Maintaining Interoperability By Open-Standards Design in The Power Distribution For Smarter Grid

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Abstract

As many of the utilities around the world took diverse steps towards smart grid, it is noticed that those steps were mostly initiated by the utilities themselves based on either internal plans or directions from their local regulatory body on the best conditions.

When the nation wise official governing bodies supporting the interoperability in power grids are not yet created, the choice of open standards and designs negotiated among all stakeholders can be the partial solution to the interoperability issue at the city wise level.

A discussion of the designs adapted in the structure of the city-wise Distribution Management System (DMS) to maintain the interoperability shall be presented in this paper. It is also discussed how the power distribution management system is considered a building block in the smart grid pyramid and the role it plays to integrate the overall power management system from generation to distribution.

1. INTRODUCTION;

The prime goal of power utilities is to provide power supply to consumers wherever they are located and to stratify high service quality. In fact, environment plays a vital role in deciding the topology of the power network and the quality of service. Power stations located outside the city in rough locations like desert, island, mountains or wild forests may have difficult access but still need to be monitored and controlled remotely to avoid degrading the quality of service as well as to avoid reducing the service lifetime of the equipments. Moreover, old substations which were erected without communication facility is another challenge for the utility to maintain the quality of supply. Power interruptions resulting from unexpected reasons like natural disasters, accidents or equipment failure may result in long term service shutdown which affects the performance of the utility. In order to keep an eye on all the power substations, a remote control and monitoring system must be expanded and a communication network must be built effectively. In this way, interruption duration and frequency can be reduced with the available real time substations' data. Thus, the security of power supply is clearly affected by the utilized communication network.

Power substations as considered an infrastructure of any development plan will make the power grid a mixture of old and new designs. This fact forces that the DMS equipment including communication network, Master Station and field devices must be carefully selected with certain reference. Any future expansion of the power grid is considered a new load on the existing equipment. Expansion shall be always possible. Thus, it very clear now how important is the DMS system to utilities and how the open standards and interoperability concerns must be addressed thoroughly.

In literature, the interoperability term was inspired for computers and Information Technology systems to guarantee that two systems or more are able to inter-operate together and exchange data successfully [1,2]. In my opinion, as the power grid existed before the computer era. The interoperability concern started with the birth of the first grid. The natural results of interoperability is to think for the open standards establishment among vendors in certain fields. Nowadays, both the open standards term and interoperability term exist in engineering life and must not be used interchangeably. For system of systems the engineers may utilize both.

1.1. GEOGRAPHICAL NATURE OF THE CITY

Al Ain city is the capital of the eastern region in the Emirate of Abu Dhabi. The eastern region covers an area of approximately 13,100 km² with a population over than 400,000 (2010) where the mean annual rainfall is 96 mm and the average relative humidity is 60%.

The maximum load recorded in year 2010 was 1799 MW and energy consumption of 7950.88GWh, with number of consumers reached 106,841 including bulk load consumers [3]. Based on the recent study performed by Al Ain

Distribution Company (AADC), The expected load in Al Ain City by the year 2014 is 2869 MW with expected energy consumption of 13520.236 GWh including bulk load consumers with average consumer energy consumption of 75.273 MWh per year and expected number of 172,364 consumers [4].

1.2. POWER DISTRIBUTION SUBSTATIONS

The distribution utility is responsible for the distribution of electricity coming from the transmission company. The transmission level ends by 220 kV. The utility responsibility covers the voltage level 33 kV, 11 kV and down to the consumers' voltage level 415V. at the end of transmission lines the "Grid" Stations step down voltage from 220 kV to 33 kV through 80 to 140 MVA power transformers. AADC has mainly two types of primary distribution S/S:

- Permanent Brick Built Substations
- Temporary Ready-made Package Unit Substations

The first type of substations is mainly used. The firm power capacity is 30 MVA. Recently, it has been raised up to 40 MVA and up to 60 MVA in some cases. Equipments complying with latest technology and state-of the-art are used. They include 10 to 12 of 33 kV switchgears and around 24 to 30 of 11 kV switchgears. The second type has all equipment housed inside a container at the manufacturing/assembly yards. The container is placed as a whole system on concrete foundation at site that was previously prepared. The 33kV and 11 kV switchgears are either housed separately in two different containers or housed together. The available power capacity usually ranges from 7.5 up to 30 MVA at each location.

The Secondary distribution substations (S/S) are fed from the Primary distribution S/S by means of underground cables and overhead lines or both. On average, the available power capacity of these substations is around 500kVA to 3000 kVA. The Secondary distribution S/S is one of the following types:

- Brick Built with Four-Panel switchgears
- Packed Ring Main Substations
- Unpacked Ring Main Substations

The Brick Built S/S contains four switchgears' panels, two of which for transformers and two feeder panels. The available power capacity of such type is around 500 kVA to 1500 kVA for each transformer. The Packed Ring Main Switch S/S contains two-feeders ring main unit (RMU) with one transformer and the LV Panel, all housed in one fibreglass or metal container. The available power capacity of such type is either 500 kVA or 1000 kVA for each transformer. The operation is done manually. The Unpacked Ring Main Switch S/S is the same as the previous type except that it has no housing and the Ring main switch can have three or four switches (incomers and transformers).

