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Object Oriented Mobile Computing Based Numerical Methods For Harmonic Analysis in Electrical Networks

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Abstract:

This paper illustrates a novice method of computation of network currents affected by high order harmonics. The data is received from numeric meters installed at electrical substations and consumers situated at remote end. The data processing are done on a smart phone. The main benefit of these methods is saving in time required for visiting electrical installations and getting appropriate value of harmonically distorted currents. The numeric meter sends data to the web server of Central Monitoring System either through internet or through PLCC/OFC links. The web server is connected to GSM Network through which the data is received by the smart phone. This data is processed by conducting Object Oriented Numerical Methods based source code available in smart phone. For this purpose, the relevant compilers can be installed in the smart phone. The results are compared with numeric meter data installed at substation end and consumer end. The difference between ideal theoretical load current and actual harmonically distorted load current is found out from which the degree of harmonic distortion can be ascertained.

Key words: Harmonics, Smart Phone, Sampling, Global System for Mobile Communication (GSM), Object Oriented Programming Language (OOPL), Iterative Numeric Methods

1. Introduction

This paper illustrates a novice method of computation of harmonic distortion in the electrical network using object oriented iterative numerical methods. The relevant data is received from numeric meters installed at remote end installations and its processing is done on smart phone through which the concept of Automatic Meter Reading (AMR) can be implemented. [1] [2].

Harmonics are the integer multiple of the fundamental frequency of mainly current and voltage. In India the fundamental frequency of electricity is 50 Hz. High order harmonics are generated by the non-linear loads such as computers, ac and dc drives, inverters, home protectors, soft starters etc.[3] In short, harmonics are generated when electricity is controlled by electronics. Fig 1 shows fundamental and other harmonic components giving rise to a resultant harmonic wave. If high order harmonics other than fundamental are more, the resultant wave would be highly distorted. The effects of high order harmonic distortion such as overheating and failure of electrical equipments, erroneous meter readings, failure of capacitor banks, undue tripping of transformers and transmission lines etc. are quite detrimental. The problem of harmonics can be tackled by installing harmonic filters for which the detailed analysis of harmonics is required to be carried out. In order to conduct harmonic analysis, it is required to measure current, voltage and power harmonics in the system. Over a period of time, there had been significant developments in measurement of harmonics.

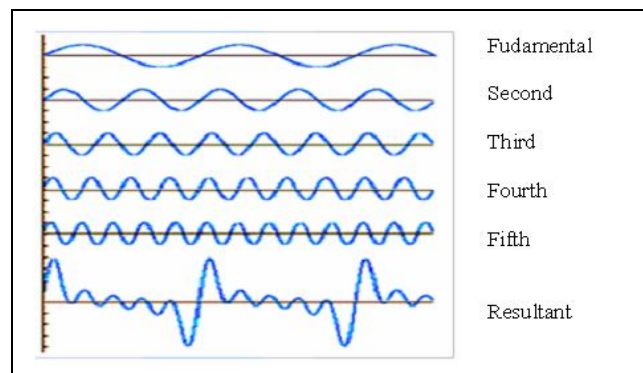


Figure 1: Fundamental and Other Harmonic Components Giving Rise to Harmonic Distortion

Harmonic Measurement has always been significant. Harmonics are measured at the point of common coupling between linear and non-linear loads. Therefore usually harmonics are measured at billing meter. The harmonics of current and voltage are measured by using the method of Fourier transforms. Harmonic waves are viewed basically on Cathode Ray Oscilloscope (CRO). However, it is not possible to accurately measure and analyze harmonics on CRO. The parameters such as Total Harmonic Distortion are not displayed by the CRO. The measurement and analysis of harmonics can be conducted on the traditional device called Harmonic Analyzer. It is a portable digital electronic device for harmonic measurements. During late nineties, the microprocessor based meters called numeric meters or digital meters were developed. These meters are provided within built Central Processing Unit (CPU) and Random Access Memory (RAM). These meters are also capable of conducting harmonic measurements. However, these existing equipments viz. Cathode Ray Oscilloscope, Harmonic Analyzer and Numeric meters do not perform remote measurements. In order to save time in visiting various electrical installations, it was felt necessary to transmit meter data over a longer distance and meet requirements of AMR. [4]. The remedy is implementation of mobile computing. As such, smart mobile phone is a convenient tool.

2. Data Transmission

At the utility substation, numeric meters are installed in a control panel. These numeric meters are connected to the 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. See Fig 2.

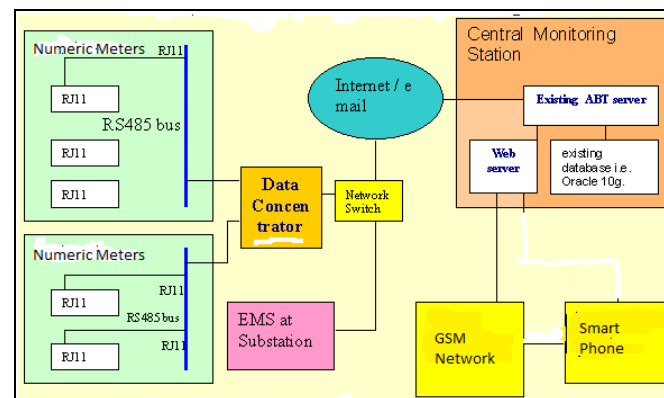


Figure 2: Functional Block Diagram Showing Flow of Data Signals From Numeric Meters Installed At Utility Substation to the Smart Phone

Through a wireless internet media, the data is sent to the Central Monitoring Station (CMS) via internet switch (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.

