PREFACE

Distribution network is most challenging part of power system. There are several problems associated with distribution network such as load unbalancing caused as a result of single phasing, occurrence of unsymmetrical faults, flow of overcurrent through feeder, power theft. Consumers randomly operate their loads causing problem to distribution system.

A Smart grid architecture requires its complete automation. Distribution network is more challenging compared to transmission network as it is partially in the hands of consumers. A smart metering scheme for distribution system seems to be a feasible solution for tackling most of its challenges. Power supplier may be able to interface with consumers through smart metering scheme, and thus may be able to control them to protect the grid against failures. Theft and illegal connection may also be identified by supply utilities through smart metering scheme. Smart meters installed at consumer premises may record variables such as voltage, current, frequency, power factor, real and reactive power demand. Recorded variables may be sent to Data Collection Devices (DCDs) installed at substations, which may further be transmitted to Central Data Collection System (CDCS) through bi-directional communication link.

A smart grid requires complete automation of distribution system apart from transmission system. An automated smart distribution system should be capable to exchange flow of electricity and informations between supplier and consumers in bi-directional fashion. Bi-directional flow of information may take place through fast communication protocol either wired or wireless.

Available power at the substation is prone to change as a result of voltage variations. An under voltage may cause decrease in available power whereas, over voltage may increase it. Accordingly, connected loads on feeders supplied by substation are to be switched OFF and ON. Manual switching of loads are time consuming and prone to human mistakes which may deteriorate the situation. Therefore, automatic control of loads is required based on availability of supply at the substation. No effort seems to be made by researchers in automatic control of demands based on availability of power at substation. A distribution system is prone to several threats such as load unbalancing, flow of overcurrent through feeder thus causing overheating of conductors, power theft. Manual correction of these challenges may not be much effective to protect the grid against failures. Very limited effort seems to be made in handling such challenges through automatic control.

Real-time monitoring of health of power systems has become possible through Supervisory Control and Data Acquisition System (SCADA) supplemented with Wide Area Monitoring System (WAMS). Time stamped measurement of voltage and current phasors has become possible through Phasor Measurement Units (PMUs). PMUs optimally placed at selected locations are able to observe complete network. However, application of PMUs in phasor measurements seem to be limited to transmission systems. PMUs may play a crucial role in automatic monitoring, control and protection of distribution networks through its time stamped measurements.

Therefore, motivations behind the work carried out in this thesis are:

- To investigate the benefits of implementation of smart metering scheme in Indian power system through case studies performed at some ongoing Automatic Meter Reading pilot project in India.

- To suggest a smart distribution network architecture that is capable to carry bidirectional flow of electricity and informations between consumers and suppliers through fast communication link, and is capable in automatic monitoring, control and protection of distribution system.

- To develop model of PMU in MATLAB/SIMULINK and LABVIEW that can be used to study effectiveness of PMUs in monitoring, control and protection of distribution networks in smart grid architecture.

- To propose a communication-assisted scheme for automation of distribution networks using Phasor Measurement Units.

The thesis has been organized in following six chapters:

Chapter 1 presents a comprehensive literature survey on related work, and sets motivation behind work carried out in this thesis.

Chapter 2 presents a case study for implementing an Automatic Meter Reading (AMR) project that has been carried out in south area of Delhi. This project proposes a use of SYNC interface communication unit i.e. SYNC 2000 data concentrator unit and SYNC 5000 meter data acquisition system. These units may collect the data from the meters, convert it into the Device Language Message Specification (DLMS) protocol and transmit it to the Northern Regional Load Dispatch Center (NRLDC), which may act as the Central Data Collection System (CDCS).

In Chapter 3, a smart distribution system with two-level control architecture has been proposed, where, secondary controller (master controller) installed at substation checks availability of power and decides load shedding/load reconnection based on that. Primary controller (local controller) installed at distribution transformer performs tasks of load balancing, overcurrent protection of feeder and power theft detection in the real-time framework. In the proposed architecture, all customers have been provided with smart meters that are capable to interface with the local controller in a bidirectional fashion. All local controllers can interface with the master controller in a bidirectional manner. The two-way flow of information has been proposed to take place through Informations and Communication Technology (ICT). Case studies have been performed on a test distribution network comprising of two identical areas each having 21 loads. Simulations have been carried out on a developed MATLAB/SIMULINK model of the test system, and results have been validated on eMEGASim® OP5600 OPAL-RT real-time simulator.

Chapter 4 presents the MATLAB and LABVIEW models of PMU that have been developed in this work to estimate phasors by use of Discrete Fourier Transform (DFT) using non-recursive as well as recursive algorithms.

In Chapter 5, a modified architecture of the distribution system has been proposed, where Phasor Measurement Unit (PMU) has been placed at the main substation receiving supply from the grid through the incoming feeder, as well as at all Distribution Transformers (DTs). PMU installed at the main substation is linked to master controller (secondary controller) through IEC-61850 communication protocol. PMUs placed at DTs are connected to the corresponding local controller (primary controller) through the IEC-61850 communication protocol. Estimated voltage and current phasors together with frequency are transmitted from PMU to the local controller through IEC-61850 communication protocol. Controllers perform different tasks based on the data received from PMUs. Each local controller is linked to master controller as well as to all smart meters placed at loads supplied by the DT. Bidirectional exchange of information takes place between master and local controllers as well as between local controller and smart meter.

Available power at the substation and distribution transformer is calculated in real-time with the help of PMU measurements.

Finally, Chapter 6 concludes the thesis with its important findings and observations, and suggests future research required to be carried out in this direction.