ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 11(43), DOI: 10.17485/ijst/2018/v11i43/131589, November 2018*

RFID Enabled Framework for Substation Maintenance Management

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Abstract

Objectives: Effective substation maintenance management based on low cost and reliable Radio Frequency Identification (RFID) enabled implementation framework. **Methods/Statistical Analysis**: Economical operation of substation by minimizing the equipment maintenance cost is the prime concern for all the power distribution utilities. Number of maintenance management strategies has been developed for optimizing the substation equipment maintenance cost. Effectiveness of these optimized maintenance strategies lies on the actual implementation in the field. Currently equipment maintenance activities are carried out with off-line association with equipment. Also, equipment maintenance data is acquired and populated manually into host computer which is running maintenance cost optimization applications. Inherently manual process suffers from various drawbacks and results in poor maintenance management. RFID based technology along with embedded system is identified for making the above off-line process into an on-line process with data integrity. **Findings**: Present paper proposes a Radio Frequency Identification (RFID) enabled implementation framework to perform the maintenance with on-line association with equipment. This allows on-line access with the equipment and eliminates the manual process of acquiring data from equipment at the substation level. Also, ensures the on-line update of pre-maintenance and post-maintenance information of equipment in the Computerised Maintenance Management System (CMMS). Conventional RFID readers which are based on multi-purpose hand-held computers are driven by high level operating systems and programming languages. Due to high level system software on handheld readers, the network latency increases and data refresh rate decreases. This paper proposes a low cost microcontroller based RFID reader with up-stream data interface using low level network programming to address the above issues. Host computer data interface is implemented using a TCP/IP protocol which assures the data integrity. The low level programming at the host computer for network communication minimizes the network latency in the data transfer and improves the data refresh rate. Maintenance process with RFID framework is designed and explained. **Application/Improvements:** Maintenance management strategies can be implemented effectively using the proposed RFID enabled framework with customized RLU along with low level network interface to CMMS. Present implementation based on Ethernet interface over TCP/IP can be extended seamlessly for wireless (Wi-Fi) as well.

Keywords: JSP, Maintenance, RFID, Substation, TCP/IP

1. Introduction

Present day T and D business environment is facing immense pressure for the economic operation of substations. Effective maintenance management plays a crucial role in the minimization of operational expenditure. Driven with this objective number of optimized maintenance strategies like RCM (Reliability Centered

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Maintenance), Condition Based Maintenance (CBM), etc., are in practice. However, effectiveness of the above optimized maintenance strategies lies on their implementation. Normally maintenance activities related data like maintenance schedule, maintenance history, maintenance spares, faults, etc. which are required for the maintenance personnel are being handled manually over off-line association with equipment. Pre-maintenance and post-maintenance information of equipment are exchanged manually between the Computerised Maintenance Management System (CMMS) and equipment. This manual process inherently possesses number of drawbacks like improper or incomplete information, inconsistency in the collected data, more time consuming, data inaccuracy, mismatch in the maintenance tasks scheduling, etc. In order to circumvent the above drawbacks, on-line association with equipment and on-line data exchange between the equipment and computers where the optimization algorithms are executed is required. Main advantages of such solutions for substations are:

- Instant update of equipment data.
- This will eliminate the time gap for uploading the real field data along to the application.
- The planned maintenance activities can be created and updated instantly.
- Details of the maintenance activities carried on the equipment can be uploaded with the equipment code along with times stamp.
- Equipment maintenance history can be uploaded directly to CMMS.

In the past many solutions are reported for implementing the on-line association with equipment using the various available sensor technologies[1–3]. Barcode based implementations have been tried but did not succeeded due to the inherent drawbacks of Barcodes[4]. In recent times RFID based systems are gaining popularity due to various benefits of RFID technology as given below:

- Established technology.
- Commercially successful.
- Precise identification of objects.
- Affordable RFID tag prices.
- Availability of flexible and economical interface hardware.
- Ease of integrating into the end user applications.

The main objective of tagging the equipment with RFID is to track and record the information about each asset right from its commission stage to replacement which is basically its life cycle. This enables utility to take appropriate and accurate decisions about each asset and to operate it effectively. Due to various advantages of RFID technology, RFID solutions based on Personal Digital Assistant (PDA) with integration to CMMS are reported in the literature[4]. These solutions are architected around the standard RFID readers based on hand-held computers which are driven by high level operating systems and programming languages. Due to high level system software on handheld readers, the network latency increases and data refresh rate decreases. Current solutions which are architected around the standard RFID readers suffer from the following drawbacks:

- Difficult in customization to meet the substation requirements.
- Data interface with the RFID tag is fixed and not optimized for host computer applications.
- Data exchange rate gets limited and reduces further as data volume increases.
- Host computer applications are to be made compatible to specific RFID reader.
- Relatively higher implementation cost for the complete system.

