American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-5, pp-102-117
www.ajer.org
Research Paper Open Access

An Optimized Scheme for Data Acquisition and Processing For an Electric Distribution System

OsunborOsayomwanborCollins[1], IdamaOmokaro[2]
[1]*Nnamdi Azikiwe University,Awka. Nigeria*
[2]*Delta State Polytechnic, Ozoro, Delta. Nigeria.*

Abstract: *This research work develops an optimized data collecting and processing scheme for a distribution system as part of efforts to enhance power systems operations. This thesis proffers a solution that comprises data generation using a substation model, improved data collecting from modelled apparatus and finally application of data processing and consistency checking algorithms. The process of data collecting and processing is automated and repeated in equidistant time intervals. Results of processing and related reports are displayed for those monitoring the substation operations in remote locations and even on remote devices in real time without redundancy.*

***Keywords**: IED, distribution system, optimization, data acquisition, data processing*

I. INTRODUCTION

An electric power system is a network of electrical components that generate electrical power from any source of power (such as coal, water, gas, wind, nuclear energy etc.) which then transmitted and eventually distributed to nearby homes and industries. Electric Power Systems (EPS) consist of three parts in the most general case; generation, transmission and distribution (Glover and Sarma, 2002). They play important roles in providing electrical power to customers over a power network.

Electricity distribution is the process in which the high-voltage power is stepped down, converted and disseminated to the consumers through a mesh network of cables reaching all the way to consumer premises. A distribution system serves as the link from the distribution substation to the customer. This system provides the safe and reliable transfer of electric of electric energy to the various customers throughout the service territory. Typical distribution systems begin as the medium voltage three phase circuit; typically 30 - 60KV and terminate at a lower secondary three or single phase voltage typically 0.4kV at the customers' premise.

Distribution subsystem (DS) is used to lower transmission voltages of distribution process to end users (Blackburn, 1998). They normally serve a single small area, being located near end users. The voltage levels are: 240V, 11kV and 33kV (Keezunovic, 2003).

The word substation comes from the time where only one power generation existed and the other substations were subsidiaries of the power generation.

Substations generally consist of devices for switching, protection, control and transforming voltage (IEC 61850, 2003). They are inevitable components in all power networks. Their operation facilitates maintaining quality service to the customers.

A great variety of instruments and devices coexist in substations for taking accurate of measurements depending on the sources of the measurements.

Local substations use status data as necessary information in the decision-making process.

Electric power may flow through several substations between the generating plant and the consumer, and the voltage may be changed in several steps.

Distribution substations typically operate at 2.4–34.5 kV voltage levels, and deliver electric energy directly to industrial and residential consumers. Distribution feeders transport power from the distribution substations to the end consumers' premises. These feeders serve a large number of premises and usually contain many branches. At the consumers' premises, distribution transformers transform the distribution voltage to the service level voltage directly used in households and industrial plants, usually from 110 to 600 V. Distribution substations may use re-closer circuit breakers or fuses for the protection of the distribution circuit.

Distribution systems consist of transformer, feeder circuit, switches, protective equipment, primary circuits, secondary circuits and service line. Distribution feeder circuits usually consist of overhead and underground circuits in a mix of branching laterals from the station to the various customers.

There are several conventional distribution devices used to improve the safety, reliability, and power quality of the system. They include(Bergen and Vittal, 2000);

- Switches
- Breakers
- Reclosers
- Capacitors
- Fuses:
- Lightning arresters.

The dependence of daily activities on electricity makes it very important for the electrical utilities to maintain continuous service to their customers and this is not possible to do so if there is no efficient power data acquisition and processing scheme.

Electric power systems include variety of elements such as generators, substations, transformers, transmission lines etc. They are all connected in a certain manner to achieve power flow from the generation point to the end user.

The equipment described here possesses some types of setting, monitoring and/or control parameters. The managing of these devices and the enabling of the various devices for intercommunication in a fast and efficient manner is performed by the substation automation system (SAS). Substation Automation (SA) is a supervisory management and control system for industrial electrical distribution systems.

The most significant elements of a SA system include relays and/or Intelligent Electronic Devices (IEDs) that perform various control, monitoring and protection related operations.

The order of control process in this system involves the exchange of information between the devices and the device that coordinates all substation devices. The success of this system relies heavily on the use of an effective communication system to link the various control, monitoring and protection elements within a substation.

An example of this is the acquiring of empty or load voltage values, in order to access whether they are within the limits.

The development of power systems has been going on for more than a century already. It was influenced in part by steady increase in electric energy consumption over the years and in part by advancements in technology. This development brought about many changes in the substation operation practice. As the power system was growing, new substations were built and the power networks became rather complex. That required new techniques to be devised and implemented to support required substation operations. New technical systems and solutions were constantly added to improve the operation of existing ones. Development took off in several directions. Functions that were emphasized through the development became more-less independent. They were concentrating on particular substation functions that needed to be handled. An example is protective relaying function. Relays detect faults on the system and initiate disconnecting of a faulted element or a section from the rest of the system.

Their role is to remove a faulted section as quickly as possible because a fault typically creates high levels of current that can damage or destroy equipment and endanger lives.

Protective relays rely on information obtained from measurement system that is independent from other substation functions. This is in part due to enhanced reliability and in part to specific requirements applied in protective relaying practice. Latest developments introduced digital relays, devices with great processing power and versatile usage also utilized out of the area of protective relaying.

Other substation devices like certain automation modules remained focused on the designated operation. One of the consequences is that automation function usually operates locally, without being controlled from remote locations or without communicating valuable outcomes to the remote sites.

Having an important role within the power system, substations are equipped with great variety of monitoring and control devices (Keezunovic, 2003). Number of different functions are implemented, such as revenue metering, protective relaying, apparatus monitoring, automated switching etc. Reliable and efficient operations can be achieved with complex monitoring, control and protection systems that are developed and improved in this research.

II. LITERATURE REVIEW

In the earlier days, the telephone was used to communicate line loadings back to the control centre and if problems on the substation occurred, orders were given to the operators for performing switching operations at substations.

In the mid-1930s (EPRI, 1997), the telephone line was used to remotely control switching-based remote control units and to provide status and control about the position of the contacts. When digital communications became a viable option in the 1960s (EPRI, 1997), data acquisition systems (DAS) were installed to automatically collect measurement data from the substations.

As we move into the digital agethousands of analogue and digital data points are now available in a single Intelligent Electronic Device (IED) and communication bandwidth is no longer a limiting factor. It thus became a priority to define the formats of messages, transmission times and other criteria, with the purpose of connecting IED from different vendors and the devices into the substation(EPRI, 1997).