2. THE DIGITAL GRID; OVERVIEW OF THE DMS SYSTEM

In response to the business goals and commitments of a distribution company, the management of AADC decided to implement the latest technology and select one of the off-the-shelf solution to replace the limited functionality SCADA system which also had a limited number of substations with a larger system that has number of powerful applications for power studies and planning keeping the system as open to all vendors as possible by adapting the standard architecture available in information technology and industrial control systems.

The stakeholders i.e. the utility engineers, representatives from the electricity authority and the consulting engineers formulate a design team to discuss all proposals and to meet the potential vendors who presented their initial proposals. After finalizing the discussions and selecting the successful bidder the final design was ready to implement with its standards and in some areas despite all the efforts to implement a standard architecture some customized design was included! In the next paragraphs, we shall see the standard and non standard systems in the DMS.

2.1. MASTER STATION ARCHITECTURE

The Master Station for the DMS system was designed in a standard computer network consisting of fiber optic backbone and off-the-shelf switches. All the servers, printers and user interfaces are connected with standard network cards, see Figure 1.

The operating system was Solaris 8.3 which runs the distribution software and all the related applications i.e. SCADA, power flow applications and other power studies related applications.

The advantages of such standard IT design that all switches, servers or printers are fully replaceable with any equivalent devices as long as the same interface configurations are maintained and the database are copied to the new equipment. The workforce is required to be aware of the usual IT skills with awareness of the data modeling techniques for electric network equipment.

The real challenge comes in the software that runs the power applications where any bugs clearance, update, upgrade or system expansion has to be done by the original supplier where the cost is subject to negotiations with the

OEM. This is the only drawback in the human machine interface that is totally dependent on the OEM for any support.

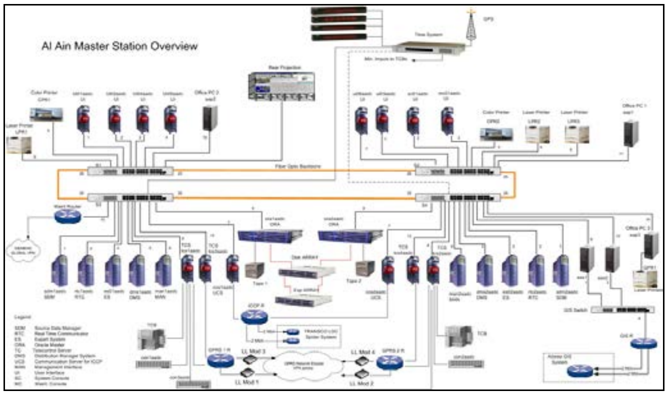

Figure 1. Overview of the Master Station servers' network

Although the Master Station appears to be a standard network with all the necessary application, but no international standard were followed in the design as the IEC 61986 [3] which specifies the conformity of applications in the DMS. This situation was due to the fact that this standard was under developing the time the DMS project was prepared.

To maintain interoperability of all outstations equipment with the Master station equipment and software, the tables for field signals with their addresses were formalized and the interoperability documents of the communication protocols IEC 60870-5-101 and 104 were customized to be followed for any future project.

Thus, we can consider that in the Master Station two issues were applied; the open standard in communication protocols and the interoperability among all applications servers.

It is recommended that any utility trying to implement the DMS system to check the proposed solution conformity with the mentioned protocol. That protocol can support the addition of any proposed applications that were not planned during the preparation of the scope from any vendor as long as the new application is compatible with this protocol.

2.2. OUTSTATIONS' EQUIPMENT DESCRIPTION AND INTEROPERABILITY

The outstations equipment are the Remote Terminal Units (RTU) and the communication modems. These equipment were selected to match the communication protocols of the Master Stations which are IEC 60870-5-101 and 104 among a wide range of protocol selections. For the modems, they were selected to match the available media (wireless, copper cables or Fiber cables). The modems as the reader can directly concludes that they are obviously off the shelf products that can suit a wide range of equipment with the correct configuration. Well, it started like this but for the GPRS modems a problem was encountered and it ended up with a customized solution inside the firmware of the RTU and modem in order to overcome the interruption in service from the telecom provider that held the operation of the modem until it was reset by the RTU internal communication. Thus, the system provider owns the solution!

As we can see, the solution was not totally a standard referenced solution or even from the service provider. The management decided to adapt the engineers recommendation to integrate diversity of RTUs and modems to the Master Station to encourage the bidders to develop their products for even price and service competition. Again, it is a combination of open standards and interoperability techniques to reach the final solution.