Even though RFID sensor technology is growing, above drawbacks are persistent at the solution level. In

order to address the above issues this paper proposes a new RFID framework with an embedded RFID Up-Link Unit (RLU). RLU is designed using a low cost microcontroller with RF interface to RFID tag on the equipment and up-stream data interface to CMMS over Ethernet. In order to achieve the network efficiency and latency, communication is implemented using low level network programming in the RLU.

2. System Architecture

In this paper a new framework for monitoring the substation equipment using RFID is proposed. The architecture of the implementation is shown in Figure 1. Each RFID is programmed with a unique identification tag which serves as an equipment identification address. A low cost portable embedded RFID Up-Link Unit is designed to capture the data from each equipment. RLU is architected with suitable interfaces like RS 232 serial, RS485 and Ethernet for all web applications running on a web server or an application server i.e., for web-architected applications running on host computer. Whenever RLU is brought near to the equipment fitted with RFID, equipment specific data is uploaded to the RLU along with time stamp including its unique identification code. Such data for all the equipment are acquired through RLU and the complete acquired data set is then uploaded to the local host or to any remote central computer over wired or wireless Ethernet. By this approach the information from the number of equipment is uploaded to the host computer from a single unit and from anyplace. Proposed system can be easily scaled up to any number of equipment simply by downloading the new configuration to the RLU.

In addition to the above advantages, present system is highly reliable as equipment data is uploaded directly into the host with unique identification. The proposed system

