EFFICIENT DIGITAL GSM/GPRS METERING FOR RURAL ELECTRIFICATION

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I. INTRODUCTION

The onset of rural electrification provides opportunities for new and more efficient metering technologies to be implemented. The traditional electro-mechanical meters, still widely used today, are prone to drift over temperature and time as a result of the analogue and mechanical nature of the components in these meters. Collection of meter readings is also inefficient, because a meter reader has to physically be on-site to take the readings. This method of collecting of meter readings becomes more problematic and costly when readings have to be collected from vast, and often scattered rural areas. Meter readers are reluctant to make the effort to travel to such areas and will often submit inaccurate estimations of the amount of electricity consumed.

Recent developments have seen a move towards the implementation of electronic meters [1] and the utilisation of telecommunications systems for automated transmission of data to facilitate efficient remote access energy management.

The Digital Telewattmeter System [2] is an example of a microprocessor based meter. The meter was implemented to transmit data on a monthly basis to a remote central office through a dedicated telephone line and a pair of modems. Reference [3] utilised a DSP-based meter to measure the electricity consumption of multiple users in a residential area. A master PC at the control centre was used to send commands to a remote meter, which in turn transmitted data back, using the Power Line Communication (PLC) technique. Reference [4] designed and implemented a Bluetooth energy meter where several meters in close proximity, communicated wirelessly with a Master PC.

The meters in [2-4] were mainly implemented in areas that had a fixed telephone network or a high population density. This paper presents a novel approach of using an energy measurement technique that encompasses the GSM network as a means of transmitting energy data. The GSM/GPRS network offers most coverage in most developing countries, like South Africa. This is especially useful in rural areas, which are not densely populated, and in which, most people do not have access to a fixed telephone network.

This paper consists of the following sections: Section II describes the design and implementation of a low-cost, single-phase digital electricity metering system. The system includes a microcontroller, which transmits power consumption values periodically, via an existing GSM/GPRS network, to a remote station. Section III, shows the results of tests done on the system to determine its accuracy and the effect of the GSM network on the data that is transmitted and finally, Section IV concludes the paper.

II. IMPLEMENTATION

The metering module shown in fig. 1 consists of a metering IC (Integrated Circuit), a microcontroller and a GSM/GPRS modem. An SA9903B CMOS mixed signal, analogue/digital, single-phase metering IC [5] performs the measurement of instantaneous active power. The metering IC measures current and voltage signals and generates instantaneous active power. The instantaneous active power values are continuously integrated to an active energy register, the value of which is periodically accessed by the microcontroller via an SPI (Serial Peripheral Interface).

The microcontroller uses the retrieved active register value to calculate the active power consumed. A real-time clock is also implemented on the microcontroller, which enables timestamps to be generated, so that synchronisation between the remote station and meter can be established. At regular intervals, the microcontroller sends data, as SMSes [6], to the GSM/GPRS modem. The data, which consists of the power consumption value, a timestamp and a meter number, is then sent as an SMS

(Short Message Service) to the remote station. The remote station consists of a master PC that communicates with another GSM/GPRS modem. The received data is then used to calculate tariffs incurred and generate bills.

The microcontroller was programmed to read data from the metering IC every second. The active register of the metering IC is not reset after it has been accessed, thus when the microcontroller reads the data from the active register, this value is stored and then subtracted from the next reading to determine the actual instantaneous power value. The difference between the current value and previous value is called a delta value. The active register of the metering IC also wraps around every 52 seconds and this is rectified in software. For each reading the new delta value is added to the previous delta values and the accumulated value is compared to a threshold value. The threshold value is the amount of energy measured by the meter before a pulse is generated. The threshold value is calculated by dividing the energy represented by a light emitting diode (LED) pulse by the energy per register count i.e.

$$Threshold = Epp/Epc, \tag{1}$$

$$Epc \text{ (Energy per count)} = I_{max} * V_{nom} /32000, \tag{2}$$

where Epp is the energy per pulse, Epc is the energy per count, I_{max} is the maximum load current and V_{nom} is the nominal voltage.

The active register increments at 320000 samples per second, therefore a single count of the energy corresponds to an amount of energy expressed in Ws (Watt seconds). The pulse rate required for the meter is usually expressed in pulses/kWh. A single pulse on an LED is a fraction of a kWh and is converted to energy in Ws/pulse i.e.

$$Epp \text{ (Energy per LED pulse)} = 1000*3600/Mpr, \tag{3}$$

where Mpr is the pulse rate of the meter in pulses/kWh.