The Connectivity of substation is determined by the current operating state of the power system as well as the needs for economically and technologically justified power flow (Keezunovic, 2003).

(Nunn and Sullivan, 1992) describes a new power line carrier metering system which was tested in several major pilots. The system is believed to be unique in offering fast data rates of up to 19,200 bits per second over both LV and MV (11kV) distribution networks.

Novel, low cost, non-invasive inductive signal coupling techniques have been developed to facilitate cost-effective communications over underground and overhead MV networks.

(Smith and Modzelewski, 1999) describes the advanced features and capabilities of modern Remote Terminal Units (RTUs) presented in this article can be used to enhance the capability of any Energy Management System (EMS). As utilities continue to upgrade equipment to increase operating efficiencies, the multi ported RTU will play an ever-growing role.

(William J. Ackerman, 1999) describes the use of IEDs in substations will impose many changes on the design and implementation of the Distribution Management System (DMS) /SCADA/EMS/ system. The increased data volume will require new methods for data transmission, processing and storage. New methods for checking out the transmission of data from a substation IED to a master station are required if the task is to be accomplished in a reasonable amount of time. Newer IEDs already incorporate facilities to accomplish this.

On the positive side, the availability of additional data will lead to more accurate and reliable application programs such as state estimation, load flows, contingency analysis, etc. The improvements in these programs will, in the long run, result in the ability to operate a power system with greater safety, reliability and economy.

(Moser and Ejebe, 1999) explains in many places throughout the world, the electricity supply industry is undergoing dramatic changes. Efforts to create competition in the power generation segment of power systems operation is leading to significant restructuring.

Components of electricity supply are being unbundled and managed separately. The responsibility for various aspects of power systems operation is being spread out across more participants. All these changes impact the various information technology systems that support power systems operation. This paper has looked at some of the impacts of restructuring on traditional EMS applications. It has also described several new applications, namely, Available Transfer Capability, Dynamic Security Assessment, Voltage Stability Analysis, and Locational Marginal Price Calculation.

(Hoppe et al, 1999) describes Real-time monitoring and dynamic rating systems have matured from being used as off-line engineering tools to systems which are used on-line by system operations, as well as being used by planning, engineering and maintenance. The paper described the integration and presentation of real-time ratings to the planner, engineer, maintenance and operating personnel using existing utility communication schemes.

(See et al, 2000) describes the Electric utilities are finding it increasingly necessary to better monitor, analyse and control their distribution systems. Planning and operation of the grid is increasing in complexity on one hand but subject to ever more binding constraints on the other. Real-time analysis is being seen as necessary to achieve acceptable operational efficiencies and quality of service.

(Qiu et al, 2001) describes the Load shedding takes place as an emergency measure in cases of falling frequency conditions or loss of power generation.

Particularly in isolated (island) systems, due to lower inertia and limited reserves, the rate of frequency decay due to loss of generation can be more pronounced. Therefore, a more carefully designed load-shedding scheme is required in an island system than in a large interconnected system.

Grasberg et al, 2001) describes the traditionally SCADA/ EMS/ DMS systems will evolve into concepts containing smaller independently released products. The different products will be adapted to emerging standards and may come from different vendors. There will be the traditional vendor that take full responsibility for the delivery and installation at the customer site and vendors that specialize on one or a few of the different products.

(Rochelle et al, 2001) describes Restoration of distribution systems is a complicated process, especially after storms, when a large number of outages can occur. Many utilities are implementing Automatic Meter Reading (AMR) systems that can aid in the restoration process. The paper presented work done to utilize the capabilities and information provided by a wireless AMR system, including the on-demand read feature, to develop a polling procedure to identify system conditions. It takes advantage of the connection information provided by a utility and the performance of thewireless meter communication systems.

(Pimpa and Premrudeepreechacham, 2002) in their work presented the type of expert system for controlling the 22kV voltage levels of power system in northern region of Thailand based on the SCADA system. At present, for the operation, the operators have to make decision by their knowledge and experience to control the voltage. This expert system is obtained for alleviation of voltage violation in the day to day of distribution substation in the system and process the data from the SCADA for helping the operator detect buses experiencing abnormal conditions.

(Liu et al, 2002) describes the advances in computer applications and technologies are providing more and more data about the distribution system that can be used for analysis. One new technology is AMR systems. AMR systems provide access to the consumption and status of individual customers. This summary outlines research work to incorporate AMR information in outage management. The first technique combines AMR data with SCADA and trouble call data to identify an outage and then uses AMR polling to verify the outage and its level. The second technique provides a way to use AMR to confirm restoration of all customers below an out aged device.

(Wu et al, 2003) describes the SCADA system as a communication and control system used for monitoring, operation and maintenance of energy infrastructure grids.

Compared with traditional applications, a SCADA system has a harsh deadline for critical tasks. There is special time constraint for the real time database used in a SCADA system. The real time database in SCADA extends traditional database to include in-memory database. Such real time database management is designed to operate in the harsh environment of real time systems, with strict requirements for resource utilization, and is ready to provide the performance and reliability required by real-life applications. In this research, the main principle of real time database has been introduced. Its implementation in power system SCADA is discussed.

(Kusic and Garrison, 2004) describes the Transmission line equivalent circuit parameters are often 25% to 30% in error compared to values measured by the SCADA system. These errors cause the economic dispatch to be wrong and lead to increased costs or incorrect billing. The parameter errors also affect contingency analysis, short circuit analysis; distance relaying, machine stability calculations, transmission planning, and State Estimator Analysis. An economic example is used to demonstrate the effect of transmission line errors. SCADA measurements from several utilities are used to compute the ‘real world’ value of the transmission line parameters.

State Estimation with the estimated parameters is compared to the computations using the theoretical values.

(Xiaofeng et al, 2005) describes the changing requirements due to privatization and deregulations in power industry have created needs for analysing information from different sources. These needs require new high performance solutions represented by the new data warehouse of (SCADA)/ Energy Management System (EMS) and its characteristics and structure outlined in the paper. Utilities have started to take advantage of this new technique and many other plans to follow.

As the industry gains experience from this new tool new applications will evolve on the SCADA/EMS system.

(Terry Chandler, 2005) describes the technology and Power Monitoring knowledge base has had a very significant impact on AMR and Power monitoring in the past few years. Historically power monitoring systems have been either AMR or Power Quality (PQ) and power usage monitoring systems. As the network technology, communication protocols and computing power technology increased the costs have decreased and we are observing a merger of the system capabilities. New AMR systems combine some PQ functions and PQ monitoring systems include AMR functions.

