Design of smart power meter for local electrical power generators in Baghdad city

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Abstract. The shortage in electrical power generation in Iraq due to several wars, forced the people to use an alternative solution. One of such solutions is the local power generators that distributed rapidly in Iraqi cities. The investors whom owning these generators make the prices for delivering the power to the consumers without power meters. In this paper, a smart power meter for such generators can be used in each customer place. The smart power meter simply is composed of an Arduino Pro Mini microcontroller with an ACS712 current sensor and DS3231 Real Time Clock. The sensed data is proceed using simple algorithm to calculate the required bill according to the consumed average amperes multiplied by the ampere price setting by the provider during the delivery period. The proposed meter with its low cost and fair bill calculations can be used at each end-user location for local generators.

1. Introduction
Starting from the first Gulf war, Iraq has witnessed severe crises in providing electrical power. Many attacks on the power plants led to destroy almost the entire power generation in the country. The Iraqis succeeded in repairing some of these power plants but not to solve the entire problem. Due to that people had established their own solution by investing in electrical power generation and distributing. However, and due to limited capitals, the installation and distribution of local electrical power units had faced a lot of criticism.

The records for the electrical power statistics approve the great shortage in providing the power for the available demands in Baghdad city as an example. The report published in the website of Iraqi ministry of electricity for the year of 2017 records that the actual demand for the electrical power in Baghdad is about 5000 MW while the delivered amount of power is in the range of 3600 MW with shortage percentage of 30% [1-4]. These facts appear clearly in power cuts especially during summer times between 8-16 hours a day; making regular people to depend on local generators [5]. In order to compensate this shortage in providing the power demands, many alternative solutions have been created by the citizens. One of the successful solutions is the establishing of local gasoline generators in many sections in Iraqi provinces.

Investors in providing the electrical power for the customers starting this market after the first Gulf war in 1991 and especially in the southern part of Iraq while Baghdad as a capital was not suffering from long hours of energy drop. After 2003, local power generators began to be found in Baghdad and its cities. These generators have a capacity of 150 KVA to 250 KVA and it is clear that, depends on
this power capacity the number of customers will vary. Fig. 1 shows a photo for one of these generators, the owners of the generator has to establish its control box as shown in Fig. 2 which usually composed of a set of automatic circuit breakers that cuts the connection to the load when the drawn current exceeds its determined value. After a short period (not more than 2 minutes) the circuit breaker allows the power to pass through line to the load again. The distribution networks for such local generators are made of set of single wires with gages (1.5-4) mm. The single wire carries the positive part of the electrical connection between generators and costumer load while both of the sharing the grid earth.

![Figure 1. local private generator in one of Baghdad street](image1)

![Figure 2. control board for the local generator](image2)

The prices for providing the power for the customers determined by the owners of these generators without any meters. These prices change according to the period of generator work which vary from season to season and depends on the period of government electricity cuts. So, during summer time the power could be cut for more than 12 hours a day and the price for the ampere may reach 25 thousand Iraqi Dinars which is about 20 US dollars. People according to their incomes may buy from 3A up to 25A. So, on average of 10A the customer has to pay an amount of 250 thousand ID or about 210 US$ for each month.

This cost is determined for the full period of delivery to the customers, i.e. more than 12 hours a day. However, these power cut hours varying from month to month and may vary from 0-20 hours a day. But the price for the Ampere of the local generators is not changed relative to this wide change and approximately still constant. During nice weather in Iraq where the demand for electric power is not severe the period for power cuts could reach zero but in spite of that the customer has to pay the monthly price according to the number of Amperes he buys. Because of this unfair situation, this paper proposed a smart power meter that calculate the price for the power delivery from the local generators based on the actual working hours multiply by the average Amperes consumed by the load.

In the next section, some of related works in the literature will be presented. The system model is described in section 3. Section 4 is dedicated for results and analysis and the conclusions are listed in section 5.

2. Related works
The literature includes many projects that touch the idea of our paper, however the principle of our calculation for the required bill is differ. Introducing the Arduino microcontroller open a wide gate for many smart projects that have many smart applications [6-10]. A smart energy meter using an Arduino
Uno attached to voltage and current sensors is presented in [11]. The proposed design sends an SMS message for the consumed energy bill through a GSM module. A wireless power meter has been implemented by Rashid et al [12] based on ZigBee module. The power calculations are made with the aid of current and voltage sensors attached to PIC microcontroller. The meters in [11,12] may have the same idea presented in this paper, however the main difference is the use of communications module and the way of bill calculations. An interested feature of the smart meters is the ability for dynamic bill pricing [13]. In [14], the smart meter utilizes GSM network access to detect the illegal access for the providing electricity by using a prepaid card. The Internet of Things (IoT) concept has witnessed a great interest in the designing of smart meters. The design of such smart meters is to construct a wireless sensor network and proposed controlling algorithms for sensing the energy data and utilize smart application to access of these energy meter reading [15-17].

