Design of an Intelligent SMS Based Remote Metering System for AC Power Distribution to HT and EHT Consumers.

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Abstract

Electrical distribution utilities are facing problems due to high energy losses that amount to 8% of the total generation. 4% of the losses are unaccounted. The problem is mainly associated with sub-transmission and distribution networks. This paper presents a unique solution to devise a unit which is tamperproof, cost effective, fast, accurate and remote metering at any level of the distribution system. The system helps to access accurate and sufficient data from metering devices to measure the electrical parameters, eliminating the use of energy meters and human intervention. The software application provides a real time parameter like line voltage, line current, power factor, true power, apparent power and reactive power from remote substations. Remote metering system is implemented using microcontroller based mixed signal circuitry.

Keywords: Global System for Mobile communication, General Packet Radio Service, Remote Metering, Short Message Service.

1. Introduction

The conventional billing system for electricity, gas, or water is that an assigned person visits each house and read the meter readings manually. Then the collected meter readings are used for bill calculation. This manual process can become very time consuming and tiresome. It can cause human error and can open an opportunity for corruption done by the human meter reader. Thus the billing system can become inaccurate and inefficient. The recent advances in the field of information technology have made the exchange of information fast, secured and accurate.

The digital revolution caused the rapid drop of digital devices such as computers and telecommunication devices. Communication networks like the internet, GSM networks, etc. are available almost all the countries of the world. In the work presented here, a technique has been developed to read electricity meter readings from a remote server automatically using the existing GSM networks for cellular phones. This technique can be applied for gas or water meters as well. The meters send the meter readings like kilo-watt-hour (kWh), voltage, current, bill, etc. by SMS to a central server. The SMS based data collection can be done very quickly and efficiently. Data can be collected after any desired time interval such as hourly, daily, weekly, or monthly basis. As there is no human intervention in the entire process, there is no chance of human error and corruption. Also, unwanted weather conditions like heavy snow, rain, storm, etc. will not hamper on collecting data as long as the GSM networks are stable. By applying complex encryption algorithms on the data SMS, data security can be ensured.

Traditional meter reading, which depends on manual reading on site at a fixed date, has many deficiencies in real-time and accuracy. GPRS automatic meter reading system is a gradually developed intelligent system combined with the power meter reading characteristics, it can collect the real time data of industrial and residential electricity, and then sends the data to the remote management through GSM/GPRS network. By the system, it can not only save the human resources, but also can supply accurate and reliable meter reading data for the power enterprises to do load prediction and control, so that the overall economic efficiency of the power industries can be improved and the management level progressed.

2. Materials & Methods

2.1 Working Principle

The working principle can be explained as follows. The system helps utilities to access accurate and sufficient data from metering devices installed at a remote substation. The software application provides real time parameters like line voltage, line current, power factor, Apparent Power (VI), Reactive Power (VI–R), True Power (VI–A) from a remote substation and the same is transmitted to a centralized station. The centralized station receives data to be processed from the distribution system through a GPRS link. This module collects data from a network of metering devices installed at incoming and outgoing feeders within the substation or from the feeders at different locations.

2.2 Functional Block Diagram

The proposed hardware is realized with various building blocks based on functional aspects. The functional block diagram with all the blocks is depicted in Fig 2.1.

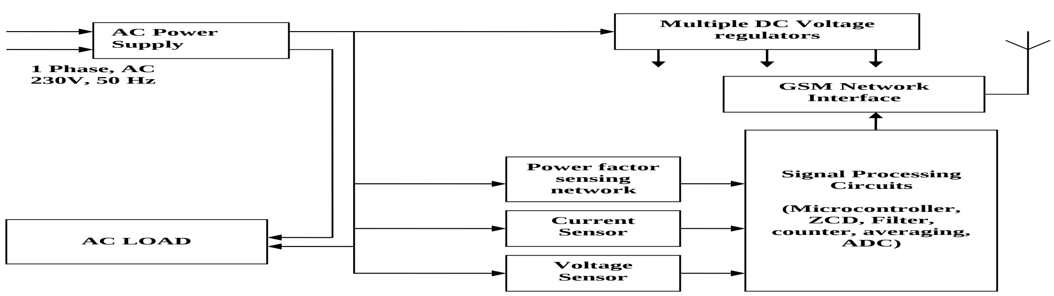

Fig. 2.1: Functional Block Diagram.

3. Hardware Design & Development

3.1 The Power Supply

The power supply unit is designed to deliver ±12V @500mA, +5V @1A and +3.8V @150mA to power up the whole electronics. The power supply is realized using fixed voltage linear regulator ICs 7812, 7912 and 7805 and a variable voltage regulator LM 317 along with appropriate filter capacitors.