(Bose, 2007) explains the power grid is not only a network interconnecting generators and loads through a transmission and distribution system, but is overlaid with a communication and control system that enables economic and secure operation. This multi-layered infrastructure has evolved over many decades utilizing new technologies as they have appeared. This evolution has been slow and incremental, as the operation of the power system consisting of vertically integrated utilities has, until recently, changed very little. For example, the monitoring of the grid is still done by SCADA systems whose hierarchical design for polling data was appropriate for vertically integrated utilities and whose speed in seconds still reflects the conceptual design of the 1960s.

(Helmy et al, 2007) describes the Electrical energy consumers are demanding better customer service, higher power quality, higher energy measurement accuracy and more timely data. Utility companies all over the world are being forced to find solutions giving greater information on the population’s power consumption. The AMR system is one of the ways in which utilities are go-getting to achieve these goals. Power lines are one of the communication mediums used in the AMR system.

A detailed literature review of many papers from International journals clearly indicates that, it is worthwhile and important to carry out research work on developing an efficient data acquisition and processing scheme so as to improve the general operations in a distribution system.

Data is collected from various data collection points in distribution section of an electrical power network and those data should be processed to provide meaningful analytical reports which will help for taking

right decisions that would improve the general operation of the distribution system.
The main objective of this thesis is to develop an improved framework for data acquisition and processing with ability to record, store, and process power consumption data in a distribution system. The power consumption data is accessible to operators in remote locations

III. DESIGN

In this proposed system is a simulation model is designed and characterized leveraging mathematical formulation in an embedded design.

3.1 Formal Integrated Embedded Method of Engineering Design (FIEMED)

This research work defines the **Formal Integrated Embedded Method of Engineering Design (FIEMED).**
After the initial conceptualization of the proposed model, it would be followed by stage block by block design. These individual block designs would be simulated and characterized. A certain degree of formal design to gate level oriented design and programmable VSLI in the sense that mathematical equations for the optimizing the data acquisition capacity of the system.

The behaviour characterization of the proposed formulation is then embedded in the control code after gate level components are logically connected together and used to characterize various components in this system. For e.g. logical components where used in the design of this model.

Programmable microprocessor chips were embedded in this design to serve as the brain of the design. All the logical components characterized or modelled to describe true life scenarios so as to present an improved context in the simulation model.

Proteus ISIS version 7.8 was used to develop a real time simulation scenarios using program description language which later was coded with Assembly language for embedded systems. All the logical components characterized or modelled to describe the real life scenarios. The advantages of this particular quantitative approach are numerous in this methodology.

The simulation system is not faced with the problem of component failure (because virtual components are connected together under ideal conditions; factors like temperature, life span of components etcetera do not come into play) or the issue of troubleshooting (in the eventuality of component or system failure, the fault would need to be detected and might even require a complete change of the affected component), which could adversely affect the overall performance of the system.

Secondly, the algorithms and flowcharts used for the implementation of this methodology are much easy to comprehend.

Thirdly, the code used to configure the brain of the model is machine language and after each stages of the system is developed; it is subject to review and can easily be modified.
Again, components are modelled into the proposed design thus enabling the designer to pass across the ideas used in conceptualizing the model.

This method also leaves space for improvements in future work. The designer can incorporate more mathematical models for better responses by simply re-characterizing already existing logical components to suit his new ideas or concepts.

3.2 Tools used in design

- Program Description Language (PDL)
- Proteus 7.8 Isis
- MATLAB

3.2.1 Proteus 7.8 Isis

This is the primary simulator used in this project. It gives a platform whereby components at the gate level are logically connected together under a near ideal environment. The logical components can be characterized to emulate various stages of the design. Proteus Isis is used to develop a simulation model that can descriptively visualize the proposed system

This environment monitors the responses of the simulation model to evaluate if the model is behaving in the intended manner. It has tool boxes from which electronic, solid state or logical components can be brought together and logically connected to give us the desired results.

3.2.2 Program Description Language

For this proposedscheme, Program Description Language (PDL) which is a subset of C# can be implemented into any programming language of choice. It can be translated into VLSI languages or System on chip language or VHDL or VERILOG for Field Programmable Gate Arrays (FPGA) or Complex Programmable

Logic Device (CPLD) but for the purpose of this research, assembly Language is used for the implementation of the code algorithm.

3.2.3 MATLAB

This research work makes use of MATLAB SIMULINK modelling tools for modelling the substation section in a distribution system by making use standard power block set elements in SIM POWER in the SIMULINK environment. It is in the MATLAB Simulink environment that the control signals for optimization of substation operation are generated.

3.3 Substation Modelling

The simulation of the data acquisition and processing section of a substation in a distribution system would be effectively achieved using Proteus Isis 7.8 to produce a characterization of real time operations of the system.
MATLAB Simulink would be used in this research to give a detailed block by block representation of the substation model with the standard key block-set elements and functions.
The substation model is designed to constantly generate raw data that simulate information obtained from the physical substation in reality. This data is communicated in predetermined intervals for further processing by other software components. Several major blocks are implemented in order to model important elements and functions in the substation.
The distribution (location) of analogue and digital measurements in the substation model is determined considering following rules:

- Each circuit breaker has two current measurements (one at each side).
- Each transmission line has one current measurement, one voltage measurement, and calculated active and reactive power measurements.
- All switch elements have contact status measurements.

All measurements are single-phase measurements.

Four main Simulink blocks are developed for the substation model to describe different elements:

- equivalent source block,
- switching element block,
- measuring unit block
- Triggering block.

3.4Mathematical Characterization of the Data Acquisition/ Processing System

During normal operation of the system, there is continuously processing of data samples taken from the measurement of instantaneous voltages and currents.

Using sequential samples, the algorithm can extract information about the measured values, such as amplitude and phase angle. Faulted or other system conditions can be determined by comparing the measured values to predetermined settings.

