21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

CIGRE US National Committee
2018 Grid of the Future Symposium

Use of Cellular Communication to Remotely Deploy Distribution Automation Functionality

J. VALENZUELA
National Grid
USA

SUMMARY

The following paper describes the methodology followed by National Grid to remotely deploy Distribution Automation capabilities using cellular communication. The document describes how the Company is exploiting the benefits of its flexible communication network design to introduce Distribution Automation functionality remotely. With the methodology presented, several benefits are obtained while solving some of the challenges encountered by 3rd party applications used in the past.

KEYWORDS

Distribution Automation, Wireless Communication

Jorge.Valenzuela@nationalgrid.com

1. INTRODUCTION

In August of 2012, National Grid received approval from the Department of Public Utilities to proceed with the implementation of a Smart Grid Pilot in the city of Worcester, MA. During its execution, engineers were faced with several obstacles that required innovative solutions.

One of the most significant developments that came out of that project was the design of a flexible hybrid communication network that can be expanded to accommodate several services. The benefits that this design brought to the pilot, made it a model for future integration of intelligent devices into the Company's systems. National Grid has recently implemented a similar solution at a much larger scale in preparation for the deployment of existing and new technologies, including Distribution Automation. The flexibility of having a network solution that, amongst other benefits, can efficiently, realiably and securely communicate to remote devices using both cellular and private RF connectivity has opened the door for exploration with deployment of remote sensing and control schemes.

The use of centralized data concentrators that have the capabilities to process data and be programmed to run control algorithms such as a Distribution Automation platform, has brought the desire to re-think the approach taken by the Company in the past for this type of schemes.

The following paper describes the methodology and challenges of the process followed by National Grid to implement Distribution Automation functionality for remote devices utilizing cellular communication through its data concentrators.

2. FLEXIBLE COMMUNICATION INFRASTRCTURE

As mentioned in the introduction, the design and implementation of a flexible communications network for the Smart Grid Pilot was key for the simplified deployment of diverse services, including Distribution Automation functionality. The ability to securely and economically integrate wireless-based devices into the network allowed for the addition of automation capabilities to any distribution feeder where cellular coverage is available. This alone, saved thousands of dollars in communication equipment and IT infrastructure development. Figure 1 presents a general diagram of the architecture used for this approach.

As the Figure shows, one of the main characteristics of the network is the existence of a DMZ created exclusively to isolate traffic from distributed devices from the existing EMS infrastructure. The implementation of that segmented area allows for a faster and simplified deployment of devices, compared to regular integration into the National Grid EMS/CNI data network, from a Digital Security point of view. In this environment the data is collected from the distibuted devices by the Data Concentrators that in turn act as a slave to requests from the National Grid EMS system. As such, all data traffic from and to the distributed devices is controlled by Firewalls set up to eliminate the possibility of unknown requests originated in the network out in the field.

Among other services, this design allows for the simplified integration of line reclosers distributed through the Company's Distribution and Sub-T system via cellular communication, as shown in Figure 2.