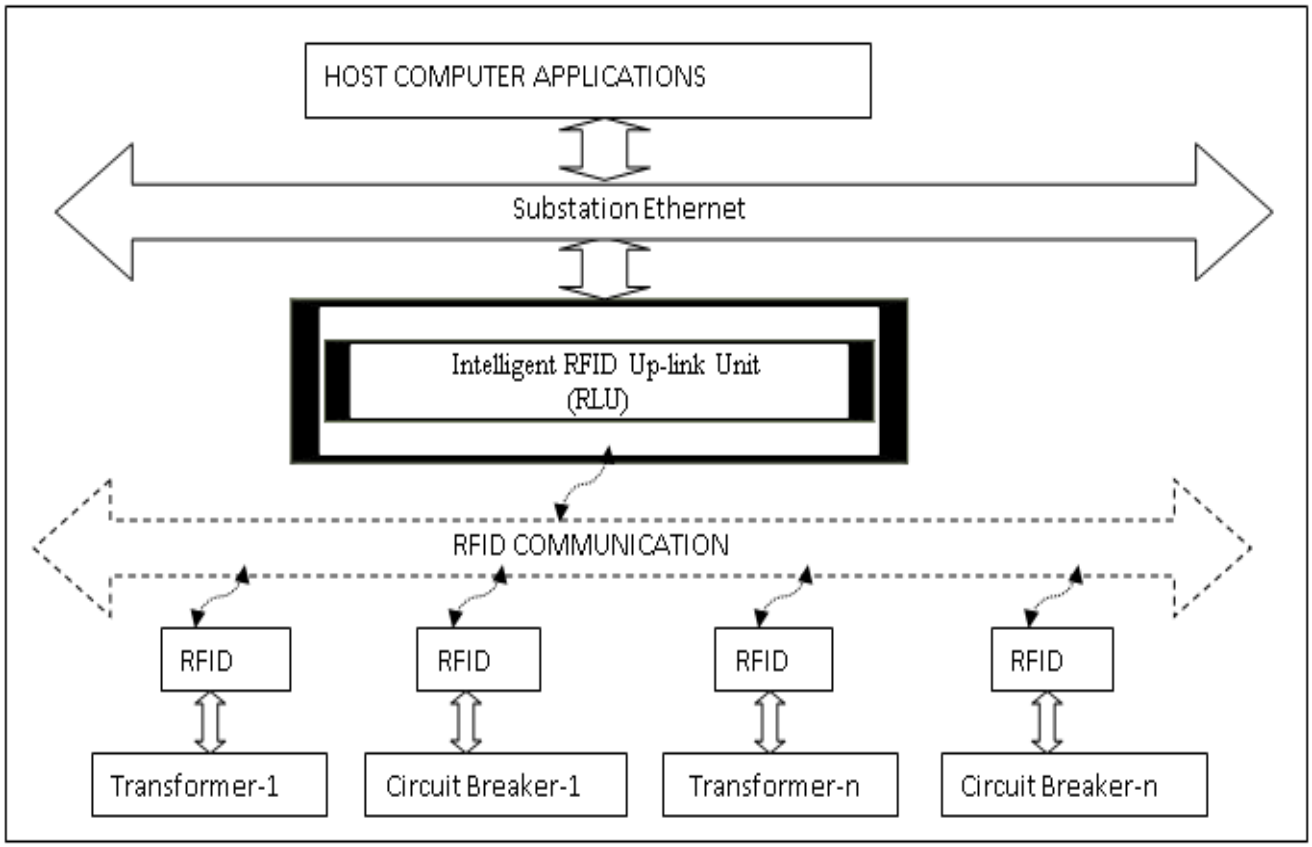

Figure 1. System architecture.

is implemented using a low cost micro-controller and read/write RFID tags. Each substation requires as many RFID tags as equipment which is required to be maintained. However, irrespective of the number of RFID tags only one RLU is required.

3. RLU (Intelligent RFID Up-link Unit)

Each equipment in a substation is fixed with a RF tag containing the unique identity numbers (ID's) of it. RLU which is a RFID reader scans the RFID tag and stores the data read from them. RLU is a RFID reader having embedded microcontroller module with RF interface to RFID tag. The embedded module is designed based on Rabbit microprocessor. The Rabbit 3000 is designed specifically for embedded control, communications and Ethernet connectivity. The Rabbit 3000 is fast, running at up to 55.5 MHz, with compact code and direct software support for 1 MB of code/data space[4]. Hardware architecture of the embedded module is shown in Figure 2.

As shown in the Figure 2 the reader interface module based on Rabbit 3000 microprocessor, reads the data from tags with the help of antenna and transceiver. Received tag information is made available over Ethernet to host computer. The RWM600 ISO15693 reader interface module works with RFID tags with transponders operating at a frequency of 13.56 MHz. Depending on the size of the antenna, the reader module has a read distance up to 200mm. As discussed in the previous sections, RLU reads the tags and associated information and sent to the software application running on host computer through Ethernet over TCP/IP. The entire TCP/IP client server architecture is implemented in RLU through socket programming. TCP/IP follows client server architecture i.e., request and response protocol between the two ends. By establishing TCP/IP communication with RLU, data can be read by any host application. The connection requests and processing between the two end systems is taken care of by TCP/IP stack which is more reliable than the high level case which uses http. RLU firmware is developed in Dynamic C for Rabbit3000 microprocessor to perform the reading tag information and sending it to the host application upon request from the host computer as a client.

4. System Operation

Entire application can be divided into following building blocks which are represented in the architecture diagram in Figure 3.

