Monitoring Water in Treatment and Distribution System

Joyanta Kumar Roy and Subhas Chandra Mukhopadhyay

Abstract This chapter reviewed and explained the importance of water quality monitoring and its technology from generation to the distribution. The authors are reporting a SCADA based intelligence sensing system which is utilising the Internet of Things to improve easy access to monitor water quality, treatment process and plant health in real time. Internet of Things, a new era of computing technology and a smart connect, machine to machine, machine to infrastructure, machine to environment an intelligent system which can talk each other, make operational functions in universal network in the cloud. Continuous surveillance of potable water quality during production and delivery, what is happening in a plant and information required to apply needs in the water distribution network requires huge connection infrastructure and its availability with time. IoT is the solution of these problems of platform. In North 24 parganas Arsenic area water supply scheme uses Internet of Things 1st time in India to access water quality information, plant information, and water supply information globally anywhere in the earth having the network of internet. This paper describes how IoT works in a water treatment process, production and distribution in a scalable way. This will be the convergence of consumer, business and industrial internet considering environmental impacts. This will be the way to get the information in your pocket. This chapter also describes how SCADA works with IoT to assist in the production of potable safe drinking water. The case study describes the functionalities of Supervisory Control and Data Acquisition System (SCADA) and Internet of Things (IoT) system installed which proves its sustainability for last 10 years. It helps to minimize the cost of production, smooth delivery and maximize water quality to help rural people from menace of various water contaminations like Arsenic threat. This chapter also described the features of future water monitoring through indigenously developed sensors.

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S.C. Mukhopadhyay (ed.), *Next Generation Sensors and Systems*,
Smart Sensors, Measurement and Instrumentation 16,
DOI 10.1007/978-3-319-21671-3_12

1 Introduction

Water is very important component of life, on an average; the body of an adult human being contains 60 % water. Most of the water in the human body is contained inside our cells. In fact, our billions of cells must have water to live. The most of the diseases are water borne. The waterborne disease is reserved largely for infections that predominantly are transmitted through contact with or consumption of disease infected water. Many of the Protozoa infections, parasitic infections, Bacterial infections and viral infections are water waterborne. This overall Bacteriological contamination play a vital role in Nation's health. Beside the bacteriological contamination our natural resources of water are being continuously contaminated by industrial waste. One of the Millennium Development Goals is to improve access to safe water defined as engine for socio-economic growth. Therefore in this contest the importance of information on water resources systems is very valued and cannot be overestimated the environmental status of our world as well as in the socio-economic development process of nations. Access to clean water for drinking and sanitary purposes is a precondition for human health and well-being. Unpolluted water is also essential for ecosystems. Plants and animals in lakes, rivers and seas react to changes in their environment caused by changes in chemical water quality and physical disturbance of their habitat.

According to the European Environment Agency (EEA), "the pollution can take many forms and have different effects:

Faecal contamination: The common source is sewage. It makes water unsafe and aesthetically for human consumption and recreational activities, such as swimming, boating or fishing. Many organic pollutants, including sewage effluent and farm and food processing wastes consume huge oxygen, suffocating the aquatic life. Ultimately these contaminations affect groundwater resources used for drinking water purposes.

Nutrients: Nitrates and phosphates, from farm fertilizers to household detergents can over fertilize, the water causing the growth of large mats of algae; some of which can be toxic. When the algae die, they sink to the bottom, decompose, consume oxygen and damage ecosystems.

Pesticides and veterinary medicines from farmland and some industrial chemicals can threaten wildlife and human health. Some of these damage the hormonal systems of fish, causing 'feminisation' (endocrine disruption).

Metals, such as zinc, lead, chromium, mercury and cadmium are extremely toxic. Copper complexes are less toxic, and cobalt and ferrous complexes are only weak toxicants. Concentrations of cyanides in waters intended for human use, including complex forms, are strictly limited because of their high toxicity.

Arsenic contamination of ground water may occur in two ways: anthropogenic activities and aquifer naturally contain. Ground water contamination cross the permissible limit of WHO (0.01 mg/l), excess arsenic has been detected in tube well/hand pump drinking water supply in many country about 200 million people under risk. Arsenic found in widely the earth's crust, it's mostly in organic, inorganic and gas form. Organic arsenic abundantly found in sea food, it's not harmful and Inorganic arsenic that is found in ground water is harmful to health because it's stored in the body, thus adversely affecting multiple organ systems and form many diseases sometimes cancer leads to death. Consuming arsenic contaminated water is slowly leads to death.