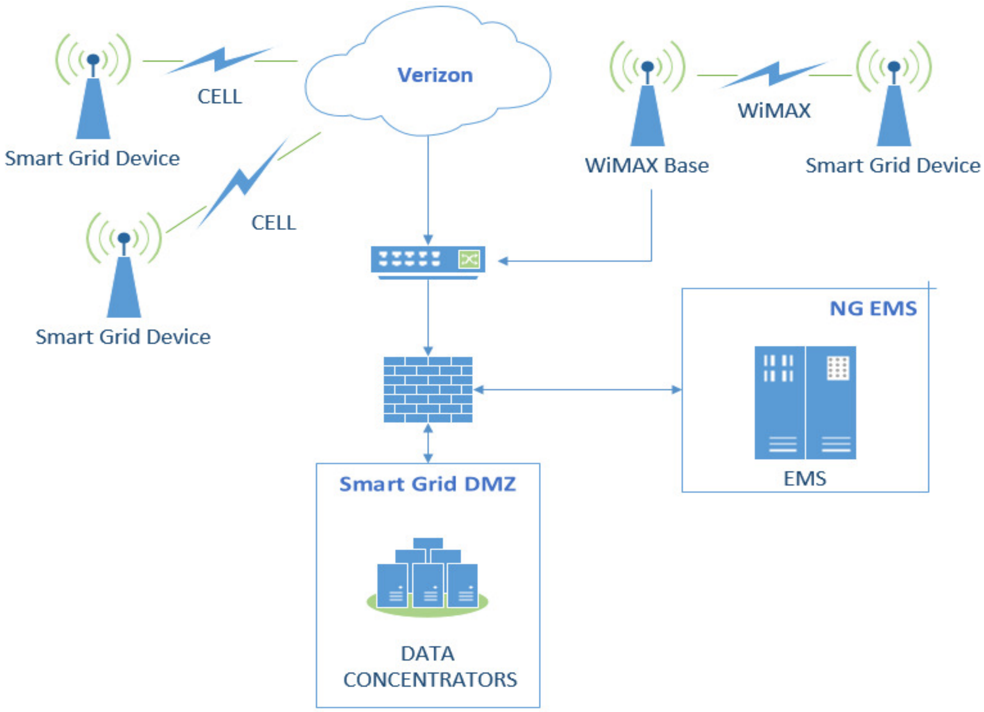

Figure 1 General diagram of the wireless communication solution implemented

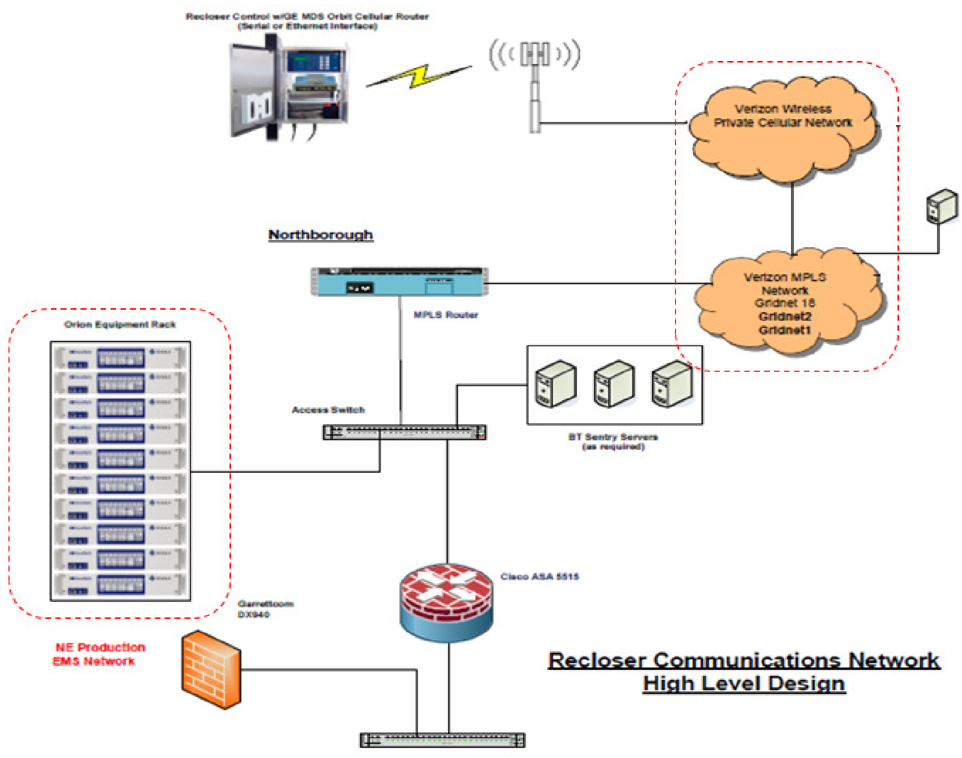

Figure 2 Network diagram of the recloser integration via cellular communication (red box right) through data concentrators (red box left)

3. DISTRIBUTION AUTOMATION SOLUTION

In the past, National Grid has been using 3rd party developed solutions for its Distribution Automation schemes. In general, such implementations have suffered from some of following problems:

- Very low latency requirement for adequate deployment (costly). In the past, this was considered a limitation for Cellular deployment.
- Additional hardware to enable automation schemes needs to be installed on-site. This translates into new standards and training for crews and technicians.
- Hardware malfunction to integrate third party equipment. Some of the additional components have shown propensity to electrical failure.
- Lengthy process for firmware upgrades. This has translated into long periods of automation schemes being disabled.
- Lack of flexibility for customized performance and event logging. This makes the reporting and troubleshooting process cumbersome.

As shown in Figure 2, National Grid has a vast number of reclosers distributed along the Compny's territory and some Distribution Automation schemes already in place.