The various requirements for the project are:

1. +12V/–12V 500mA for all OPAMPS.
2. +5V DC for Hall Effect Current Transducers.
3. +3.8V DC

3.2 The voltage Sensor

An input AC of 230V and current of 5A cannot be measured directly using a microcontroller. The high input voltage needs to be conditioned in a way suitable for the microcontroller. This is because, the microcontroller is a semi conducting device that operates at low voltages. The voltage sensor comprises of a step down transformer that steps down the 230V AC to 3V. This is rectified using a full wave rectifier, filtered using a capacitor and reduced or scaled down to a voltage approximately equal to 2.5v which represents 230v AC. The circuit is designed such that the microcontroller is able to measure a supply voltage of 230v ± 20% variations in the supply mains.

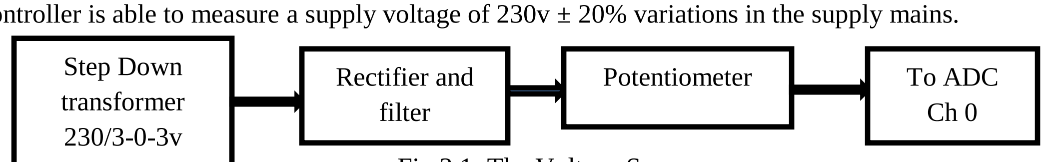

Fig.3.1: The Voltage Sensor.

The Current Sensor

Current sensors are used to sense and measure current variations. They give an output voltage proportional to the current under measurement. The current sensor used is a Hall Effect current transformer which is a transducer.

The Hall Effect is explained by the Lorentz force principle. When a charge moves in a direction perpendicular to an applied magnetic field, it experiences a force defined by the Lorentz Law, “The direction of this force is perpendicular to the direction of propagation of the charge and that of the external magnetic field”.

Fig. 3.2: The current Sensor.

Power Factor Sensing Network

Power factor is defined as the Cosine of the phase angle between voltage and current.

Power factor = Cosine φ or Cos φ

It is also defined as the ratio of true power to apparent power or volt amperes. It is also the ratio of resistance to impedance.

True power in an AC circuit is given by:

$P = V I \cos \varphi$

V = RMS value of voltage

I = RMS value of Current

Cos φ = Power factor

The phase angle between voltage and current is computed by the micro controller by accounting the pulse width of the signal applied as input. The pulse width represents the time difference between the voltage and current signals at the output of the sensors. The AC voltage and current wave forms are clipped by rectifiers and squared through the ZCD. The two diodes used act as a bi directional clipper. These signals are applied to a two input AND gate to obtain the pulse equivalent of the phase angle differences between voltage and current.

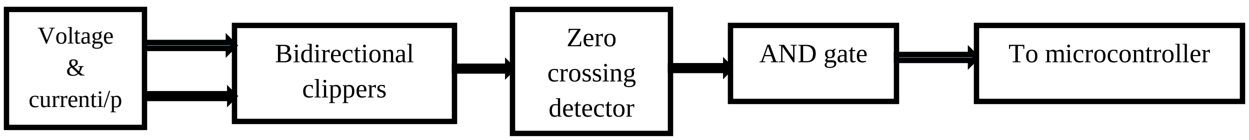

Fig. 3.3: Power Factor Sensing Unit

Microcontroller, ADC and GSM Module Interface Circuit

The analog to digital converter samples the voltage and current inputs at regular intervals and converts them into digital form. The 8-bit output is converted by the microcontroller into actual values.

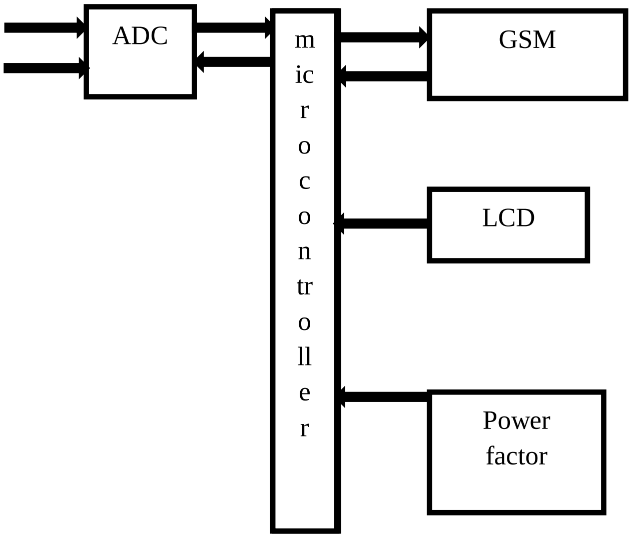

Fig. 3.4: Microcontroller, ADC and GSM Module Interface Circuit

3.4.1 Analog to Digital Converter

Out of 8 channels first two channels of ADC are used for the measurement of Voltage and current signals. The channel is selected by flipping the LSB of the selection line of ADC through the microcontroller.