All of the above systems are equipped for an official well-arranged energy providing companies while the system in this paper is proposed for private local generators almost out of government monitoring. The cost for energy delivery for customers totally determined by the owners of the generators with an obvious corrupted way. In the next sections a detail description for the system model is presented.

3. System model

This smart meter is based on measuring the consumed current by the load and the period of energy delivery to the customers. Fig. 3 illustrates the block diagram for the proposed meter.

![Block diagram of the proposed meter](image)

**Figure 3.** Block diagram of the proposed meter

The core of the system is the microcontroller Arduino Pro Mini which is utilized to suit the small size of the meter as well as its permanent usage. Fig. 4 shows the pin configuration of this microcontroller, it is mainly based on the ATmega328. For a digital I/O, this board has 14 pins (six of them are assigned as PWM outputs), another eight pins are dedicated for analog inputs. This board operates with 5V only and 16 MHz operating frequency.

As mentioned before, the cost or the price for delivering the energy to customers is based on the current drained by the load. To measure this current an ACS712 current sensor is used which is based on Hall effect. This sensor shown in Fig.5 works at 5V and generates an analog voltage output proportional to the sensed current. The second part of the cost measurement for our proposed meter is depending on the period of energy delivery. This time is measured by using real-time clock (RTC) that provides the meter with the actual time which can help in determining the energy delivery period from the generator. DS3231 RTC is shown in Fig. 6, the reason for using separate clock to indicate the time that this clock has its own power and is dedicated for time measuring i.e. we can call the current time at any instant through our code.
The sensed current as well as the current time are stored in the Micro SD Card just to return to these data whatever we want it. All these elements in the system model are equipped with the assigned power using a power module. The whole system is shown in Fig. 7.

4. Results and analysis
The main object of the meter is sensing and calculating the average consumed current and the time of consumption ($T_c$). Let the average current denoted by ($I_{avg}$) and the time of consumption labelled as ($C_{old}$). In fact, the price for the energy delivery for the customers is decided by the generators owners as mentioned before, let this price denoted by ($C_{old}$). This price means the generator has to work about 12 hours/day as minimum period, which we denoted as ($DP_{min}$). So, we can calculate the new price as ($C_{new}$):
Equation (1) represents the cost for, so to calculate the total price for a period of energy consumption, simply will be:

\[ C_{new} = C_{old} \frac{A}{h} \times T \times l_{avg} \]  

(2)

To implement the above two equations, the meter has to indicate that there is some current value \( I_{RMS} > 0 \) which represents the starting time for our period of energy delivery by the generator, this time is recorded as \( T_0 \). After that a reasonable delay is set to sense the current at periodic intervals. When the generator stops of supplying the power or in other words return to main grid energy, the current set to zero because our meter is connected to the line of generator wire the main house electric control box. This time is set to \( T_L \) so, the period of delivery is simply computed by:

\[ T_c = T_L - T_0 \]  

(3)

The above notes could simply guide the meter using the following flowchart:

![Figure 8. Smart calculation flowchart](image)

The sensed data is stored in the SD card which include the current each 5 minutes and the actual time represented by date and time. We had mounted our smart meter inside a control box that had bought 5 Amperes from the local generator as shown in Fig. 9. The results gained from the smart meter indicates that the average current consumption is often below the paid current value which is 5 Ampere. According to our smart meter calculations Table 1 illustrate the difference between the actual consumption and the paid price for the local generator bill.
Figure 9. (a) smart meter inside control box, (b) the displayed data

By making simple calculations using equations (1-3) for our case in which we have a house has a supply line carrying 5 Ampere and the generator owner making an 8.3$ price for 1 A/month assuming 10 hr/day energy delivery. So, Table 1. indicates the big difference between our suggested pricing policy (for $l_{avg} = 4 A$) with the unfair current pricing one.