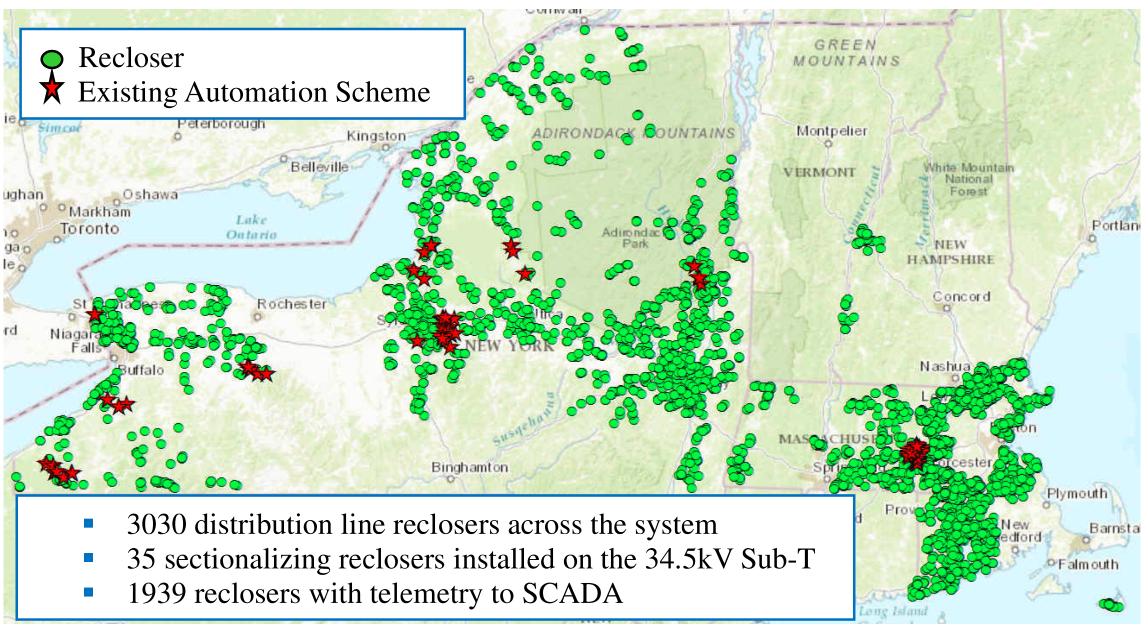

Figure 3 Overall distribution of line reclosers to be integrated using wireless communication

Now, as desribed in the previous section, all these reclosers can be integrated using Cellular communication via data concentrators. In particular, the data concentrator originally selected in this design is the Novatech OrionLX [1] model.

Commonly used for Substation Automation and Monitoring, the OrionLX can also accommodate Distribution Automation Logic as an enhancement to its standard package.

The addition of a Distribution Automation extension allows for the inlcusion of enhanced functionality covering (per data concentrator):

- Up to 512 Devices to be included in diverse schemes
- Up to 64 Zones of protection
- Up to 32 steps per Zone
- Use of virtual devices

Since the original design was based on this model of data concentrators, the addition of Distribution Automation functionality to the system can be extended to any recloser where cellular connectivity is available. Figure 3 shows the location of existing reclosers in National Grid's system that are to be integrated to EMS using this new approach.

Based on the location and requirements of the system, the automation scheme can be customized to serve each individual purpose.

The core of the solution is based on LUA [2] code hosted in the OrionLX using data points coming from the units included in the logic. Figure 4 shows the LUA programming interface to define specific functions of the Distribution Automation functionality for the scheme.