The analog inputs corresponding to the voltage and current are applied to channel 0 and channel 1 of the ADC. The clock frequency for the ADC operation from the astable multi vibrator is 1.6 kHz. The two analog inputs are selected by the ADC for conversion, one at a time.

The successive approximation frequency of the ADC is set externally with a help of an RC network and IC 7400 as shown which is configured to work as an astable multi vibrator. The clock frequency for the ADC is given by:

3.4.2 The Serial Communication Circuit

In this project mode 1 is used. That is, standard UART mode which is 10 bit full duplex transmits and receive mode.

Transmitted data is sent as a start bit, eight data bits and a stop bit.

BAUD RATE: If standard baud rates are desired, then an 11.0592 megahertz crystal should be selected. To obtain the standard baud rate of 9600 hertz, the setting of TH 1 will be as follows.

TH1= 256d- (2/32 x11.0592x106 /12x 9600d) =253.000d

TH1 =OFDh

3.4.3 LCD Interface

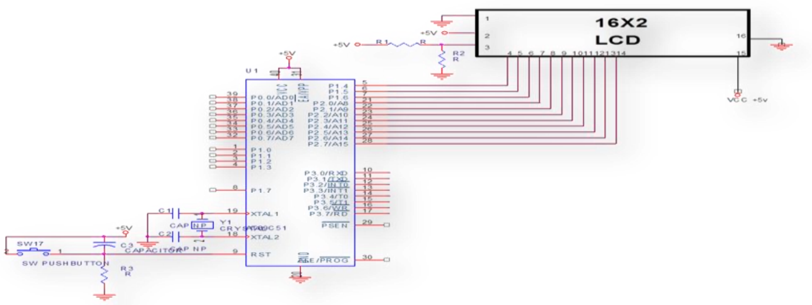

Fig. 3.5: LCD Interface.

To display data on the LCD the following steps are executed:

Initialize the LCD with a set of command words. The command words are sent on the D0–D7 data lines with RS = 0, R/W = 0 and a high-to-low pulse on the enable ‘E’ pin.

The ASCII value of the character to be displayed (say 41H to display ‘A’) is sent on the D0–D7 data lines with RS = 1 (data register), R/W = 0 and a high-to-low pulse on the ‘E’ pin.

4. Software

4.1 Flow Chart

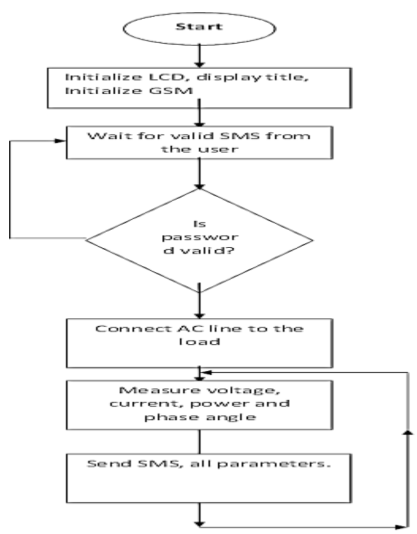

Fig. 4.0: Flow Chart

4.2 Algorithm

1. Initialize LCD and display title of project.
2. Initialize GSM into text mode i.e. "SMS" mode, and wait for password SMS.
3. After receiving password SMS, connect AC 230 line to load.
4. Select current channel and get digital value for current, Calibrate digital value into ampere and display on LCD.
5. Select voltage channel, and get digital value for voltage, Calibrate to voltage and display on LCD.
6. Measure pulse width of phase angle signal and calibrate to angle.
7. Calculate power, active power, reactive power and display on LCD.
8. Repeat steps from 4 to 7 for fixed number of times, and send all details to the base station mobile.

