lines and arranging false readings by manual meter readers etc. According to this work, in most of the developing countries including India also, some amount of produced electricity is wasted as losses; approximately 47-48% of this loss is due to electricity theft.

VIII. ANALYSIS

The analysis of this work plan is to use the concept of wireless meter reading to get the monthly usage reading of our household and society. The flow chart for the project is shown in the figure.9.

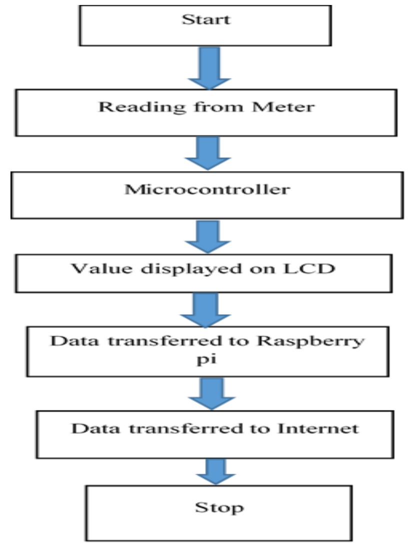

Fig .9 flow chart

IX. CONCLUSION

This paper presented an overview of electrical energy metering systems emphasizing its basic element: the power meter. Measurement of electricity is essential to the electrical system operation, being important both for the power management and energy charging, and to ensure the reliability and safety to the system. Due to the development of smart grids and the latent needs for power management improvements and maximum energy efficiency, the use of smart meters was emphasized. Then, possible advantages and benefits that can be obtained from the consumers' perspective, power utilities' and society's points of view were discussed.

In addition, the new features that characterize the meter as "smart" have been put in perspective in order to present new solutions that can enhance the use of these type of meters, mainly for the ability to extract relevant information about the electricity consumption. Therefore, the use of these devices transcends their basic function, breaking the current paradigm of electric energy meters and creating a new concept of meters: the cognitive meter. This meter can become an essential element to ensure the consumers' awareness about the electric energy consumption and to increase the energy efficiency. From the utilities point of view, especially the distributors, the installation of truly smart meters may allow a more efficient grid management, while renewing the entire consumer-provider relation.

XI. FUTURE ASPECTS

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In addition to the future incorporation one can choose Raspberry pi 3 model B+.With that benefits the efficiency of the system can be increased. The Raspberry pi is having its own operating system, micro SD card etc. It is easy to use and has better advanced features. All the meters we install for billing purposes whether it's a Smart, traditional or Prepay meters, have been tested for accuracy in order to meet regulatory requirements.

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