Combined Zigbee & GSM approach for AMR in Harmonic Monitoring and Assessment on Smartphone

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Abstract – **Today's increased use of nonlinear loads injects voltage and current harmonics in Electrical Distribution Networks and creates new problems of Power Quality in the power System. Conventional power systems are designed to operate on sinusoidal power supply. Electric utilities strive to supply consumers with reliable & pure sinusoidal electric power that does not represent a damaging threat to their equipment. In the restructured power system, prices of the power are associated to power Quality. Hence it is very important to monitor and ensure Power Quality. Harmonics is the major issue in this context. This paper presents an innovative way of real time harmonic measurement using ADE 7880 and its assessment with automatic meter reading (AMR) on smart phone. During preparation of this paper fifty sight visits are done covering the non-linear loads like IT Industries, Steel Industries, Paper Industries, workshops etc. It is observed that the current harmonics generated are beyond the tolerable limits. Readings are taken at consumer end with the help of standard power analyzer for a period of 24 hrs. Sample of the readings are considered for analysis purpose. Further it is also observed that many literatures are available in the area of Harmonic measurement but they do not have the capacity to identify the limits of harmonics as per the standards used like IEC 61000-2-2 or IEEE 519-1996 or EN 50160. In this paper GUI is developed in java to assess the harmonics and identify the harmonic presence with specific color codes. The solution will display the abnormal harmonics in red color and normal below the threshold value by the green color. Through this color coding technique an unskilled worker can easily identify the objectionable presence of harmonics. It creates the awareness in the utility for measurement and control of harmonics which in turn helps to improve the Power Quality. A combined Zigbee and GSM technology is also developed to communicate the data received at consumer end to the central server. Along with the central PC information can also be transferred on smart phone by capturing the data from remote location and processing it with a programming tool on smart phone. The main advantage of this method is Remote data logging, as it does not require collecting data physically from actual site. The numeric meter sends data to microcontroller using zigbee module and further to the web server of Central Monitoring System through GSM. This data is processed and analyzed by the source code available in smart phone. For this purpose, the relevant compilers can be installed in the smart phone.**

Keywords – Automatic Meter Reading (AMR), Central Monitoring System (CMS), Global System for Mobile Communication (GSM), Harmonic distortion, Harmonic standard, Non-linear load, Point of common coupling (PCC), Sampling, Smart Phone, Total Harmonic Distortion (THD), Zigbee.

I INTRODUCTION

Power Quality is one of the ever growing concerns to utilities and customers. The problem associated with high harmonic content in the power system not only results in poor quality of supply but also the operation of the system will get affected. The modern electronic devices and circuits are mostly non-linear. According to energy conservation act, demand of energy efficient devices is increased [13]. These energy efficient devices have two-fold problems with regard to harmonics. They not only produce harmonics but they are also very sensitive to the resulting harmonic distortion than the traditional power system devices. It is therefore important to

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measure, analyze and limit harmonics in power distribution network [4]. This paper illustrates a novice method of reading harmonics from numeric meters installed at remote end using Zigbee at local level & GSM at global level and its processing on smart phone through which the concept of Automatic Meter Reading (AMR) can be implemented [1], [2]. During late nineties, the microprocessor based meters called numeric meters or digital meters were developed. These meters are provided with inbuilt Central Processing Unit (CPU) and Random Access Memory (RAM) . These meters also conduct harmonic measurement in terms of THD. In the presented work a meter hardware is developed using ADE 7880 which will measure the harmonics in terms of voltage THD, current THD and also power THD. In addition to it, it will also measure individual voltage, current and power harmonics along with its assessment with respect to specified standard. Thus the proposed system is a complete close loop solution under one roof. However, the existing equipments viz. Cathode Ray Oscilloscope, Harmonic Analyzer and Numeric meters do not perform remote measurements and also do not assessment of harmonics as per the standard. In order to save time in visiting various electrical installations, it was felt necessary to transmit the meter data over a longer distance and meet requirements of AMR [4]. IEEE standard 519 -1992, has been used for comparing the presence of harmonics.

II FIELD VISITS

Measurement of harmonics [8] has been done by using Advanced Harmonic Analyzer "Yokogawa" (model CW240). Wiring connections for this harmonic analyzer is 3 phase 4 wire. C.T. Ratio is 100/5Amp.The table no.1 given below shows the harmonic measurement at twenty four different sites covering various types of non-linear loads. Total 50 site visits were conducted and readings were taken for 24hrs each, but only sample readings are listed in the table 1.