5. Experimental Setup, Test Results and Analysis

A technique for remotely reading the power drawn by the load using short message service is developed and tested. The existing global system for mobile communication networks is used for sending and receiving short messages. The prototype has been designed, developed and experimented. The functioning of the prototype was tested by creating conditions in the laboratory similar to the conditions in which it is expected to operate. The load curve is a peak-valley curve indicating the variation in power demand during different hours of the day. The load is normally resistive between 6.00 P.M. and 9.00 A.M. It becomes complex between 9.00 A.M. and 6.00 P.M. due to industrial loads. These conditions are simulated by subjecting the prototype to resistive and complex loads and the performance is evaluated.

5.1 Test Setup

The circuit schematic of the experimental setup to evaluate the performance of the hardware is as shown in Fig. 5.1. The setup includes a voltmeter, ammeter, the prototype of the remote metering system, resistive, inductive and capacitive loads and a global system for mobile communication network receiver. The voltmeter and ammeter are required to compare the input voltage and current with the output readings of the prototype on the liquid crystal display.

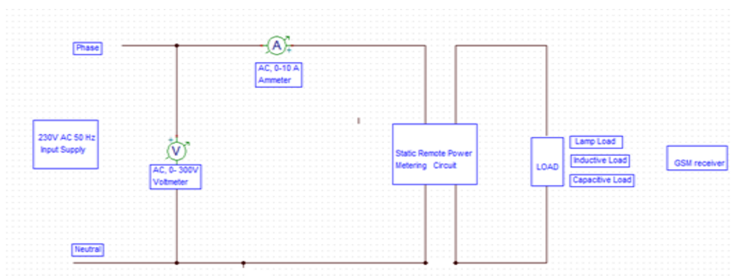

Fig. 5.1: Laboratory Setup to test SMS based Remote Metering System.

A photograph of the experimental setup is shown in Fig. 5.2. It consists of the hardware unit, loads and the display unit.

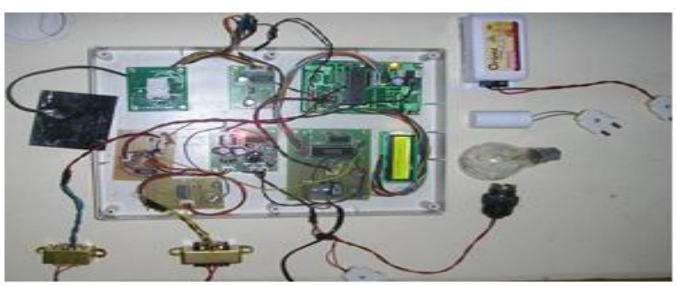

Fig. 5.2: Experimental setup.

Steps involved in testing the performance of the proposed system are:

- The system is initialized and zero reading on the liquid crystal display is ensured.
- A load is connected at the prototype output.
- The magnitudes of voltage and current on the voltmeter and ammeter are compared with those on the display.
- The parameters phase angle, true power, reactive power, apparent power computed by the microcontroller is also available on the display.

- At every 30th measurement as set by the program, an SMS is sent by the microcontroller to the initialized mobile number.
- The results of true power and reactive power are tallied with the power ratings of the load.

Fig. 5.3 shows the display when the GSM was initialized on no load, on a lamp load, sending an SMS to the initialized mobile and displaying the various parameters.

