EXPERIENCE IN THE IMPLEMENTATION OF A FEEDER AUTOMATION SYSTEM USING WIRELESS DIAL-UP

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ABSTRACT

In TNB (a major power utility company in Malaysia), faults on the MV distribution network still contribute to more than 70% of System Average Interruption Duration Index (SAIDI), an index used for measuring supply reliability. In an attempt to improve SAIDI by shortening the duration of the failures, TNB Research (TNBR, a wholly owned subsidiary of TNB) implemented a "Feeder Automation SCADA system" project in order to bring drastic improvement in restoration time to less than 15 minutes. The scope of the project is to automate 110 units of 11kV distribution sub-stations in Senai Industrial Area, Johore and to enable the monitoring and controlling of the 11kV distribution network remotely from Southern Regional Control Center (SRCC).

This paper will highlight and share our experience in the implementation of a feeder automation system which uses a combination of wireless dial-up communication and DNP 3.0 protocol. The combination of these technologies was the first time being used in feeder automation in TNB's 11kV distribution network. We believe the experience and feedback gained from this project can be used in future distribution automation projects of similar nature.

Among some of the challenges we encountered are, for examples, the long communication delay due to the dial-up communication; the interfacing problem due to the mixed fiber and wireless communication media environment that caused the Data Concentrator Unit (DCU) to hang quite often; congested channel due to heavy traffic of unsolicited events from the RTUs to the master station, etc. We will illustrate how these challenges were overcome and also on the final system performance.

The paper concludes by providing some learning points from this project in particular with regards to the suitability of the technologies used by comparing the requirements of the feeder automation system with the final system performance.

INTRODUCTION

Although TNB Distribution is consistently improving its supply reliability and quality to meet its customer demands, faults on the MV distribution network still contribute to more than 70% of System Average Interruption Duration Index (SAIDI), an index used for measuring supply reliability. This SAIDI could be improved by shortening the duration of the failures besides reducing the frequency of supply interruption. In response to this need, TNBR proposed a "Feeder Automation SCADA system" project to TNBD in which the restoration time could be greatly reduced.

This project was started in 2003 with the aim of automating 110 units of 11 kV sub-stations in the Senai Industrial Area, Johore. This is the first SCADA project implemented on a large scale at the 11 kV network. The SCADA system is capable of monitoring and controlling the 11kV distribution network remotely from Southern Regional Control Center (SRCC). In fact the successful implementation would bring drastic improvement in security level, uplifting to a new category of operation from security level 3 of 'restoration within 4 hours' to security level 2 of 'less than 15 minutes'.

OBJECTIVE

The objective of this project was to enhance the 11 kV network management in terms of operation and maintenance. It would help the controller to view the 'real time' network status at Regional Control Center and respond to operational needs remotely as opposed to past practices which required someone to travel and physically be present at the sites. Thus, it would improve SAIDI performance through quick restoration and increase the operational efficiency in network management.

The scope of the work included planning, installation, testing and commissioning of these components (Figure 1):-

- SCADA Master Control system
- Wireless data communication network
- Data Concentrator Unit (DCU)
- Remote Terminal Unit (RTU)
- Ring Main Unit (RMU) switchgear retrofitting/motorization and
- Earth Fault Indicator (EFI)

Data transfer and remote control between Master Control Centre and remote site is through wireless dial-up.

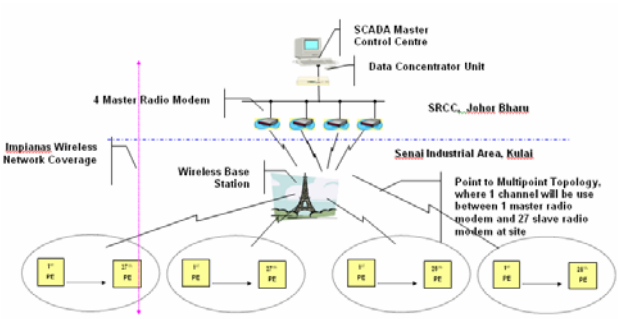

Figure 1: Original System Overview

REMOTE TERMINAL UNIT

The RTU is used for the data acquisition from remote substations. There are two types of RTU utilized:

Primary RTU system [1 unit]

- Acts as Data Concentrator Unit [Front End Processor] with standard IEC 870-101 protocol (to SCADA Master Control Centre), and DNP 3.0 protocol (to slave RTU).
- Function: to communicate with downstream (slave) RTU devices using DNP 3.0 protocol and relay this information to the SCADA Master System (IEC 870-101) over a connection on the local area network or wide area network.