If the assumption is made that the voltage and current maintains sinusoidal form under varying conditions; amplitude and phase of the signal can be obtained using a limited number of samples.
Samples obtained from the sinusoidal signal can be described as

$$v(t) = V_1 \sin(\omega_0 t) \quad (3.1)$$

Then the first derivative of the signal is

$$v'(t) = \omega_0 V_1 \cos(\omega_0 t) \quad (3.2)$$

Where:

$$v'(t) = \frac{d}{dt}[v(t)]$$

From Eqns. 3.1 and 3.2, we have

$$[v(t)]^2 = V_1^2[\sin(\omega_0 t)]^2 \quad (3.3)$$

$$[v'(t)]^2 = (\boldsymbol{\omega}_0)^2 V_1^2[\cos(\omega_0 t)]^2 \quad (3.4)$$

$$[\frac{v'(t)}{\omega 0}]^2 = V_1^2[\cos(\omega_0 t)]^2 \qquad (3.5)$$

The peak value of the sinusoidal signal can be expressed as:

$$V_1 = ([v(t)]^2 + [\frac{v'(t)}{\omega 0}]^2)^{0.5} \qquad (3.6)$$

The above equations are valid for any instant. The derivative of the signal can be obtained if, between two consecutive samples, the signal is considered linear. This research work makes a modelling assumption that the derivative will be the slope of the linear segment of the signal and can be represented as

$$v'[k] = \frac{\Delta v}{\Delta t} = \frac{v[k+1]-v[k]}{\Delta t} \qquad (3.7)$$

Where Δt is the time interval between instances when the two samples were taken.
The amplitude and the phase angle of the signal can therefore be calculated after each new sample using the following two equations:

$$V[k] = (v[k]^2 + [\frac{v[k+1]-v[k]}{\omega 0 \Delta t}]^2)^{0.5} \qquad (3.8)$$

$$\Phi[k] = \tan^{-1}(\frac{v[k]\omega 0 \Delta t}{v[k+1]-v[k]}) \qquad (3.9)$$

The above operations performed on instantaneous voltage are equally performed on instantaneous current.

$$I[k] = (i[k]^2 + [\frac{i[k+1]-i[k]}{\omega 0 \Delta t}]^2)^{0.5} \qquad (3.10)$$

$$\Phi[k] = \tan^{-1}(\frac{i[k]\omega 0 \Delta t}{i[k+1]-i[k]}) \qquad (3.11)$$

By leveraging first and second derivatives, it can reduce errors due to the decaying DC component (Russel, 1978). Using the same notations as for the previous mathematical formulations in Eqn. 3.7, the second derivatives of the sinusoidal signals

$$V''[k] = \frac{v[k+1]-2v[k]+v[k+1]}{(\Delta t)^2} \qquad (3.12)$$

$$I''[k] = \frac{i[k+1]-2i[k]+i[k+1]}{(\Delta t)^2} \qquad (3.13)$$

Thus, the amplitude and the phase angle of the sampled signal can be obtained as:

$$V[k] = \frac{1}{\omega 0}(v'[k]^2 + [\frac{v''[k]}{\omega 0}]^2)^{0.5} \qquad (3.14)$$

$$\Phi[k] = -\tan^{-1}([\frac{v''[k]}{\omega 0 v'[k]}) \qquad (3.15)$$

$$I[k] = \frac{1}{\omega 0}(i'[k]^2 + [\frac{i''[k]}{\omega 0}]^2)^{0.5} \qquad (3.16)$$

$$\Phi[k] = -\tan^{-1}([\frac{i''[k]}{\omega 0 i'[k]}) \qquad (3.17)$$

The mathematical formulations from eqns. (3.8) – (3.11) and eqns. (3.14) – (3.17) are extremely sensitive to deviations of the apparent sampling rate and as such this research further adopts Least Square Error (LSE) algorithm to effectively handle any remaining decaying DC component and odd harmonics.
The wave form with decaying component and odd harmonics can be expressed as

$$v(t) = K_0 e^{-(t/\tau)} + K_1\sin(\boldsymbol{\omega}_1 t + \boldsymbol{\theta}_1) + K_3\sin(\boldsymbol{\omega}_3 t + \boldsymbol{\theta}_3) \qquad (3.18)$$

where τ is the time constant describing the decaying exponential.
Using the first three elements of the Taylor series expansion of the DC component, the previous equation can be written as:

$$v(t) = K_0 - K_0\frac{t}{\tau} + K_0\frac{t^2}{2\tau^2} + K_1\sin(\boldsymbol{\omega}_1 t + \boldsymbol{\theta}_1) + K_3\sin(\boldsymbol{\omega}_3 t + \boldsymbol{\theta}_3) \quad (3.19)$$

using the fact that

$$\sin(\boldsymbol{\omega} t + \boldsymbol{\theta}) = \sin(\boldsymbol{\omega} t)\cos(\boldsymbol{\theta}) + \cos(\boldsymbol{\omega} t)\sin(\boldsymbol{\theta}) \quad (3.20)$$

Eqn. (3.19) can be written as:

$$v(t) = K_0 - K_0\frac{t}{\tau} + K_0\frac{t^2}{2\tau^2} + K_1\sin(\boldsymbol{\omega}_1 t)\cos(\boldsymbol{\theta}_1) + K_1\cos(\boldsymbol{\omega}_1 t)\sin(\boldsymbol{\theta}_1) + K_3\sin(\boldsymbol{\omega}_3 t)\cos(\boldsymbol{\theta}_3) + K_3\cos(\boldsymbol{\omega}_3 t)\sin(\boldsymbol{\theta}_3) \quad (3.21)$$

The above equation is valid for any value of t. With the following notations:

$$a_{k1} = 1$$

$$a_{k2} = \sin(\boldsymbol{\omega}_1 t_k)$$

$$a_{k3} = \cos(\boldsymbol{\omega}_1 t_k)$$

$$a_{k4} = \sin(\boldsymbol{\omega}_3 t_k)$$

$$a_{k5} = \cos(\boldsymbol{\omega}_3 t_k)$$

$$a_{k6} = t_k$$

$$a_{k7} = t^2_k \quad (3.22)$$

and

$$x_1 = K_0$$

$$x_2 = K_1\cos(\boldsymbol{\theta}_1)$$

$$x_3 = K_1\sin(\boldsymbol{\theta}_1)$$

$$x_4 = K_3\cos(\boldsymbol{\theta}_3)$$

$$x_5 = K_3\sin(\boldsymbol{\theta}_3)$$

$$x_6 = \frac{-K0}{\tau}$$

$$x_7 = \frac{-K0}{2\tau^2} \quad (3.23)$$

Eqn. (3.21) can be written for consecutive values $t_1, t_2. \ldots t_m$ as:

$$S_1 = \sum_{n=1}^{7} a_{1n}x_n$$

$$S_2 = \sum_{n=1}^{7} a_{2n}x_n$$

.
.
.

$$S_m = \sum_{n=1}^{7} a_{mnxn} \quad (3.24)$$

The values of $x_j$can be obtained using the pseudo-inverse of matrix A = $[a_{ij}]$,
wherei= 1, 2, . . . m and j = 1, 2, . . . 7. The matrix format of Eqn. (3.24) is:

$$S = AX \quad (3.25)$$

whereX= $[x_j]$, with j = 1, 2, . . . 7. It can be subsequently written that:

$$A^TS = A^TAX \quad (3.26)$$

$$(A^TA)-1A^TS = (A^TA)^{-1}A^TAX \quad (3.27)$$

As a result:

$$X = (A^TA)^{-1}A^TS \quad (3.28)$$

Using the values of X, the DC component, the amplitude and phase angle of the fundamental and the third harmonic can be obtained.