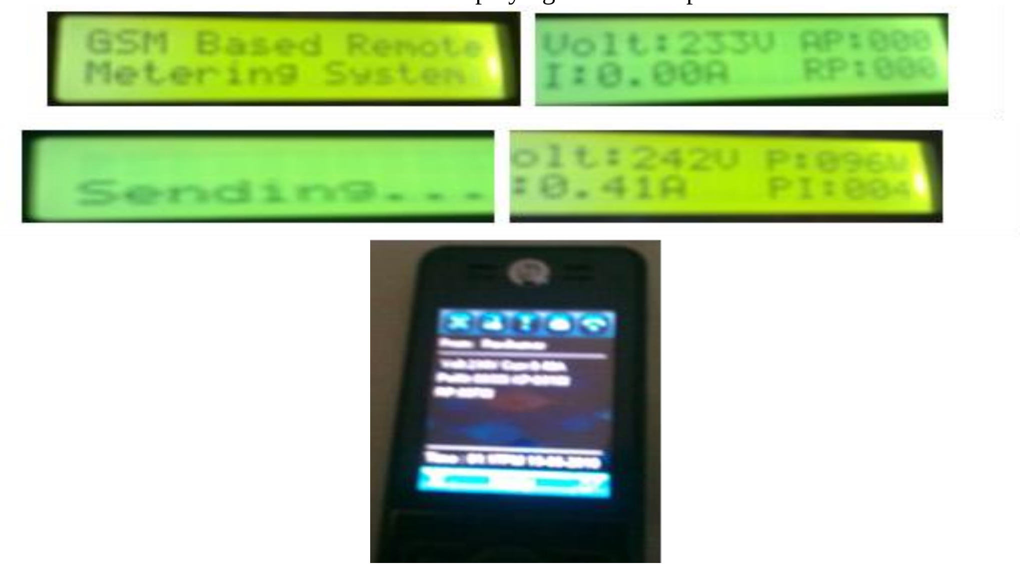

Fig. 5.3: Test Results

5.2 Results and Discussion

The measured parameters and their values for eight case studies conducted at different hours of the day are listed in Tables. It is observed that for a lamp load which is resistive the phase angle difference between voltage and current in all the cases is within 10º. The true power is larger and complies with the rating of the lamp. For complex loads comprising of resistor – inductor (R–L) and resistor – capacitor (R–C), the reactive powers have considerably increased.

Case Study 1

Table 5.1 Measured Parameters and their values.

Sl. No.	**Load Type**	**HECT Output**			**Voltage sensor DC o/p (V)**	**LCD & SMS Readings**						**ZCD AND gate o/p (ms)**
		CT o/p (V)	**Rectifier o/p (V)**	**Amplifier o/p (V)**		**Input voltage (V)**	**Input Current (A)**	**Phase Angel (Φ)**	**P=VIcosΦ (w)**	**Q=VI sinΦ (VAR)**	**S=VI (VA)**	
1	No Load	V_Q=2.2 (DC)	0	0	5.8	226	0	0°	0	0	0	Noise
2	R Load	0.16	0.5	6.0	5.8	225	0.44	9°	98	16	99	0.5
3	L Load	0.28	0.8	9.0	5.6	232	0.69	76°	38	155	160	4.2
4	RL Load	0.4	1.2	10.0	5.0	236	0.9	22°	196	80	213	1.2
5	RC Load	0.16	0.8	6.4	5.2	226	0.52	72°	36	111	117	4.0

Case study 2

Table 5.2 Measured Parameters and their values.

Sl. No.	Load Type	HECT Output			Voltage sensor DC o/p (V)	LCD & SMS Readings						ZCD AND gate o/p (ms)
		CT o/p (V)	Rectifier o/p (V)	Amplifier o/p (V)		Input voltage (V)	Input Current (A)	Phase Angel (Φ)	P=VIcosΦ (w)	Q=VI sinΦ (VAR)	S=VI (VA)	
1	No Load	V_Q=2.2 (DC)	0	0	5.6	224	0	0°	0	0	0	Noise
2	R Load	0.18	0.5	6.0	5.6	225	0.47	8°	104	15	105	0.45
3	L Load	0.28	0.8	9.0	5.5	230	0.7	72°	50	153	161	4.0
4	RL Load	0.4	1.2	9.8	4.8	235	0.92	22°	200	81	216	1.2
5	RC Load	0.16	0.8	6.2	5.2	228	0.51	70°	40	109	116	3.9

Case study 3

Table 5.3Measured Parameters and their values.

Sl. No.	Load Type	HECT Output			Voltage sensor DC o/p (V)	LCD & SMS Readings						ZCD AND gate o/p (ms)
		CT o/p (V)	Rectifier o/p (V)	Amplifier o/p (V)		Input voltage (V)	Input Current (A)	Phase Angel (Φ)	P=VIcos Φ (w)	Q=VI sinΦ (VAR)	S=VI (VA)	
1	No Load	V_Q=2.2 (DC)	0	0	5.6	223	0	0°	0	0	0	Noise
2	R Load	0.17	0.5	6.0	5.6	234	0.46	9°	105	17	107	0.5
3	L Load	0.28	0.8	8.9	5.5	232	0.68	76°	38	153	158	4.2
4	RL Load	0.4	1.2	9.8	5.0	237	0.91	24°	197	87.8	216	1.3
5	RC Load	0.16	0.8	6.4	5.2	227	0.52	72°	36	112	118	4.0

Graphs

Graphs of variations in voltage, current, phase angle and true power for the same load in different case studies is as shown in figures 5.4 to 5.15. The tabulated values are tables 5.9 to 5.12. From the graphs it is observed that the variations in the parameters measured using the prototype is due to the fluctuations in supply voltage.