Organic micro-pollutants, such as pharmaceuticals, hormones and chemical substances used in products and households can also threaten health.

Chlorinated hydrocarbons exist in the natural systems, several of which are highly toxic to humans. These molecules persist in the environment for a longer time, and threaten to contaminate aquatic and soil systems.

There are two sources of natural water i.e., Ground water and Surface water. Normally we abducted water from ground by hand or motor operated pump. The major water supply is taken from ground in India; Major possible pollutants in ground water are Faecal Coliform, Nutrients, Pesticides and veterinary medicines, Organic micro-pollutants, Arsenic and Fluoride contaminations.

The production of Arsenic free drinking water for the large community in the wide rural areas of West Bengal is a great challenge to the water sector industries. The Arsenic treat for today's world is becoming an epidemic and its intensity will reach its highest extent in near future. Due to the pressure of increasingly high population rate in India, it has become a basic need to regulate the usage of precious purified water in our community. Indian government along with the State Govt. has taken needful steps to prevent this problem. The underground-water is the natural source of water but due to excessive pumping out the Arsenic contamination is taking place due to excessive reduction of partial pressure in the underground water level. Moreover, the surface water is not able to penetrate through the land-bed to reach up to the under-ground water level to balance the deficiency of water quantity. India is a country abounds with rivers enriching the large population by its natural river water resource. River water is much safer from than the underground water from today's world scenario. Contamination of Arsenic has a minute chance in this water source. Regardless of these facts, the other chemical contamination has also very minimum chance to have. So, Government had taken a first step to implement the water treatment plant supported by distributed SCADA control system at Mongol Pandey water Treatment Plant, situated at the bank of river Ganges, at the favourable location of Barrackpore, North 24 Paraganas and W.B. Now almost all the new water supply systems are coming with water monitoring based on SCADA system.

2 Review on Water Monitoring, SCADA and IoT in Water Sector

Temido et al., in the year 2014, introduced an idea of value creation for the water sector companies using SCADA applications and Smart Metering Systems for the companies. Information technology (IT) application is also applied for the implementation of the SCADA system for the operating and maintenance of the whole system. The cost benefit was also an important aspect of this system. The two CBA (Cost benefit analysis) models have been developed in this work having potentially advanced utilizations towards the society [1]. G. Williams et al., in the year 2014, analysed SCADA for understanding the contribution of Hydraulic Pressure for failure analysis in main trunk pipeline for urban sub-network. Failure analysis using frequency analysis technique was the main theme of this research work. The pump off- peak (POP) failure was characterized by high speed, predominantly off peak pumping etc. The data failure recording option is available with the SCADA system for forensic investigation [2].Dorin Adrian Rusua et al., in the year 2013, used a novel technique for Anomaly detection system (ADS) for SCADA system based on systematic approach of pattern based technique. The technique uses graphical interface technique for model based SCADA topology and some auto generated ADS rules. The technique (system) they have used is user-friendly for anomaly detection in the SCADA network [3]. Adrian Gligor et al., in 2012, developed an oriented SCADA system to facilitate the business intelligence in any production sector (like water treatment plant etc.) by the economical respect. The author have done some analysis regarding various aspects of the SCADA system like safety, implementation, design the system etc. For that purpose, the service oriented Architecture (SOA) has been used [4]. Rezaul K. Chowdhury et al., in 2013, introduced Informatics, Logistics and Governance in Water Treatment plant using SCADA Architecture with Artificial Neural Network (ANN) in water treatment problems to make the system intelligent. They also proposed a SCADA system diagram for water treatment plant. They also proposed an idea of water governance using which the business intelligence can be achieved in water sector for public interest [5]. Maria Muntean et al., in 2011 used knowledge discovery in a SCADA system Database using data mining technique in for performance evaluation for better functionality of the whole process plant. The main purpose of this work was to analyse the classifier that is best suited to the data set provided by SCADA system. Discarding normal values and transmitting warning messages as the anomaly value by the classifier was the theme of the system [6]. Oladipupo Bello et al., in the year 2014, used fuzzy logic for the development of dynamic modelling and predictive control for coagulation chemical dosing for water treatment plants. Fuzzy model predictive control (FMPC) strategy has been proposed in regulating the dosing treatment. MIMO processes for linearized Takagi–Sugeno (T–S) fuzzy model technique have been implemented [7].