2.3. TELECOMMUNICATION EQUIPMENT DESCRIPTION AND INTEROPERABILITY

As for the outstations equipment, the media selected for the data exchange among the power substations and the Master Station varied due to several factors among these the geographical constraints, distance, availability of telecom provider services and the level of availability and quality of the media [4].

Trying to keep up with the common trends for utilities communication networks, AADC decided to built their own Fiber optic network. With every 33 kV underground power cable a Fiber optic cable is laid. As this initiative can be considered recent it started based on an international standards, different manufacturers presentations and after studying similar cases in other utilities worldwide.

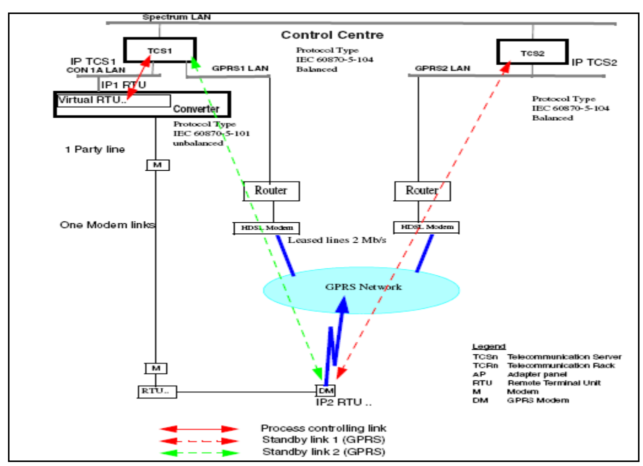

Figure 2. Communication roots for substation

3. THE ROLE OF STANDARDS REVISIONS TO SERVE SYSTEM INTEROPERABILITY

As it is a common practice in the utilities around the world, AADC under the electricity authority (ADWEA) has their set of standards and specifications for the acceptable equipment or systems to conform with the existing systems. Among the utilities that are working in the Emirate (state) of Abu Dhabi.

Over the years, the engineers as they develop the network and gain deeper experience about their network and equipments keep revising the specifications in light with the international standards, recent technology development and even towards more open and standard solution.

Theses sets of standards are excellent example of maintaining the open standards and the interoperability in the power network. These sets are only applicable for one emirate (state) as the national grid is connected in the transmission level but not the distribution level. In case the interconnection is to be made through the distribution level, a unified technical specifications for the utilities are to be developed.

4. THE MERGE OF FUTURE SMART GRID APPLICATIONS

In order to keep up with the smart grid initiatives, the what so called the infra structure for the smart grid must be built or enhanced. For the distribution utilities with available communication backbone and database of a real time data for the monitored substation, adding the smart meters system will provide a complete overview of the power distribution network. Utilizing a strong outage management application software shall open the door for the utility to start optimizing the consumption by enabling the consumers to be part of the grid optimizing process which is the dream of the planning engineers.

AADC started the Automated Meter Reading project (AMR) as an initiative for a smarter grid. The two real challenges are the replacement of all meters (400,000 meters) with smart meters and establishing a wide communication network to carry the data to their servers. The meters were selected from few vendors and communication network was a wide area wireless network with a fiber backbone. The meters interface to the network used different technologies like the power line carriers, Wi-Fi, or GPRS according to location of the meters whether in a tower, building basement or even in a farm. Due to non-availability of open standard or protocol to connect all these meters and interface them to the communication network a protocol converter was used to unify the data format and to maintain the interoperability.

5. CONCLUSION

We can conclude that as long as the open standards and interoperability features are maintained in the existing and any planned new systems the performance is almost guaranteed. It is almost impossible to start with open standard solution and continue to the end of the project without including the principle of interoperability to overcome the shorting of an open standard solution. The regulator takes the responsibility of managing the technical standards that should be followed in the design and installation of any power related equipment for the sake of obtaining and maintaining fully interoperable systems.

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References

[1] Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.

[2] James O'Brien, George Marakas: Introduction to Information Systems, McGraw-Hill/Irwin; 13 edition, ISBN 0-07-304355-9

[3] "Actual Peak And Off Peak Annual Load Study", Al Ain Distribution Co., Al Ain, UAE, 2010.

[4] "Five Years Planning Statement Report", Al Ain Distribution Co., Al Ain, UAE, 2010.

[5] IEC 61968 Standard Document

[6] V.C. Gungor, F.C. Lambert, "A Survey on Communication Networks for Electric System Automation," in Computer Networks Journal (Elsevier), vol. 50, 2006, pp. 877-897

Biography

The author received his B.Sc. degree in Electro- mechanical Systems Engineering from Al Balqa' Applied University, Amman, Jordan in 2002, and his M.Sc. degree in Mechatronics Engineering from the American University of Sharjah (AUS), Sharjah, UAE in 2006. He is currently SCADA Instrument Sr. Engineer at Al Ain Distribution Company, the electricity and water distributer in Al Ain City, UAE. He is licensed as Incorporated Engineer from the UK Engineering Council and member in the IET. His research interests are smart grid and SCADA and telemetry.