The 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.

3. 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 2. 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 with in built CPU and RAM. The mobile operating system used by the smart phones are Google's Android, Apple's iOS, Nokia's Symbian, Microsoft's Windows phone and HP's webOS. [8][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. [10]. 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. The program output is displayed by emulator on the mobile screen. [11].

4. Numeric Analysis

Let us consider a simple example of a two bus system connected by a transmission line, as shown in Fig. 3.

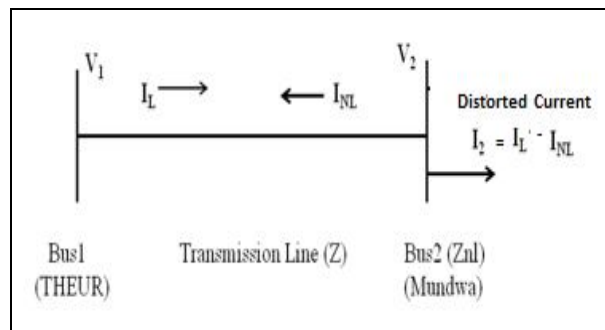


Figure 3: Two Bus System Model

The voltages at sending end (Theory) and receiving end (Mundwa) are V_1 and V_2 respectively. The voltage V_1 at sending end is known. Due to fluctuations and high order harmonics, the voltage at receiving end is unknown and is required to be found out. Current I is flowing through the transmission line connecting Bus1 and Bus2. Bus2 is connected to consumers having non-linear loads. Therefore, load current I is flows through the Point of Common Coupling (PCC) of these consumers.

The impedance of transmission line is Z and the impedance of Bus2 is Z_{nl} . Now the following two equations can be written in terms of voltage and current at Bus2.

$$V_1 = I \cdot Z + V_2 \quad (1)$$

$$V_2 = I \cdot Z_{nl} \quad (2)$$

The Iterative Computation Using Numerical Methods:

The parameters V_1 , Z and Z_{nl} are known. The parameters I and V_2 are required to be calculated. For simplicity, let us assume that $V_2 = x$ and $I = y$. the above equations can be re-written as follows-

$$V_1 = y \cdot Z + x \quad (3)$$

$$x = y \cdot Z_{nl} \quad (4)$$

Now the values of x and y are found from equations (3) and (4) respectively as follows-

$$x = V_1 - y \cdot Z \quad (5)$$

$$y = x / Z_{nl} \quad (6)$$

Now let us apply the numerical iterative methods to compute values of x and y . The commonly used numeric iterative methods are Gauss Iterative, Gauss Seidel and Newton Raphson Methods.

4.1. Gauss-Iterative Method

The initial solution is guessed approximately and is used in conjunction with the original equation to compute first iteration. This first iteration is used to find the second iteration and the process is continued till convergence is achieved.

Applying Gauss-iterative method to eqn (5) and (6)-

Let $x(0) = 1$ and $y(0) = 1$.

$$x = V_1 - Z = k_1 \text{ (say)} \quad (7)$$

$$y = 1 / Z_{nl} = k_2 \text{ (say)} \quad (8)$$

Substituting x and y in (5) and (6), we get,

$$x=V_1 - k_2Z = k_3 \text{ (say)} \quad \dots(9)$$

$$y= k_1 / Z_{nl} = k_4 \text{ (say)} \quad \dots(10)$$

Again substitute values of x and y in (5) and (6). Continue this process till the convergence is obtained.

In general,

$$x_{n+1}=V_1- y_nZ \quad \dots(11)$$

$$y_{n+1}=x_n/Z_{nl} \quad \dots(12)$$

In this way we can obtain voltage and current at receiving end using Gauss iterative method.

4.2. Gauss-Seidel Method

In this method, the results of first iteration immediately replace the previous values in the next step.

In order to apply Gauss-Seidel method in the above example, we would still compute x_{n+1} using equation (11), and we have to substitute just computed x_{n+1} to compute y_{n+1} . Thus instead of eqns (11) and (12), the equations for Gauss-Seidel method will be as follows-

$$x_{n+1}= V_1- y_n.Z \quad \dots(13)$$

$$y_{n+1}= x_{n+1}/Z_{nl} \quad \dots(14)$$

4.3. Newton-Raphson Method

Newton Raphson Method is based on Taylor’s series and partial derivatives. The analysis is conducted by forming matrix and Jacobean models.

The objects of voltage V_2 and current I are created using Object Oriented Programming Language (OOPL) and accordingly classes are formed .The source code would support OOPS based concepts such as inheritance, polymorphism, encapsulation and code reuse.

The harmonic distortion of current is calculated from the difference of measured value and actual value at receiving end. The difference between current at sending end and receiving end is also noticed.

5. 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.



Figure 4: Text Editor of Smart Phone Compiler

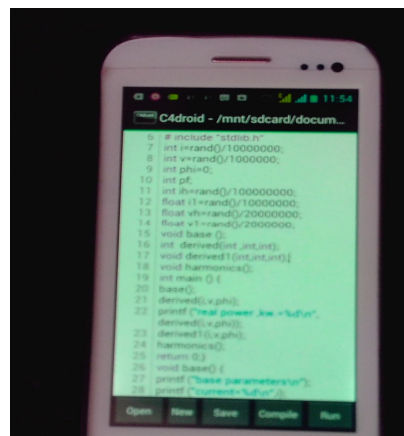


Figure 5: Use of Smart Phone as a Compiler

The example of Android based C compiler is shown in Fig 4. 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 5 shows smart phone as a compiler. [12][13]. Fig 6 shows a display on terminal emulator.