Shri Prabir Kumar Dutta discussed his view over SCADA system for business intelligence in water treatment plants first time in India. Arsenic contamination in drinking water was a major problem for most of the rural areas in west Bengal. Portable drinking water production plant for rural areas in North 24 Paraganas (at Mongol Pandey water Treatment Plant) has been developed under this mission. The treatment plant has 7.5 MGD capacity, two Booster Stations and fourteen overhead reservoirs distributed over 7.4 million people covering 369 sq. km area. The SCADA system has good amount of plant running data for technical analysis purposes [8]. R. Wang et al., in the year 2014, analysed Water hammer assessment techniques for water distribution Systems for the mass community to protect valuable life and wealth that can be destructed by this problem. The business intelligence is one of its sole aspects to calculate the water hazards due to five different reasons discussed in this paper. Pipe rupture risk factors have been analyses for maximum water pressure, maximum vacuum, maximum vapour volume, and maximum transient force by the knowledge of hydraulic transient flow analysis [9]. The application of automation in modified SCADA system had empowered the overall plant efficiency and surveillance the functionality of the plant for the Great lakes-upper Mississippi River to provide service for the public health and Environmental aspects [10].

By definition the Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals [11, 12]. In the smart world environment the goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service [11, 12]. Internet of Things is a revolution of the Internet application. Objects in the cloud of internet make themselves recognizable and they have their own intelligence by making or enabling context related decisions through communicating information about themselves. They access information that has been aggregated by other things, or they are the components of complex services and systems. This transformation is happens with the emergence of cloud computing capabilities and techniques and the transition of the Internet towards IPv6 with an almost unlimited addressing capacity. The revolution is all emerging technologies developing in all areas of electronic products like sensors, transmitters, and communication devices have the facilities of inbuilt internet capability and have smart function to talk each other.

Now we are making real from the imagination talking about creation of Smart Planet to make Green environment, trying to make smart cities with connected communities, applying smart energy system in electrical grids, implementing Smart homes and building, improving electric mobility through Smart Transport, creating Smart Industry for flawless efficient production, applying Smart Health Care system with target goal of Smart living. All these application requires IoT technology which makes the thing real (Fig. 1). All the devices, equipment, ubiquities, equipment for wellness, military whatever the available electronic novelties and research appliances will be IPV6 enabled can talk each other, data mobility worldwide through high speed internet and our twentieth century expectation is everything is available in hand.

Dr. Ovidiu Vermesan et al. [11], in the year of 2013 written a book on “Internet of Things- Converging technology for Smart Environment and Integrated Eco System”, Published by River Publishers Series in communications, IERC Book open access, 2013, TP- 343. In this book the vast idea on Internet of things can be gained and its different application sides are also depicted [11]. Dr. Ovidiu Vermesan et al., in the year of 2014, written another book on “Internet of Things- From research and innovation to Market Deployment”, Published by River