Secondary RTU system [110 unit's]

- Configured as Slave RTU with DNP 3.0 RTU protocol.
- Function: acquire all available information at remote substation to the SCADA Master station, and also to execute control command to remote substation, such as:

  Status Monitoring Function
  - RMU Switchgear Open/Close [feeder LBS switch]
  - Lock/Unlock [earth switch]
  - Local/Remote/Supervisory [mode]
  - Earth fault status
  - Battery, RTU, Fire Alarm and Unauthorized Entry Alarm

  Analog Measurement Function
  - Ampere loading (HT customer)

  Control Operation Function
  - RMU Switchgear LBS Open
  - RMU Switchgear LBS Close

TELECOMMUNICATION NETWORK SYSTEM

Initially, there are two type of telecommunication network system to facilitate the communication between the SCADA Master Control System and Secondary RTU's:

Local Area Network (LAN)/ Wide Area Network (WAN)

- To provide communication paths among the components of the SCADA Master System and Data Concentrator Unit [DCU].

Wireless Data Network System

- To provide a communication medium between Secondary RTU and primary RTU under DNP 3.0 protocol with the Point-to-Multipoint network topology at speed between 1200 to 9,600 bit/s in duplex mode.

This wireless network employs a radio communication device called Radio-PAD. The network is based on the X.25 packet switched radio technology [2].

Utilisation of X.25 packet switched radio technology for providing communication medium between SRCC and Senai Industrial Area (figure 2), with the following configuration:

- Full duplex wireless data transmission, operating in the 400 MHz - frequency range, with 12.5 kHz channel spacing.
- One Base Station at Senai Industrial Area
- 4 RPad Radio Modem, which will act as Master RPad Radio Modem with DNP 3.0 protocol and place at PMU Senai. Each Master RPad Radio Modem will provide a communication channel with n-number of Slave RPad Radio Modem located at remote substation
- 110 RPad Radio Modem, which will act as Slave RPad Radio Modem with DNP 3.0 protocol and place at 110 remote substation.

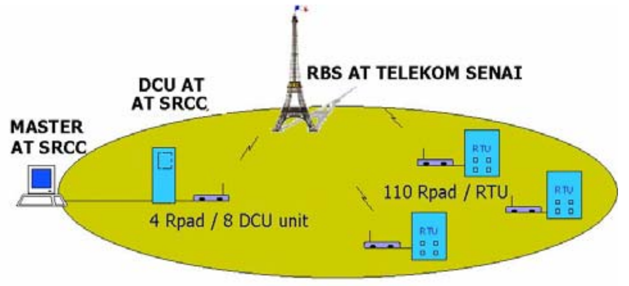

Figure 2: Original Network Setup

CHALLANGES

The use of a combination of fiber optics and dial-up wireless communication and the use of DNP3 protocol posed a challenge to our project team. This was the first time such technologies were being used in feeder automation in TNB. Due to this, several technical challenges were encountered in the implementation process. One of the main challenges was that the DCU was not stable and it stalled very often. Several tests were carried out and analyzed. It was found that the cause was the communication handshaking problem due to the placement of components in a mixed fiber and wireless communication medium. At this point, the link between DCU [SRCC] and Radio Master Modem [PMU Senai] was through TNB fiber network. To overcome this problem, we relocated the DCU from SRCC to PMU Senai so that it has direct connection to Radio Master modem (Figure 3).