This summary describes mathematically the process of substation data collection and processing for the system. Virtual substation model is devised to make up for an actual substation system. Details of substation elements modelling and mathematical formulations for the proposed data acquisition scheme in a distribution system have been presented.

Data collecting and pre-processing are discussed as the necessary steps that need to be performed. Particular emphasis is also given to the processing and consistency check algorithms. Here substation level data acquisition architecture is used to describe the physical connection of devices and the flow of data within the system;

3.5 Stages Involved in Data Acquisition and Processing in the Distribution System

The foremost mission in power distribution system is control and protection. It is not efficient to manually monitor and control the level of voltage, current and frequency of a substation all time. The human interference may cause errors at times that may lead to serious destruction. Substation automation entails the of use data's' from Intelligent Electronic Devices (IEDs), control and automation capabilities within the substation, and control commands from remote users to control power system devices.

The acquisition and processing of data is the most important section in a substation automation system. The steps involved in current architecture of substation automation are

- Substation design.
- Collecting the data from substation equipment.
- Send the collected data to a control and monitoring device.
- Operation on the data fed to IEDs.
- Transmitting the control from the monitoring devices to the protective relays and circuit breakers.

3.6 Proposed System

This research would entail the implementation of the system design and development in a simulation platform and the following steps would be implemented.

A. Interfacing of sensors with Data Acquisition System

Many interfacing applications require the acquisition or generation of signals from the interfaced system; hence a DAQ (for short) is used in the process. Mostly, the substation data are real world signals that are analogue. Most of the instrumentation systems can handle only the digital or discrete data. So the analogue signals are converted into digital signals.

B. Data transfer to the Computer

Typically, DAQ boards are installed in a PC with a high speed data bus like the PCI bus. A DAQ communicates with PC via RS232/485, USB protocol or IEEE 1394. Data transfers can occur between microprocessor and memory at about 20MHz to 40MHz.

C. Selecting a DAQ device

The physical properties that need to be measured now and in the future are determined. The transducers are selected accordingly. The signal conditioning unit required is determined. The allowable A/D conversion error is set. The sample rate required to accurately capture the physical properties is calculated. A DAQ device is then selected that would meet the requirements.

D. Dataflow in the System

The system is set up for continuous acquisition and the data is read repeatedly until the user decides to stop the acquisition. Fig 1 shows the dataflow model.

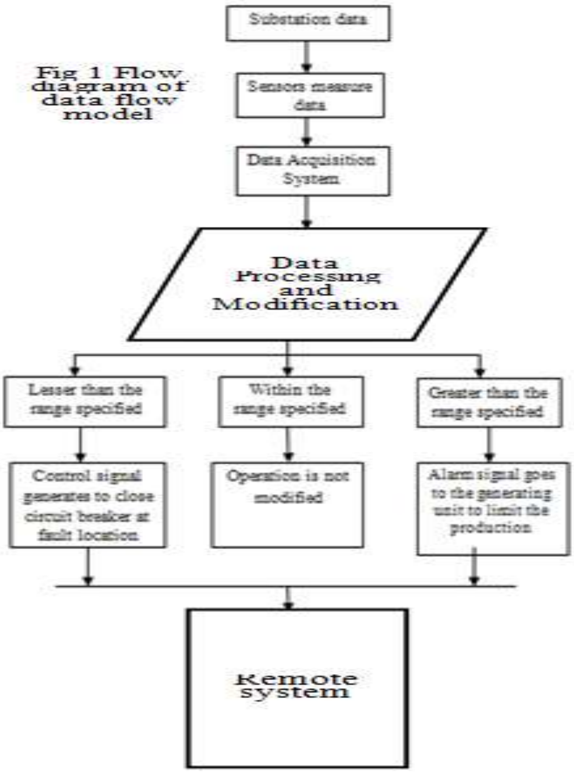

Fig 1 Flow diagram of data flow model

The possible outcomes are separated for three categories equals to, greater than and lesser than. If the data read is in the specified range the operation is not disturbed. Two separate event cases are created of which one is for lesser range than specified and the other is for greater range than specified. If the values are lesser than specified range the circuit breaker at the point of fault occurrence is made open and the load is shed off from the substation and if the values are greater than specified range value the information is given to the main station or generating station and the generation is limited.

As the process is continuous the data are recorded for different instants of time and if once the normal conditions are met the system again allows the substation to perform the activities it meant for. The control is transferred to the appropriate sections through Data Acquisition system.

IV. SYSTEM IMPLEMENTATION AND RESULT ANALYSIS

Proteus 7.8 Isis was used to characterize proposed system (see appendix for schematic capture). Proteus 7.8 provides the platform through which the proposed system was characterized.

Typical applications of Proteus 7.8 Isis include standard-based electronic and logical component feature characterization. The Proteus 7.8 Isis environment is organized into; probe/simulation environment, component editor, sub circuit editor with a comprehensive collection of simulation tools that was used to characterize the proposed system. The Proteus 7.8 Isis environment provides several modules for the simulation comprising a vast enterprise of digital and analogue tools which with friendly graphical user interface can be manipulated to achieve desired results. Key features of Proteus 7.8 Isis include;

- Detailed simulation log
- Hierarchical modes and options
- Flexibility (enabling one to manipulate custom designs and values to achieve desired target).
- An interactive animation process (allowing variable's manipulation)
- Graphic specifications

Figure 2 Snapshot capture of the system on Proteus Isis acquiring and processing data across the distribution section system.

MATLAB SIMULINK was also used in this research work for the characterization of blocks used for measurement in the proposed system like the

- equivalent source block,
- switching element block,
- measuring unit block
- Triggering block.

Key features of MATLAB include:

- Object orientation
- Hierarchical modes
- Graphic specifications
- Flexibility to develop detailed custom models
- An integrated post-simulation analysis tool
- Interactive analysis

Project editor, m-script editor, model editor, function block parameter editor, probe/simulation environment and analysis environment. Also, the environment provides several modules for the simulation comprising a vast enterprise of engineering tools ranging from electronics, fuzzy logic, automation, mechanical to even biomedical engineering function design block sets.