It is observed through site visit readings that the current harmonics generated are beyond the tolerable limits. Due to harmonic presence true power factor gets reduced and power consumption only due to harmonics is up to 20% in Harmonic rich loads. Hence the proposed solution of measurement will definitely inculcate the awareness regarding the measurement and controlling of harmonics.

III PROPOSED SYSTEM

As shown in the Fig.1, clamp on CT's are used with ratio of 100/1Amp. ADE 7880 is the power measuring IC from Analog devices with consideration of harmonics. This data is taken on PC for analysis purpose. A GUI is developed in JAVA for pictorial representation. Color coding technique is utilized to identify the abnormal presence of harmonics. The assessment result is also displayed on the LCD screen along with the display of main system parameters

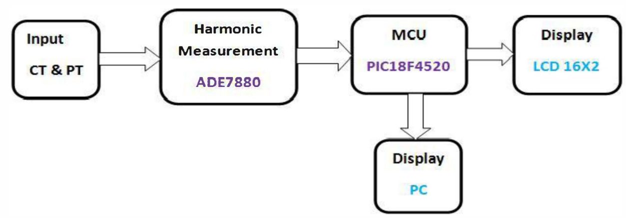

Fig.1: Block diagram of proposed smart meter

Fig.2: Actual hardware of developed meter using ADE 7880.

Fig.2 shows the actual photograph of developed hardware for measurement of harmonics and other system parameters.

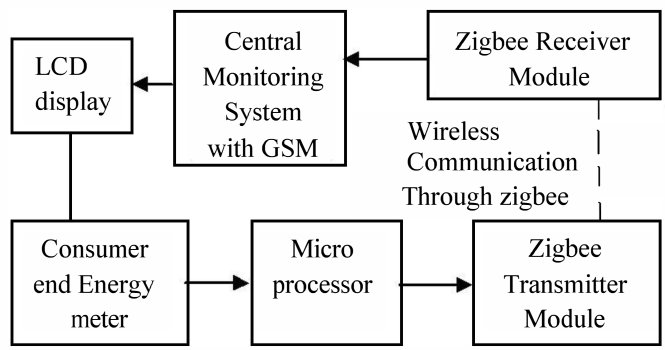

Fig.3: wireless communication with Zigbee

Data is collected with the zigbee module and then it is transferred to zigbee receiver and further to central computer using GSM communication. Automatic Meter Reading is a process in which meter data is read and processed automatically via special equipment using wireless communication and computer network technology. Compared with the existing meter reading, it effectively saves human resources and can get real-time consumption of every user, helping the management. The communication data rate is set 9.6 kbps and the frequency band is 2.4 GHz. The proposed AMR system is divided into two sections i.e. transmitter section and receiver section. The working of AMR can be explained through following flowcharts.