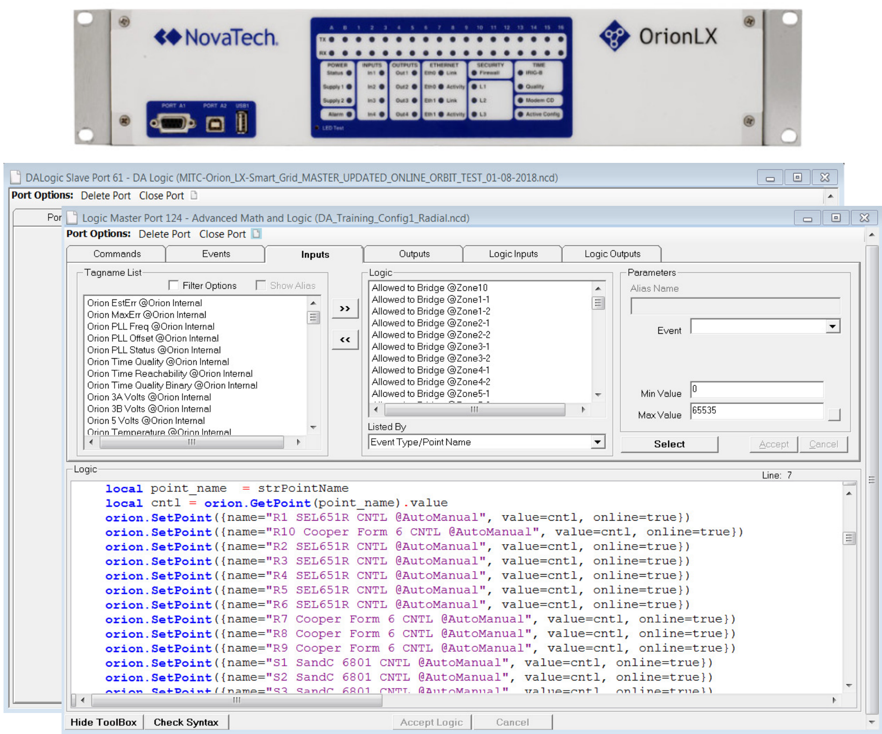

Figure 4 Distribution Automation LUA programming interface

4. LOGIC PROGRAMMING

The interface provides basic zone configuration and sequencing of events based on the data points held in the data concentrator. The events can be configured on the basis of head-end devices operation. This basic approach requires the use of non-standard programming to account for operation in schemes with multiple sources where the head-end device can change. The logic used to solve this problem is to define virtual devices and configure the system as a state machine with known configurations for each state.

Virtual devices are units that are defined and live only in the data concentrator. They can be used to hold pieces of information in the same way that it would be done for a real device. This is particularly useful when defining status and loading information for zones. It can also group points that can be verified/changed by operators in the Control Center to regulate the overall behavior of the scheme. Examples of this are:

- Enable/Disbale of functionality of the scheme (sectionalizing, restoration, etc.)
- Hold status of the scheme or components (abnormal configuration, comms status, etc.)

Information held in virtual devices, if configured correctly, can also be used to trigger automation events. This is particularly useful when there is not enough monitoring hardware installed on the field and certain decisions need to be made based on calculations done in the logic.

An example of that is voltage loss and load verification during load transfer in locations where there's no nearby monitoring equipment besides the automated devices. A combination of measurements from virtual devices and state machine indication can provide an estimation of the voltage condition and load to be transfer and the load on the receiving section.

For example: in a 3 switches scheme [SW1 SW2 SW3] with 2 sources, the machine can be considered to be in a state [1 1 0] where 1 represents a switch closed and 0 open. If the system changes to state [0 1 1] the middle device has a different source. In this scheme there are 2 zones [Z1 Z2]. When the system is in state [1 1 0], loading on Z1 can be calculated by substracting the load registered in SW2 from SW1, but when it's in state [0 1 1] it can be calculated by susbtracting the load regsitered in SW2 from SW3. Similarly, for a sectionalizing due to loss of voltage, if the system is on a [1 1 0] state and a loss of voltage is detected in SW1 but SW2 has healthy voltage, sectionalizing may be avoided and determine that a failure of sensing leads has occurred.

In addition to quantities verification, state machine logic programming provides an easier way to generalize the coding for diverse systems. This can be easily accomplished by using the object oriented elements of LUA to define the configuration of the system per each state of the switches.

5. IMPLEMENTATION

The first couple of implementations considered simple Distribution Automation schemes with few automated devices. The typical protection device used in these configurations is a recloser controlled by a SEL-651R integrated via Cellular communication. The protocol used for data and control is DNP3 over TCP/IP. Figure 5 shows a simple 3 switches scheme designed to transfer load during fault conditions