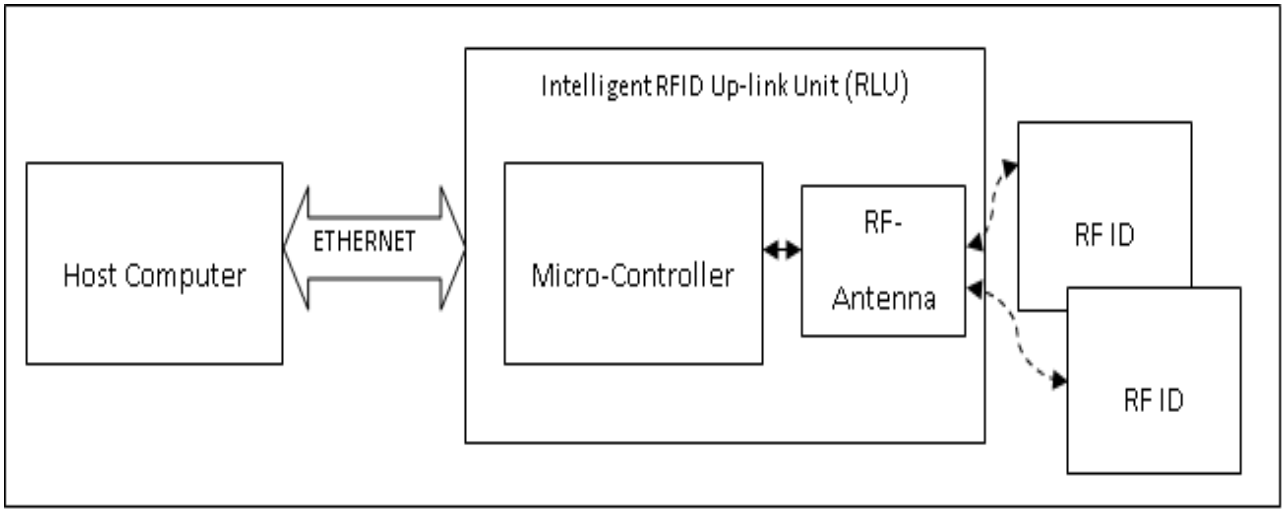

Figure 2. RLU- RFID hardware interface.

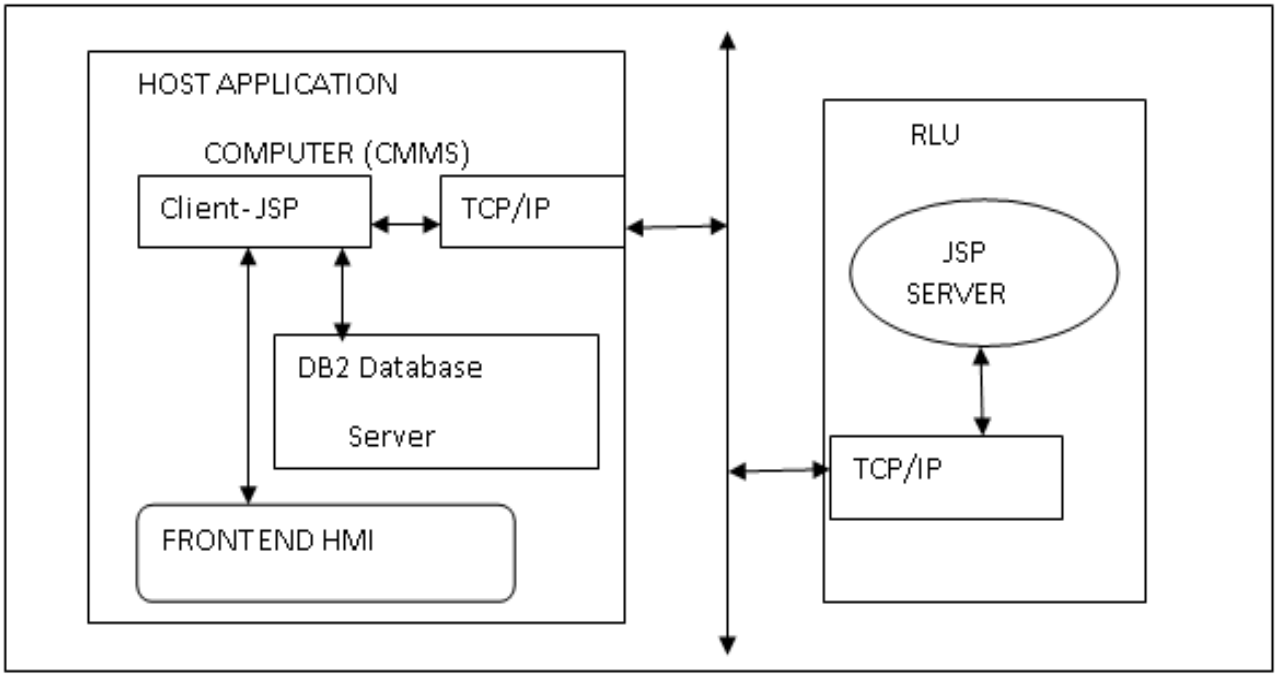

Figure 3. RLU- RFID software architecture.

- RLU as an embedded RFID reader.
- Client programs run on host application computer through JSP (Java Server Page).
- DB2 used as a back end Database in the host computer.

The dataflow diagram shown in Figure 4 explains the processing of data throughout the communication between the embedded server and the client and that of the data within the client. The context diagram is the top-level data flow diagram that has the process and gives the functioning of the entire system in relationship with the external entities.