A. Transmitter Section Flowchart

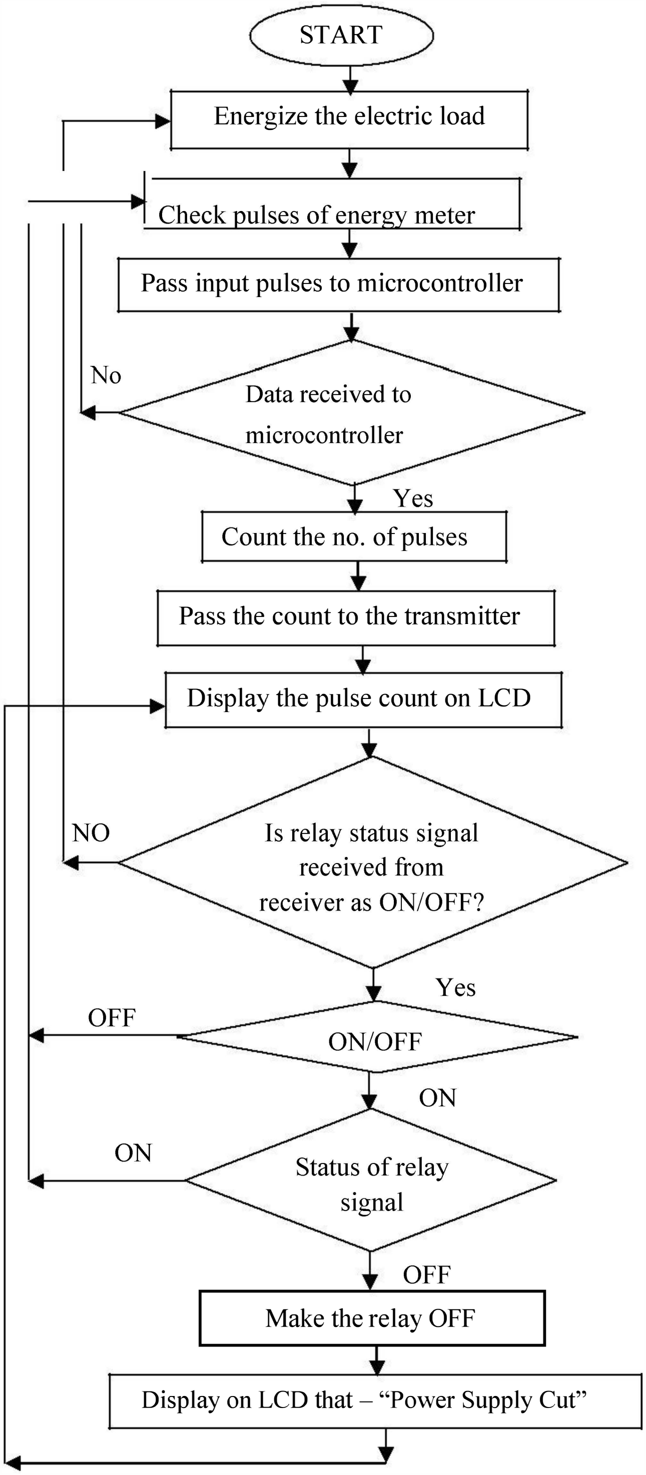

Fig.4: Flowchart for Transmitter Section

B. Receiver Section Flowchart

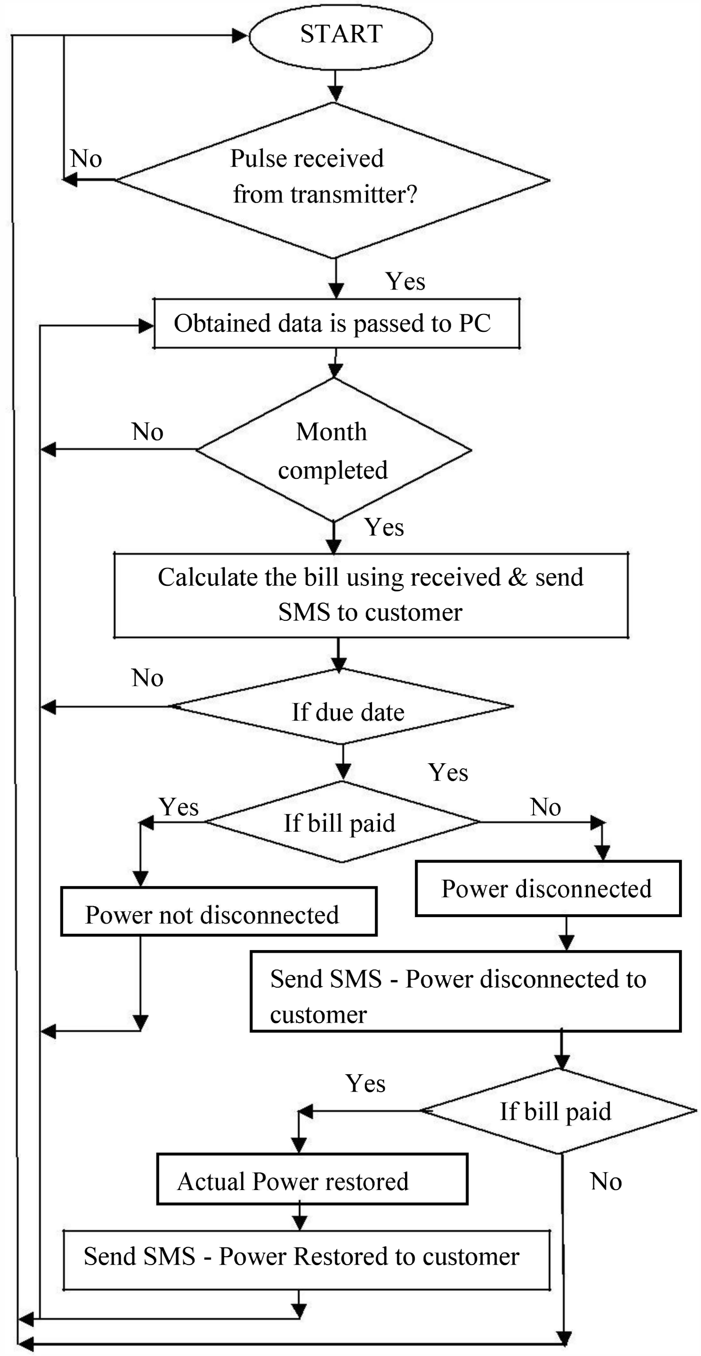

Fig.5: Flowchart for Receiver Section

Table 1: Harmonic Measurements at different sites

Sr. No	Visited Site no.	Contract Demand	Connected Load	CT ratio	PT Ratio	Voltage Harmonic Distortion in %			Current Harmonic Distortion in %		
						R	Y	B	R	Y	B
1	Site No.1	15000 KVA	45000 KW	100A/1A	220KV/110V	0.44	0.47	0.67	7.67	8.79	8.79
2	Site No.2	15000 KVA	45000 KW	100A/1A	220KV/110V	0.39	0.61	0.67	9.12	9.13	9.13
3	Site No. 3	2500 KVA	4000 KW	50A/1A	33KV/110V	0.97	1.07	1.09	4.21	4.51	4.51
4	Site No.4	2460 KVA	3570 KW	50A/5A	33KV/110V	2.13	1.72	2.16	16.23	18.79	18.79
5	Site No.5	1150 KVA	1600 KW	50A/5A	22KV/110V	1.10	1.32	1.31	11.21	16.54	16.54
6	Site No.6	4800 KVA	14500 KW	150A/5A	22KV/110V	0.47	0.57	0.56	5.3	8.6	8.6
7	Site No.7	4900 KVA	14500 KW	150A/5A	22KV/110V	0.43	0.47	0.41	8.62	7.49	7.49
8	Site No.8	2600 KVA	6500 KW	100A/5A	22KV/110V	0.52	0.52	0.61	4.50	5.05	5.05
9	Site No.9	1300 KVA	3250 KW	75A/5A	22KV/110V	0.96	0.96	1.06	8.59	5.77	5.77
