REAL TIME VOLT/VAR CONTROL USING ADVANCE METERING INFRASTRUCTURE SYSTEM IN FAHAM PROJECT

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ABSTRACT

Voltage regulation is an important subject in electrical distribution engineering. It is the utilities' responsibility to keep the customers voltage within specified tolerances. Recently, the concept of smart grid adds some new features to Volt/Var Control (VVC) of distribution system. Smart grid technologies will improve control and monitoring process of distribution system. The smart grid project in Iran has been started with implementing smart meters for about one million customers. This project is called FAHAM and is a large pilot project that pursues some determined goals. This paper presents the communication architecture of this project with focus on daily VVC in Iran smart distribution system. In the proposed model, all devices such as tap changer of transformer, switched capacitors, and distributed generation were considered. This paper shows that the real time voltage control being possible with AMI system has a better capability to maintain the voltage in specified range.

1- INTRODUCTION

From the time when distribution systems were first developed in the late 1800s, the reactive power and voltage control were considered as a top issue in the distribution network operation. Since the X/R ratio of distribution lines is small and the configuration of distribution network is radial, the daily Volt/Var Control (VVC) is one of the most important control schemes in distribution networks, which can be affected by DGs or load fluctuations. The daily VVC is defined as regulation of voltage over the feeders and reactive power (or power factor) at the substation bus [1]. The control is achieved by adjusting the Load Tap Changer transformers (LTCs), Voltage Regulators (VRs) and capacitor banks as control variables to minimize an objective function considering the constraints. So far, many researchers have investigated reactive power and voltage control in distribution networks [2-3].

To keep customer voltages within acceptable range, the switched and fixed capacitor banks and LTC transformer were utilized. Also real power losses reduction and freeing up the capacity of generation, transmission and distribution are the other objective of VVC in distribution system.

Local VVC were the first control approach that was introduced for fist generation of distribution network. The distribution system operator (DSO) is utilizing LTCs, switched shunt capacitor banks and line voltage regulators to control the voltage locally.

With local VVC control, there is no centralized coordination of volt/var devices at the whole distribution level, and implementation of VVC is far from optimal. In addition, there are costs for field personnel to travel to a site to check for the setting of devices and mach the regulation according to seasonal load.

Today, VVC typically stops at the substation using load tap changer, or maybe on some of the medium-voltage feeders using voltage regulator or capacitor banks. Bringing active VVC to the all part of distribution network has been too complex to manage. First step to achieve the active VVC is to have an Advanced Metering Infrastructure (AMI) to monitor and measure and gather all of required electrical parameters within the distribution network.

Best economic benefits of VVC are achieved by meeting several attitudes and objectives, such as mitigating violations, reducing power losses, and shaving peak loads, through voltage reduction. Also the integrated Volt/Var Control (IVVC) is an important attitude in this field. Integration means optimize the setting of all voltage control devices, simultaneously.

IVVC utilizes a dynamic operating model of the distribution system, in conjunction with an accurate mathematical optimization algorithm, to reach a given operating objective.

2- FAHAM SYSTEM ARCHITECTURE

Deploying an Advanced Metering Infrastructure (AMI) is an essential early step to grid modernization. AMI is not a single technology but it is an integration of many technologies such as smart meter, communication network and management system that provides an intelligent connection between consumers and system operators. AMI gives system operator and consumers the information they need to make smart decisions, and also the ability to execute those decisions that they do not currently able to do.

Iran Energy Efficiency Organization (IEEO), responsible for implementation and deployment of Smart Metering project (that is called FAHAM) in Iran [4]. The IEEO follows promoting energy efficiency and load management, improve system reliability, and reduce operational costs by implementing smart metering project.

