DECENTRALIZED INTELLIGENT SCADA FOR INTELLIGENT CONTROLLING AND DG INTEGRATION IN THE ELECTRIC DISTRIBUTION GRID

Kiyan ELYASIBAKHTIARI
GTEDC – Iran
tardid@gmail.com

Elham AKHAVAN-REZAI
GTEDC – Iran
akhavan.elham@gmail.com

ABSTRACT

The Greater Tehran Electricity Distribution Company (GTEDC) is actively pursuing more and more developments to achieve its visions as a smart grid. In this paper the developments of SCADA systems in GTEDC operation area is represented. It includes the philosophy and architectural design of different levels of smart grid vision in GTEDC, their interactions, SCADA software structure, and communication infrastructure. Moreover, the implemented and pilot projects on SCADA, automation, and DG interconnection are explained by details.

INTRODUCTION

Power system structure has change from the paradigm of a vertically integrated utility to a new paradigm that involves new set of players. Integration advanced technologies, control methods and communications into the current electricity grid, as the term "Smart Grid", is becoming a popular concept. At the distribution and customer levels, this concept includes functions that provide opportunities for energy efficiency and better integration of distributed generation to reduce carbon emission. Although, electric distribution system have been evolving in the last decades, by adopting new methods and techniques, but the overall philosophy of the distribution system operation remains the same, with punctual changes. The technological and methodological changes must be addressed in global terms for future distribution grid to address the new challenges in a flexible and secure way. Distribution networks require new protection, control and operation philosophy to be redesigned to cope with these challenges; SCADA and distribution automation, by remote communication, are relatively new concepts which rapidly appeared as a good solution for distribution network. Another significant change is the increase of distributed generation (DG), which is recently investigated as a secure and flexible electric resource to supply end users and customers. In terms of DG integration, the present schemes of protection and automation in electric distribution grids are functionality limited to meet the safety requirements.

SCADA systems, as a vital infrastructure of the electric network, need flexible and smart design adaption to accommodate 2-way communication between intelligent devices of the network, all DGs and other network players. Effective SCADA systems should be designed in a way to support multi-level decentralized decisions and actions which is the result of smart and strategic behavior of the networks operators, network components and control devices.

The Greater Tehran Electricity Distribution Company (GTEDC), as the largest electric utility in Iran, is developing number of projects in Greater Tehran electric distribution network to transition in to a smart grid. Among those plans, implementation of control centers (local and central headquarter centers as decentralized affairs of SCADA), monitoring and automation of medium voltage substations and feeders, and DG interconnection are the main concerns of the GTEDC's smart grid planners.

In this paper the developments of SCADA systems in GTEDC operation area is represented. It includes the philosophy and architectural design of different levels of smart grid vision in GTEDC, their interactions, SCADA software structure, and communication infrastructure. Moreover, the implemented and pilot projects on SCADA, automation, and DG interconnection in GTEDC are represented in the final section.

ARCHITECTURE AND DESIGN PHILOSOPHY

Features of SCADA and Automation Projects in the GTEDC

GTEDC operates the distribution network of The Greater Tehran, the capital city of Iran. It is the largest electric utility in the country and providing almost 16600 [GWh/year] for more than 3000000 customers through 13300 medium voltage substations. Like many other utilities, GTEDC is continually making an effort to improve the performance of the system through benefiting from advanced technologies [1].

Number of features affects the implementation of SCADA and automation projects in the GTEDC. These features are mainly due to the nature of the Greater Tehran as a metropolitan, and are categorised as:

- Expanded area,
- Large number of substations and their geographical expansion,

- Limitations on the location of substations,
- Limitations on communication medias next to the household loads,
- Demanding high reliability regarding sensitive loads requirements,
- Future expansion possibilities for the existing automation and communication plans, as a result of sudden changes in network under operation.

Decentralized SCADA

The conventional SCADA system has been used for many years in the GTEDC to manually supervise the limited number of equipments, mainly some substations only, which were owned and operated by one entity. The new concept of decentralized SCADA is going to be implemented with respect to large set of diverse entities, such as customers, DG owners, electric vehicle, aggregators, other storage devices, and etc.

There are three levels of decentralization in GTEDC's smart grid vision. These levels start from SCADA centers and end up with user's agents. Due to geographical expansion and the high load density, operation of the GTEDC's network is divided to four separate service areas, as four SCADA (dispatching) affairs; North West (NW), North East (NE), South West (SW), and South East (SE) [2]. These affairs formed the first level of decentralization. This decision has been made by working groups of the GTEDC since 2007. The four dispatching centers have real time communication with the headquarter, as can be seen in Fig.1. The second level includes other entities and intelligent agents which interact with the upper and lower levels. This level provides a flexible network that operates as a smart grid using RTUs, aggregators, signals from DG side, and other parties such as market players. The last level includes customer's interactions with the network, mainly by AMIs.