In this implementation, every second a reading is taken and compared with the threshold value. When the threshold value is reached, a pulse is generated on an LED, denoting 0.001kWh power consumption, thus a 1000 pulses result in 1kWh power consumption. Every time a pulse is generated, the power consumption value is integrated with the previous value and stored until the data is sent to the remote station. The formulas used in this section were based on information obtained from [5].

As mentioned above, timestamps are generated by the microcontroller in real time, however they do not reflect the actual clock time. Considering that the system is also unidirectional (data is sent from the meter to the remote station, but not visa versa), this poses a problem, especially when bills have to be generated. To alleviate this problem, the meter transmits an initialisation SMS to the remote station. At the remote station the received timestamp is referenced to the actual time of the remote PC. When the remote station receives readings from the meter, the timestamp is used to increment the reference time. In this way the exact time the reading was taken can be determined and synchronisation between the meter and the remote station can be achieved.

III. RESULTS

The meter was tested against different loads to determine both it’s accuracy and it’s adaptability to varying loads. As can be seen in fig. 2, the linear loads varied from 340W to 2800W. The measurements were taken on the same day, in 1-minute intervals, each of 15 minutes duration i.e. for each load the power consumption values were transmitted from the meter each minute, and the readings were recorded for 15 minutes. These tests were also performed on different days for determining the correlation of the results.

The constant lines (P_x), in fig. 2, indicate the actual power consumed by the load and the dashed lines indicate the measured power consumption. The minimum error between the measured values and the actual calculated values was found to be 0.58 % while the maximum error was 5%. The average error for all the various load conditions was found to be approximately 2.62%. The actual values were determined by dividing the power of the load by the time over which the reading was taken.

Tests were also done during off-peak and peak conditions to determine the latency of the data transmitted in a typical urban environment in South Africa. These results of this are shown in fig. 3. The test involved transmitting data over an 18-hour cycle at different times of the day and determining the amount of the delay in receiving the data on a normal business day. The results indicate that we achieved a maximum delay of 5s and a minimum delay of 1s. On average, the delay was found to be 2.1s. Similar tests were conducted during weekends and we found on average, the delay improved by about 1s. Since network traffic is greater in urban environment and prone to congestion, which can lead to delays, it is assumed that at least similar if not better could be achieved for rural environments.

During the tests for meter accuracy and latency, the reliability of the system was also determined. This was done by periodically testing the loss of data from the remote meter to the control station. If the timestamp that the remote station received did not appear in numerical order, then it would have been established that either the meter did not send the reading, or that due to network congestion/failure the SMS was lost. This however did not occur during the times that the meter was tested. The meter was also tested across different lengths of time and under different loads to ensure that it could still perform its meter reading and transmission functions under varying conditions.

IV. CONCLUSION

Various electronic meters have been developed and are still being developed. However the use of GSM in this particular system provides numerous advantages over methods that have been previously used. Data transmission is charged at standard SMS rates, thus the charges are not based on the duration of the data transmission. The cost efficient transmission of readings ensures that power consumption values can be transmitted more frequently to a remote station. The implications of being able to transmit readings more often are that energy utilities will be able to generate timely bills, better understand energy demand patterns for network dimensioning and Demand Side Management (DSM), maintain meter failures more efficiently and manage fraud better.

The use of the metering IC also ensures the accuracy and reliability of the meter readings. Often with microcontroller based meters, the sampling of voltage and current signals and the calculation of power consumption are done within the microcontroller. The high sampling rate of the metering IC ensures that the measurements taken are far more accurate than those that would take place within a microcontroller.

The entire system can be cost effective and significant amounts of time and money can be saved, by implementing an automated system, as opposed to one involving the human element. The system also poses much less of a safety risk since human interaction has been minimised.

V. REFERENCES

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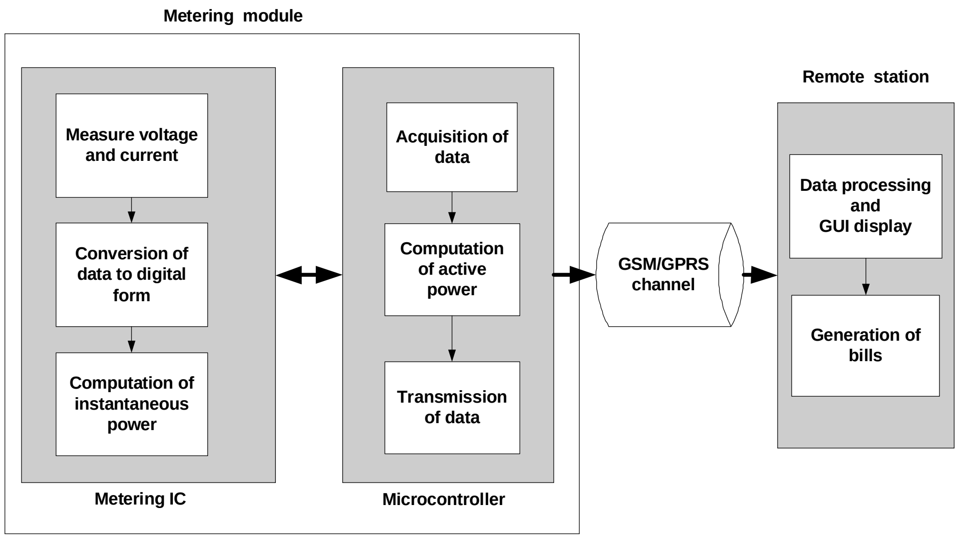