2-1 FAHAM system components

In this project the smart meters will be installed for about one million costumers and the communication infrastructures for data exchange will also be implemented. The simple structure of communication system in FAHAM project is shown in Fig. 1which consists of:

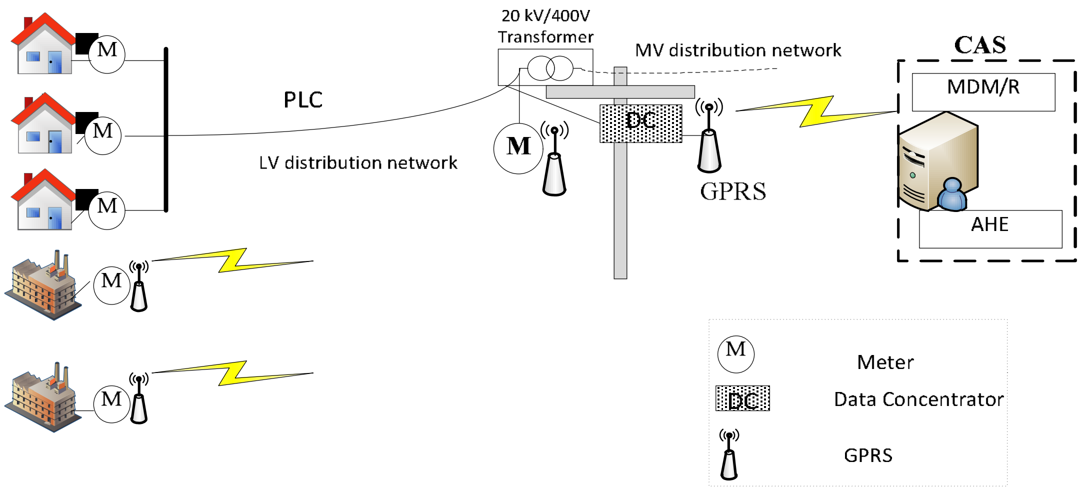

Fig.1 The communication architecture of FAHAM project

- **Smart meters** with PLC communications, installed at the customer premises. They may be single phase or three phase smart meters.
  Electricity meter provides the various information for customers such as amount of consumption (kWh, KVarh), consumption parameters (voltage and current), equipment status and last information of water and gas meters.
- **Communication interface:** Power Line communication (PLC) and General packet radio service (GPRS) are two communication interface that connect two different part of FAHAM subsystem together.
- **Data concentrators** installed in 20kV/400V transformer to manage all smart meters "measured data" from such installations. Data concentrators integrate PLC communications that exchange information with smart meters to communicate with central meter data management systems.
- **Central Access Systems (CAS)**, mainly Meter Data Management systems. CAS is responsible of the management of all information and data related to smart metering, as well as the configuration, control and operation of all system components. The CAS in order to manage the FAHAM network shall have 2 following parts: a) AMI Head End (AHE) that has the responsibility to manage the configuration, WAN and LAN network management system, managing the equipments in the network, Registration of equipments and Operation & Maintenance of filed equipments in the network. b) MDM/R shall manage and archive the acquired data from the AHE.
- **Legacy Systems** are the existing commercial or technical systems that manage the business processes of the utility. Volt/Var control is one of the legacy systems that include an optimization program to regulate the distribution nodes voltage using the received data from CAS.

2-2 Voltage reading

In FAHAM use cases, it is determined which the actual voltage information shall contain the following information:

- Identifier for the meter from which the actual voltage originates;
- Time stamp of the actual voltage;
- Actual voltage specified in Volt (V).

3- THE PROPOSED VVC FOR FAHAM PROJECT

Volt/Var Management Software (VVMS) is one of the important legacy systems in FAHAM project that optimizes distribution feeders Var flow and circuit voltages. Optimized Var flow improves power factor and can effect on considerable savings in cost of energy and infrastructure utilization. Optimized voltage improves power quality by avoiding over-under voltage conditions and by achieving flatter voltage profile along distribution feeders.