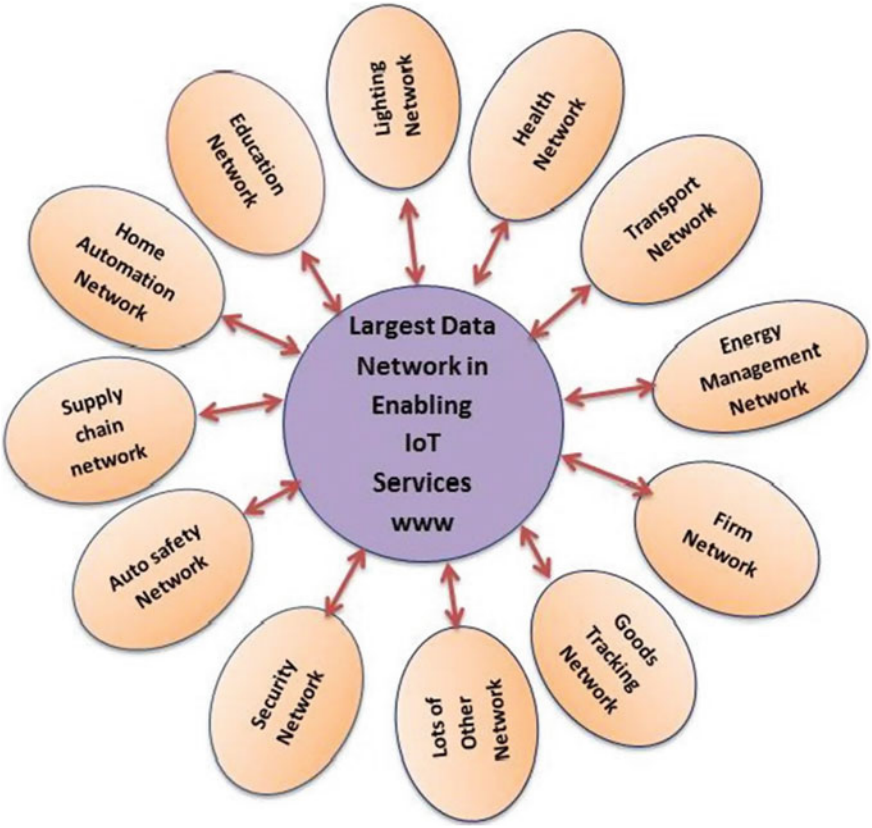


Fig. 1 IoT enabled green world

Publishers Series in communications, IERC Book open access, 2014, TP- 143. From this book the idea on Internet of things in the market deployment to different plant automation techniques are discussed [12]. Shri Prabir Kumar Dutta discussed his view over SCADA system for business intelligence in water treatment plants first time in India. Arsenic contamination in drinking water was a major problem for most of the rural areas in west Bengal. Portable drinking water production plant for rural areas in North 24 Paraganas (at Mongal Pandey water Treatment Plant) has been developed under this mission. The treatment plant has 7.5 MGD capacity, two Booster Stations and fourteen overhead reservoirs distributed over 7.4 million people covering 369 sq. km area. The SCADA system has good amount of plant running data for technical analysis purposes [13]. Dave Evans, in the year 2011, written a book on “The Internet of Things How the Next Evolution of the Internet Is Changing Everything”, published by Cisco Internet Business Solutions Group (IBSG) [14]. K. Karimi, in the year 2012 has written the book on “What the Internet of Things (IOT) Needs to Become a Reality", Tp. 16, 2012. In this book the basic idea along with the application criteria of the IOT model can be achieved [15]. Joseph Bradley et al., in the year 2014 implemented the idea on "Internet of Everything: A $4.6 Trillion Public-Sector Opportunity" [16]. Simon Bunn, in the year 2007 discussed on "Closing the Loop in Water Supply Optimization" [17]. Merchant et al. [18], in the year 2014, proposed an Analytics driven water management system for Bangalore city. His is an ongoing project for the minimization of the complexity in instrumentation and control mechanism in water sector. They have developed new software using customizable key performance indicator (KPI) to implement the business intelligence which has great importance in the water sector to handle different problem situations. The software developed for this purpose is Smart, reliable and easy to use by the plant officials. The business level optimization was also a great achievement of this system minimizing different losses like energy loss, produced water loss etc. which helps to build the business intelligence in a productive way. The Minneapolis Province of USA [19] has utilized SCADA technology [13, 20, 21] for real time energy usage that can be connected with other system parameters like storage levels of water and he intake volume. The essence of this system is to have an efficient control using minimum staff support. Vlastimir Nikolić et al., in 2010, implemented a new idea of intelligent decision making system based on Fuzzy controller [22] for waste water treatment plant using SCADA system. The main emphasis was given by the authors on the development of remote monitoring and controlling of systems for wastewater treatment and its improvement. The development of RTU module for this type of systems has been discussed with its intelligent attributes [13].

3 Motivation

Most of the water treatment and supply plants use the conventional methods for treatment of water. From raw water suction to the filtration using rapid gravity filter bed and distribution to the community through high speed pumping systems, which require lots of attention regarding production, distribution and water quality. The status of pumping machineries, plant and process parameters for entire water distribution network require continuous surveillance which are not possible with human intervention considering large inspection area of production and distribution zone. Most of the conventional water treatment plant do not have any surveillance system for monitoring plant and process parameters on-line. They suffer from production target as well as in quality too. Similarly most of modern treatment plant having Plant wise SCADA, do not have any monitoring system for distributed remote Booster stations or overhead reservoirs, therefore they are facing problems in managing the flawless distribution to keep water quality well as per standard specified by ISO/WHO. These water treatment plant and distribution systems also have minimum monitoring facilities, which are local panel based system. The operators are used to visit monitoring equipment location and take data into log book.

