Implementation of Industrial Communication Networks using OPC UA for Industry 4.0

Author

Raheel Ali Syed

Supervisor

Dr. Arshad Aziz

Thesis submitted in partial fulfillment to the requirement for the award of the degree of Master of Science in Electrical Engineering with Specialization in Communication

In

Department of Electronics and Power Engineering

Pakistan Navy Engineering College, Karachi

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

ISLAMABAD

March, 2019

FORM TH 4

National University of Sciences and Technology

MASTER'S THESIS WORK

We hereby recommend that the dissertation prepared under our supervision by: (Student Name & Regn No.) **Raheel Ali Syed & Reg. No. 00000117296**

Titled: **Implementation of Industrial Communication Network using OPC UA for Industry 4.0** be accepted in partial fulfillment of the requirements for the award of Master Degree.

Examination Committee Members

1. Name: Dr. Dur-e-Shehwar Signature: ________________

2. Name: Dr. Lubna Moin Signature: ________________

Supervisor's name: Dr. Arshad Aziz Signature: ________________

____________________ ____________________

Head of Department Date

COUNTERSIGNED

____________________ ____________________

Dean / Commandant Date

Declaration

I certify that this research work titled "Implementation of Industrial Communication Network using OPC UA for Industry 4.0" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

Signature of Student

Raheel Ali Syed

Nust Reg. No. 00000117296

Acknowledgement

First of all I would like to offer my intense gratitude to Almighty ALLAH Ta'ala (Jalla Jalalahu) for his kindness and blessings that he has always conferred me. I pray that, Allah shower his numerous blessings and peace upon his most beloved and last Prophet Hazrat Muhammad (Sallallah O Alaihi Wa Alahi Wasallum).

The achievement of this thesis and the MS research which I have shown has been possible utterly by the blessings of Allah. Afterwards the prayers of my beloved ones which really made it possible to complete this research work. Specifically the continuous support of my dear mother kept me doing hard work on time and kept me motivated to my tasks.

I would like to articulate my earnest appreciation to my supervisor Dr. Arshad Aziz for his kind and continuous supervision with great tolerance and knowledge. His support, encouragement and motivation throughout the work made this research possible. I would like to acknowledge special thanks to all of the guidance Committee members, Dr. Lubna Moin and Dr. Dur-e-Shahwar Kundi for their timely instructions and guidelines that helped me a lot to complete this work. Lastly, I would like to acknowledge the help of academic administration at PNEC and at HQ NUST, this research could be very difficult without their support and gentle help.

Dedication

Dedicated to my exceptional parents and adored siblings whose tremendous support and cooperation led me to this wonderful accomplishment!

Abstract

The technological revolution in the industrial sector drastically increases the productivity and efficiency of the plant. The industry has seen three industrial revolution. Industry 1.0, industry 2.0 and industry 3.0.Now the industry is passing through the fourth industrial revolution. The idea of industry 4.0 describe the utilization of the Internet of Things within the context of the factory/industry to remarkably higher scalability and adaptability of production system. In this revolution, the machine started to manage themselves and production process, so there is no need for manpower for their management. The machine utilize the advance internet technology which is called Internet of Things which allow factory to manage its self virtually.

The problem with existing system is having a vendor dependency and isolated system. The vendor dependency means devices or control systems of one brand do not communicate with other systems/ devices of other brand so there is need expensive license or drivers requirement. This type of communication is actually call Horizontal Communication. Similarly, when there is need of plant data for expert who finds out major causes of shutdowns or plant efficiency etc. portable devices are used which is not actually a good practice.

So there is requirement of plant data connected to cloud so the plant data can be utilized from anywhere and anytime. This paper, focuses on Horizontal communication which resolve the problem of vendor dependency and isolated control system so there is no need for expensive license and drivers from vendor this paper also focuses on Vertical communication through which data could be accessible from anywhere and anytime for data analysis.

Keywords: Industry 4.0, IIOT, OPC UA, Node-Red, IBM Watson IOT Platform

Table of Contents

List of Table

List of Figure

Chapter 1

1 Introduction

1.1 Motivation

The OPC is abbreviated as Open Platform for Communication which is a set of standards and specifications for industrial telecommunication. In 1996, the task force established original standard under the name OLE for Process Control (Object Linking and Embedding for Process Control). The real time plant data from controller of different vendors can be monitoring and control using a communication medium of OPC. The OPC Foundation was created to maintain the standard. In 2011, OPC Foundation change the name to Open Platform for Communication. [1].

Programmable Logic Controllers (PLCs) are playing very important role in manufacturing automation sector. Industries use PLC to reduce production cost and increase the quality of products. Every manufacturer has its own programing environment to program the PLCs but in 1993, the International Electro-technical Committee (IEC) published the IEC 61131 International Standard for PLC. This standards contains four programing languages which are as follows:

- Ladder Diagram (LD)
- Functional Block Diagrams (FDB)
- Instruction List
- Structured Text

The Distributed Control System (DCS) is advanced control system with respect to PLCs as more complex loops and variables are controlled. Usually it is used for heavy industry like Power Plant, Oil Refineries, Distilleries, Sugar Plant and Cement Plant etc.

Since, in a plant there is diversity in the selection of PLCs vendors. Schneider, Siemens, Allen Bradly, Mitsubishi, Fatek etc. PLCs are installed in a different section of a plant. Every vendor has its own programing tool, SCADA software and historian.

1.2 Problem Statement

In the hierarchy of industrial network there are two categories of communication. The communication between different vendor devices is called Horizontal Communication while communication among four layers of industrial network is called Vertical communication.

The major problem is that there is no common platform for SCADA and historian through which data from PLCs of different vendors can be monitored and controlled and saved the history data into the common database. In simple world there is no horizontal communication in existing system installed in industries. Sometime expensive licenses are purchased to for data monitoring and controlling from a centralized system.

Similarly, control system are not connected with business level or enterprise resource management level. The business need or requirement does not affect the plant's operation which causes loss of energy resources. Hence there is no vertical communication.

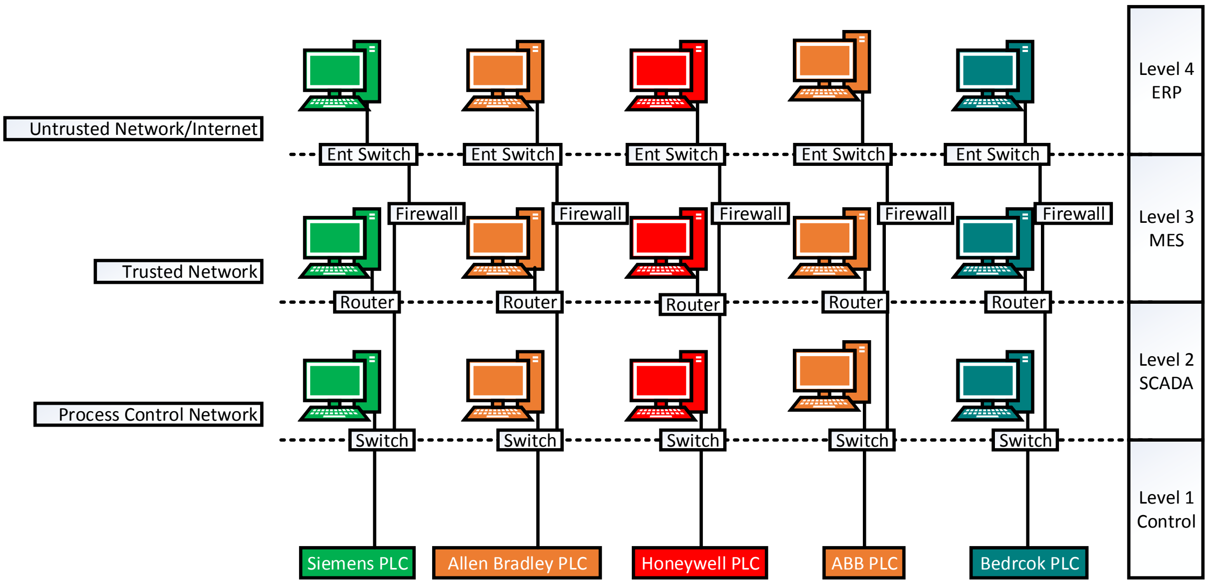


Figure 1.2 Vendor Dependency

1.3 Thesis Scope

In this research work, horizontal communication of PLCs or DCS will be implemented and tested using OPC UA as this protocol is having number of device drivers and standard library of protocol. Furthermore, PLC data can visualized from remote location at any time for data analysis which is actually a vertical communication. In this paper the OPC UA sends data to from level 2 to level 4 which is enterprise business level. In Industry 4.0, all the plant's devices can be accessible from anywhere and at any time. The summary of scope this research work are as follows:

- Solution for horizontal communication among different vendors PLCs.
- Solution for vertical communication so data can securely be accessible from anywhere at any time.

1.4 Chapter Organization

Chapter of the thesis are organized as follows: Chapter 2 introduces the industrial communication network and its distribution by layers. Moreover it discusses about SCADA system Chapter 3 introduces the OPC, discusses its needs. This chapter also discusses OPC Classic and OPC Unified Architecture. It also discusses the KEPServerEX Version 6.0.
Chapter 4 introduces the second part of thesis which Industry 4.0. Its applications and IBM Watson Platform for IIOT will be discussed. Chapter 5 discusses Middleware (MW) and its categories and how Node Red has been used as middleware in this research thesis. Chapter 6 discusses proposed Network Architecture and implementation techniques and finally Chapter 7 show the result and future direction of this research study.

Chapter 2

2 Industrial Communication & SCADA System

2.1 Introduction

The industrial sector of Pakistan is resistive in implementing latest technologies because of number of reasons but its people are adopting it for personal use for instance majority people is having latest smart phone. So the use of smart phone for plant's specialized data is good idea to implement. In this regards number of research papers have been reviewed which are discussed in this chapter.

2.2 Industrial Network Hierarchy

The Industrial network is divided into four levels as the figure 3.2.1 depicts and the description of each levels are below:

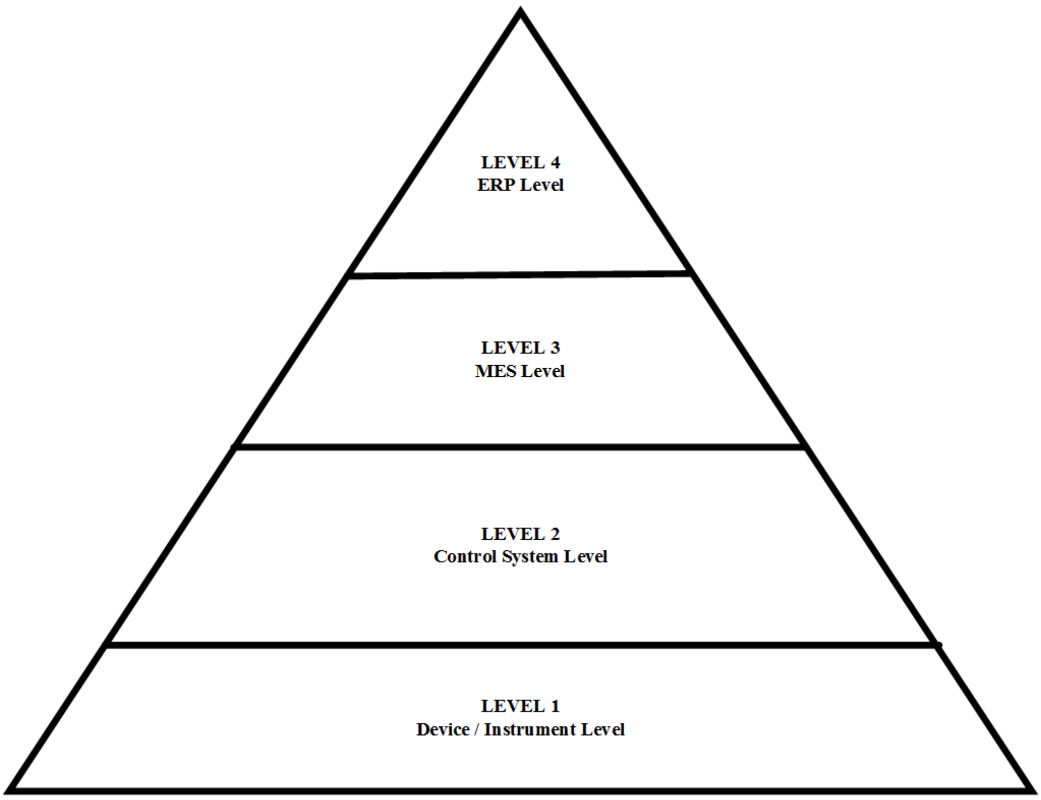


Figure 2.2 Industrial Communication Network [2]

2.2.1 Level 1

Instrumentation of the plant is at this level for instance Pressure, Temperature, Flow and Level (PTFL) transmitters, ON/OFF or control valves etc. are at level of industrial network.

2.2.2 Level 2

Control System and SCADA for controlling the parameters of plants i.e. PTFL and valves, motors, pumps etc. is at level 2 of industrial network.

2.2.3 Level 3

This level is the Manufacturing and Execution System are used to tract and document the transformation of raw materials to finished goods. The decision maker can optimize the plant performance at the level.

2.2.4 Level 4

It is a business Level and it is administered by the corporate IT department.

2.3 Vertical Communication

The latest technology such as cloud computing, big data analysis or intelligent data processing requires new services from plant floor control system. The currently installed system on plant, controls the operational plant's parameters based on local data. A secure communication is required between level 1 system and up to level 4 which is ERP, in order to achieve the goals the Industry 4.0. [3]

2.4 Horizontal Communication

This communication is at layer 2 most of time in which different vendor communicate with each other that is system interfacing is possible

2.5 SCADA System

Daniels and Salter researched on SCADA terminology, and from their research it was concluded that the term SCADA is quite common in industrial sector, abbreviated as Supervisory Control and Data Acquisition. The physical devices and instruments installed in the plant can monitored and controlled by SCADA. As the name indicates it's not a fully control system but rather it's a software package that reside on top of the hardware which is to interface such as Programmable Logic Controller. [4]

Their research also describe SCADA hardware and software architecture which are describe in following sections

2.5.1 SCADA Hardware Architecture

The hardware architecture is divided into two main layers. The top most layer is Client which is the interaction between human and machine while the second one is data server layer which is for process data control. These two layer are shown in the figure 3.2.1. [4]

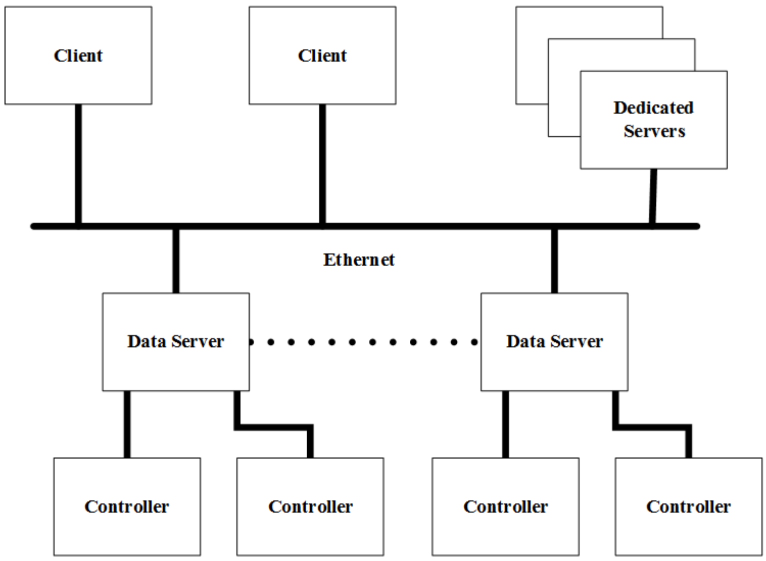


Figure 2.5.1 SCADA Hardware Architecture [4]

2.5.2 SCADA Software Architecture

The Supervisory Control and data acquisition (SCADA) is Software package installed on a server grade machine with following major function:

- Process Monitoring
- Process Controlling
- Data and events logging

These systems are plays a vital role in plant because they provide assistance to maintain efficiency, decision making for process data and reduces downtime. For instance, the plant operator monitors the whole plant. The alarm configured in the system informs operator that the process is not at operation is not at optimal condition so corrective action must be taken to remove the alarm.