There was also a problem of congested channel with heavy traffic. This was caused by unsolicited analogue values from the RTUs to the master station. To make the communication problem worse, SCADA Master System also kept polling all slave RTUs for updating of status. This problem was primarily due to insufficient communication address at the DCU and a lack of polling strategy. Subsequently, the problem was overcome by increasing the DCU communication address from 4 to 8 addresses. Equally important, a new polling strategy was introduced in order to reduce communication traffic between Master and Slave modems.

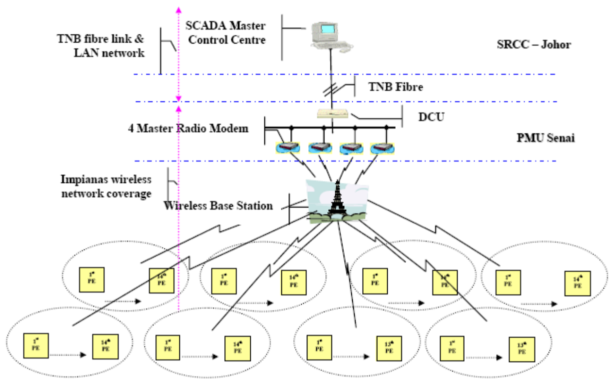

Figure 3: Revised System Configuration

In an attempt to improve the transaction cycle-time, we also found out that the dial-up wireless communication had an inherent network delay time of around 4 seconds during data transmission. This might render it not so suitable for more time-critical mission.

SYSTEM INTEGRATION TEST

TNBR has conducted several integration tests between RTU and wireless communication system at TNBR laboratory. The objectives of the tests are:

- To confirm that RTU is compatible with wireless communication data network, suitable for use in SCADA application with DNP3.0 protocol
- To verify the communication system and network performance under normal condition.

The parameters include; modem transmit delay time, link timeout at master, link timeout at RTU, numbers of retry RTU to master, numbers of retry master to RTU, call period time out and period of cyclic call RTU to master.
From the results, average time taken from the occurrence of an event plus the radio dialing until the status changed at the DCU is roughly about 12 seconds.
The tests have shown that the Wavenet Wireless Data Communication Network is suitable to work with DNP3 protocol in SCADA system environment. The sequence of event happened during data transmission is shown in figure 4.

SYSTEM SIMULATION TEST

The purpose of System Simulation Test (SST) is to measure the performance of the system during simulated outages. With these SST test, we can see how long the system will take to complete the reporting of the simulated outages.
Test was performed with ASE 2000 placed at the DCU to record the communication activities on the master modem and was divided into two levels:

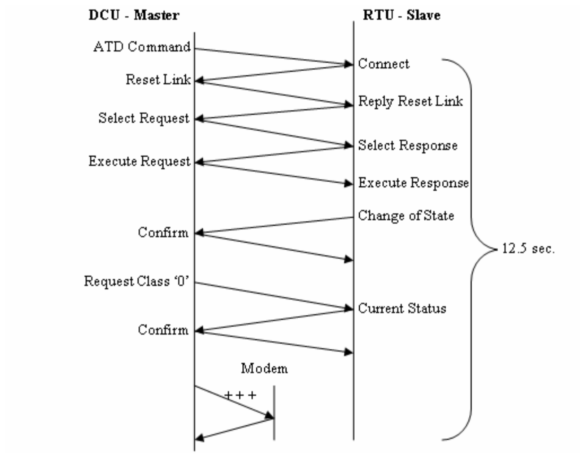

Figure 4: Control Command Event

Communication Line Level - Unsolicited

- EFI testing point at 3 substations in one feeder [within the same modem number] are used as our triggering point and simulated simultaneously.
- The longest time for these three events to reach Master System at SRCC is between 4 to 5 minutes.

DCU Level - Unsolicited

- EFI testing point at 3 substations in one feeder [within the same modem number] are as our triggering point and simulated simultaneously.
- Total time for each event to reach Master System at SRCC is around 1 minute.