Table 5.4: Variation in measured parameters at every 30th measurement (Resistive Load)

Sl. No.	Measurement No.	Voltage in Volts	Current I (A)	Phase Angle° (f)	Power (W)
1	30	225	0.44	9	98
2	60	225	0.47	8	104
3	90	234	0.46	9	105
4	120	226	0.49	8	109
5	150	232	0.44	7	101
6	180	228	0.45	8	101
7	210	230	0.46	8	104
8	240	229	0.45	9	102

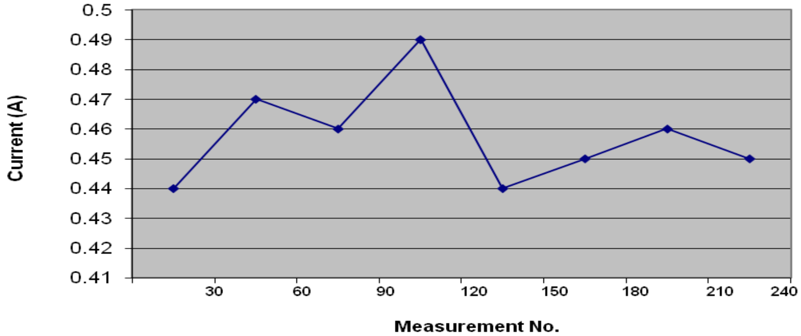

Fig. 5.4: Graph of Variations in Current at every 30th measurement.

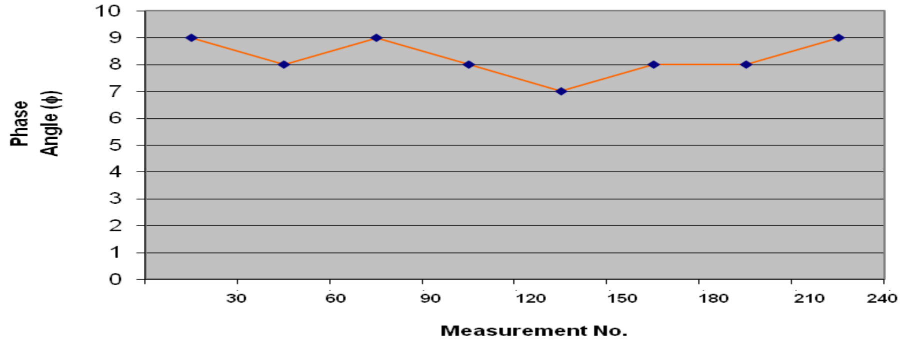

Fig. 5.5: Graph of Variations in Phase Angle at every 30th measurement.

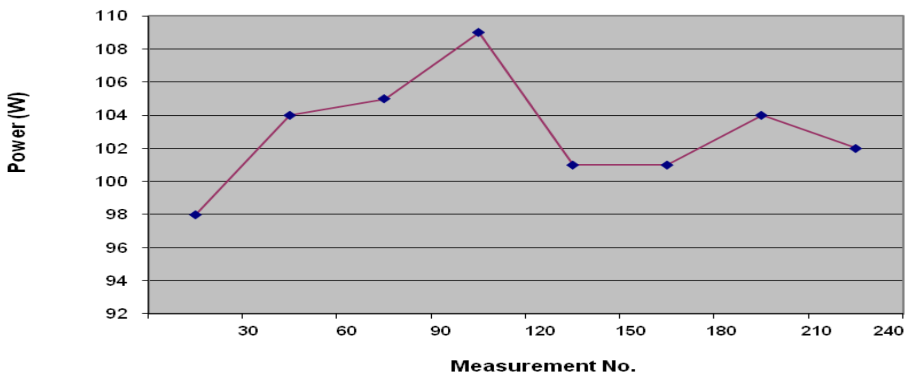

Fig. 5.6: Graph of Variations in Power at every 30th measurement.

Table 5.5: Variation in measured parameters at every 30th measurement (Inductive Load)

Sl. No.	Count No. (Every 30th Measurement)	Voltage (V)	Current I (A)	Phase Angle° (f)	Power (W)
1	30	232	0.69	76	38
2	60	230	0.7	72	50
3	90	232	0.68	76	38
4	120	232	0.7	72	50
5	150	228	0.71	76	39
6	180	226	0.7	72	49
7	210	232	0.72	72	51
8	240	230	0.68	76	38