Fig. 1 The functional diagram of the metering system

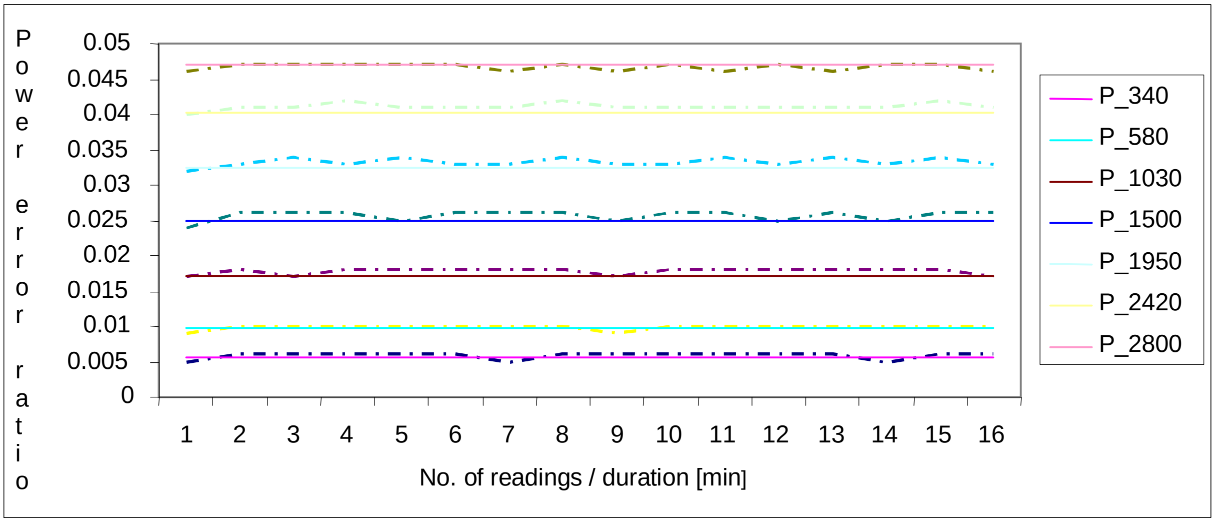

Fig. 2 The ratio of the power error for various resistive loads

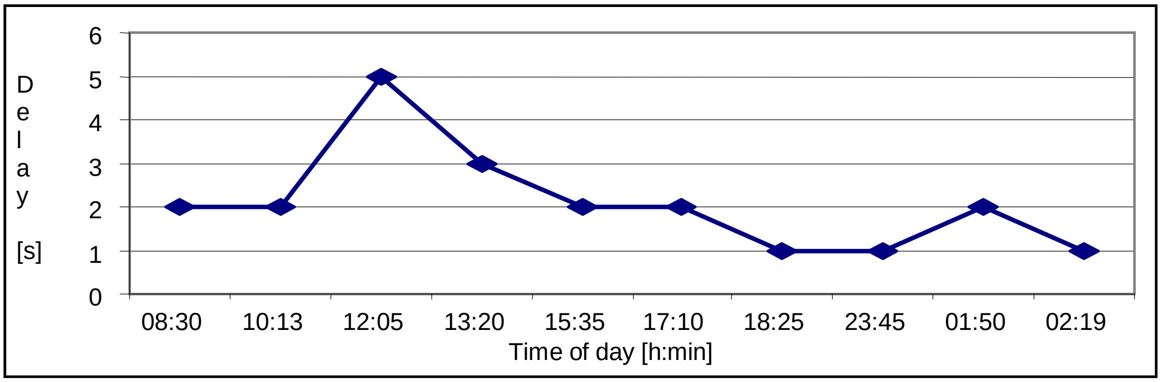

Fig. 3 Data rate delays through network at different times of the day.