10	Site No.10	16000 KVA	29944 KW	100A/1A	132KV/110V	0.95	0.85	0.90	7.38	5.71	5.71
11	Site No.11	16000 KVA	29944 KW	100A/1A	132KV/110V	1.25	1.09	1.04	10.09	8.25	8.25
12	Site No.12	2000 KVA	5787 KW	50A/5A	22KV/110V	0.80	0.82	0.63	13.50	15.57	15.57
13	Site No.13	2500 KVA	400 KW	50A/5A	33KV/110V	0.57	0.57	0.45	2.21	1.82	1.82
14	Site No.14	2000 KVA	6800 KW	50A/5A	22KV/110V	1.00	1.01	1.06	2.73	3.31	3.31
15	Site No.15	6340 KVA	9341 KW	150A/5A	33KV/110V	1.35	1.42	1.55	10.10	18.29	18.29
16	Site No.16	6340 KVA	9341 KW	150A/5A	33KV/110V	1.037	1.64	1.71	17.81	17.79	17.79
17	Site No.17	2400 KVA	7000 KW	100A/5A	22KV/110V	0.5	0.35	0.63	8.04	9.96	9.96
18	Site No.18	2000 KVA	3000 KW	50A/5A	33KV/110V	0.8	0.77	0.69	8.43	10.02	10.02
19	Site No.19	7750 KVA	12100 KW	150A/5A	33KV/110V	1.99	2.07	2.04	17.06	17.04	17.04
20	Site No.20	7750 KVA	12100 KW	150A/5A	33KV/110V	0.98	1.13	1.01	20.04	20.64	20.64
21	Site No.21	2250 KVA	2790 KW	75A/5A	22KV/110V	0.9	0.84	0.87	31.10	27.70	27.70
22	Site No.22	1335 KVA	2260 KW	50A/5A	22KV/110V	0.81	0.77	0.78	3.29	2.90	2.90
23	Site No.23	1400 KVA	1800 KW	50A/5A	22KV/110V	0.77	0.72	0.76	23.84	21.98	21.98
24	Site No.24	1050 KVA	1733 KW	50A/5A	22KV/110V	1.67	1.67	1.64	14.71	14.88	14.88