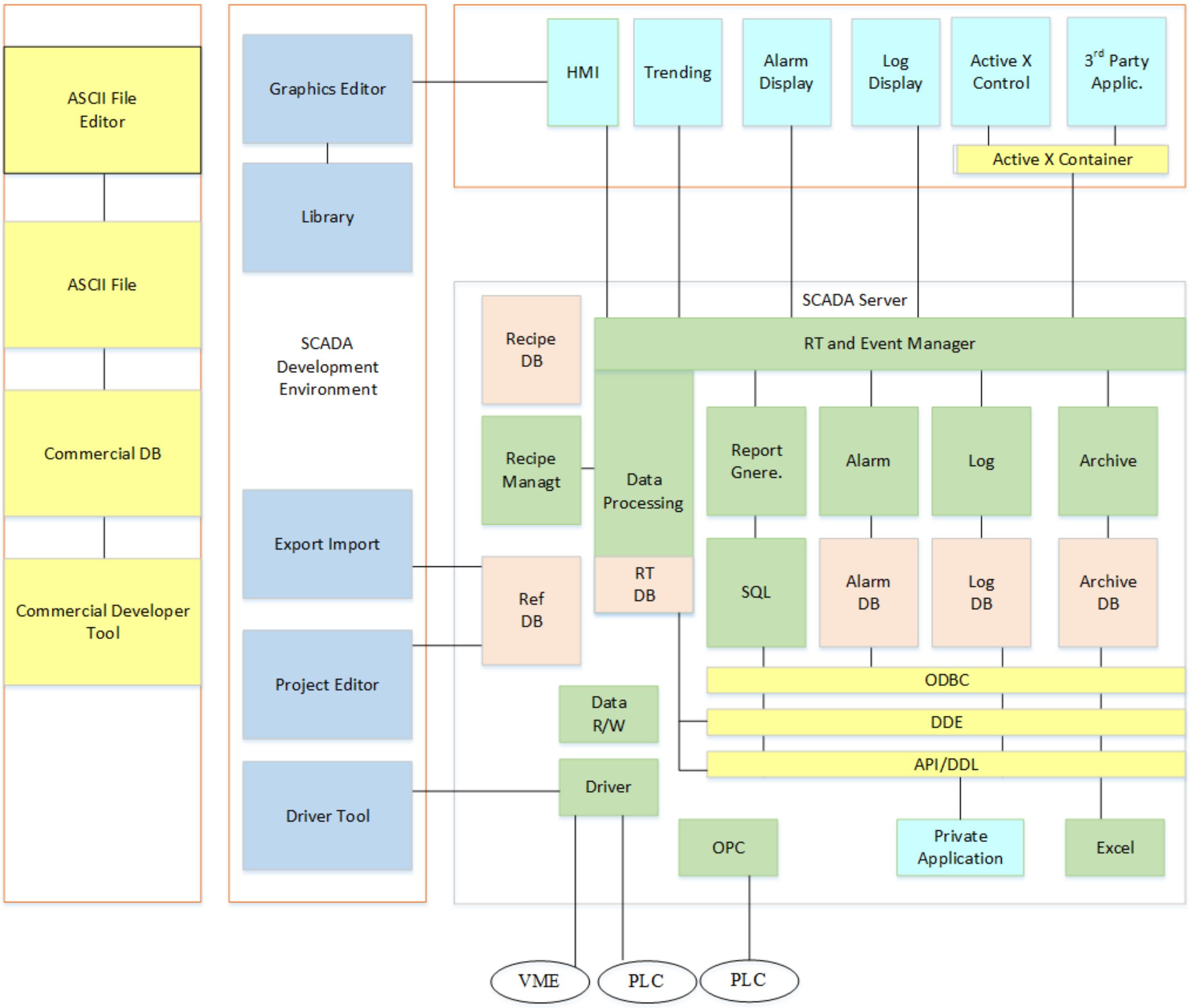


Figure 2.5.2 Software Architecture [4]

Chapter 3

3 OPC Unified Architecture

3.1 Introduction

The plant and factory efficiency depends on information or data transferred to concerned person that is the main reasons of system integration as there are number of control system in the plant or factory. The information system integration is expanding plant or factory boarders with partner companies. The demands of integration of information is getting high which leads to standard and common solution for all vendor system This common platform or standard solution ultimately reduces the cost, and time. [5]. This chapter covers the details about OPC UA, its application and how it's implemented in this this research.

3.2 Common Platform for Communication

The control system vendor create their propriety software and drivers. This creates the problem in the industry as number of vendors increased. The common platform should be developed to overcome this vendor dependency and data could be shared across boarder of the plant or factory.

3.3 Why Need of Common Platform?

The need of Common Platform for communication is due the fact that when industries access data from control devices they used independently developed device drivers. The following are the number of problems when used independent developed drivers.

- Every software must include a driver for particular hardware device.
- Conflict between hardware and drivers
- Driver failure when functionality of hardware changes or upgraded
- One driver cannot be used simultaneously

There is another important factor for common platform is that maintenance of the system and plant operation become sophisticated otherwise when there are number of engineering work station and located in different areas of plant then engineering requirement becomes more and more similarly operational staff requires operational training of different displays making operation quite complicated. When a plant does not contains common platform for all control devices or electronic devices.

The following figure 3.1 shows the industry faced problems without Common Platform.

There are three devices and each device is having an application so there is need of an operator for each devices so operationally it becomes expensive.

When technology aspect is concerned, drivers are required for each device. If device 2 data is required for application 1 then there is driver 2 should be purchased and installed on the system and sometimes it becomes complicated.

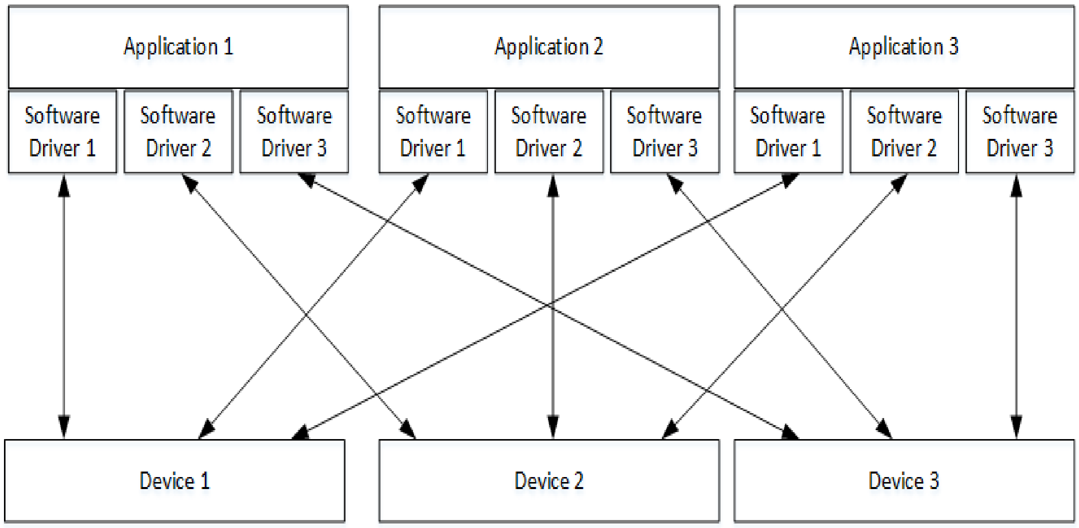


Figure 3.3 Conventional Industrial Communication Architecture [6]

Therefore, this is not a cost effective. The conventional system becomes expensive as drivers or licenses required to communicate other devices with common device or platform.

The technology simplifies the problems faced in conventional system by developing a common standard of communication which unifies whole plant into a single nucleus for controlling as well database.

3.4 What is OPC

The need of common platform or standard solution is addressed by OPC Foundation. The OPC terminology originally was OLE for Process Control but now the interpretation has changed to openness, Productivity and Collaboration [5] , The OPC Foundation has changed its abbreviation to Open Platform for Communication. The figure 2.2 shows how the problem resolved after having OPC Software.

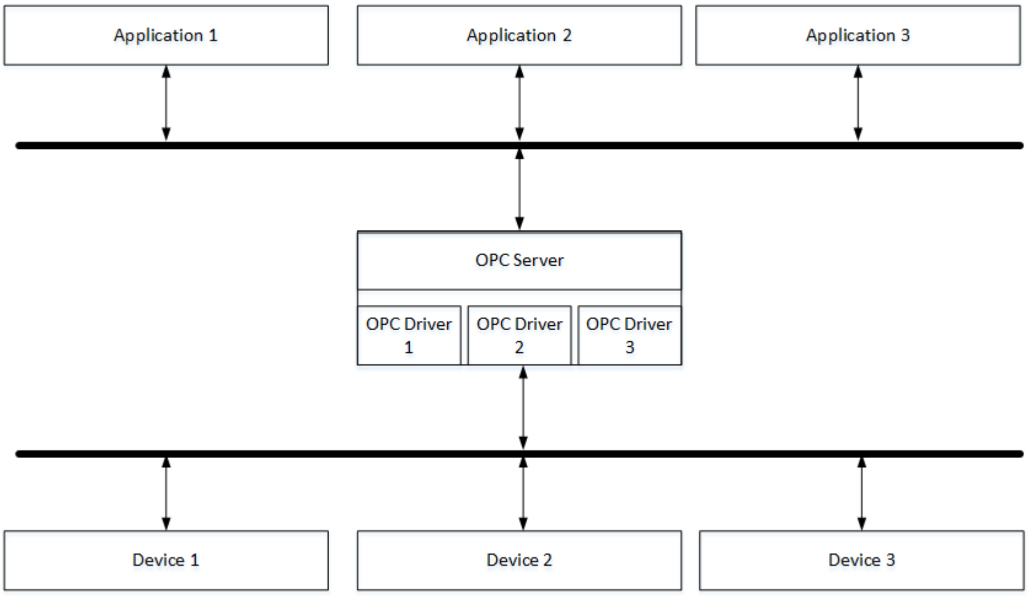


Figure 3.4 Communication Architecture based on OPC [6]

The standard for worldwide industrial automation and control product is now OPC which based on Distributed Component Model by Microsoft. This standard not only connects industrial automation and control products but also links with Microsoft office products. Moreover Enterprise resource planning (ERP) and Manufacturing Execution System (MES) Since the implementation is based on Server and Client architecture, the OPC server interface to OPC COM objects through which OPC client not only exchanges data but also send command. The major advantage of OPC Client is that it can also connect with other vendors or suppliers of OPC Servers.[6]

3.5 OPC Specification

The specification and standardization of OPC has been developed by considering worldwide industrial automation and control products OPC is standard set of objects, method according different requirement of industries. The first version of OPC was released in 1996 by OPC Foundation [6]

The following are specification of OPC:

3.5.1 OPC Data Access

This define a set of standard for COM objects that is reading or monitoring, writing or control of data to the automation system. It standardizes the communication of system whether the system could be industrial controller or database it’s only suitable for windows platform.

3.5.2 OPC XML DA

It’s a standard which provides a web service interface for reading and writing data to and from industrial controller it’s basically provides horizontal and vertical communication

3.5.3 OPC Historical Data Access

The plant historical data is required for root-cause analysis of abnormal events, improves the plant efficiency and other critical issues during plant operation. This standard provides raw data which is stored in data base and aggregated data which is extracted from raw data.

3.5.4 OPC Alarm and Event

Alarms, events notification and operator notification are generated by this standard.

3.5.5 OPC Batch

It defines data access for batch processes.

3.6 OPC Unified Architecture

This is a platform independent industrial standard for communication. The purpose of this standard is to create a communication medium for sending messages between clients and servers over different kinds of networks. It is basically for data modelling and transport. The techniques used by this platform is object-oriented which includes hierarchies and inheritance to model information. There are number of ways through which information can be connected with main server using OPC-UA address space [7]

3.6.1 Scalability OPC UA

Jahanzaib Imtiaz and Jürgen Jasperneite investigated features of OPCUA and they considered a specific industrial application domain that deals with self-configurable production system. This type of systems involve specific automation applications, technologies and requirements on data communication within and between these technologies. [7]

They demonstrated using a case study of Lemgo Smart Factory (LMF) where bottles on conveyor belt are filled to particular level, pick and placed using robot for further processing. So finally they demonstrated that OPC-UA can scale down to a chip level while its prominent features to remain useful. Furthermore they shows memory space is 10KB is required for the server functionality with a basic set of services. So they used one of the smallest OPC-UA servers with high scalability of the OPC-UA. There are number of advantages for using this approach for instance, inn Internet of Thing, OPC-UA makes Software integration easy, its channel is used for smooth communication from sensor to the internet without any additional engineering efforts at different level of automation pyramid.[7]

3.6.2 Interoperability using OPC UA

Adrian Korodi and Ioan Silea worked on inter-operability using inexpensive middle ware OPC UA and case study of water plant. In this paper, first field instruments are controlled via PLC with data monitoring on Level 2 which is SCADA. Moreover higher levels SCADA integration are essential these days for operator. The integration is extended further to level 3 such as MES, ERP, and SAP. The interfacing is a universal way of communication so the main objective of IoT/IIoT is to establish a universal way of communication medium. In this way data transfer up to hierarchy levels.[8]

3.7 PLC Data to MATLAB/SIMULINK

In previous research has shown the implementation of KEPServer EX as OPC Server between Allen Bradly PLC and MATLAB/SIMULINK for SCADA application of industrial boiler. Which has three loops mostly but most critical is drum level which consists of steam flow out of the drum, water flow into the drum and a small percent of water level in the drum.