TCP/IP communication between RLU and JSP application: Since the RLU and the JSP application communicate over TCP/IP (established with Java network

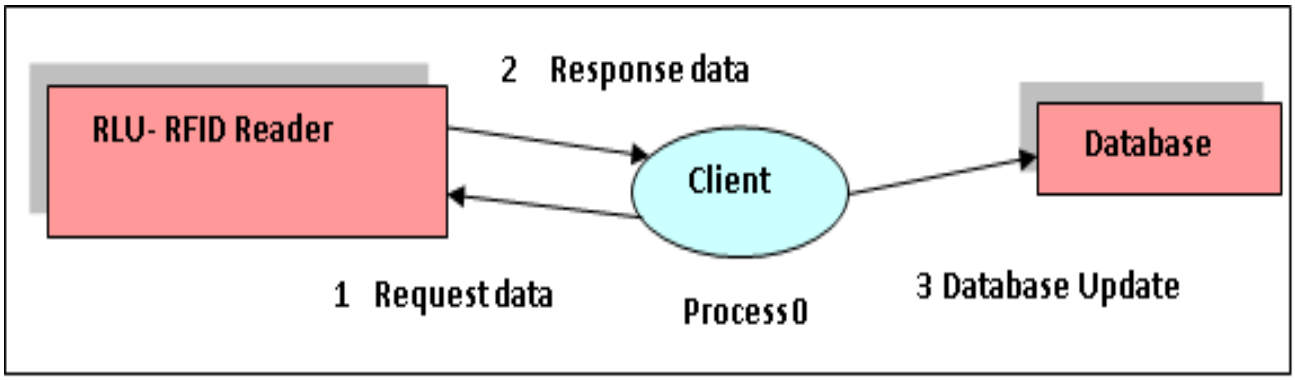

Figure 4. Data flow diagram.