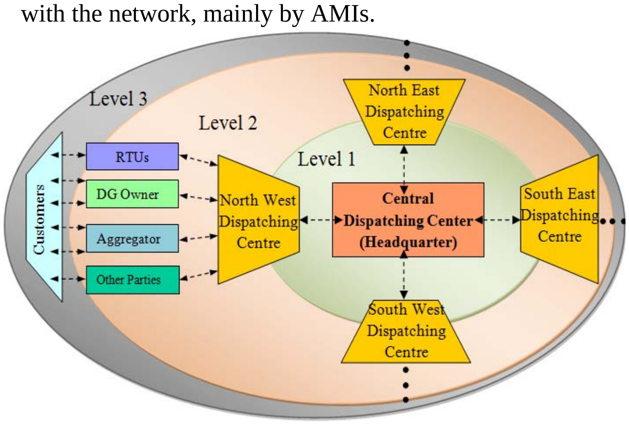

Fig. 1 Levels of decentralization of SCADA in GTEDC

LEVEL 1: DISPATCHING CENTERS

SCADA software Structure

The four decentralized affairs interact with the headquarter through the client/server architecture with IEC 61850 communication protocol, which runs over TCP/IP network.

To achieve smart grid and sustainability goals, it is essential for the decision makers to investigate on the SCADA software for sub-transmission and distribution sectors. The SCADA software here in GTEDC's control centre is a software implemented by Survalent Co., which is called QPL [3].

This software provides the users with the smart operation of the network through a distribution management system (DMS). The modules include:

- **Network Topology:** is a graphical editor, called *World View Map*, in which the topology of the network and its parameters are represented.
- **Topology Processing**: this module provides the line section connections and current status in breakers and other switches based on the real time network topology. There is a especial processor which track energized lines and switching actions to avoid sections to form a ring.
- **Load flow**: the load flow module updates the data base continuously (based on pre-defined intervals) through load flow analysis. The load flow analysis is performed automatically when feeders are reconfigured or a huge variation occurs to parameters of a substation.

All DMS reports are accessible through the *World View Map* interface, which includes:

- Load transfer information,
- Short Circuits,
- Capacitor information,
- Fault analysis,
- Line section information,
- Load flow reports (voltage profile and loss analysis),
- Customer consumption,
- Switching devise status and history.

Communication Infrastructure

The communication system plays a significant role in successful implementation of SCADA and automation plans since reliable data communication will be guaranteed through it. Therefore, the communication system considers as one of the most important merits for SCADA feasibility studies. For designing the communication infrastructure for the SCADA in GTEDC number of assumptions has been considered, as:

- The area under operation is divided to four sub-area,
- The substations are located around the dispatching centres by 10 km diameter,
- It is possible and secure to install the communication devices in each substation.

These assumptions are based on the network characteristics and based on IEEE recommendations; a unique communication media might not be an efficient solution for a spread network. Based on comprehensive studies on communication infrastructures a hybrid solution has been implemented for different levels and the corresponding plans, as:

- For SCADA centres, communications with sub-transmission centre, and feeder monitoring: *Fibber Optic*
- For substation monitoring and DG controlling: *General Packed Radio Service* (GPRS),
- For substation automation: *Radio UHF*

LEVEL 2: AUTOMATION AND DG INTERCONNECTION

Number of different projects is being implemented in second level of decentralization. These plans will provide the network with high level of flexibility to operate as a smart grid. Distribution automation including substation monitoring and feeder automation, as well as distributed generation interconnection are main concerns in this phase [2].

Monitoring Plans

Monitoring project includes two different plans, as:

- Medium Voltage Feeder Monitoring, and
- Substation Monitoring

MV Feeder Monitoring

Monitoring medium voltage feeders in GTEDC pursuing the main following goals [4]:

- Real time evaluation of line loading, as well we status of breaker and other switches, and protection relays of sub-transmission substations within outage.
- Short term and medium term load shading scheduling.
- Tie points and new manoeuvre points designing
- Providing reports for managers and decision to be able to tracking the network.