RESULTS

4.1 Simulation Analysis Scenarios

For the analysis purpose this research work looks at frequency response and Analogue analysis of waveform of the distribution voltage and current.

4.1.1 Procedure for Frequency Analysis using Proteus:

- From main page of Proteus, click on 'P' to pick device from library.
- In pick device, insert the component which has to be selected & click on 'OK'.
- Place the all components on the Proteus screen.
- Right click and select edit properties to change the values.
- Add voltage probe at input and output.
- Select the 'graph mode'& choose analogue Analysis graph window
- Right click and select 'add traces'(input & output trace).
- Right click & activate simulation graph.
- Observe and analyse waveforms.

AC sweep analysis aims at evaluating the Frequency response of the proposed DAQ and data processing system over a range of frequencies. In this system a graph of distribution voltage vs. frequency and distribution phase vs. frequency.

If the frequency is double it is called an octave. If the frequency is increased by the factor of 10 it is called as decay increase. The decade increase in frequency the magnitude changes by-20 and the slope of magnitude block is -20db/dc there are different type of sweep analysis. We have to consider following certain parameter in the frequency sweep i.e. starting frequency and ending frequency. We have to specify the scale both linear, octave and decade.

4.1.1.1 Linear sweep

The frequency is sweep linearly from the starting frequency to the ending frequency with a step (number of step) the next frequency generated by a constant to a present value

4.1.1.2 Octave sweep

The frequency is sweep logarithmically by octave the next frequency is generated by octave the next frequency is generated by multiplying a present value by a constant the larger than the unity octal sweep is use when frequency range is wide.

4.1.1.3 Decade Sweep

The frequency is sweep logarithmically by decade. Decade is used if frequency range is widest

4.1.2 How to do the AC Sweep Analysis using Proteus Simulation Tool

- ❖ AC sweep analysis is nothing but a frequency response analysis.
- ❖ It is a linear analysis (small-signal analysis).
- ❖ It means it only considers the gain and phase response of the circuit; it does not limit voltages or currents.
- ❖ The nonlinear devices (like transistor amplifier) must be liberalized to run the analysis. To do this conversion, we have to
- Compute the DC bias point for the circuit
- Compute the complex impedance and/or trans-conductance values for each value for each device at this bias point.
- Perform the linear circuit analysis at the frequencies of interest by using simplifying approximations.
- ❖ The Proteus tool will take care of all these activities i.e. Proteus tool calculates the small-signal response of the circuit to a combination of inputs by transforming it around the bias point and treating it as a linear circuit