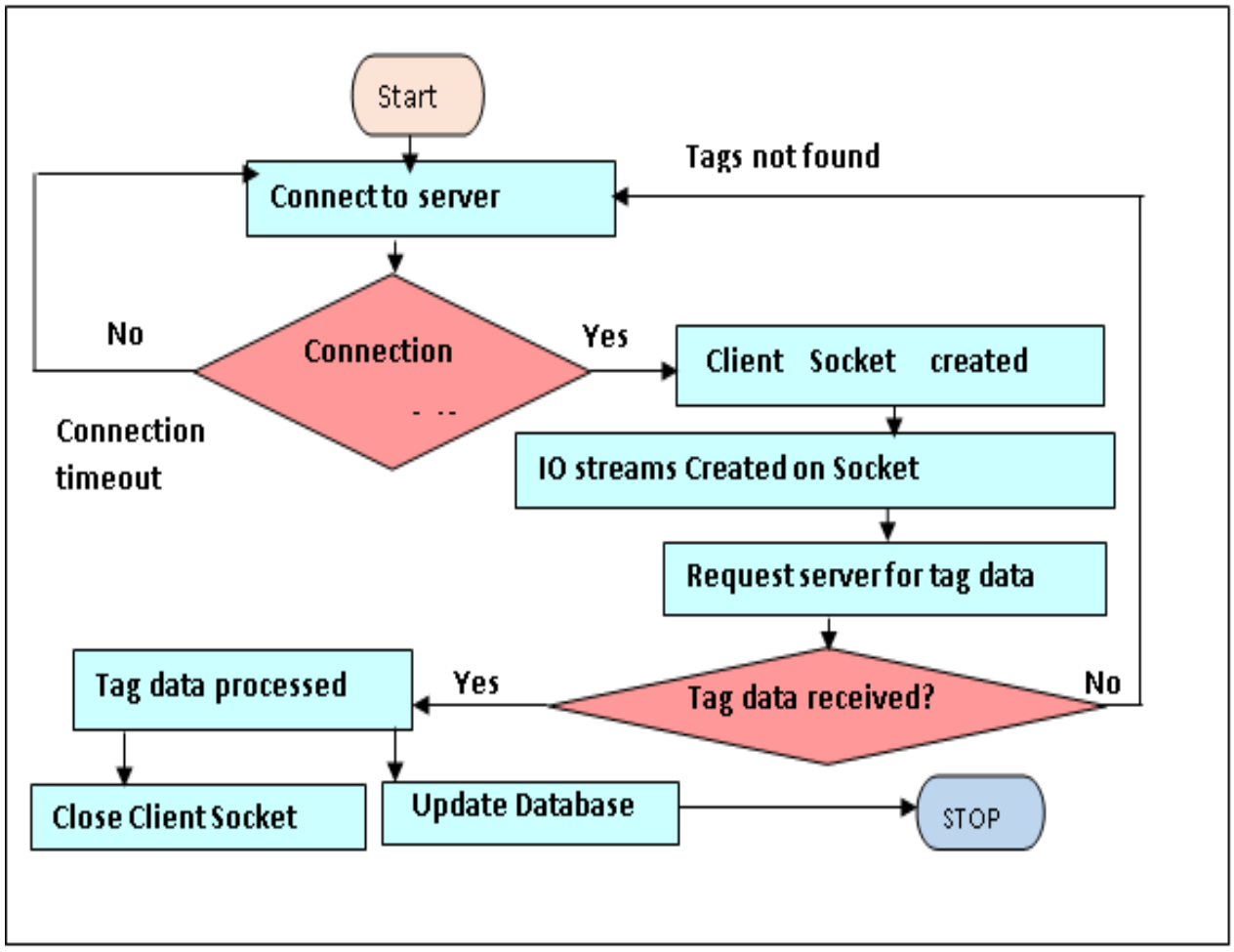

Figure 5. Process flow chart.

socket programming) they follow the server-client protocol. Here the RLU which is an embedded module is considered as the server and the JSP application is considered as the client. The server responds to client upon the request of the client i.e. the embedded module sends the tag information to the JSP application upon receiving the request from the JSP application. This data can be viewed on the Java Server Pages, which are web pages that provide Graphical User Interface (GUI). Sequence of steps that take place as part of the communication between the embedded RFID reader and the client are given below:

- Start the RLU and read the tags.
- Client tries to connect to the server and if the connection is successful it receives the information over the input output streams of the socket but if the connection attempt is unsuccessful it tries to connect again.
- The received tag information is processed and the connection between the client and the server is closed.

Flow chart showing the detailed implementation is shown in Figure 5.

Table 1. RFID template

Tag Data	Tag Data Details
Equipment ID	Unique Equipment Identification code
Equipment Commissioned Date	Equipment put to service date
Equipment Status	Running /stopped/major overhaul/minor overhaul/etc.
Last Inspection Date	Date of Last Inspection
Last Maintenance Type	Major/Minor
Last Maintenance Date	Date of Last Maintenance
Maintenance Status	On-going/Completed
Spares Batch code	Equipment spares group ID as per Database

5. RFID Integration with Maintenance Management

In the literature number of ways is reported for integrating the RFID based system into maintenance management[1–3]. The architecture shown in Figure 4 is generic in nature and applied to all types of integration methods. However, specifications of the RFID chip embedded into the equipment will change as per the type of implementation due to the amount of the application specific data stored in the RFID chip. In the present paper following template as shown in Table 1 is used for the RFID chip:

Maintenance operator approaches the equipment with RLU and scans the equipment through the RFID before initiating the new maintenance action. Complete data as per above table will be read by the operator and uploaded to the host application indicating the initiation or starting of maintenance activity as per the maintenance schedule from CMMS. Subsequently assigned maintenance or inspection activity is completed and the maintenance data is updated onto the RFID through RLU. Also, the same data is sent to CMMS indicating the completion of maintenance and for necessary database update. Above process ensures the execution of optimized inspection or maintenance (major/minor) as per the maintenance management strategy.

6. Conclusions

Economic operation of substations by optimizing the maintenance cost is the main focus of the distribution utilities. Host of maintenance management strategies are evolved for minimizing the operational cost. However, due to off-line association with equipment and CMMS, these strategies are not getting implemented as desired. Keeping the various advantages of RFID technology, this paper proposed a new RFID enabled framework with on-line equipment association to CMMS for carrying out maintenance effectively and efficiently at the substation level. Proposed system captures the maintenance data of the equipment through RFID tag with unique equipment code and populated in the CMMS database for further processing at the host computer. This avoids the manual entry of equipment related data into the host applications and ensures the data integrity and data consistency and enable the effective implementation of

maintenance strategies. Normally RFID readers are built over the hand-held computers with high level operating systems and such readers are having certain limitations and also relatively costlier. Customized and cost effective embedded RFID reader with efficient interfaces for web based applications is proposed. Implementation based on Ethernet interface over TCP/IP is explained and it can be extended seamlessly for wireless (Wi-Fi) as well. Hence, maintenance management strategies can be implemented effectively using the proposed RFID enabled framework with customized RLU with low level network interface to CMMS.

7. References

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