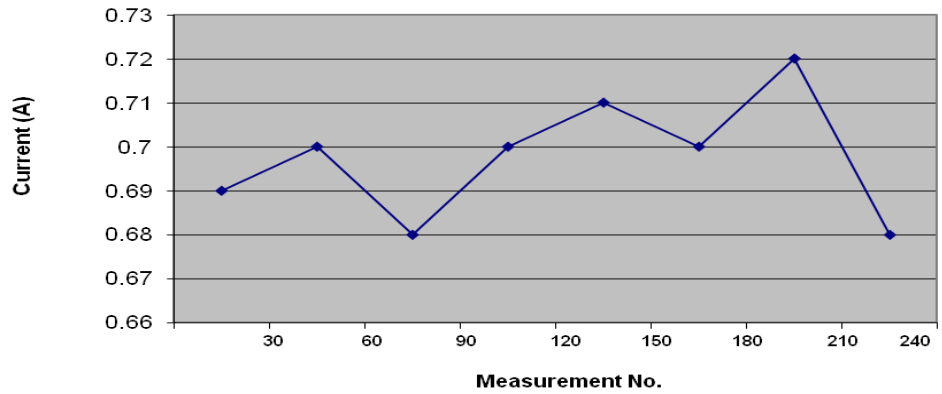

Fig. 5.7: Graph of Variations in Current at every 30th measurement.

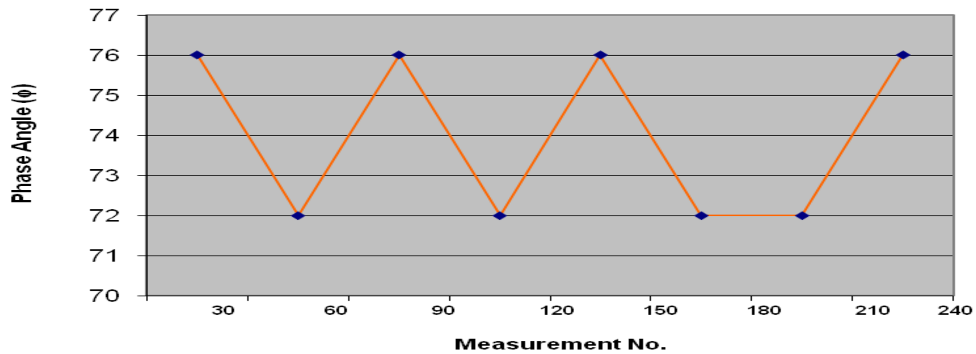

Fig. 5.8: Graph of Variations in phase angle at every 30th measurement.

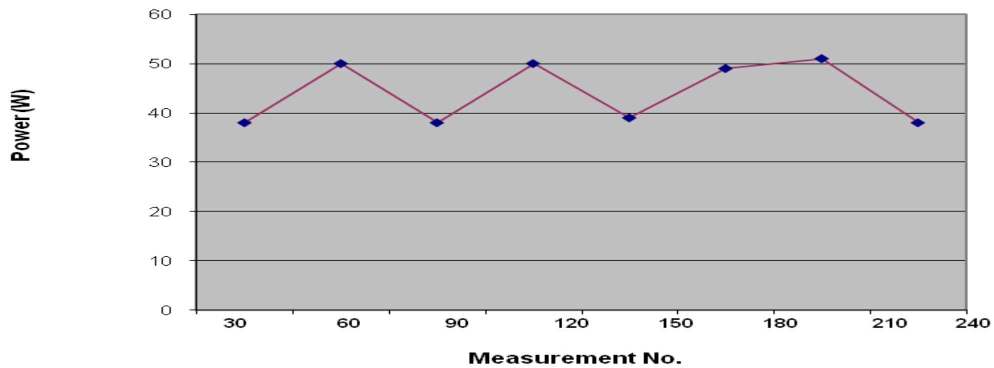

Fig. 5.9: Graph of Variations in Power at every 30th measurement.

Table 5.6: Variation in measured parameters at every 30th measurement (Resistive Inductive Load)

Sl. No.	Count No. (Every 30th Measurement)	Voltage (V)	Current I (A)	Phase Angle° (f)	Power (W)
1	30	236	0.9	22	196
2	60	235	0.92	22	200
3	90	237	0.91	24	197
4	120	238	0.89	25	192
5	150	238	0.86	24	186
6	180	236	0.84	25	179
7	210	232	0.89	22	191
8	240	235	0.9	24	193