Sankalp Nayak and Sudhir Agashe has implemented this critical loop in Allen Bradly MicroLogix 1400 PLC. This loop has been simulated in MATLAB/SIMULINK. OPC server which KEPServer EX in this case has been used to transfer data from PLC to MATLAB/SIMULINK. [9]

3.8 KEPServer EX Version 6

In this research thesis, KEPServer EX version 6 is being used which is product of Kepware. It provides a common platform of connectivity for industrial devices or control systems. Since control system are license dependent system that is propriety based system so expensive licenses are required to get data from one system to another. This platform allows user to connect, manage, monitor and control number of automation devices and software applications through a single interface. It not only provides OPC (OLE for Process Control) for interoperability but also information technology (IT) standard protocols for instance SNMP, ODBC, and web services in order to allocate a common source for industrial data.

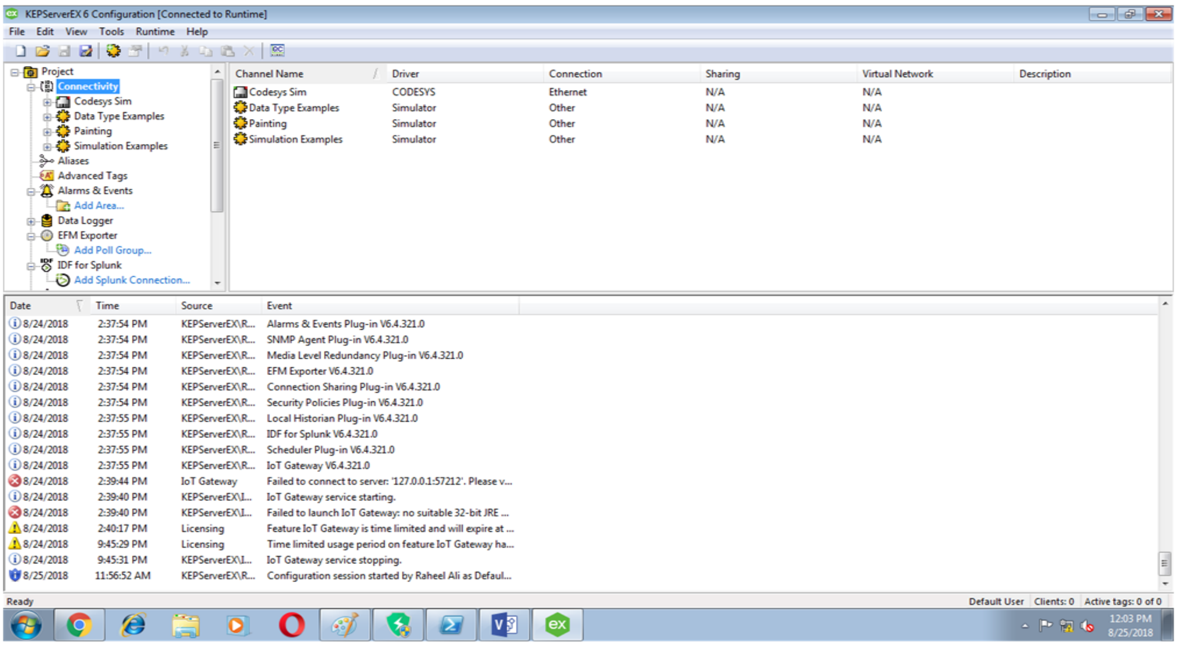


Figure 3.8 KEPServer EX version 6

3.8.1 Features

The number of features are as follows:

- Provides interface for horizontal communication that is communication among different brands of control system or devices.
- Provides interface for vertical communication that is plant floor data could be sent to business floor.
- Cloud gateway
- Compatible with hypervisors for instance VMware and Hyper-V
- SSL and TLS for secure messaging across network
- For critical applications, redundancy option is also available
- Installation, maintenance and troubleshooting are quite simple

3.8.2 Application Connectivity Support

- OPC Data Access Version 1.0a, 2.05a, 3.0
- Fastdde & Suitelink for Wonderware, PDB Interface for iFix
- DDE Format CF_Text, DDE Format Advanced DDE
- Plug-in Device Driver Connectivity
- KEPServerEX supports serial and Ethernet connectivity to the
- Widest range of industrial control systems, including: Allen Bradley,
- Automation Direct, BACnet, GE, Honeywell, Mitsubishi, Modicon, Omron,
- Siemens, Texas Instruments, Yokogawa and many more…

Chapter 4

4 Industry 4.0

4.1 Introduction

Industry 4.0 is the technology which means continuous improvement of plant or a factory. There are number of software used for getting plant data to make decisions at a right time. In this chapter historical background of industrial evolution will be discussed and in depth knowledge of industry 4.0 will be discussed. This is the emerging field and there are number of researchers working on centralized data center of the plant at plant floor and the data can be accessible from remote location and at any time. In this way, reduction traveling cost, and other expense can be saved. The industry expert can makes decisions for the improvement of the plant or factory by utilizing this data with other software and give direction to operators and other business stake holders.

4.2 The Industry 1.0 to 3.0

The manufacturing industries have gone through a drastically changes and development in technology. The main reason is behind this Industrial Revolution. In the nineteenth century, steam engine was used for main source of energy by the industry [10].The major benefit in this era of industrial revolution is that the labor had been removed by machine which ultimately resulted lower cost and less time consumed.

The second industrial revolution appeared after hundred years of first revolution in slaughterhouses in Cincinnati, Ohio and found the increase in production of Ford Model T in United States [11]. The advancement in industrial technology continues and conveyor belt was introduced which reduced the labor cost in the production lines of industries [11].Since the major success and advancement is due to electricity hence this era is termed as Electrification. The relay and hardwired logic was used to control different machine and motors mostly ON and OFF devices.

The third Industrial Revolution or Industry 3.0 was began in 1969 with the invention of first Programmable Logic Controller by Modicon which introduced the digital programing of automation.[11] The programing language used by Modicon was the first millstone for industrial controller which highly popular in today's industrial control system programing.

This phase brought huge evolution in the industrial world with network complexities that exceeds and the reliabilities and strength of automation systems. So there is a need for more reliable and sophisticated ways of information exchange which ensure interconnection on a wider and more refine scale The industry 4.0 is the gateway which connect instruments and devices intelligently[2].

4.3 The Industry 4.0

Since the development of in the information technology and the introduction of smart devices, there was a need to make industry smarter for next generation industry. This phase is termed as Industry 4.0 which comes from a Hanover Fair in 2011[12]. The German government took initiative as a major plan of High Tech Strategy 2020 Action Plan in 2011 [13].

The figure 1.1 is all phases of the industrial revolutions. It is important to focus on the important factors which are Complexity and production. The production increases as industrial revolution moves higher. The complexity factor is very less when labor were being used while complexity increases towards Industry 4.0 due to reason of machine to machine communication The Germany started major debate on intelligent manufacturing which spread in countries like USA and Korea [11].

4.4 Advantages

- This is the latest trend of automation and data exchange in manufacturing technologies.
- It enables faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs.
- Converts industry into smarter one
- Gather and analyze process data across machine
- Its fourth Industrial Revolution which converge OT into IT

4.5 Nine Technological Utilization

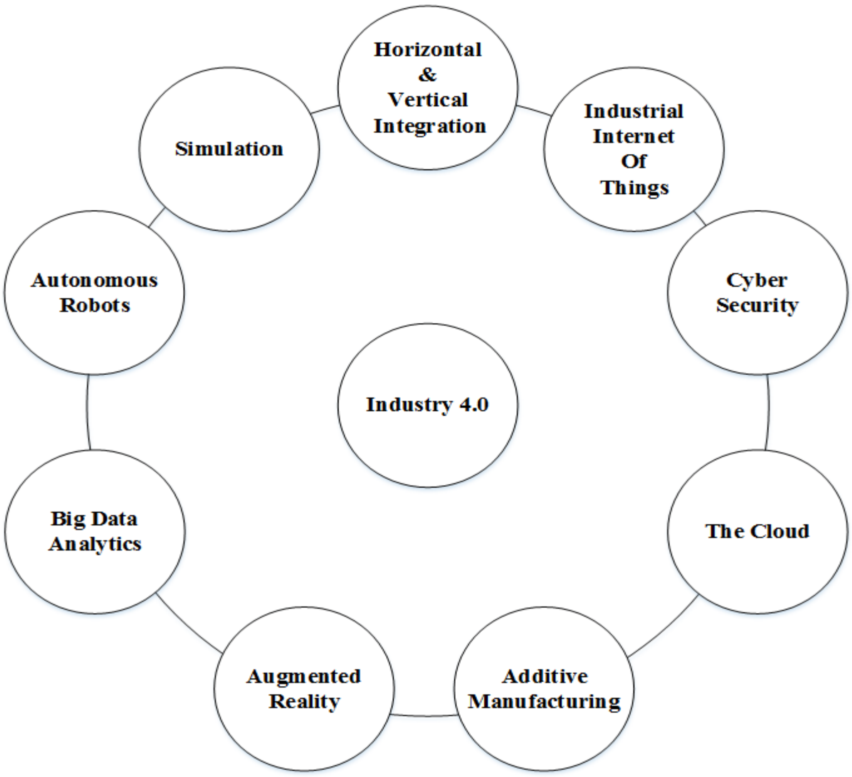


Figure 4. 1 Applications of Industry 4.0

4.5.1 Cyber Security

The systems which are connected to internet are exposed to cyber-attacks so it's basically the protection against such attacks. The unauthorized access to data centers and other computerized systems must be secure. Information security, which is designed to maintain the confidentiality, integrity and availability of data, is a subset of cybersecurity.

4.5.2 Industrial Internet of Things

The IIOT is a subset of Internet of thing. It combines information and technologies to enable real time monitoring and provide controlling for industrial domain. In the context of smart grids, the vision of deploying IIOT relies on using low-power communication technologies by employing standard Internet protocol (IP). [14]

4.5.3 The Cloud

The Information Technology always requires a way to increase the capacity existing system without purchasing new and large infrastructure. The Cloud computing extends IT's existing. There are three types of Cloud Service which are:

- Platform as a Service
- Software as a Service
- Application as a Service

4.5.4 Horizontal & Vertical Integration

The Integration is basically connecting devices with each other. Horizontal Integration connects devices or control systems which reside at same layer while vertical means connecting devices which reside at different layers.

4.5.5 Big Data Analytics

The high velocity data storage and analysis requires the support of latest technology which is Big Data Analytics so data sources extend beyond the traditional corporate database to include emails, mobile device outputs, and sensor-generated data where data is no longer restricted to structured database records but rather instructed data having no standard formatting. [15]

4.5.6 Additive Manufacturing

This method will widely be used to produce small batches of customized 5 products that offer construction advantages, such as complex, lightweight designs.

4.5.7 Augmented Reality

Augmented reality based system provides all installation and repair guide.

4.5.8 Simulation

It help industry to find out problem in the process before implementation

4.6 Industrial Internet of Thing Platform

There are number of platform available for industrial internet of things some of them are as under GE Predix, IBM Watson IIOT Platform, and Honeywell IIOT Analytic Platform Uniformance Suite etc.

4.7 IBM Watson

IBM Watson IoT was announced by IBM in December 2015 as a way to couple the analytics with IoT business opportunity. The devices in the any organization can be connected securely with this platform. It provides organization new ways for information and transformation by using cloud based services and analytics.

Since devices can be connected with this platform, the decision can be taken from anywhere at any time. The quintillion bytes of data is generated every day and its not going to decrease but rather increases. So there are requirement of faster transactions and real time analysis system.

The IBM Internet of Things Foundation provided powerful application access to devices. The powerful connection is established as data can be accessible from remote location with internet connection.

4.8 Applications

IBM Watson is big platform for number of applications and some of them are as follows:

- Automotive industry
- Electronics
- Energy and Utilities
- Insurance
- Manufacturing
- Super Store for retail

Chapter 5

5 Internet of Things Middleware

5.1 Introduction

This Chapter introduces the middleware, its features and application. In this thesis, Node Red is implemented as a middleware. Node Red is a flow based development tool for visual programming. It was developed by IBM. It was developed in order to wire up hardware devices together, APIs and online services as a part of Internet of Things.

Node Red is a browser based flow editor. In this thesis, Node is installed on same virtual machine in which KEPServer EX version 6 installed.

5.2 What is IOT Middleware

It is software layer above the Operating system and it is below the application program that provides a common programming abstraction across a distributed system. [16]

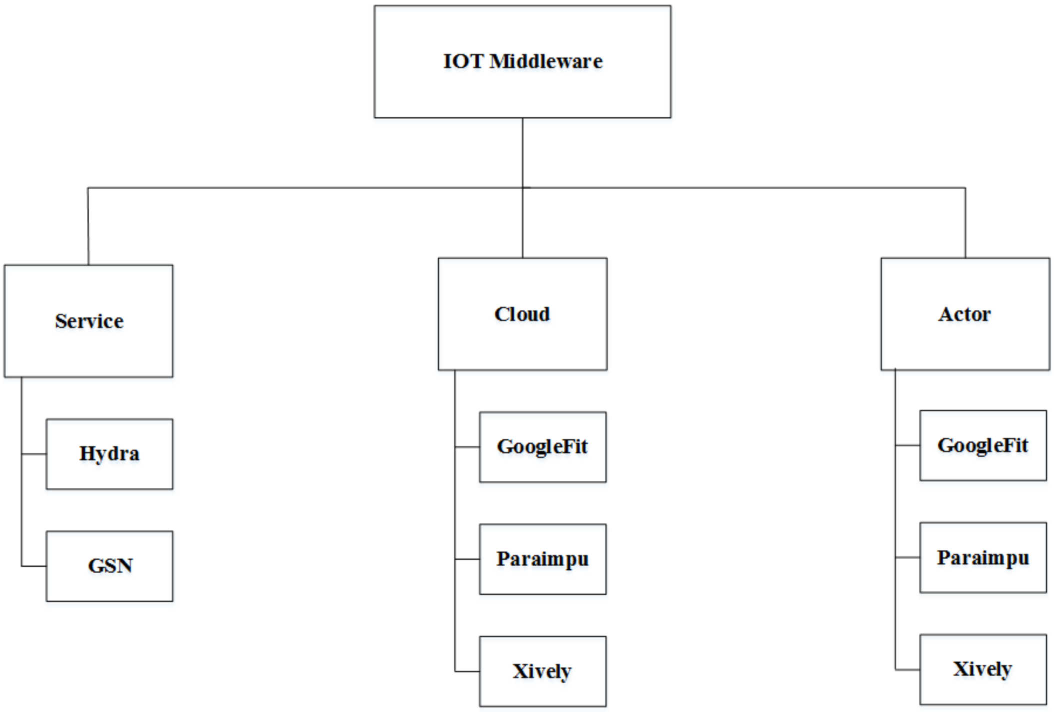


Figure 5.2.1 Types of IOT Middleware [17]

5.1 What is Node Red

It is interactive tool which is used for developing Internet of Things applications. It is very simple and easy to understand the programming. There is no programming like java, C++ etc. rather it simplifies by using predefined blocks of code which are known as nodes. There are commonly input, processing and output nodes. When these node are wired up than it is called flow. [17]

In 2013, IBM developed it as an open source Project as they were facing problems of connecting quickly hardware devices to web services and other software. So in late 2013 they successfully developed it. Now it is used as IoT programming Tool. IoT application developers are increasing rapidly and they are adding new nodes which allows programmers to Node-Red code for large number of task. [17]

5.2 Node Red and IoT Applications

When the IBM launched Node-RED, it was used mostly for Internet of Things applications as it develops application rapidly so it is a powerful and flexible tool. The main reason it that it combines two main factors.[17]

The number one factor is that it is flow based programming model in which messages representing events flow between nodes, triggering processing that results in output. This programming technique is best for IoT applications. The real world scenarios cause some kind of processing which ultimately results in real-world actions. The Node-Red takes the input using simple node and there are processing nodes available and generates the output which becomes a package of the whole event. Therefore it is said that it simplifies events as messages which offer a simple and uniform model for events as they flow between nodes that make up the flows.[17]

The another factor is that there are number of useful and pre-coded building block known as nodes which are powerful, interactive with drag and drop programming technique which allows developer to build IoT applications without worry of programming using languages like JAVA, C sharp, C++ etc.[17]

This tool is not always best for IoT applications. It is quite often becomes complicated so it is not always best.[17]

The complex multi functions IoT applications it not a best solution because for larger application the user interface get bottleneck.[17]

The flow based programming is not always good for application development because there is a weaknesses in flow based programing for instance it is not good in loops handling so it get slow and inefficient.[17]

Flow based programming does not fulfil special or targeted purpose requirements. For instance it is not good for Data Analytics or User Interface development.[17]

5.3 Node Red and IIOT Applications

These days the Industrial Internet of Things (IIOT) is emerging field. The researchers working on it to simplifies the industrial network and connect industry irrespective of time and location. Node Red is open Source and it is also use for IIOT.