3-1 Controllable Components

In distribution system, there are some components that have considerable effect on voltage. These components shown in Fig. 2 are Tap changer of transformer, shunt capacitor, distributed generation and demand fluctuation.
Many works has been carried out to analyze the effect of LTC and shunt capacitors on distribution feeders. In [5], the author focused on the tasks of substation transformers with Load Tap Changers (LTCs) on smart grids. Voltage and reactive power control are one of LTCs' tasks. In [6] the problem of voltage regulation has been well addressed by studying the impacts of DGs on the voltage profile and the operation of step voltage regulators (SVR) and feeder shunt capacitors.

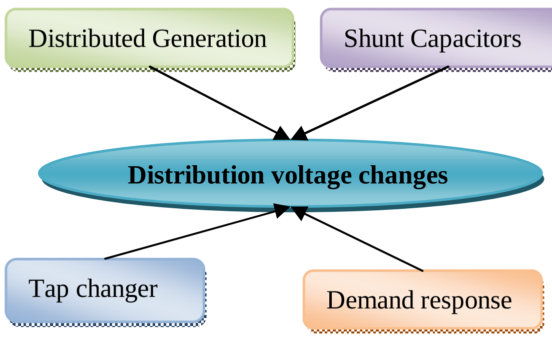

Fig. 2 the important components in VVC

Distributed generation units connection to distribution system will strongly affect on feeders flow and voltage profile. These effects will so remarkable because of small X/R ratio of distribution feeders. This aspect of DGs on distribution system was shown in Fig. 3. The voltage on bus 2 is calculated as (1) [7-9]:

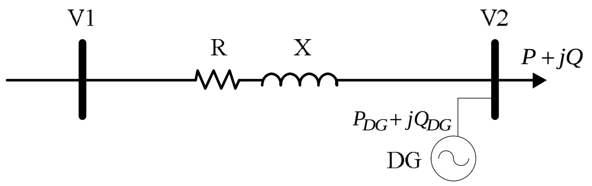

Fig.1. Two bus test system

$$V2 = V_1 - (R + jX) \times \left[\frac{(P - P_{DG}) - (jQ - Q_{DG})}{V_2^*} \right]$$

$$V_2 = V_1 - \frac{[R(P - P_{DG}) + X(Q - Q_{DG})]}{V_2^*} - j\frac{[X(P - P_{DG}) - R(Q - Q_{DG})]}{V_2^*} \quad (1)$$

Since the X/R ratio of distribution network is low, the imaginary part of voltage could be ignored. In per unit, the equation (1) can be written as follows:

$$V_1 - V_2 = R(P - P_{DG}) + X(Q - Q_{DG}) \quad (2)$$

So with changing the output power of DGs, the voltage on DG node will change.

While the load consumption changes, the voltage on load node is affected. In [10], the effect of price-based DR has been considered on distribution voltage profile. Consumer behaviour modelling has been done by developing a demand-price elasticity matrix for different types of consumers. This model just considers the price-based DR and it does not use the control option to execute incentive-based DR programs.

3-2 Conservation Voltage Reduction

FAHAM Volt/Var control includes Conservation Voltage Reduction (CVR), where the system demand is reduced by controlled voltage reduction at customer load points. This can typically reduce demand by 2 to 4 percent.

Demand Minimization, which helps shave off the load peaks during periods of high demand. This minimization can be achieved via voltage reduction to minimum values without violating equipment operating limits and other constraints set by the user. This objective enables utilities meet their critical needs during high-demand conditions with their existing resources.

With a goal of cutting energy losses and consumption by operating at the lower end of approved voltage ranges, voltage conservation is a beneficial way to access energy and revenue savings while increasing customer satisfaction with no additional effort on the customer's part.

3-3 Integrated Volt-VAR Control

As multiple devices and actions are available to control and regulate the distribution voltage, it is necessary to make a intelligent decision to which devices and with what priority act. This means the control action should be an integrated scheduling of many actions. Integrated Volt/Var Control (IVVC) gives utilities the advantage of being able to simultaneously evaluate and recommend controlling capacitor banks, transformer taps, DGs output setting and demand response concurrently.