The water treatment plant machineries are distributed in vast areas. Simultaneous measurement of water monitoring data is physically impossible. Therefore use of online water monitoring equipment along with distributed SCADA system are the perfect choice to integrate all distributed Plant and Process system under single umbrella which give on-line pictures of water quality trends, health of the pumping machineries and also support as useful tool to the engineers. Therefore sustainable water supply system has been established. Now days various on-line smart measuring system for on-line water quality parameters are available. Some of them can measure water quality in continuous real time, some are using sampling method. These equipment can give water quality data on demand. Each water treatment plant has a water testing laboratories for routine testing of water quality at various locations from source to destination. There laboratories are well equipped with all test equipment for the measurement of different water quality parameters as per Table 1. But these laboratories do not have facilties to publish on-line Water quality data. Plant engineers are also interested to monitor laboratory and plant data in real time at their office which is far off from the treatment plant. This is important requirement for operational and maintenance aspect for smooth supply of safe drinking water to the consumer. The laboratory normally test some parameters daily, some parameters weekly and some parameters on monthly basis. Normally one or two water samples are taken from various locations of water resources within the plant in routine manner. This procedure does not ensure variance of water quality with variation of time and water flow. In this chapter, some aspect of distributed SCADA system with IoT and business intelligence has been discussed.

4 SCADA System in Mangal Pandey Water Treatment Plant, India

4.1 Description of Hardware Infrastructure:

The Distributed SCADA system is installed and commissioned in 2003 in Mangal Pandey water Treatment plant, Barrackpore. It has two Boosting stations, one at Madavpur with aerial distance 11 km and other at Naksa with aerial distance of 26 km from Barrackpore, N24 Parganas [8]. These two Boosting stations are getting water supply from the Mangal Pandey Water Treatment Plant and are delivering potable water to 15 nos. overhead reservoirs at various locations. These OHRs are supplying water under gravity flow to the population through house to house connection system. Each of the Boosting Stations and OHRs have Remote Terminal Unit (RTU), which is PLC based Data Acquisition system with built in Radio based data telemetry connected in a dedicated wireless network.

Table 1 Plant and process parameters and its measuring systems for SCADA

Sl no	Location	Parameter	Unit	Equipment used
1	Raw water Pump house	*Plant parameter*: a. Raw water pump status (on-off-standby) b. Raw water Header water flow c. Raw water delivery pressure *Process parameter*: a. Raw water pH b. Raw water turbidity c. Raw water pump house operation time	Logical M^3/ hour kg/cm^2 NPU Hour	Electrical contacts with opto electronic isolators Electromagnetic flow meter Smart pressure transmitter Smart pH transmitter Insertion type smart Turbidity analyser Virtual timer
2	Clari-flocculator	a. Bridge drive motor b. Mixture motors c. Flow to clariflocculator 1 and 2	Logical Logical M^3/ hour	Electrical contacts with opto electronic isolators Ultrasonic open channel flow meter
3	Filter house	*Process parameter*: a. Filter bed operation (Running-shot off—stand by) b. Flow through filter c. Loss of head d. Flow meter for back wash e. Backwash overhead reservoir level	Logical M^3/ hour Metre M^3/ hour Metre	Virtual sensor Open channel flow meter with capacitive transducer Differential pressure transmitter Electromagnetic type of flow meter Ultrasonic non- contact level transmitter
4	Sludge pump house	a. Sludge water level b. Sludge mixing motor status c. Sludge pump house operation time	Metre Logical Hour	Ultrasonic non-contact level transmitter Electrical contacts with opto-electronic isolators Virtual clock
5	Compressor room	a. Compressor and blower status	Logical	Electrical contacts with opto-electronic isolators
6	Chemical house	a.Chemical dosing pumps b.Coagulant dosing status c.Pre chlorination and post chlorination status	Logical Logical Logical	Electrical contacts with opto-electronic isolators Electrical contacts with opto-electronic isolators Electrical contacts with opto-electronic isolators
7	Sub station	a. Incoming feeder voltage (3 phase) b. Plant feeder voltage(3 phase) c. Plant feeder current(3 phase) d. Power factor e. Frequency f. Active power	KV V A Theta Hz KW	Potential transformer Potential transformer Current transformer Multi parameter transmitter Multi parameter transmitter