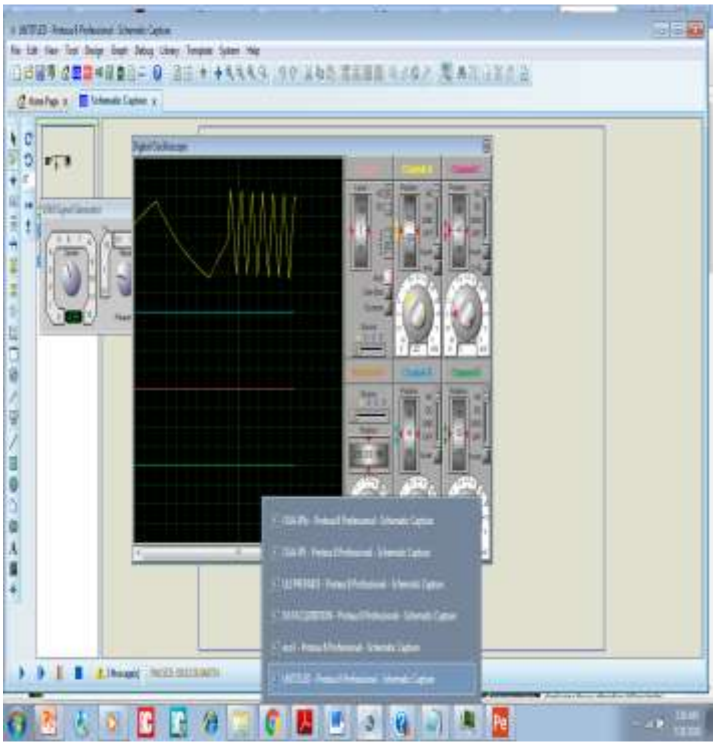

Fig 3 snapshot of proposed system with linear sweep in Proteus Isis

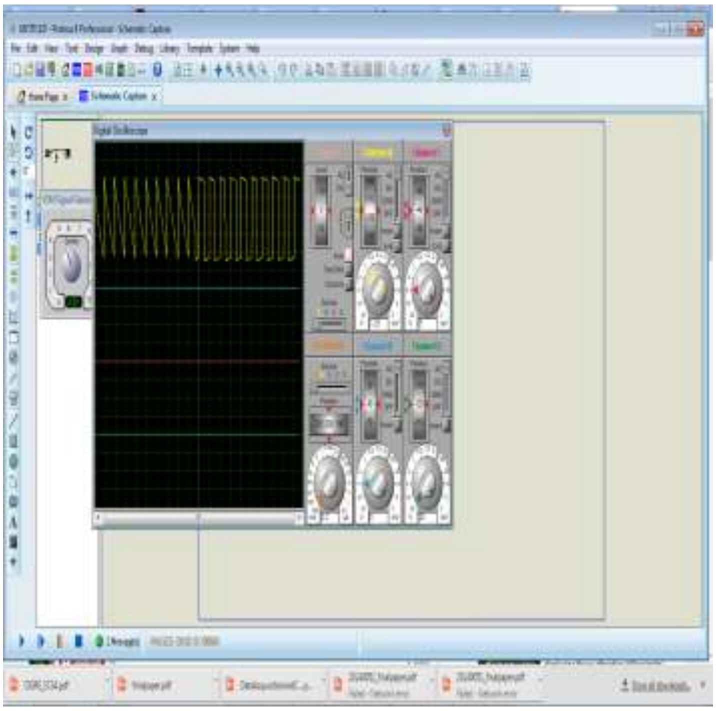

Fig 4 snapshot of proposed system with octave sweep in Proteus Isis

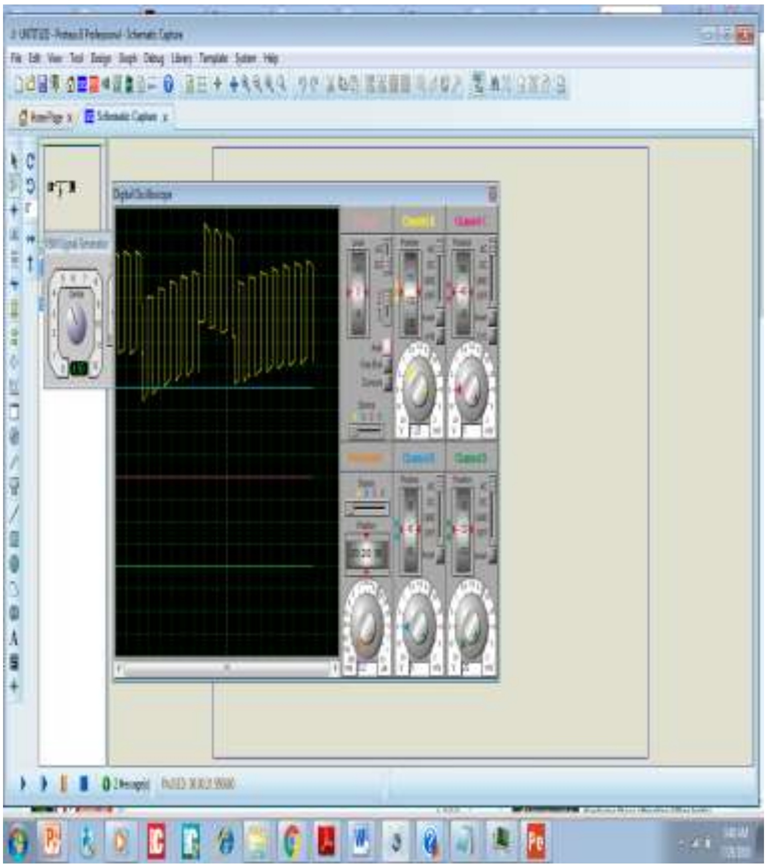

Fig 5 snapshot of proposed system with decade sweep in Proteus Isis

Fig 6 snapshot of proposed system showing transient analysis of a waveform of distribution voltage

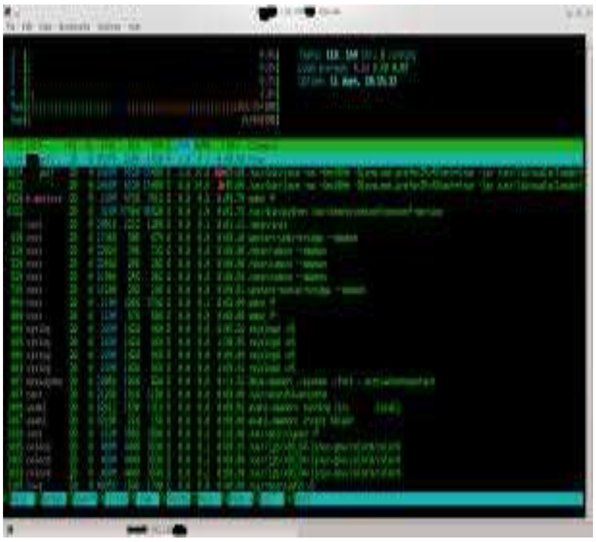

Fig 7 snapshot of proposed system showing voltage from different sections in the distribution system.

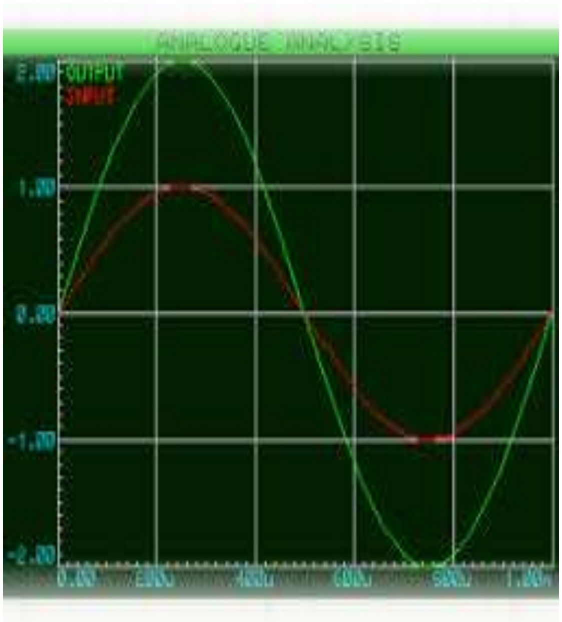

Fig 8 snapshot of proposed system showing analogue analysis of a waveform of distribution voltage

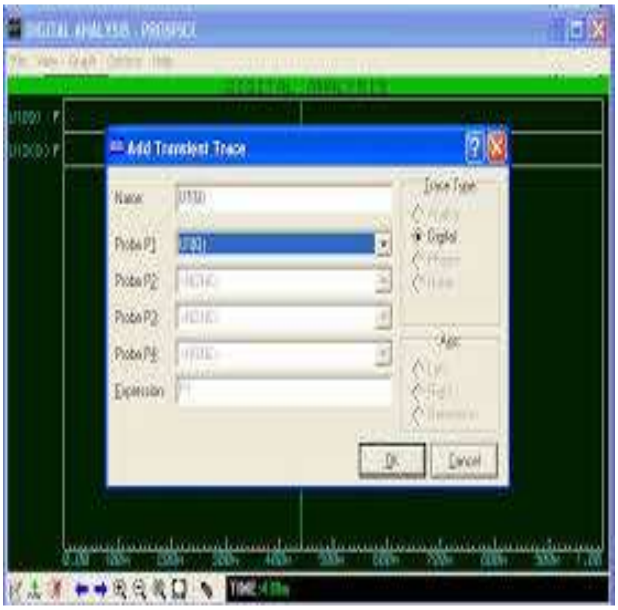

Fig 9 snapshot of proposed system showing tuning of parameters for digital analysis of a waveform of distribution voltage

V. CONCLUSION

We have developed and simulated the proposed system that acquires real time data in the distribution sub section of an elect power system parameters in real time and takes into cognizance the dynamic behaviours of these parameters. The developed a system that has embedded in it a real time DAQ and supervisory control from a remote location for intensive monitoring and processing of data from various components of the distribution section of a power system.