Information sharing between operational technologies that is OT Information Technology that is IT is the driving factor for Industrial Internet of Thing Adoption.

The Node-Red makes the way between PLC from vendor A to communicate with the predictive analytics software vendor B. Similarly, for cognitive analytics application like IBM Watson IoT Platform get data from automation controller using this tool.[18]

There are number of nodes available on in this tool for instance, Siemens, Advantech, OPC node are developed. There are other vendor nodes which can easily get data from PLC and other industrial devices.

5.4 Application

Node-Red is very flexible and powerful tool so it can be used on number of different application either it could be a simple home automation to machine automation. The following are some application of Node Red

- Home Automation
- Internet of Thing Application
- Industrial Internet of Things Application
- Machine Automation and smart monitoring

- Cloud Computing
- Integration

5.5 Water Storage Utility

The Node-RED is used in small scale industries like water treatment plant, RO plant with few number of input and output. For instance, consider a water pumping station of small town there are two number of pumping stations and two water storage tanks. The function of first pump is to pump the water from well up to first tank while second pump function is to transfer water from the first storage tank to the second tank which main tank for the transferring of water to town. There are four pumping station in at different location. Each has a PLC with Modbus TCP/IP as a communication protocol. This SCADA system was developed using Node- RED which reads values from tanks and start, stop pumps providing alarming and HMI.

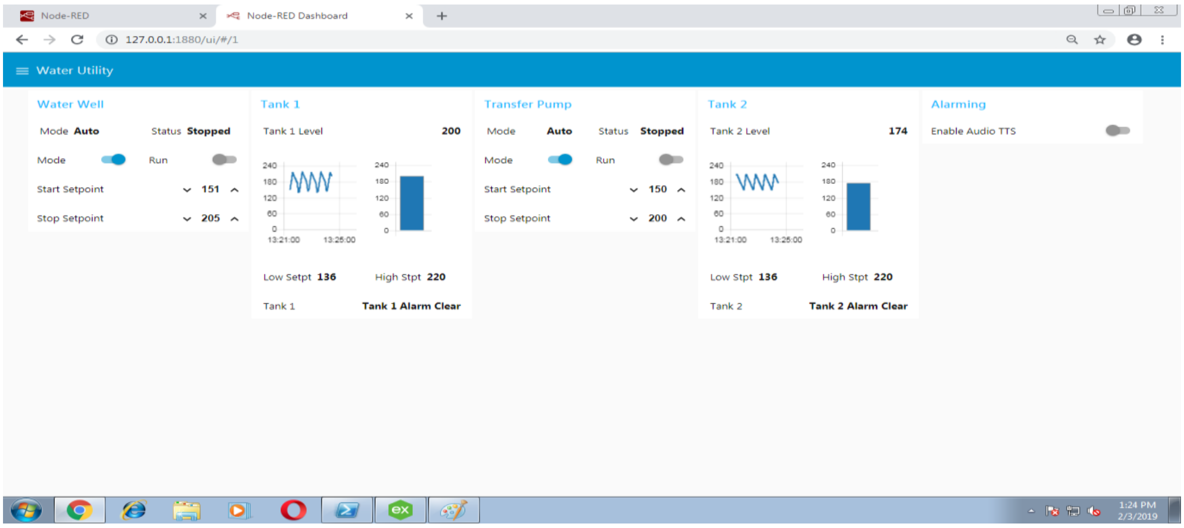


Figure 5.5.1 Water Pumping Station SCADA using Node Red

Chapter 6

6 Literature Review

6.1 Introduction

The motivational point that conceived us to work in this direction comes from few practical research papers that drives our attention toward this technology and convinced us to work on this technology for industrial domain. The glimpse of few paper and research gap are mentioned in this chapter.

The Europe and USA industrial sector is getting benefits of Industry 4.0 similarly Germany is very advanced in this sector and improves manufacturing sector because industries operate according to demand of products.

Pakistan industrial sector is lacking in this field. Our country needs Industry 4.0 technology so that we can save investment cost, energy and improves efficiency of plants or factories.

6.2 PLC data transfer to Cloud

Gavlas with his team programed the S7 1200 PLC and connects to cloud platform. The main objective of this paper is to introduce a solution for transmission of process data between PLC and Cloud Platform also latency between real device that is PLC and Cloud Platform. [19]

They used Node Red as IOT Gateway. The Node Red gets input from PLC and and sends data to two Cloud Platform one is Commercial IBM while the other is free platform with the name Ubidots. [19]

In this paper they did not use OPC server which contains number of PLC or devices drivers which means different vendor PLCs or systems communicates with a OPC Server. The gap in this paper is that Node Red does not contain drivers of number of devices. It can be said that very few PLC can be connected with Node Red.

6.3 Modbus TCP/IP in Node Red

The industrial Internet of Things is a subset of Internet of Things and this is the hot topic in the industrial technological solution. There are number of research papers which have been published in this domain.

In this research thesis, the idea to implementation of OPC UA comes with a paper presented by Muhammad Tabba

Muhammad Tabba at all proposed new architecture for industrial network and used Modbus protocol which based on a hierarchical structure between a master and several slaves devices as shown in the figure 2.2.1 [2]

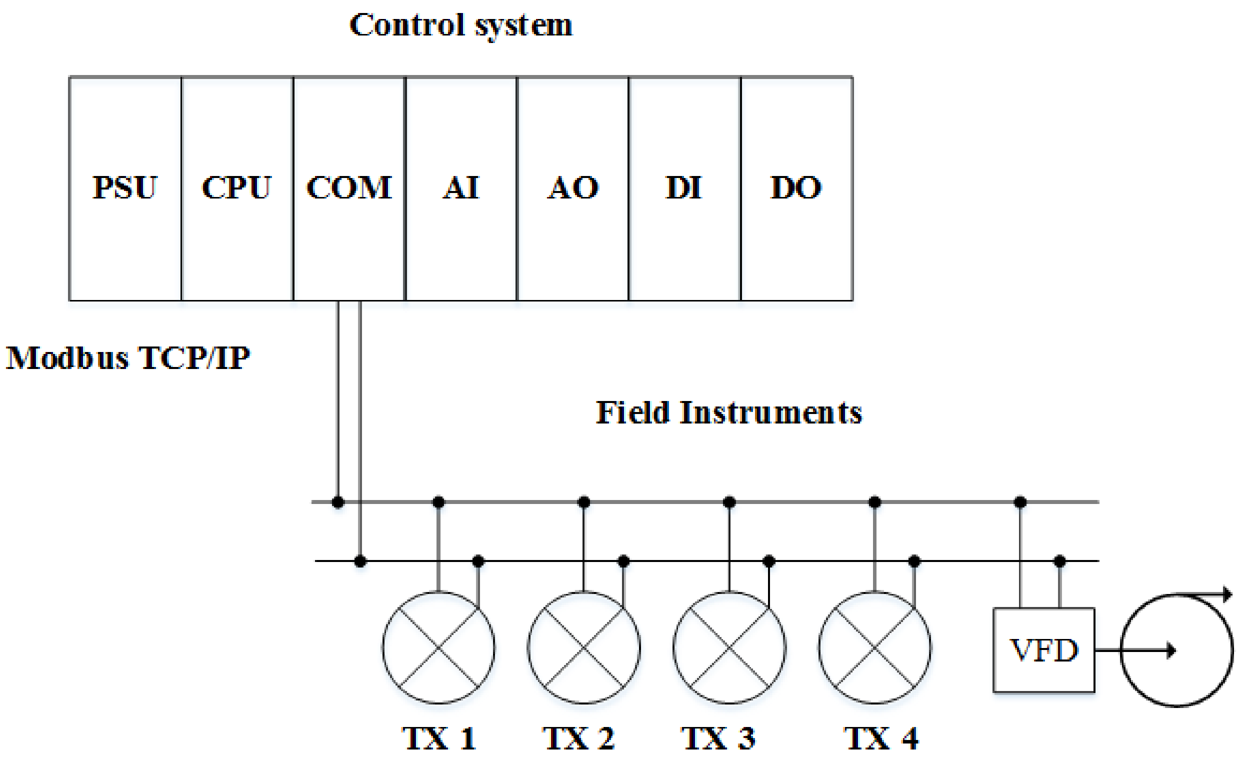


Figure 6.3.1 Network between Instruments and Control System [2]

The field instruments are connected through wireless sensor- actuator network that operate in real time for industrial systems. They implemented the idea using node-red as shown in the figure 5.4 [2]

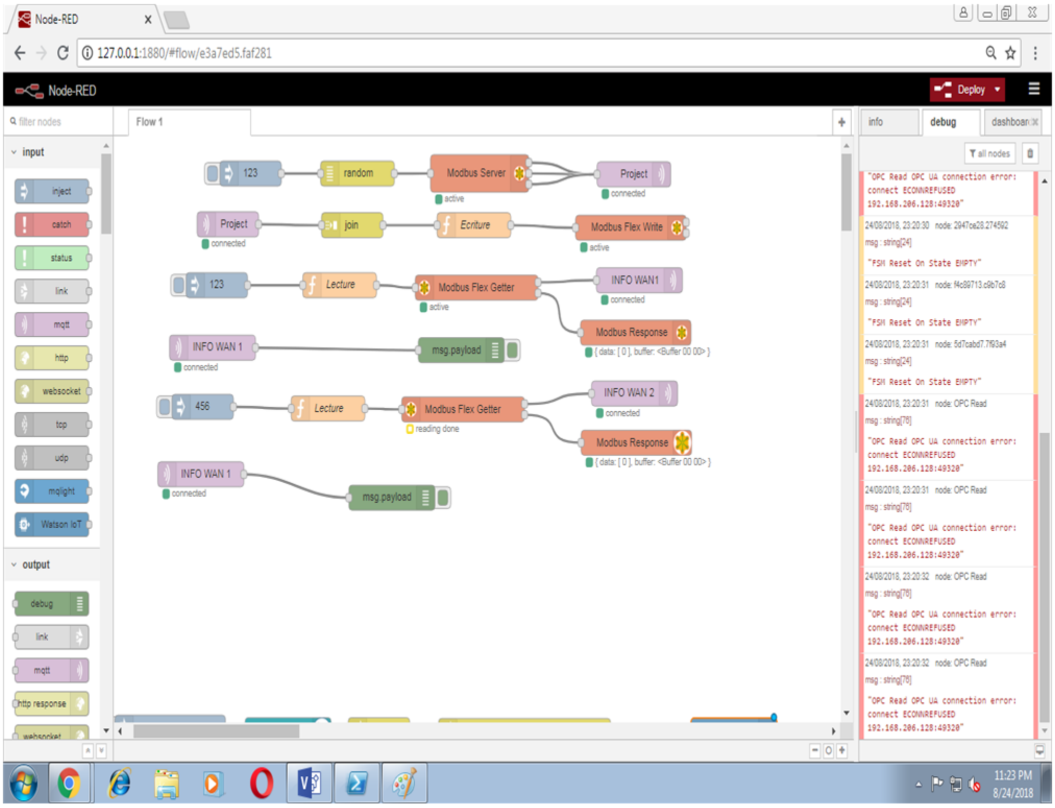


Figure 6.3.2 Implementation of Previous work [2]

So they concluded that the smart factories do not requires cable for getting sensor or actuators connected with control system rather wireless sensor networks in industrial environments is undoubtedly beneficial to the development of automation technologies [2]

In this paper Modbus server node have been used. I implemented the work using node red as shown in the figure 5.4. This paper did not shows the real time implementation of Modbus. So its implementation is only for simulation purpose. There is no practical implementation as Modbus flex node cannot be active without Modbus Server node which was not present in the paper.

6.4 SCADA System for Water Treatment Plant

In water treatment plants automation and SCADA system are very essential these days and its implementation for controlling the whole water treatment process. The complexity in automation and SCADA system is actually faced in water and waste water treatment plant. Since PLCs and communication networks, SCADA servers with standby nodes are the basic requirements of plants, therefore these plants contain functional OPC UA Servers for instance IGSS/Ignition/WinCC, etc at level 2. In this way these systems are integrated with higher level monitoring and control structures. In some cases, the OPC DA Servers are installed with SCADA software. [8]

In PLCs and HMIs or other industrial devices lacks the universal interface which forces the industries top either completely changes the existing systems or use installed system vendor for new installation.

Korodi and his co-workers discussed the case study of water treatment plant in which they found problems faced by not having a universal interface. In water treatment plant there are multiple areas such as water sources for instance wells/water-pumping and chlorination stations and reservoirs, water quality measuring points, waste-water-pumping station are not connected with universal interface that is why all areas of water treatment plant faces the interfacing problem. Some of the devices or PLCs are interfaced via proprietary protocols. However, some are integrated via OPC/OPC UA servers configured on the upper level SCADA system. [8]

Korodi and his team highlighted the issue faced by water industry. In system up gradation, the local SCADA system did not support the latest technologically advanced SCADA system. Therefore, OPC UA Server was installed that ultimately integrated old SCADA system with new one. The OPC UA is necessary for water industry not only because it is installed locally but it also has the capacity to integrate old SCADA system. Moreover its wrapping structures are essential for functional developments. [8]

So Korodi used Raspberry Pi and Node Red software as a middleware to implement UA Node which is low-budget OPC UA. This setup was built to provide inter-operability of local automation system. The UA Node Wrap connects local structure as well as variables that exist in middleware application in order to access variable tag in local OPC.[8]

Finally, Korodi and his colleagues concluded it is inexpensive data monitoring and control with web accessible interface. It can also be used as local historian when it is associated with the database.[8]

The research gap in Korodi and his team was that they worked on Node Red software and use OPC UA nodes while in our work we not only integrated KEPServer with Node Red but also send data from Node Red to IBM Watson IOT Platform.