(continued)

Table 1 (continued)

Sl no	Location	Parameter	Unit	Equipment used
		g. Reactive power h. Energy consumption	KW KWH	
8	Booster pumping station(2 numbers)	a. Inflow b. Outflow c. Level d. Pump status e. Pump operating hours f. Pump status	M^3/ hour Metre Logical Hours Logical	Electromagnetic flow transmitter Ultrasonic non-contact level transmitter Electrical contacts with opto-electronic isolators Virtual timer Electrical contacts with opto-electronic isolators
9	Overhead reservoir	a. Residual chlorination pump status b. Residual chlorine value of OHR water c. Water input to the OHR d. Water level in OHR	Logical mg/l M^3/ hour Metre	Electrical contacts with opto-electronic isolators Residual chlorine analyser Electromagnetic flow meter Ultrasonic non-contact level transmitter

The electronic field equipment like sensors and actuators are installed at various point of interest at treatment plant, Booster stations and OHRs. The central monitoring room is equipped with HMI SCADA Server, Data Server and Web Servers with redundant system. These servers are connected with PLC based Remote Terminal Units located at different sections of the treatment plant, boosting stations and OHRs through communicating network. The local area network of inside central monitoring station is copper with speed 100/10 mbps. All RTUs within the treatment plant are connected with HMI servers through Optical fibre network with 1Gbps speed. The RTUs of remote boosting stations and OHRs are connected through smart cognitive radios. Field RTUs have opto-isolated inputs and outputs, which are connected with various smart metering system for monitoring plant and process parameters as a whole. The plant and process parameters available through SCADA for smart management of water supply scheme are described in Table 1.

The field units such as various on-line process parameter measuring transmitters, which are installed in the process and connected to the PLC based data acquisition system as shown in the schematic diagram (Fig. 2). Each field unit have Analogue inputs/outputs and Digital inputs/outputs called IO modules of PLC as shown in Fig. 3. The digital inputs are sensing the status of pump motors and other electrical actuators (ON/OFF, Stand by and Fault). Analogue inputs are measuring process parameters like pH, Turbidity, etc. in terms of 4–20 mA DC current from transmitters, which are digitized with 16 BIT resolution and sent to MTU through optical fibre network. HMI server is collecting these raw data for processing and broadcasting in the network for display, logging etc. A typical construction of RTU panel and brief technical specification has been shown in Figs. 2 and 3. The electrical