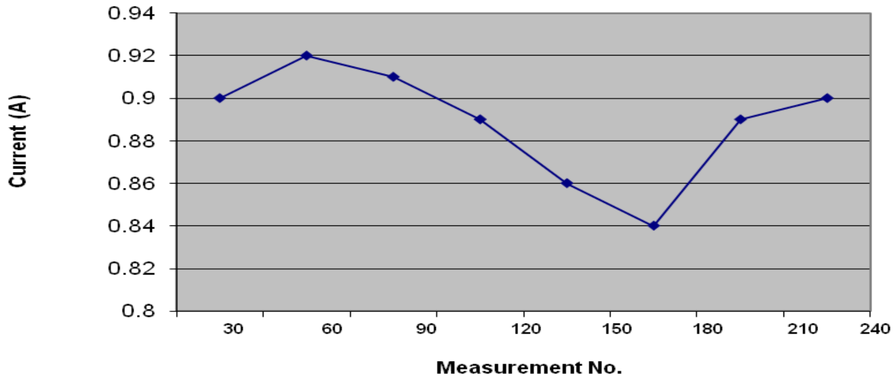

Fig. 5.10: Graph of Variations in current at every 30th measurement.

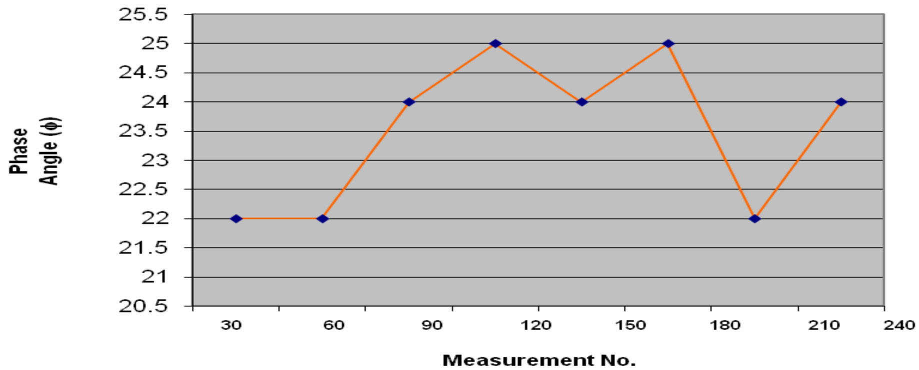

Fig. 5.11: Graph of Variations in phase angle at every 30th measurement.

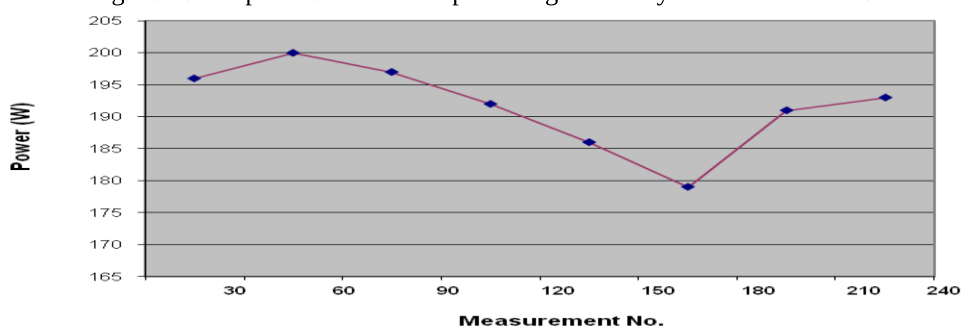

Fig. 5.12: Graph of Variations in Power at every 30th measurement.

. The experimental values and the time of processing data indicates that the present work has improved the overall performance of the system. This result is different as there is no interaction with any conventional energy meter to record the power consumed by the consumer. The experiment has clearly suggested that there is no need to have a separate energy meter for recording energy. It means that the present hardware itself acts as energy meter.

6. Conclusion and Future Scope

6.1 Conclusion

In this work, an SMS based remote metering technique for the energy distribution sector has been proposed. The developed prototype has been tested over the GPRS link. The proposed solution is used to read the voltage and current remotely and the same is verified with those of physically measured values while experimenting. The results computed using remote metering system were accurate, fast, and has avoided human intervention. This technique can well be utilized at various levels of the power generation and distribution sector. The time taken to collect one set of data and compute the power consumed by the client is about 4.5ms. This needs to be added with the network time delay for the completion of the total measurement and computation via SMS. The system can be extended to compute the energy bill for the consumers and the same can be sent through SMS.

Current design and development of the networked digital metering system for AC power distribution can be used in power stations and substations wherein the power generated and its usage can be tracked. Similarly the system can be used in substation where the power consumed and metered can be tracked for high tension and low tension loads.

6.2 Future Scope

Future scope of the work can be as follows:

- The system can be implemented at any stage in the power system right from generation to distribution with slight modifications.
- It is possible to include billing if implemented on the consumer end.
- Details pertaining to the energy consumption can be sent through SMS to the consumer without human intervention.

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