6.5 PLC and MATLAB/SIMULINK Integration

In this paper Nayak and his team worked on a control strategy which is based on industrial boiler three element control which gives accurate Drum level control. Micrologic 1400 PLC was used and the simulation of drum level loop control has been don using SIMULINK. The OPC is also used in this paper for communication between PLC and MATLAB/SIMULINK [9]

In this paper OPC which is KEPServer EX has been used for communication medium between PLC and MATLAB. So Nayak and his team successfully implemented Boiler Drum level control and simulated the important PID loop.

The study gap in this paper is that Nayak and his team worked on level 2 of industrial Network hierarchy while this research thesis start from Level 1 and go through level 2 and level 3 and finally ends at level 4 which is ERP level. In simple the availability of plants floor data at ERP level.

Chapter 7

7 Proposed Architecture and Implementation

7.1 Introduction

The domain of Industrial Internet of Things is an active research area and lot of research papers have been done but there are some of drawback in previous research work. The major one is that unified architecture for different legacy industrial control system, another one is that the availability of plant floor data is high so to overcome all these limitations, the architecture is proposed for industries in which existing PLCs of different vendors in the plant are connected to OPC UA Server. So new installation of system are not being required. So we consider a plant with number of PLCs and single loop controller. We assumed that communication protocol of all PLCs and SLCs is TCP/IP.

As the plant or industrial data is very important for maintenance, efficiency and optimization that is why plant data should be accessible irrespective of location and time. This thesis proposed a solution for high availability of plant‘s data.

7.2 Experimental Setup

In order to practically realize our research concept, we install a Siemens PLC on a test bed available in the PNEC embedded system research lab, PLCs was programed using TIA portal 2013. We install KepServer version 6.0 and the node red on the system provided in the lab.

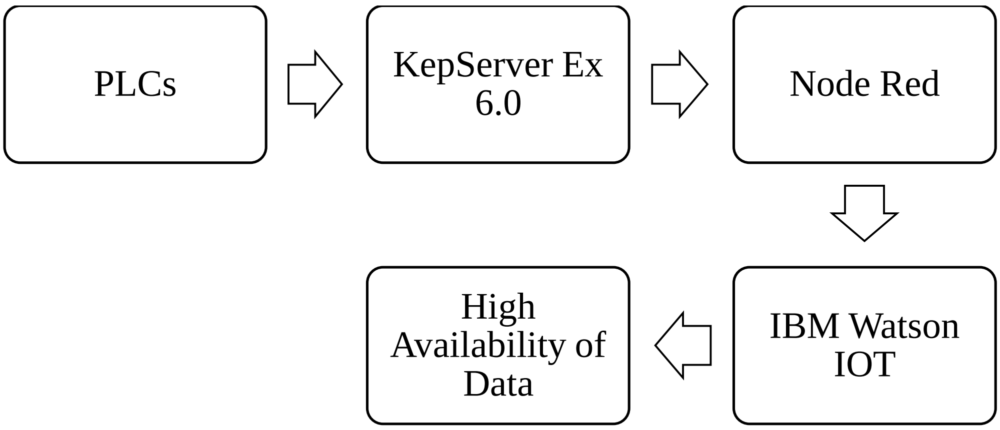


Figure 7.2.1 Block Diagram of Experimental Setup

In figure 7.2.1, the high availability of data is achieved by sending data to KepServer EX. The data is available on the KepServer, from this server, the data can be send to SAP, Cloud. In this thesis we send data to node red which light middleware. There are number of ways to show data. Dashboard of Node Red can be used to show data on local server with interactive displays. These displays can be remotely accessed but for analytic, we are using IBM Watson Platform in which number of tools are available for data analytics for plant operational improvement.

7.3 System Architecture

In this thesis, we consider a plant with different vendors PLCs/DCS installed on numbers of Server machines. A Server is developed which gather data from various PLCs/DCS and instruments. We consider that the PLCs/ DCS and instruments having Modbus TCP/IP communication protocol which is most commonly used in the industry for connecting devices.

Furthermore, main server machine is connected to the secure internet via firewall. We use IBM Watson IOT Platform for securely monitor data and use this data for plant maintenance and improvement purpose.

.In this thesis, we created a test bed for having real time PLCs data. A virtual machine have been created with windows 7 as operating system. The requirements of KEPServer EX version 6 have been provided to the virtual machine.

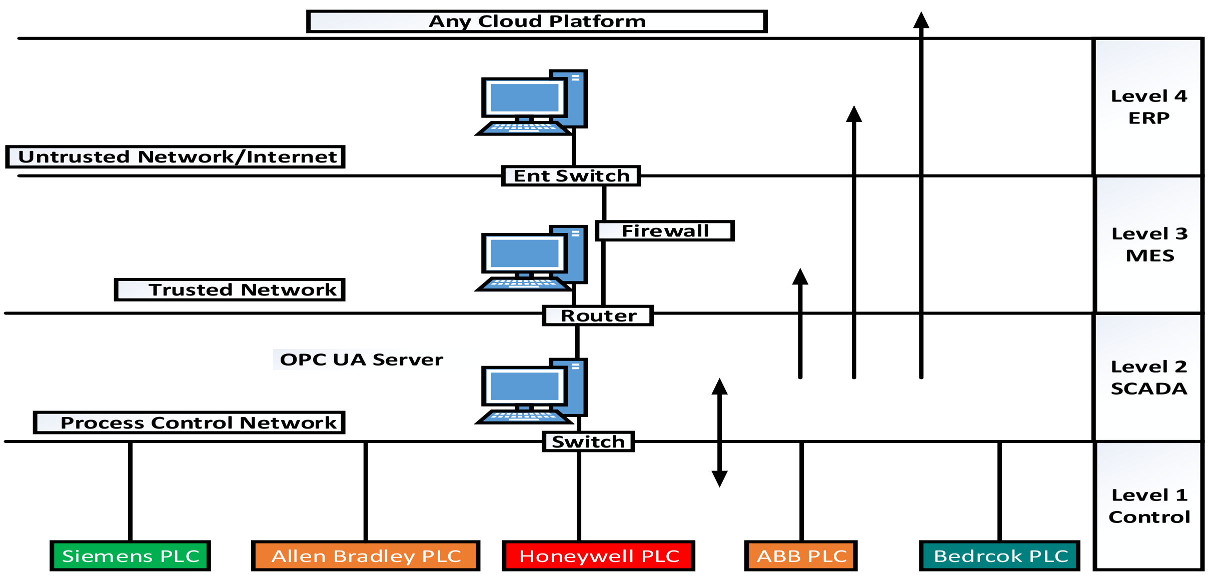


Figure 7.3.1 Proposed Network Architecture

7.4 Implementation Flow Chart

The implementation of proposed architecture has been done in PNEC embedded system Research Lab as Siemens PLC S7 1200 and software TIA Portal 14 were provided. VMware was used to implement the test bed. Virtual Machine with windows 7 as operating system was used.

The KEPServer was installed in Virtual machine. This virtual machine and PLC are connected through a switch so both are on same network (LAN) To extends this network number of PLCs of different vendors are connected through the same switch. Since due to test bed, secure internet connection was provided so firewall was not required for simulation purpose.

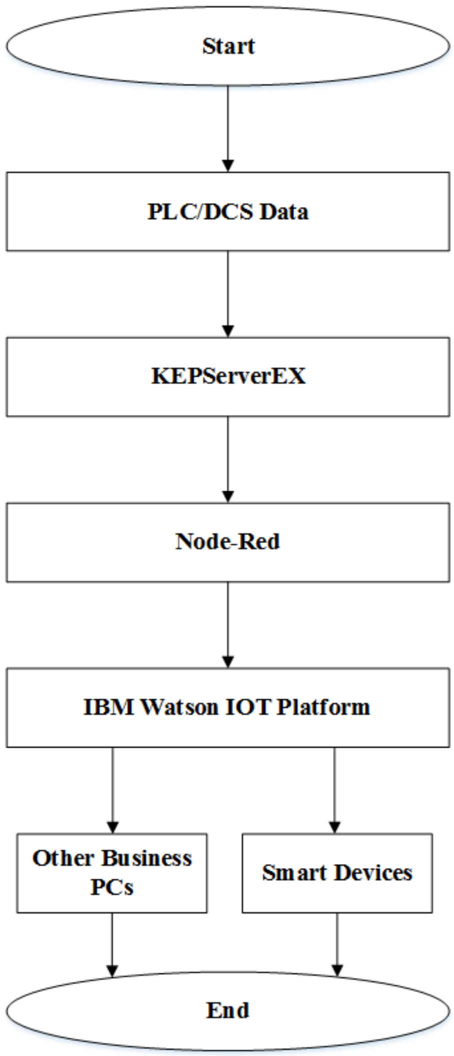


Figure 7.4.1 Data Transfer Flow Chart

7.5 PLC Programing and Simulation

We used Siemens TIA portal 15 to program PLC. As the PLCSIM is available on TIA portal 15 which allows comprehensive simulation of functions during configuration and engineering. Since there is no hardware required to simulate the program so we developed our program. PLCSIM support virtual controllers for to test the function.

The realistic testing procedures of the STEP 7 TIA Portal option allow early fault detection as well as fast validation of functions.

The testing of program is very realistic which allows early fault detection and validation fo functions. It the interactive user interface can be developed using Win CC and through user interface operator can be trained. The figure 8.5.1

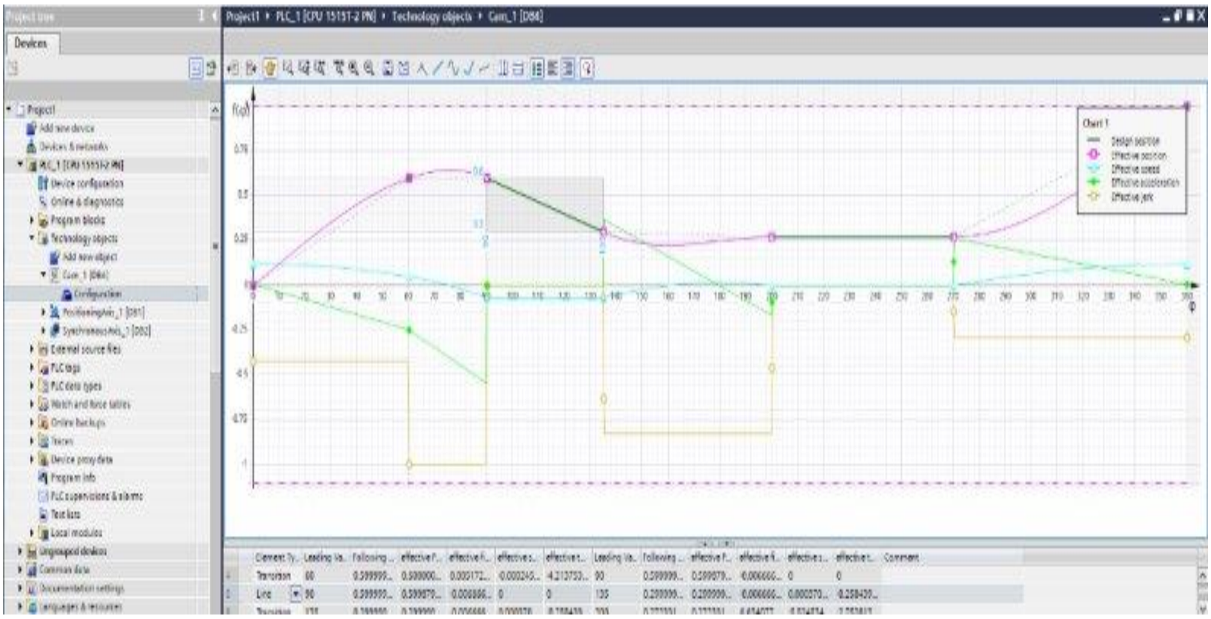


Figure 7.5.1 Simulation on PLCSIM [20]

7.5.1 Functions and Benefits of PLCSIM

- It reduces the commissioning time
- The time to production becomes shorter
- It allows high quality of automation projects
- It is fast and compact mode without a simulation project
- In simulation devices can be exchanged, so that SIM sequences, table can easily be utilized
- Sequences can be started automatically based on a trigger condition
- Sequences can be temporarily disabled
- Distributed IO devices can be simulated in the device view

7.5.2 Why PLCSIM for OPC UA

There are number of reason for selecting Siemens TIA portal 15. The PLCSIM simulates and validates S7-1500 with other option which includes:

- Webserver,
- OPC UA
- Traces
- Motion
- Memory card simulation
- Process diagnostics
- S7-Communication

7.6 PLC Program and Simulation

The PLC program was developed for analog inputs only. There are four process variables Level, Temperature, Fan Speed or RPM and Pressures. Since these process variable are analog inputs.

7.7 Memory Addressing

The data is stored in different locations which depends on the type of the data. For example, there are separate locations for input, output, Data Blocks etc. The Siemens PLC Data Addressing Format is basically a string which defines the location of data in a Siemens PLC and consist of device type letters followed by one or two decimal numbers.

Device Type	**Format**
Input	Innnn
Output	Qnnnn
Flags	Mnnnn
V Memory	Vnnnn
Data Block	DBbb.nnnn

Table 7.7.1 Siemens PLC Data Addressing Format

The one byte is the combination of eight bits so two bytes is the combination of 16 bits. The address I0.0 means input single bit address. So the address are I0.0 to I0.7, I1.0 to I1.7 etc. The IW0 is the two bytes input variable which is called word. There is a formula of using word type of input which is IW(n+2). Similarly, ID0 is the double word input variable and its formulae is ID(n+4).

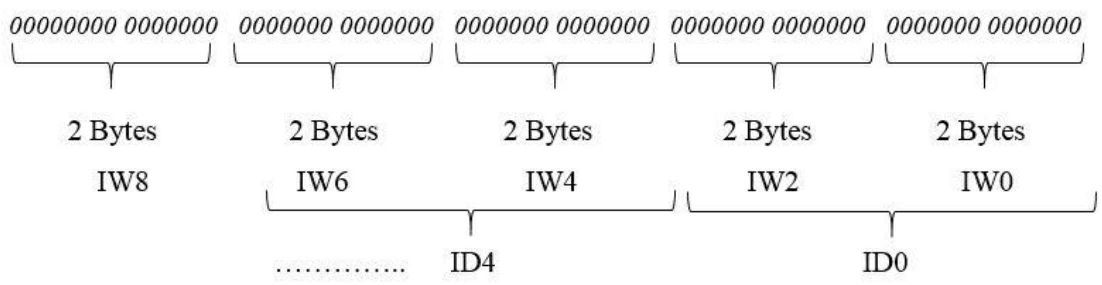


Figure 7.7.1 Data Types

7.8 Analog Signal Standard

In industries, there is a standard of analog signal which is 4 to 20 mAmp of the current signal. The standard analog signal in PLC is taking 16 bit resolution which 2^0 -1 to 2^{15} -1 which equivalent to 32767.