| Delivery period/hr/day | Current payment | Smart meter suggested payment |
|------------------------|-----------------|-----------------------------|
| 2                      | 40$             | 6.6$                        |
| 4                      | 40$             | 13.3$                       |
| 8                      | 40$             | 26.6$                       |
| 10                     | 40$             | 33.33$                      |

5. Conclusion
The open source applications of Arduino motivate the designers for more attractive projects. This paper presents a performance investigation for one of most practical sensors which is the ultrasonic sensor. This sensor is mainly dedicated for distance estimating in a way similar to the radar distance measuring principle. We had investigated the distance resolution for this sensor which means that its ability to distinguish between two adjacent objects. The experimental results approved that this sensor has distance resolution ability within 7 cm between two adjacent objects. This poor resolution comes from its small radiating aperture. The paper conclude that this ability can be modified by increasing the diameter of the sensor aperture.

References
[1] Iraq ministry of electricity report 2017 available at: https://www.moelc.gov.iq/
[2] H. Harry, 2014 Iraq's electricity crisis, in Magnetism, The Electricity Journal 27(4),pp. 51-69.
[3] J. A. Baker, L.H Hamilton, The Iraq Study Group Report: The Way Forward – A New Approach., Vintage Books: A Division of Random House, Inc., New York,2006.
[4] I. J. Hasan, 2014 Optimum Feeder Routing and Distribution Substation Placement and Sizing using PSO and MST, Indian J. Sci. Technol, pp. 1682-1689.
[5] H. al-Khafaji “Electricity generation in Iraq Problems and solutions” Al-Bayan Center for Planning and Studies. Available at www.bayancenter.org.
[6] I.J.Hasan, N.A. Salih ,N. I. Abdulkhaleq,M.J. Mnati 2019 An Android smart application for an Arduino based local meteorological data recording, In IOP Conference Series: Materials Science and Engineering 518(4), p. 042014. IOP Publishing.
[7] N.A. Salih ,J.J.Hasan, ,N. I. Abdulkhaleq, 2019 Design and implementation of a smart monitoring system for water quality of fish farms, Indonesian Journal of Electrical Engineering and Computer Science 14(1), pp.45-52.
[8] M. J. Mnati, A. Van den Bossche, and R. Chisab, 2017 A Smart Voltage and Current Monitoring System for Three Phase Inverters Using an Android Smartphone Application Sensors, Sensors J. 17(4), pp. 872

[9] M. J. Mnati, A. Hasan, D. Bozalakov, A. V. Bossche, 2018 Smart monitoring and controlling of three phase photovoltaic inverter system using lora technology, 6th Eur. Conf. Ren. Energy Sys. 25-27 June 2018, Istanbul, Turkey.

[10] I. J. Hasan, N. A. Salih, N. I. Abdulkhaleq, Three-phase photovoltaic grid inverter system design based on PIC24FJ256GB110 for distributed generation, Int J Pow Elec & Dri Syst 10(3), pp. 1215-1222.

[11] S. H. Mir, A. Sahreen, S. Bhat, N. Beigh, 2019 Review on Smart Electric Metering System Based on GSM/IOT, Asian Journal of Electrical Sciences 8(1), pp. 1-6.

[12] M. T. Rashid, Design and Implementation of Smart Electrical Power Meter System, Iraqi Journal for Electrical and Electronic Engineering 10(1), pp. 1-14.

[13] W. A. Indra, F. B. Morad, N. B. M. Yusof, S. A. C. Aziz, 2018 GSM-Based Smart Energy Meter with Arduino Uno, International Journal of Applied Engineering Research 13(6), pp. 3948-53.

[14] M. S. Vidyashree, 2017 GSM Based Smart Energy Meter to Implement Billing System and To Control Electricity Theft, International Journal of Current Engineering and Scientific Research (IJCESR), 4(1).

[15] S. Pandit, S. Mandhre, M. Nichal, 2017 Smart Energy Meter using internet of Things (IoT), VJER-Vishwakarma Journal of Engineering Research, 1(2), pp. 222-229.

[16] W. Hlaing, S. Thepphaeng, V. Nontaboot, N. Tungsunantham, T. Sangsuwan, C. Pira, 2017 Implementation of Wi-Fi-Based Single Phase Smart. Meter for Internet of Things (IoT), 5th International Electrical Engineering Congress, Pattaya, Thailand, pp. 8-10.

[17] B. k. Sahani, T. Ravi, A. Tamboli, R. Pisal, 2017 IoT Based Smart Energy Meter, International Research Journal of Engineering and Technology (IRJET), 4(4).