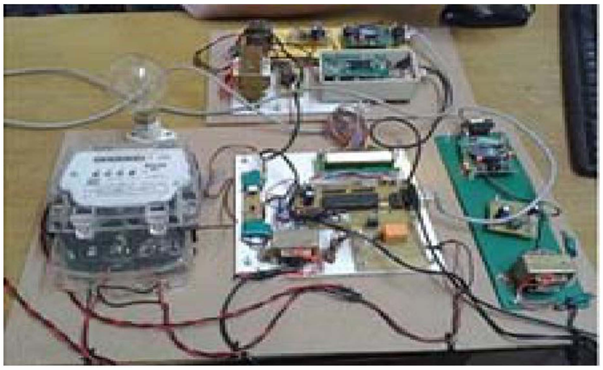

Fig.6: System hardware with Transmitter and Receiver Sections

IV GUI DEVELOPMENT FOR HARMONIC ASSESSMENT

A GUI is developed for harmonic assessment which plays a very important role in an Industry. The bar chart shows the identification of abnormal and normal harmonic level presence with RED and GREEN color respectively as shown in Fig.7. The assessment is done based on IEEE standard 519-1992.

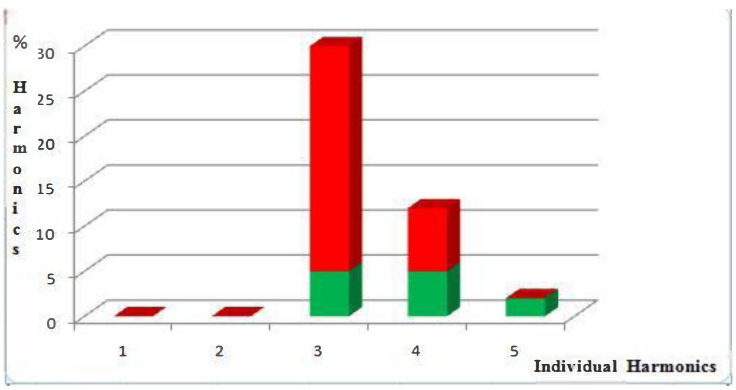

Fig.7: bar chart shows the identification of abnormal and normal harmonic level

As shown in the above Fig.7, identifying the presence of harmonics is made simple using color code. A non-technical person can also identify it, which creates an awareness to maintain the power quality standard**s.**

V DATA TRANSMISSION

At the utility substation, numeric meters are installed in a control panel. These numeric meters are connected to modbus through RJ11 connectors. The RJ11 is an Ethernet connector. Modbus is RS485 / USB compatible bus. The meter data received at modbus is collected by Data Concentrator Unit (DCU). This data is stored in the local substation server.

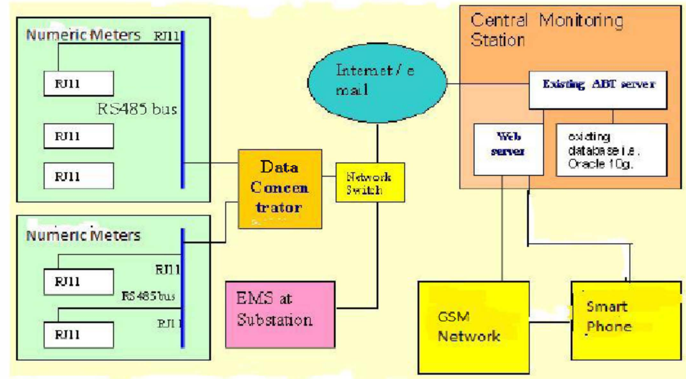

Fig.8: Functional block diagram showing flow of data signals from numeric meters installed at utility substation to smart phone

As shown in the above Fig.8; through a wireless internet media, the data is send to the Central Monitoring Station (CMS) via router and other network devices such as modem, bridge, hub, repeater etc. The data is transmitted through a communication satellite named as Very Small Aperture Terminal (VSAT). The data thus received at CMS is stored permanently in the Database server. Usually the RDBMS based Oracle server is provided. The data is also stored in the local server installed near metering installation. Now, let us understand the working of network components in brief. Modem is the unit comprising of two components - modulator and demodulator. These components perform the function of modulation and demodulation of signals. The repeater amplifies these signals to reduce noise and attenuation. Number of repeaters is combined in a single unit called hub. Bridge is used to connect or disconnect the networks. Another channel of data communication is a wired media. The data is sent through Remote Terminal Units (RTU) Data Acquisition System or Power Line Carrier Communication (PLCC) network integrated with Optical Fiber Cable (OFC). The wired communication is however, out of scope of this paper. Both channels wired and wireless are used in practice.