The proposed algorithm of volt/var control in FAHAM project is presented in Fig. 3. In this model, the installed meters in the distribution feeder measure voltage of some selected point. The data are continually sent to central access system. After that, the VVC legacy system will receive the required data and with running its integrated voltage control optimization program, makes a smart decision. According to measured data, the priority and changes in tap changer setting and steps of switched capacitors will be determined.

Here is how this solution would be implemented by distribution system operator:

1. The Volt/VAR control legacy system initiates communication with the central access system to receive its required measuring data.
2. CAS will send the reading command to meters and sensors to receive the required parameter.
3. The data of each point are continuously updated from smart meters, such as voltage, reactive power, and power quality.
4. The gathered data by CAS are delivered to Volt/Var control application.
5. The Volt/VAR software analyzes the data points and alerts the volt/VAR control system if the voltage measured by the smart meters is too low or too high, or if reactive power is too high, based on all available sensor data from the medium- and low-voltage networks.
6. Also, the Volt/Var control software run its optimization program to determine what action should be carry out to bring the voltages back to their permissible range.

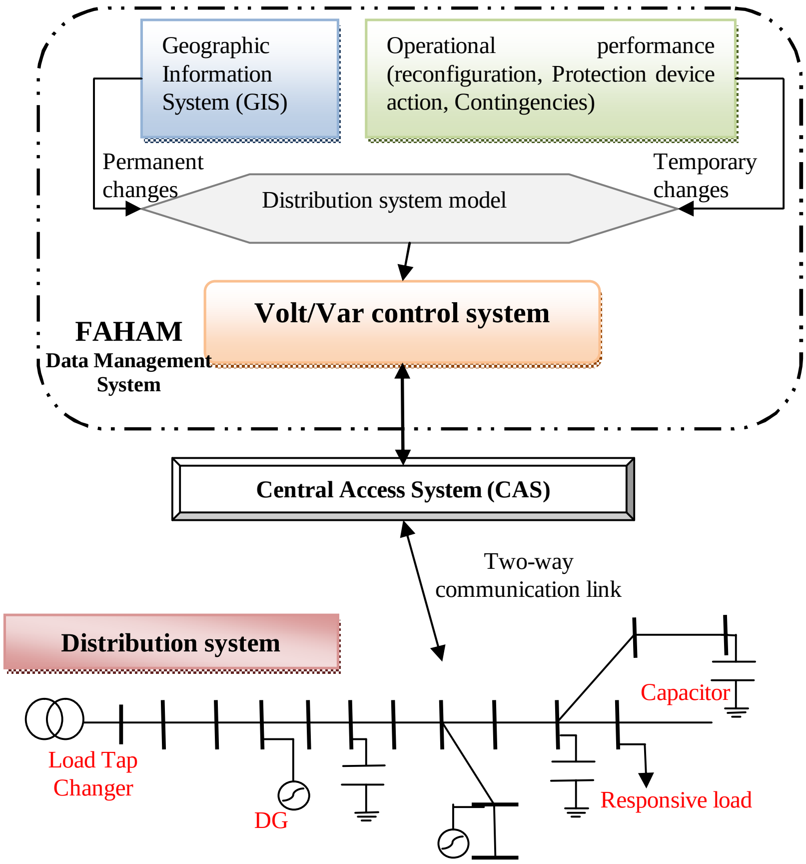

Fig. 3 The architecture of VVC in FAHAM

7. Finally the voltage regulation actions send to CAS. Then CAS sends these commands to the controller of tap changer, switched capacitors, DG or loads.

Conclusion

FAHAM Volt/Var control system includes regulating voltage by setting tap changer, shunt capacitor, DG and responsive load as well as conservation voltage reduction.

VVC system now allows distribution companies to implement voltage and var optimization under real-world conditions and with several advantages over previous methods.

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