As it is illustrated in Fig. 2, the MV feeder monitoring includes data transferring form sub-transmission SCADA to the distribution SCADA headquarter. This plan has been implemented in two phases:

- **Phase 1:** Software and hardware design, construction and installation in sub-transmission SCADA,
- **Phase 2:** In the second phase the fibber optic communication media is implemented as the communication infrastructure among sub-transmission and distribution SCADA. Moreover, the IEC 61850 protocol is adopted for the distribution headquarter's software (QPL). This phase terminated with importing the one line diagram plots of MV feeders to the QPL software and point-to-point tests.

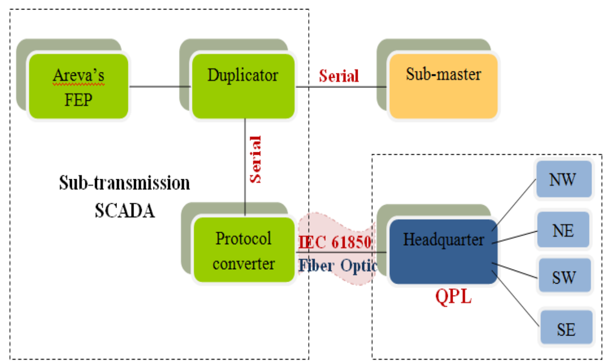

Figure 2. Feeder Monitoring Architecture Scheme

Substation Monitoring

Substation monitoring in GTEDC includes substation equipments' condition monitoring. The Main goals on this project in GTEDC can be describe as follows:

- Measuring electric parameters on low voltage side (voltage, current, power factor, etc.),
- State of the substation transformer (including transformer loading and energizing/de-energizing) to recognition the substation outage occurrence,
- Recognition outage type to dispatch the crew and reduce outage duration,
- Monitoring the status of the substation entrance door to control people entrance,
- Shading heavily-loaded substation.

In the first phase of the project, 10% of the total MV substations are being monitored.

Controlling Plans

The controlling plans mainly include two projects:

- Substation Automation
- DG controlling

Substation Automation

A limited number of pilot substation automation (almost 1%) is implemented all over the GTEDC following the main goals, as:

- Reducing outage duration and energy not supplied,
- Reconfiguration and outage management,
- Reliability enhancement,
- Human error reduction.

DG Controlling

Besides of improving the conventional network operation plans, GTEDC is actively pursuing more and more developments to achieve its visions as a smart grid. As a result, integration DG as the distributed backup supply is another area of planners concerns. Each scenario on interaction DG with the distribution grid should guaranty the safe operation of the network and meet load requirements as well. This goal cannot be achieved with the traditional operation scheme of the distribution system.

Although, centralized operation is easier to design and practice for industry, it leads to a lack of flexibility and limits the DG penetrations (since DG connections might be refused due to technical constrains).

In this concept, the main role of the SCADA to interact with DGs is providing the network operator with the data on DG side to enjoy the proper contribution of DGs in restoration procedure and voltage profile management. Functions for DG interconnection to the network and suitable interactions are illustrated in Fig 3. These functions assure reliable and efficient SCADA and DG contacts to achieve the desire goals and GTEDC is pursuing to implement the same schemes for the network under operation.

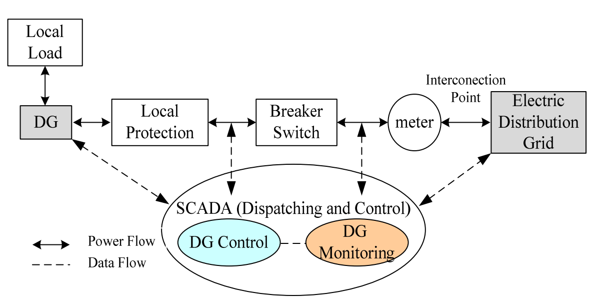

Fig 3- Functions for Integration of DG to the Distribution Grid

The underdeveloped DG project in GTEDC includes four 972kW DGs, which are connected through the 20 kV feeders to supply the load. According to the capacity of the DG, it cannot supply the total installed load and meet the voltage-frequency requirements and the islanding operation is not possible [5]. Therefore, it must be disconnected while the main substation is exposed to an outage. The Headquarter controlling centre is responsible to control DG status in normal and outage conditions. The DG status signals are monitored directly from the headquarter through a GPRS communication infrastructure and DNP3 protocol.

CONCLUSION

This paper presents the developments of SCADA systems in GTEDC operation area. It includes the philosophy and architectural design of different levels of smart grid vision in GTEDC, their interactions, SCADA software structure, and communication infrastructure. The decentralization levels started form SCADA centers and ended in end user's interactions with grids through AMIs.

The first two levels of decentralization including the implemented and pilot projects on SCADA, automation, and DG interconnection in GTEDC are represented by details. The last level which will be AMI implementation on customer side is going to be developed as future plans.

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