System	Current Measuring Range	
32767	22.96 mA	Overflow
32512		
32511	22.81 mA	Over Range
27649		
27648	20 mA	Rated Range
20736	16 mA	
1	4 mA + 578.7 nA	
0	4 mA	
-1	1.185 mA	Under Range
-4864		Underflow
-32768		

Table 7.8.1 Analog Signal Representation

The table show the range of analog signal is 0 to 27648 and this value is actually a raw value. The conversion of raw value into engineering value is called Scaling. The Engineering value is the actual value of process variables for example, in industry the level is measured in terms of percentage which is 0% to 100%. Similarly, Pressure is measured mostly in bar or some time mmHg. Temperature is measured in terms of Temperature is measured in terms of °C. The speed of fan or pump speed is measured in RPM.

7.8.1 Norm X Block

It is use to normalize the value of the tag at the VALUE input by mapping it to a linear scale. The minimum and maximum parameters are required to define the limits of a value range which is required to scale. The result at the OUT is calculated and stored as a floating point number which depends on the location of the value to be normalized is to the value at input MAX, output OUT returns the value "1.0" [21]

7.8.2 Scaling Analog Values

In PLC software there is block available for scaling of the analog signal and this block name is SCALE block in Siemens PLC. The SCALE block basically use the equation of a straight line which $y = mx + c$

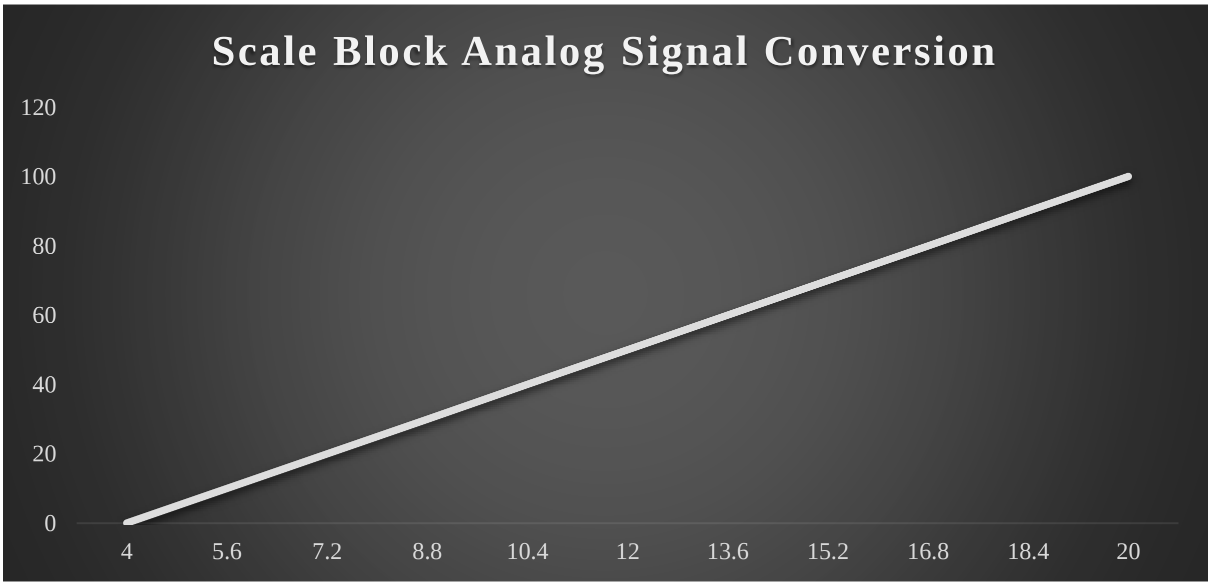


Figure 7.8.1 Scale Block Function

The development of the program is by considering of the plant requires level indication of tank, Speed of Fan, temperature of water in the tank and the pressure of the tank. These parameters can be accessed from any remote location and at any time.

These parameters are analog so NORM_X and scale_X block are used for indication of level, pressure, temperature and speed of the fan. Therefore four networks are built with these two blocks

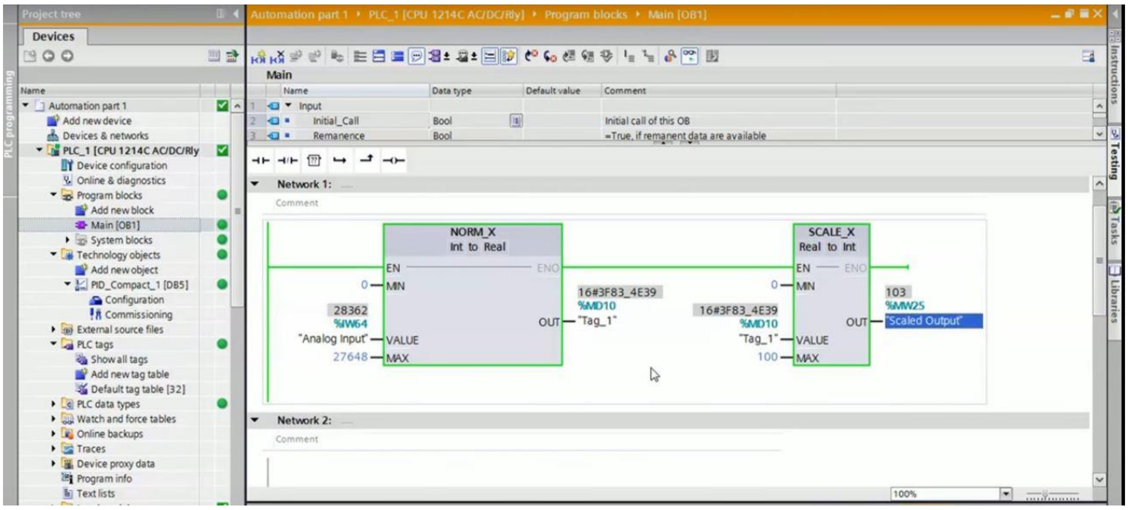


Figure 7.8.2 Analog Signal Simulation

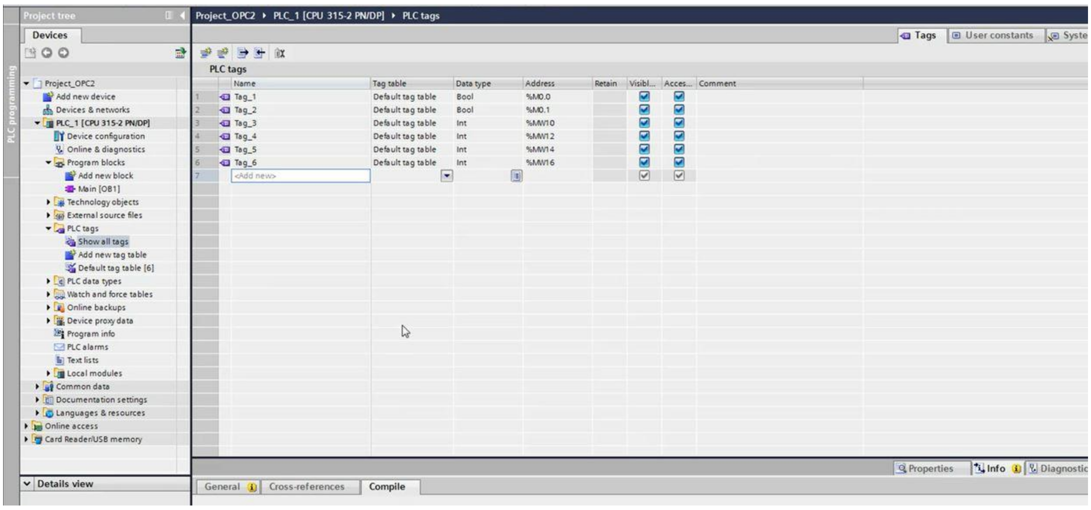


Figure 7.8.3 Tag list of program for simulation

In figure 8.6.4, the Tag_1 (Bool), Tag_2 (Bool), Tag_3 (Int), Tag_4 (Int), Tag_5 (Int), Tag_6 (Int) name of points or parameters with addresses M0.0, M0.1, MW10, MW12, MW14, MW16.

7.8.3 NetToPLCsim

It allows the system to access the simulated PLC from the network through TCP/IP (Iso-On-TCP) communication, using the network interface of the PC on which simulation is running. So we installed it as we need to access the data.

7.9 KEPServerEX for Siemens PLC

PTC provide Siemens Suite for KepServerEx. It is a package of Siemens device-drivers. It supports common network protocols of Siemens that provides a simple and high available way to connect Siemens-Ethernet and Serial-based PLCs/devices to client applications which includes HMI-SCADA, MES-Historian, ERP, IoT and custom OPC client applications. This suite is designed to aid in manufacturing industry/factory.

7.9.1 Siemens Drivers

The Siemens Suite of Kepserver Ex provide the following number of siemens drivers which are as follows

- Siemens TCP/IP Ethernet
- Siemens TCP/IP Unsolicited Ethernet
- Siemens S5 AS511
- Siemens S5 3964R
- Siemens S7 MPI
- Siemens S7-200

7.9.2 Siemens Devices

The devices which can be connected using Siemens Suite of KEPServerEX are as under:

- Siemens S7-200, S7-300, S7-400, S7-1200, and S7-1500
- Siemens S5

In order to solve the problem faced by the industries, Siemens S7-1500 PLC is used to simulate the results. As S7-1500 PLC is having TCP/IP communication medium, so Siemens TCP/IP Ethernet Driver is used from Siemens Suite.

7.9.3 Siemens TCP/IP Ethernet Driver

It is highly available way to connect devices. The HMI, SCADA, Historian, MES, ERP and other application can be connected using this Siemens Suite. There are two ways of communication.

7.9.3.1 Industrial Ethernet TCP/IP Interface communication processor (CP).

It is designed for S7 messaging on industrial Ethernet over TCP/IP as defined in RFC 1006.

7.9.3.2 Hilscher's NetLink Adapter

This adapter requires an MPI port only. This adapter is not compatible with the S7-200 model. There is requirement of special hardware and software. The only requirement is Ethernet card which be easily available.

7.9.4 Channel Properties

As the KepserverEX with Siemens Suit support multiple communication drivers to collect data from number of devices simultaneously. A channel is defined as a protocol or drivers which is used in a server under project. There are many channels in a projects with same or different communication drivers. The basic building block of OPC link is known as channel.[22]

There are four important channel properties which are discussed below.

- General
- Ethernet or Serial Communications
- Write Optimization
- Advanced

7.10 Siemens TCP/IP Ethernet based Channel Addition

There are number of channels available in the KepserverEX that's means channel available for different vendor devices establishes the communication. In this thesis, the Siemens PLC was added into KepServerEx by selecting a Siemens TCP/IP Ethernet channel.

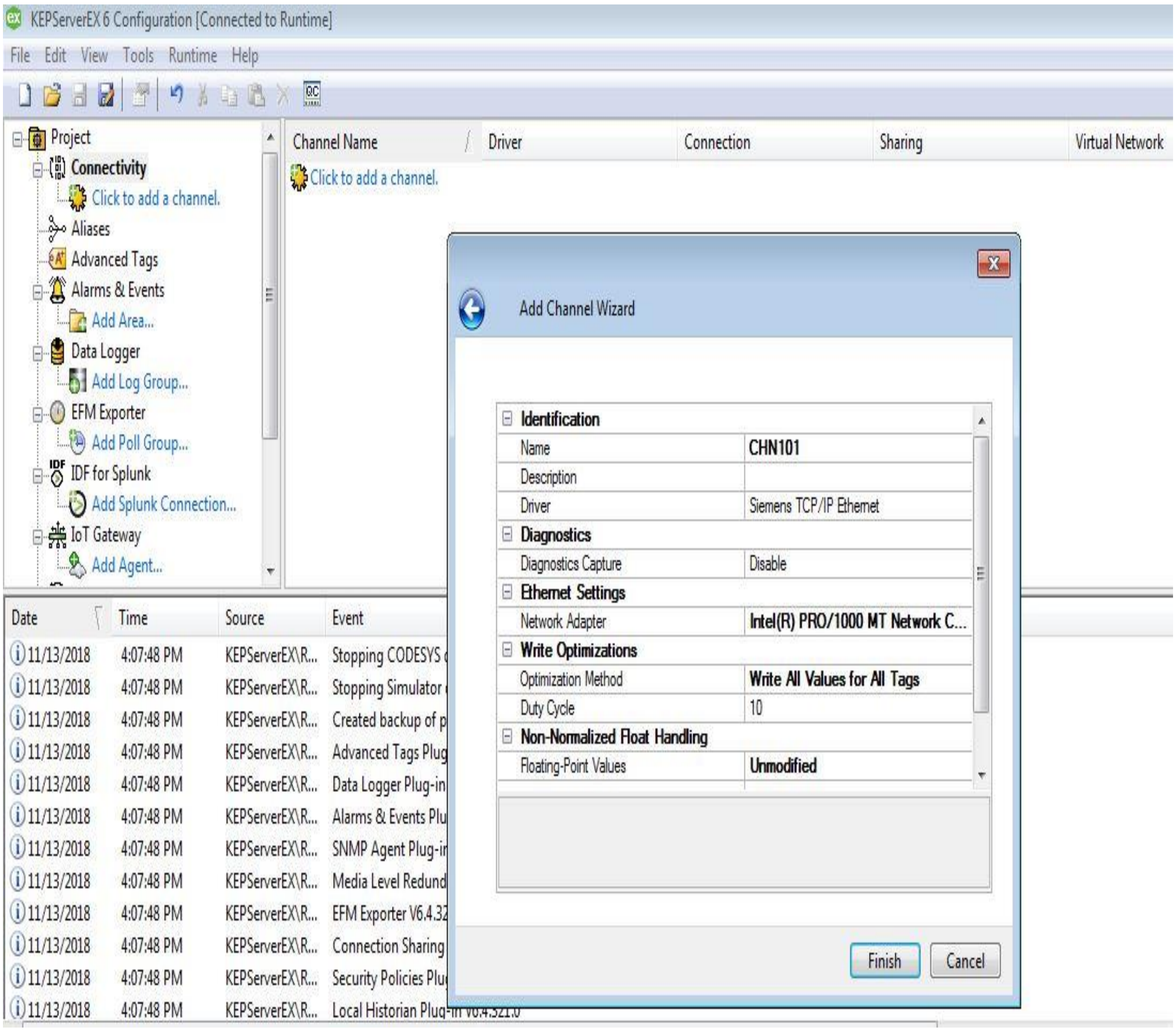


Figure 7.10.1 Siemens TCP/IP Ethernet Channel

7.11 Siemens Device Addition

Since the channel has been added into the server, the next thing to do is to add PLCs. There are number of Siemens PLC option are available so S7-1500 PLC was added which is shown below:

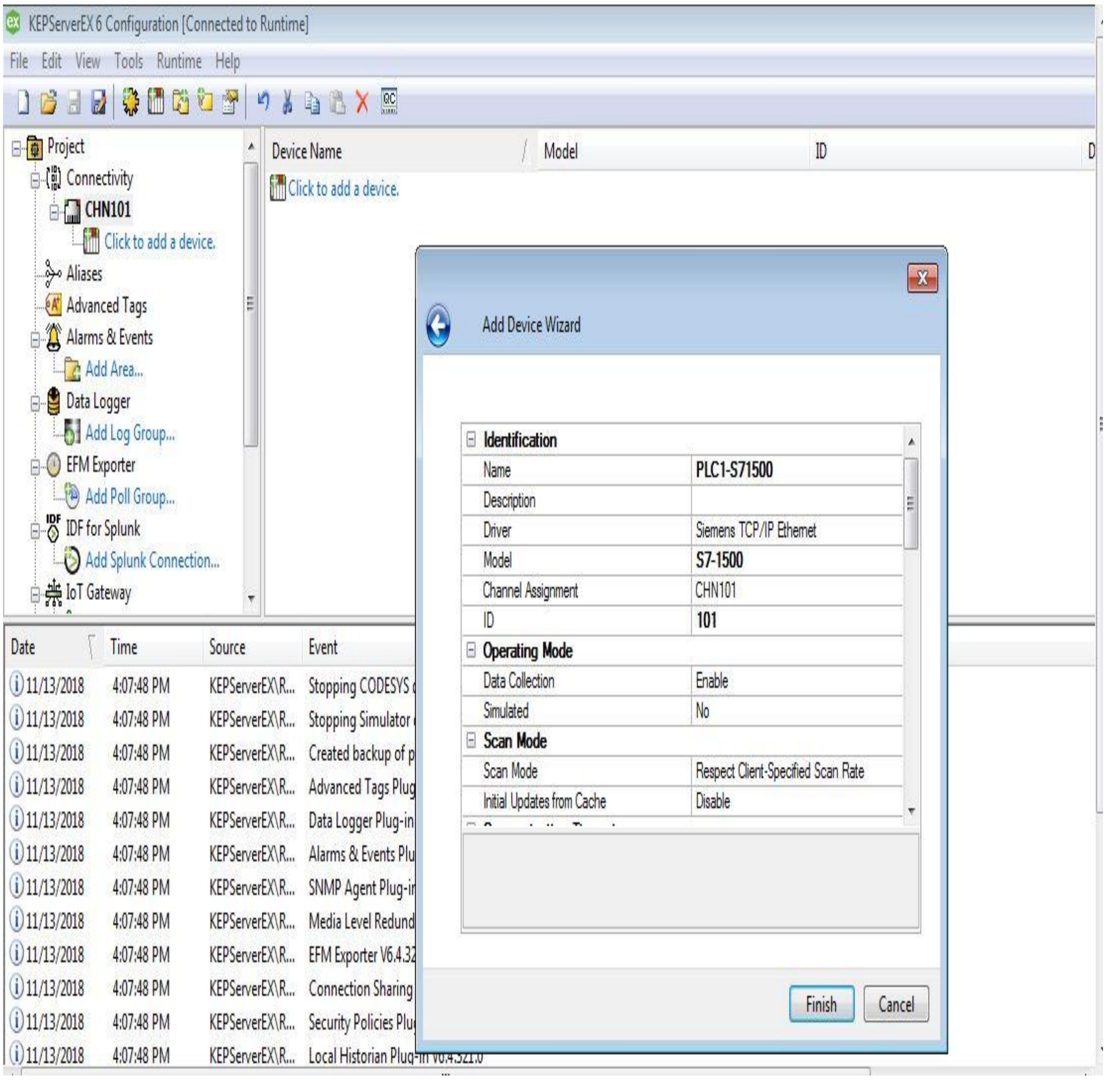


Table 7.11.1 Siemens S7-1500 PLC

7.12 Node Red

The Node red was installed into same virtual machine in which kepserver was installed. The Node Red is used as a middle ware for connecting KepServerEX with IBM Watson. After installation, local host with IP address 127.0.0.1 and port 1880 was used to browse the Node Red programming Platform. Some of the required node was installed as existing environment did not contain nodes which are required in this thesis.

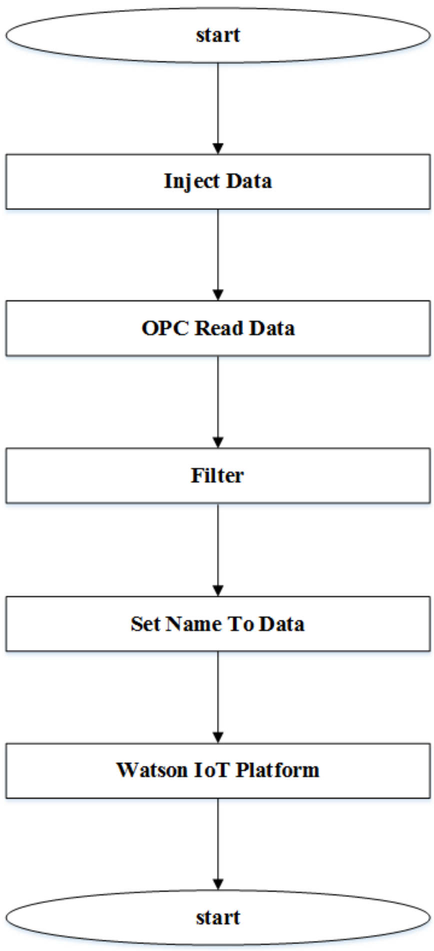


Table 7.12.1 Node Red Programming Flow Chart

7.12.1 Node Red Programed Implementation

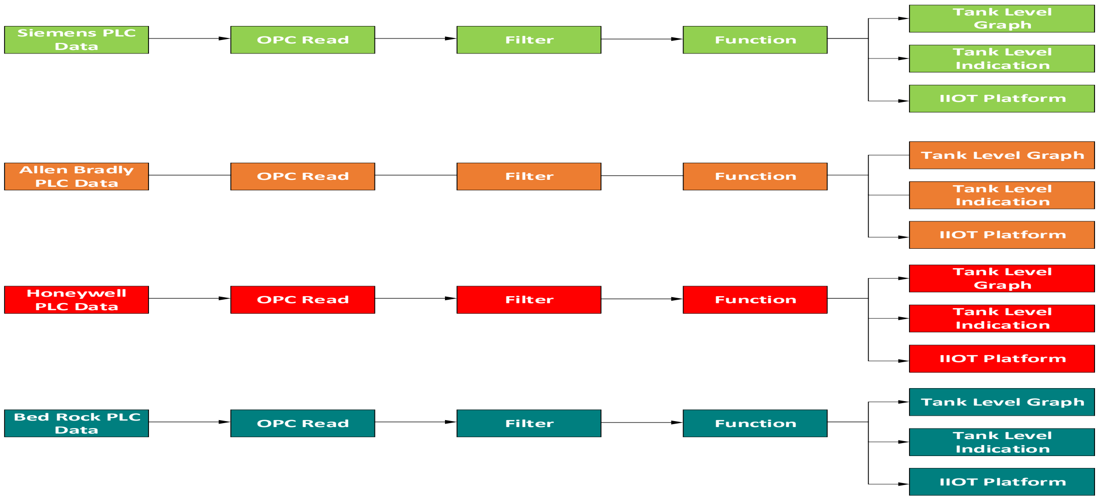


Figure 7.12.1 Node Red program

7.12.2Inject Data Node

Injects a message into a flow either manually or at regular intervals. The message can be a variety of types, including strings, JavaScript objects or the current time. In this node, Temperature, Level, Pressure and Speed are set which is the input node for OPC Client node.

The configurations of the parameter is that it set the payload to timestamp for all parameters. The temperature topic is ns 2; s= painting.oven.temperature; datatype= Float, pressure topic is ns 2; s= painting.oven.pressure; datatype= Float, Level topic is ns 2; s= painting.tank.Level; datatype= Float and finally Speed of fan topic is ns 2; s= painting.Fan.speed; datatype= Float. In this way inject node is configured and this node's output is the input of OPC UA Client node.

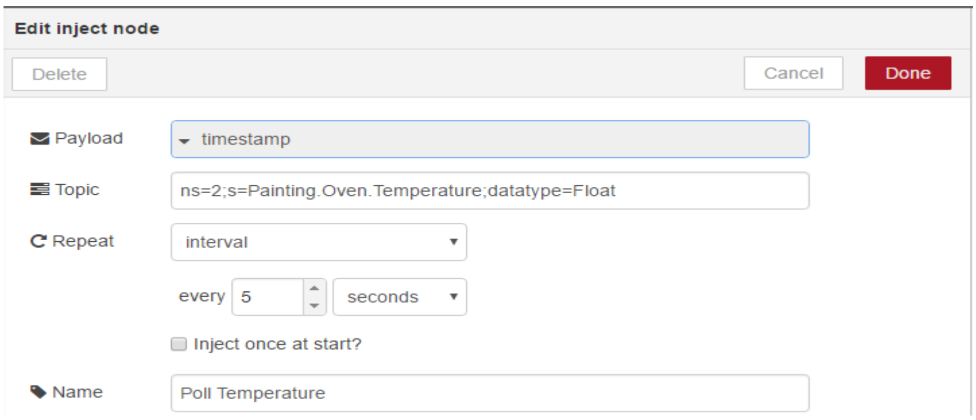


Table 7.12.2 Inject Node Configuration

7.12.3 OPC Read Data Node

OPC UA is not already installed in node red so it is installed by using the command node-red-contrib-opcua. The OPC UA Client node is used. The input of this node is inject nodes which are configured for level, temperature, speed and pressure. The configuration of OPC UA Client node is that End point is set to opc.tcp://127.0.0.1:49320/KEPServerEX and the Action is Read and OPC Name is set to OPC Read. The OPC UA end point node configuration is that the End Point is set to opc.tcp://127.0.0.1:49320/KEPServerEX and Sign is set to none.

7.12.4 Filter Node

It route the messages which are based on their property value or sequence position. When the node gets a message it will be evaluated as per defined rule and optionally, the node can be set to stop evaluating rules once it finds one that matches. The rules can be evaluated against an individual message property, a flow or global context property or the result of a JSON expression. Since OPC sends some null messages to they are ignored by using filtered node

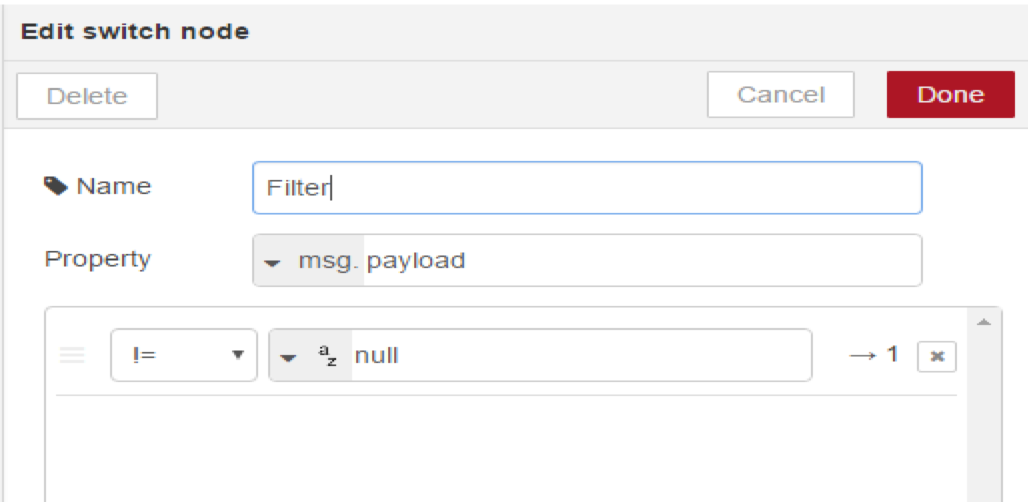


Table 7.12.4 Filter Node Setting

7.12.5 Set Name to Data Node

This node function has the following actions on the message properties

- Set
- Change
- Delete
- move

7.12.6 Node Red Program

Send device events to the IBM Watson Internet of Things Platform. The node can connect as either a Device or Gateway, in registered mode or using the Quickstart service. When connecting using the Quickstart service, the connection will use a device type of node-red-wiotp and a randomly generated device id, which can be configured in the node. The events from the node can then be viewed on the Quickstart dashboard. The type of the event sent can be configured in the node or, if left blank, can be set by the msg.event property. If using the Quickstart service, the event type must be set to event for the data to be seen on the Quickstart dashboard.

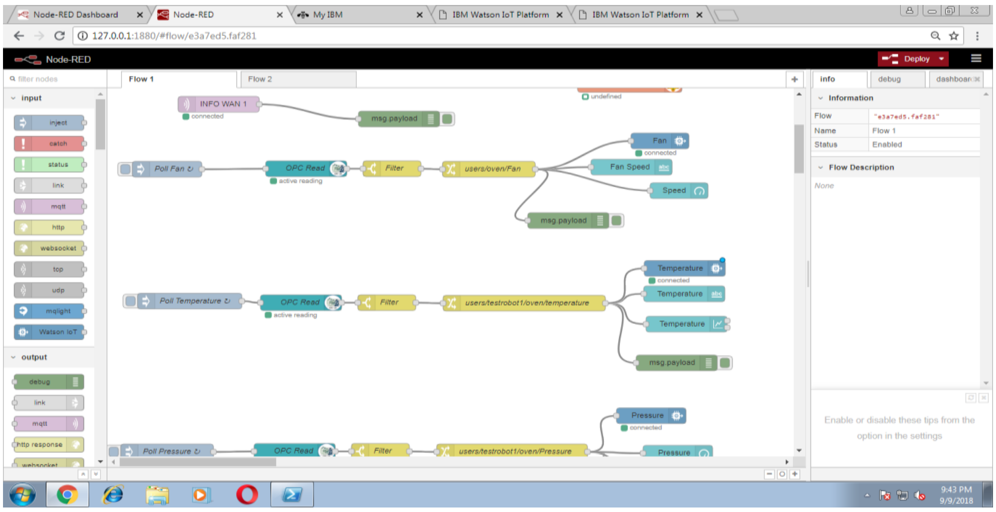


Table 7.12.6 Implementation on Node Red

7.12.7 IIOT Platform

The address on Watson IoT node used to connect IBM Watson Platform. Using the quick start of this platform, put the device address on Go bar. In this way the real time monitoring of data is achieved.

Chapter 8

8 Results

All the result are on real time based. A web link of IBM Watson platform is provided through which all data can be monitored from any location at any time. The result are obtained using from remote Personal computer and smart devices. The results includes sensor data for monitoring.

8.1 Kepware Integration with Siemens PLC

The tags which we downloaded on PLCSIM are shown on the kepServer.