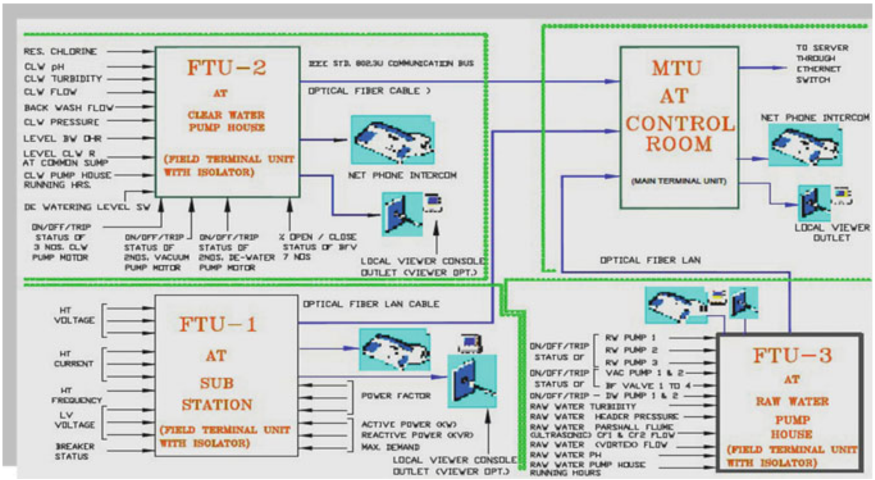


Fig. 2 Part of the schematic diagram of plant-wise interconnected RTUs

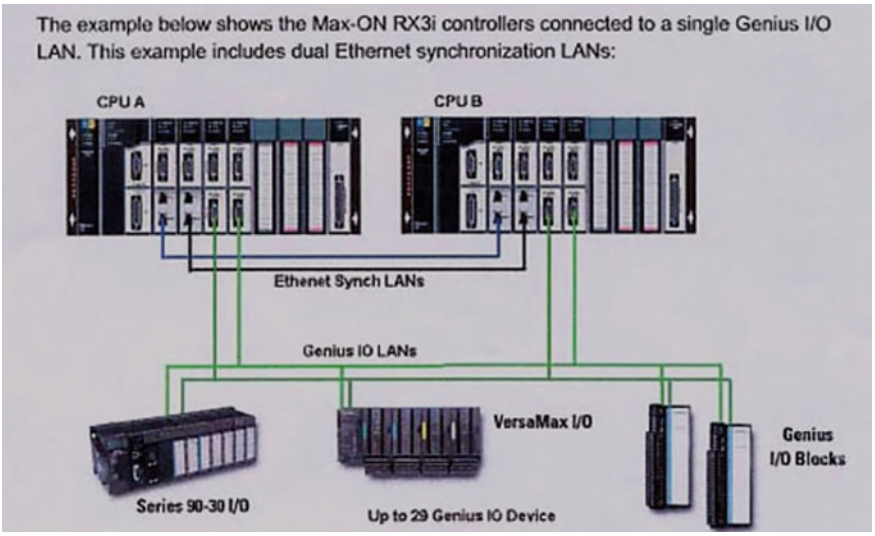


Fig. 3 Example schematic of PLC based SCADA hardware

status of pump motor and other actuators are collected from isolated contact of individual circuits through Opt-isolated digital interfaces.

The fault status are collected from fault sensing relays. The substation parameters are collected from multi parameters electrical transducers installed at Sub

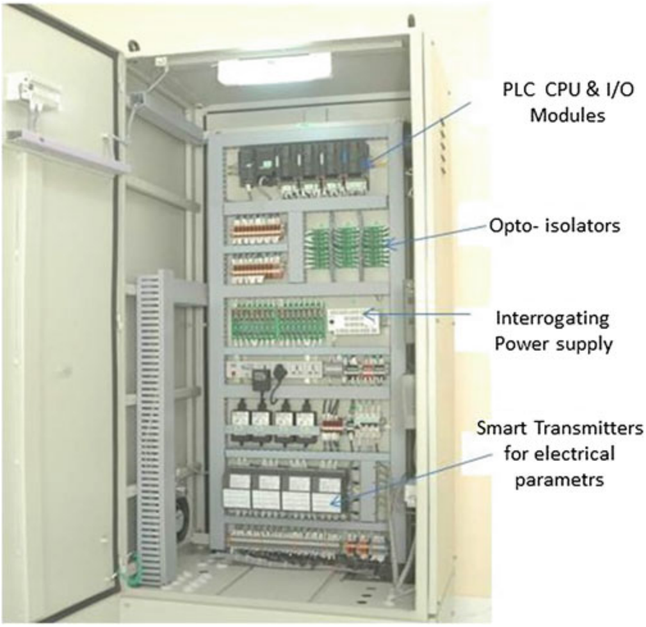


Fig. 4 Example schematic of PLC based SCADA hardware

Station. The Field terminal units are floor standing panel consisted of Genius I/O panel with mixed signal I/O modules.

The Digital and Analogue Inputs and outputs are connected to Genius I/O LAN or GE Fanuc make Versamax CPU and I/O modules (Fig. 4). The LAN communication module with 10/100 Mbps speed has been used for data communication with Master Terminal Unit. The optically isolated fiber cables are connected in Ring topology. These FTU panels are power by uninterrupted Power supply of 230 V, AC, 50 Hz with ±1 % stability. The UPS system has 7 days energy storage for backup power such that all SCADA system components, Field control and measuring instruments will get uninterrupted power for data acquisition. The RTU at different OHR sites are PLC and Radio based telemetering unit. They are used to control and monitoring of Chlorine gas injection system, to measure water inflow to the reservoir and outflow to the distribution to the consumers. The OHR sites do not have any HMI monitoring for visualization. But the visualization can be available by use of Laptop computer having SCADA runtime software if connected in the LAN output of the radio system. This facility has been found very useful for maintenance purpose during fault detection of on-line water analyzer or any field transmitters and actuators. All smart on-line transmitters are HART protocol activated and can also be calibrated through PC using HART software.