The simulation based implementation of data acquisition and processing taking into cognizance data consistency checking algorithms in substation automation will greatly help the control and protection engineers to reduce the faults and error conditions that frequently happen in substation. The reliability of the system is greatly enhanced. The system also proved to be very economical. The initial and maintenance cost of the entire system is reduced and thus there is a major advantage of decrement in cost of power supply system. Also the system can be characterized to be adopted for any scale of a distribution substation. The above automation system, which is functionally based on the Proteus Isis concept and SIMULINK and can be used in procedures for developing software tools and techniques to solve the problems of data verification and error handling in the distribution section of a power system. It will help the control and protection engineers to have a clear picture of the operation of the substations even if it is located in a remote location. This research was bake to fully integrate an optimized data processing and consistency checking algorithms into the substation model.

REFERENCES

[1]. J. D. Glover and M. S. Sarma, Power System Analysis and Design, 3rd ed. Boston:Wadsworth Group, 2002.

[2]. J. L. Blackburn, Protective Relaying: Principles and Applications, 2nd ed. New

[3]. York: Marcel Dekker, 1998.

[4]. A. R. Bergen and V. Vittal, Power System Analysis, 2nd ed. Upper Saddle River: Prentice Hall, 2000.

[5]. M. Kezunovic, “Data integration and information exchange for enhanced control and protection of power systems,” Proc. 36th Annual Hawaii InternationalConference on System Sciences, Hawaii, Jan. 2003, pp. 50-57.

[6]. J. G. Proakis and M. Salehi, Communication Systems Engineering, 2nd ed. Upper Saddle River: Prentice Hall, 2002.

[7]. [Online]. IEC std 61850, Communication Networks and Systems in Substations, work in progress. International Electrotechnical Commission. Available: www.iec.ch

[8]. [Online]. Generic Object Models for Substation and Feeder Equipment (GOMSFE). Sammamish, WA: Prepared by KC Associates, Feb. 5, 2000.Available: ftp://ftp.sisconet.com/epri/uca2.0/

[9]. [Online]. Electric Power Research Institute (EPRI), Common Application Service Models (CASM) and Mapping to MMS, Editorial Draft 1.4. Prepared under the Auspices of the Profile Working Group of the MMS Forum, 1997. Available:ftp://ftp.sisconet.com/epri/uca2.0/

[10]. IEEE Std C57.13-1993, IEEE Standard Requirements for Instrument Transformers. New York: IEEE, 1993

[11]. IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronic Terms (ANSI). New York: IEEE 1992

[12]. A. Monticelli, State Estimation in Electric Power Systems: A Generalized Approach. Boston: Kluwer Academic Publishers, 1999.

[13]. A. Monticelli, “Electric power system state estimation,” Proc. IEEE, vol. 88, pp. 262-282, Feb. 2000.

[14]. K. A. Clements and P. W. Davis, “Detection and identification of topology errors in electric power systems,” IEEE Trans. Power Systems, vol. 3, pp. 1748-1753, Nov. 1988.

[15]. H. Kim and A. Abur, “Enhancement of external system modelling for state estimation,” IEEE Trans. Power Systems, vol. 11, pp. 1380-1386, Aug. 1996.

[16]. F. F. Wu and Wh. E. Liu, “Detection of topology errors by state estimation,” IEEE Trans. Power Systems, vol. 4, pp. 176-183, Feb. 1989.
[17]. N. Singh and H. Glavitsch, “Detection and identification of topological errors in online power system analysis,” IEEE Trans. Power Systems, vol. 6, pp. 324-331, Feb. 1991.
[18]. N. Singh and F. Oesch, “Practical experience with rule-based on-line topology error detection,” IEEE Trans. Power Systems, vol. 9, pp. 841-847, May 1994.
[19]. A. Abur and M. K. Celik, “Topology error identification by least absolute value state estimation,” Proc. 7th Mediterranean Electrotechnical Conference, vol. 3, pp. 972-975, Apr. 1994.
[20]. A. Abur, H. Kim and M. Celik, “Identifying the unknown circuit breaker statuses in power networks,” IEEE Trans. Power Systems, vol. 10, pp. 2029-2037, Nov. 1995.
[21]. A. Monticelli and A. Garcia, “Modeling zero impedance branches in power system state estimation,” IEEE Trans. Power Systems, vol. 6, pp. 1561-1570, Nov. 2001.
[22]. A. Monticelli, “The impact of modeling short circuit branches in state estimation,” IEEE Trans. Power Systems, vol. 8, pp. 364-370, Feb. 2000.
[23]. A. Monticelli, “Modeling circuit breakers in weighted least squares state estimation,” IEEE Trans. Power Systems, vol. 8, pp. 1143-1149, Aug. 2001
[24]. A. S. Costa and J. A. Leao, “Identification of topology errors in power system stateestimation, IEEE Trans. Power Systems, vol. 8, pp. 1531-1538, Nov. 1993.
[25]. C. N. Lu, J. H. Teng and B.S. Chang, “Power system network topology error detection,” IEE Proc. Generation, Transmission and Distribution, vol. 141, pp. 623-629, Nov. 1994.
[26]. K. A. Clements and A. S. Costa, “Topology error identification using normalized Lagrange multipliers,” IEEE Trans. Power Systems, vol. 13, pp. 347-353, May 1998.
[27]. L. Mili, G. Steeno, F. Dobraca and D. French, “A robust estimation method for topology error identification,” IEEE Trans. Power Systems, vol. 14, pp. 1469-1476, Nov. 1999.
[28]. S. Jakovljevic and M. Kezunovic, “Advanced substation data collecting and processing for state estimation enhancement,” Proc. IEEE/Power Eng. Soc.Summer Meeting, Chicago, IL, July 2002, pp. 201-206.
[29]. Simulink Manual: Using Simulink, Version 4 (Release 12). The MathWorks Inc., Nov. 2000.
[30]. Power System Blockset Manual: User’s Guide, Revised for Version 2.1 (Release 12). TheMathWorks Inc., Sep. 2000.
[31]. Matlab Manual: Using Matlab, Fourth printing, revised for Matlab 5.3 (Release 11). TheMathWorks Inc., Jan. 1999.
[32]. A. G. Phadke and J. S. Thorp, Computer Relaying for Power Systems. New York: Wiley, Research Studies Press, 1988.
[33]. A. T. Johns and S. K. Salman, Digital Protection for Power Systems. London, U.K.: Peter Peregrims Ltd., 1995.
[34]. P. M. Anderson, Analysis of Faulted Power Systems, Revised Edition. New York: IEEE Press, 1995.
[35]. P. M. Anderson, Power System Protection. New York: Power Math Associates, Inc., McGraw-Hill & IEEE Press, 1999.
[36]. [Online] Power Systems Engineering Research Center (PSerc). Available: www.pserc.wisc.edu