VI CONNECTIVITY TO THE SMART PHONE

The data received at CMS is also connected to the Web server. It is proposed to connect Web server to the GSM network (Global System for mobile communication) as shown in Fig 9. From GSM network the link is provided to the smart phone. GSM describes protocols for digital cellular networks [5].The GSM network mainly comprises of GSM / GPRS modems suitable for long duration data transmission. The GSM modem is connected to the microcontroller which would transmit data from meter to cell phone and vice versa [6]. The modem sends unit or pulses (power consumption) on regular interval or on request [7]. Smart phone is a mobile phone built on Mobile operating System having more advanced computing capability than a feature phone. It is provided within built CPU and RAM. The mobile operating system used by the smart phones are Google's Android, Apple's OS, Nokia's Symbian Microsoft's Windows phone and HP's web OS [9].The data is received at the input port of the smart phone. It is then processed by the in-built compiler of smart phone. The Android based C/C++/Java compilers are available. These compilers are installed in the smart phone. In order to process meter data, the source code is written. This source code written in high level language is compiled. The compiler translates source code into object code. These file formats are supported by Android or equivalent mobile operating system. Program output is displayed by emulator on the mobile screen [10].

VII DATA PROCESSING

The data related to harmonics received by the smart phone from numeric meters is processed. For this purpose the source code is written in a high level language such as C/C++ and Java. The source code is compiled by the compiler installed in the smart phone.

Fig.9: Text editor of smart phone Compiler

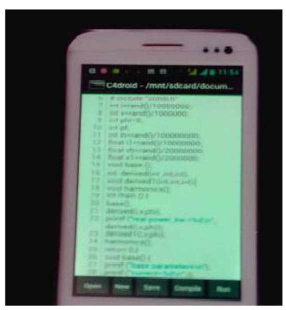

Fig.10: Use of smart phone as Compiler

The example of Android based C compiler is shown in Fig 9. The compiler checks for errors in the program, if any. The programmer has to make respective corrections in the source code. The compiler then translates the source code into object code. The results of data processing are displayed on the mobile screen through an emulator. The source code can be easily written and compiled in smart phone. For this purpose , click 'new' button to enter a source code or click 'open' to open the saved code. The 'Save' button is clicked to save changes. The program is compiled by clicking on 'Compile' button. The program is compiled and errors, if any, are displayed. After removing errors, the 'run' button is clicked and the results are displayed. Fig.10 shows smart phone as a compiler [11] [12].

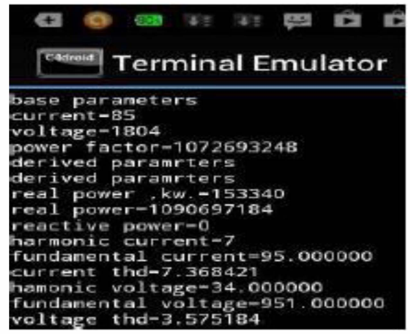

Fig. 11: Emulator of smart phone Compiler

VIII CONCLUSION

It is observed through site visits that the current harmonics generated are beyond the tolerable limits. Due to harmonic presence true power factor gets reduced and power consumption only due to harmonics is up to 20% in Harmonic rich loads. Hence the proposed solution of measurement will definitely inculcate the awareness regarding the measurement and controlling of harmonics.

Much attention is now being paid to the power quality because of increasing use of non -linear loading. In the process it is essential to improve the power factor of the system by reactive power compensation and in addition to the harmonics present in the system are required to be almost nullified. The case studies presented here are the sample examples and it is necessary to improve the existing situation of power quality. This paper represents a real time measurement, assessment & also communication on smart phone by smarter way. The data related to harmonics collected from meter installed at remote end through Automatic Meter Reading and is processed on the compiler installed in the smart phone. The validation is carried out by comparing results with traditional methods of measurements such as Harmonic Analyzer and numeric meter. The results are found to be accurate& acceptable. This also results in saving the time required for visiting electrical installations for harmonics measurements. Since processing of the real time data is carried out on smart phone, the analysis is accurate and speedy. As such, it is concluded that the technique recommended in this paper serves the purpose of harmonic measurements and analysis in electrical network at remote end. Through the color coding technique an unskilled worker can easily identify the objectionable presence of harmonics. Harmonics can be mitigated by use of appropriate Active or Passive filter.

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