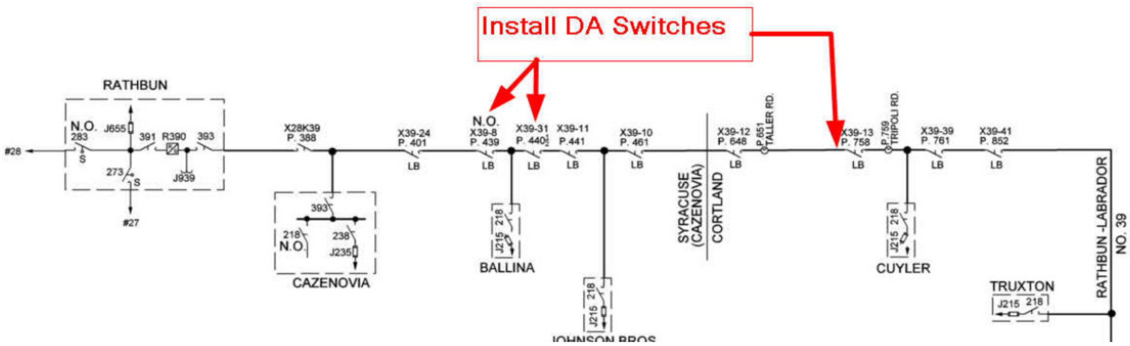

Figure 5 Distribution Automation scheme specified for the Rathbun – Labrador 34.5kV line

The logic is tested and debugged in a lab setting using the controls and communication equipment to be used on the field. Figure 6 shows the lab set up including all the equipment used for testing

Figure 6 Recloser controls set up (up), data concentrator and networking equipment (lower left) and fault tester (lower right)

The system can be monitored directly from the reclosers' controls or using a graphic interface that can be created at the OrionLX. Figure 7 shows a generic version of the automation interface created to cover the schemes typically used in our territory.

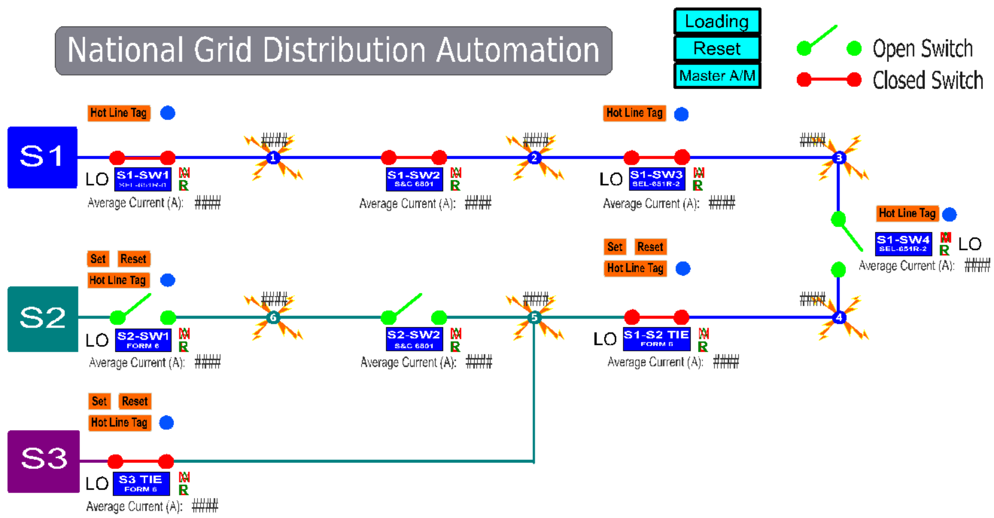

Figure 7 Graphic interface to monitor and debug the Distribution Automation Logic

5. SUMMARY

The recently developed flexible communication and IT infrastructure has opened the door to a simplified way to deploy D/A schemes through wireless communication.

By exploiting the additional functionality provided by the new communication architecture, the following benefits were obtained in the area of automation:

- Self-reliance for Distribution Automation deployment
- Elimination of on-site hardware malfunction problems
- Reduction of "offline-time" due to software updates/upgrades
- Reduction on project-related communication infrastructure development
- Simple integration of external devices to the automation schemes (enabling more complex solutions)
- Improved and customizable events and performance reporting capabilities

These benefits can be extended to units in remote areas where cellular communication is available without the need of extensive and costly communication infrastructure development.

By following this approach, National Grid continues its road to improve the quality of service for its customers at a reduced cost.

This is how National Grid creates the future, one project at a time.

BIBLIOGRAPHY

[1] Novatech, “OrionLX | NovaTech Substation Automation & Cyber Security”, https://www.novatechweb.com/substation-automation/orionlx-substation-automation-platform/, [Accessed Aug 2018].

[2] PUC-Rio, “The Programming Language Lua”, https://www.lua.org/, [Accessed Aug 2018]