The figure 9.1 shows the data from PLCSIM

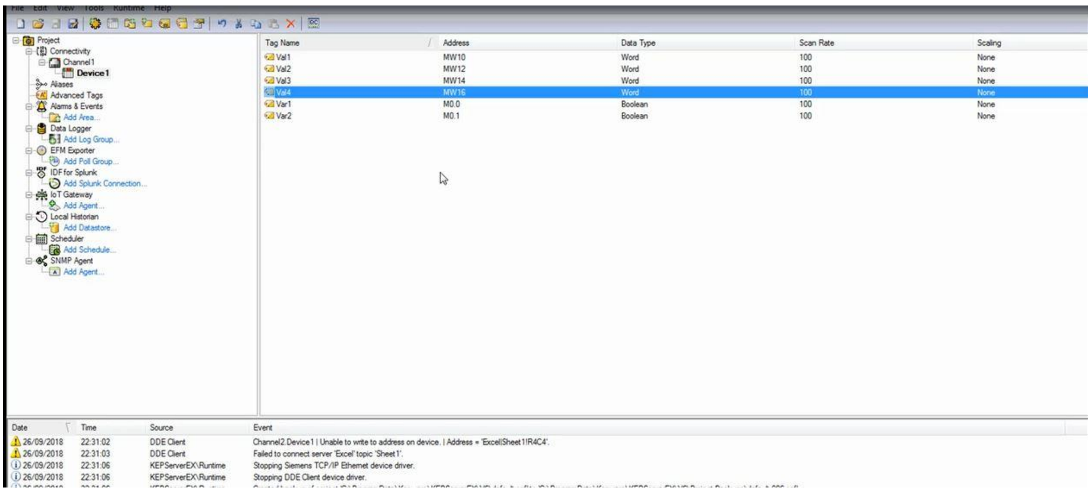
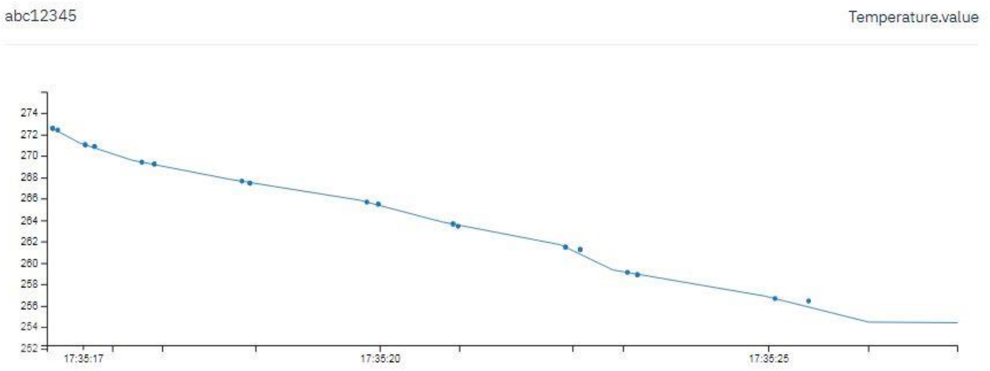


Figure 8.1.1 Data on KepServer

8.2 Graphs and Numerical Display on PC

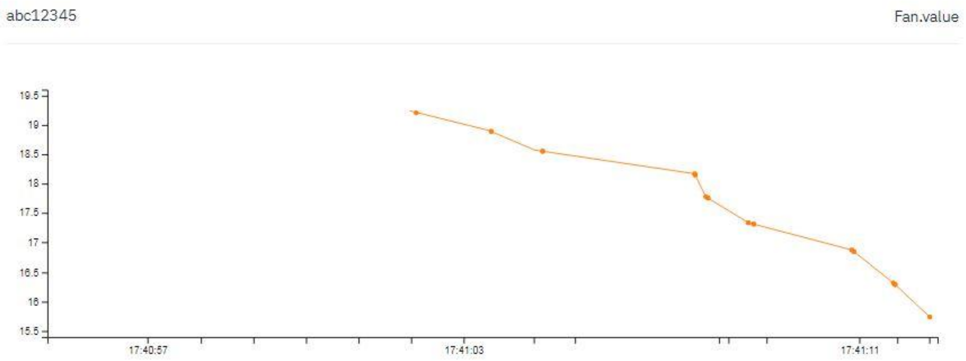
In this graph abc12345 is the connection ID in the node red. The graph and current value of temperature, Fan Speed, Pressure and Level Indications from Siemens PLC or PLCSIM with Tag_3, Tag_4, Tag_5, and Tag_6 respectively are shown below:



Event	Datapoint	Value	Time Received
Temperature	value	253.8446807861328	Aug 25, 2018 5:35:29 PM

Figure 8.2.1 Temperature real time graphical and numerical display

This is a graph and current value of Fan Speed indication which is again an analog input with PLC tag MW12.The Temperature current values is also shown below the graph.



Event	Datapoint	Value	Time Received
Temperature	value	218.92034912109375	Aug 25, 2018 5:41:13 PM
Fan	value	15.736679077148438	Aug 25, 2018 5:41:12 PM

Figure 8.2.2 Fan Speed graphical and Numerical Display

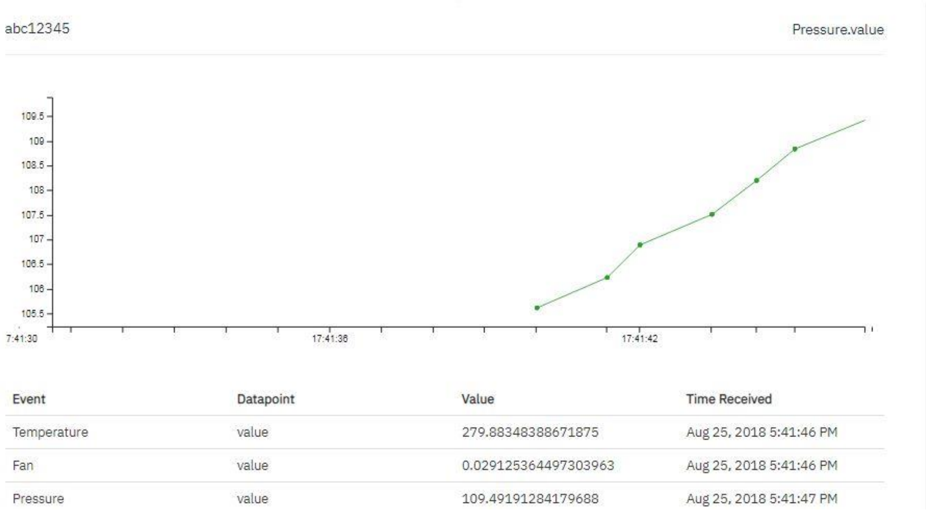


Figure 8.2.3 Pressure Indication Graphical and Numerical View

8.3 Smart Device Data Monitoring

The graphical and numerical values of temperature and Fan speed is monitored on smart devices irrespective of time and location.

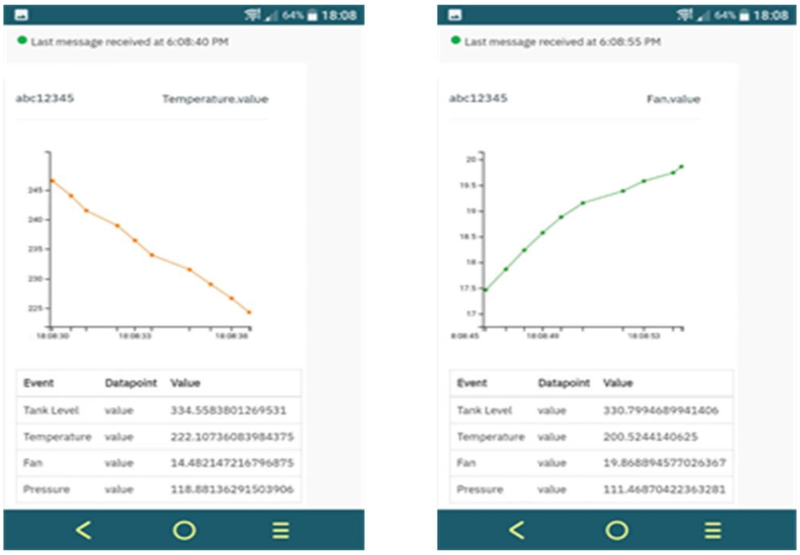


Figure 9.3.8.3.1 Graph and Numerical Displays obtained on Smart devices

The graphs show the speed of fan and temperature which comes from sensors through a PLC with the tag name Tag_3 and Tag_4. Similarly, the Tag_5 and Tag_6 represents Pressure and Level in the PLC which are monitored on smart device from any remote location and at any time.

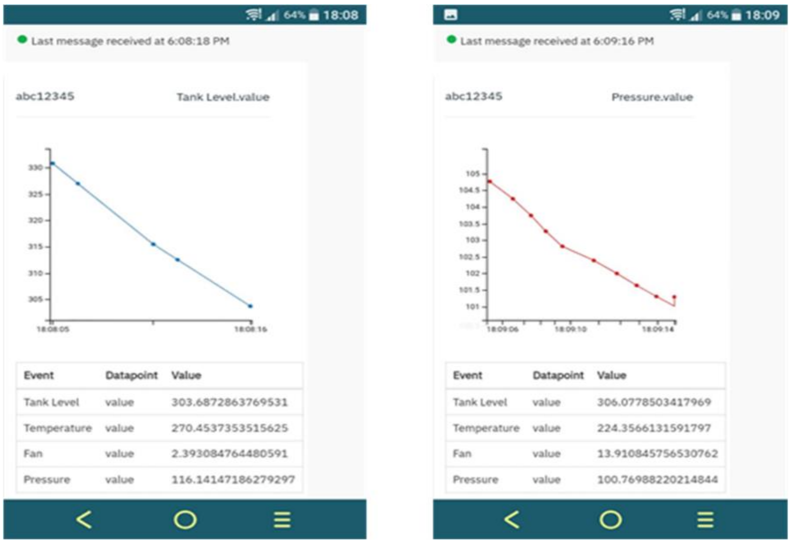


Figure 8.3.2 Graphical and Numerical Display on Smart Phone

8.4 Comparison with Previous Work

Previous Work	**Flaws**	**Merits**
Tabaa, M., et al., *Industrial Communication based on Modbus and Node-RED.* Procedia Computer Science, 2018. 130: p. 583-588.	Master and Slave Architecture Modbus Devices Only	Server and Client Modbus devices and the instruments
Scalability of OPC-UA down to the chip level enables "Internet of Things" 2013 Industrial Informatics (INDIN), 2013 11th IEEE International Conference on Industry 4.0	Feasible for vertical communication	Both vertical and horizontal communication
Evaluation of communication latency in Industrial IoT applications Measurement and Networking (M&N), 2017 IEEE International Workshop on	Low latency rate	High latency rate due to IIOT platform

Table 8.4.1 comparison with Previous Work

8.5 Achievements

According to the results when industry 4.0 is compared with conventional industrial systems the following points were withdrawn

Conventional System	Industry 4.0 System
License dependent for horizontal communication with different vendors	License independent for horizontal communication with different vendors
Plant data remains on plant floor Server storage media	Plant data can be on Cloud Storage devices
Remote access is not allowed as servers are not connected with internet	As systems are connected with internet, remote access is allowed
Normal password protection	Highly secure and password protected
High Operational cost	Low operational cost
High Maintenance cost	Low Maintenance cost
No Preventive maintenance possible	Preventive maintenance is possible

Figure 8.5.1 Comparison between Conventional system and Industry 4.0 system

8.6 Conclusion & Future Work

The results as shown in previous chapter are the utilization of Industry 4.0 concept which is plant data could not be restricted to plant floor. The data can be accessible from anywhere and at any time. There should be firewall at level 3 of Industrial Automation Network to secure the industrial Automation Network. The fault in the plant for instance pump needs maintenance so an email notification and SMS to the concern person will be generated. Furthermore, we use Node-RED for sending between KepServerEX and IBM Watson IOT Platform. The KepServer EX can directly integrated with INM Watson IOT Platform.

References

1. Force, O.T., *OPC overview.* OPC Foundation, 1998: p. 3.
2. Tabaa, M., et al., *Industrial Communication based on Modbus and Node-RED.* Procedia Computer Science, 2018. 130: p. 583-588.
3. Marcelo V. García, E.I.a.F.P., *Plant Floor Communications Integration*, in *2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA)*. 2016, IEEE: Berlin, Germany.
4. A. Daneels, C., Geneva, Switzerland and C. W.Salter, Geneva, Switzerland, *What is SCADA?*, in *International Conference on Accelerator and Large Experimental Physics Control Systems,*. 1999: Trieste, Italy.
5. Hannelius, T., M. Salmenpera, and S. Kuikka. *Roadmap to adopting OPC UA*. in *Industrial Informatics, 2008. INDIN 2008. 6th IEEE International Conference on*. 2008. IEEE.
6. Son, M. and M.-J. Yi. *A study on OPC specifications: Perspective and challenges*. in *Strategic Technology (IFOST), 2010 International Forum on*. 2010. IEEE.
7. Imtiaz, J. and J. Jasperneite. *Scalability of OPC-UA down to the chip level enables "Internet of Things"*. in *Industrial Informatics (INDIN), 2013 11th IEEE International Conference on*. 2013. IEEE.
8. Adrian Korodi, I.S., *Achieving interoperability using low-cost middleware OPC UA Warping Structure. Case study in Water Industry.* , in *2017 IEEE 15th International Conference on Industrial Informatics (INDIN)*. 2017, IEEE: Emden, Germany. p. 6.
9. Nayak, S. and S. Agashe, *Three Element Drum Level Control using MATLAB/Simulink and OPC.* 2017 2nd International Conference for Convergence in Technology (I2CT). 1: p. 3.
10. Rüßmann, M., et al., *Industry 4.0: The future of productivity and growth in manufacturing industries.* Boston Consulting Group, 2015. 9.
11. Drath, R. and A. Horch, *Industrie 4.0: Hit or hype?[industry forum]*. IEEE industrial electronics magazine, 2014. 8(2): p. 56-58.
12. Lukas, H.K.W.-D., *Industry 4.0 With the Internet of Things on the way to the 4th industrial revolution.pdf.* 2011(13): p. 2.
13. Weyer, S., et al., *Towards Industry 4.0-Standardization as the crucial challenge for highly modular, multi-vendor production systems.* Ifac-Papersonline, 2015. 48(3): p. 579-584.
14. Al-Rubaye, S., et al., *Industrial Internet of Things Driven by SDN Platform for Smart Grid Resiliency.* IEEE Internet of Things Journal, 2017: p. 1-1.
15. Zakir, J., T. Seymour, and K. Berg, *BIG DATA ANALYTICS.* Issues in Information Systems, 2015. 16(2).
16. Bakken, D., *Middleware.* Encyclopedia of Distributed Computing, 2001. 11.
17. www.noderedguide.com, *http://noderedguide.com/nr-lecture-1/*.
18. https://www.automationworld.com/article/topics/industrial-internet-things/node-red-stitches-iiot-together, *Node-RED Stitches the IIoT Together.*
19. Gavlas, A., J. Zwierzyna, and J. Koziorek, *Possibilities of transfer process data from PLC to Cloud platforms based on IoT.* IFAC-PapersOnLine, 2018. 51(6): p. 156-161.
20. Siemens, *https://w3.siemens.com/mcms/automation-software/en/tia-portal-software/step7-tia-portal/simatic-step7-options/s7-plcsim-advanced/pages/default.aspx*.
21. Siemens, *Function Block Diagram (FBD) for S7-300 and S7-400 Programming.*
22. www.ptc.com, *siemens tcp ip ethernet manual.* User Manual.