RESULTS AND DISCUSSION

Communication Medium between Data Concentrator Unit [DCU] and Slave RTU

The DCU is originally placed at SRCC office and the communication medium between SRCC and Senai Industrial Area is through TNB fiber link [from PMU Skudai/Senai to SRCC] and Impianas wireless network [covering Senai Industrial Area till PMU Skudai/Senai].
During the first Site Acceptance Test (SAT) conducted, we found that the DCU was not stable and then hang. Furthermore some data from the remote sites (substation) did not get through to the master system or date got corrupted.
Further analysis of this problem showed that it was due to the handshaking requirement of the communication system. The fiber optics link was connected using only 3 cores (Transmit, Receive & Ground) while the communication between Radio master Modem and DCU requires handshaking such as Request to Send (RTS) and Clear to Send (CTS). The RTS/CTS handshaking provides better control over the use of the shared medium. The primary reason for implementing RTS/CTS is to minimize collisions among stations. Collision occurs when users and access points are spread out throughout the facility and having a relatively high number of retransmissions occurring on the wireless network.

Action taken is to reposition the DCU from SRCC office to PMU Skudai/Senai with new system configuration. The number of DCU communication address has also been increased from 4 to 8 addresses. All system currently performed as expected with this remedial measure.

Lesson learned:

- The DCU must be placed near to radio master modem and connected directly with handshaking. No handshaking control required between DCU and SCADA master, and RTS/CTS signal is looped at SRCC.
- To limit the communication medium between DCU and slave RTU to only one type of network system
- Number of DCU communication port must be sufficient in order to provide more channels for data transfer from/to slave RTU.

Communication Signal Level Fluctuation

The signal level at each RPad Radio Modem or substation is obtained by measuring the RSSI (Receive Signal Strength Indication) and FSSI (Forward Signal Strength Indication). RSSI denotes the strength of the signal from Rpad Radio Modem to Base Station while FSSI indicates the strength of the signal from Base Station to Rpad Radio Modem. These values are measured at the substation/. The acceptable value for both this parameters is as shown below:

- FSSI > 10
- RSSI > 30

The survey that was conducted prior to modem installation indicated that all sites were having a reasonable good reception with acceptable signal strength. But during the course of the project, some sites encountered low signal level or no signal at all. This was due to the fact that the signal level fluctuated due to external factors such as bad weather conditions, blockage of the signal at remote site or modem failures itself (in this case, the modem was replaced). The signal level would go lower than the acceptable value due to these factors if the earlier measured signal strength was just marginal (FSSI ~ 10 and RSSI ~ 30).

Action taken is the antenna was repositioned for a better reception and the value of the required parameters should be more than the minimum required so that if there was a drop in signal level, the required value should be sustainable for communication with base station and vice versa.

Lesson learned:

- Detail site survey and system planning on the proposed radio network should be carried out before any system installation and implementation.
- Signal strength for all sites must be set as maximum as possible to avoid the communication problem during bad weather conditions, etc.

RTU Performance under DNP 3.0 Protocol

From the test performed, it is obvious that retries and number of dial attempts are very important to ensure that event reports arrive at DCU level. Obviously, the longer time delay introduces will cause longer “Reset Link” interrogation by DCU before “Class 0 Request” which is equivalent to report enables to be transmitted. DNP 3.0 communications over radio is very different compare to communication with leased line copper or fiber optic in which delay introduced is almost negligible. Over the radio, delay is so significant that it is affecting the effectiveness of the protocol. DNP 3.0 being a “safe” protocol requires a lot of confirmation from both side just to ensure that a correct message being send to other side.

Action taken is lot of compensation factors on physical layer, data link layer and application layer been introduced in the RTU system configuration. With all these factors taken into consideration, the system performance became more reasonable.

Lesson learned

- To have better understanding on DNP 3.0 protocol, especially when using it over dial-up communication wireless.

CONCLUSION

A lot of experiences have been gained from this project. In particular, the implementation of DNP 3.0 protocol over a mixed communication media environment by using wireless dial-up. We managed to overcome all the initial hiccup and new system is operating stably. The completed Feeder Automation System has managed to improve the breakdown restoration time from security level 3 (4 hours) to security level 2 (15 minutes) It also enhances the safety of the operational staff as the switching can now done remotely. The experiences gained as described in this paper can certainly be used in future SCADA project of similar nature.

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