4.2 Computer and Software Infrastructure:

The application software was developed for the proprietary requirement of water treatment and its distribution called Water Management System (WMS) as shown in Fig. 5.

The WMS is concerned to make decision through monitoring of health status of distributed plant machineries, water demand, water quality and other process conditions.

The HMI server is running with SCADA software "CIMPLICITY" of GE Fanuc Intelligent systems, configured similar to Clear SCADA software of Schneider Electric Co. There are two HMI servers are working in redundant mode with RAID 2 configuration, such that any failure in hardware or software of one server could trigger other server bouncelessly and the system runs almost without failure.

There are two database servers running with redundant mode in the network. The operating systems of these data base server are Microsoft SQL 2010. The raw data with tie stamped from all over the system are stored in these servers in continuous manner (24 × 7).

The entire system has power backup designed to sustain for 7 days considering catastrophic failure of power in a plant. This water monitoring system has two SCADA viewer are running thin client viewer mode. The plant operators, chemist and plant engineers are using these viewing systems for water monitoring at central SCADA room. The schematic diagram of the distributed SCADA system is shown in Fig. 6. A view of control room for central monitoring of water is shown in Fig. 7.

LMS software is called software for laboratory data management was developed for making laboratory data according to Public Health Engineering requirement.

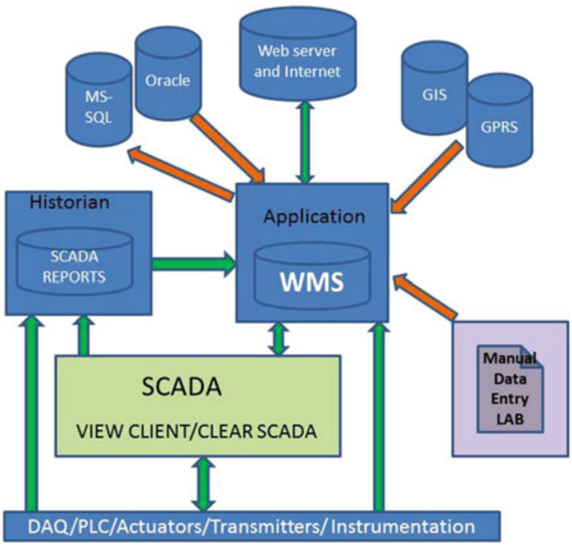


Fig. 5 Schematic of water management system

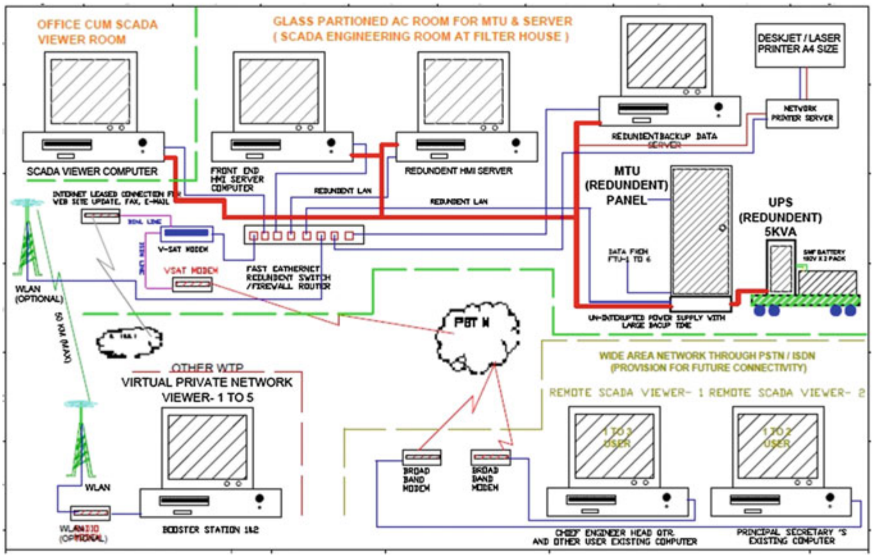


Fig. 6 Schematic diagram of distributed SCADA system

Fig. 7 SCADA rom at Mongol Pandey water treatment plant

This is running in the SCADA network. The laboratory water test data regularly feed to the LMS, Data server stores laboratory data (offline) and SCADA data (online) with time stamped. Water monitoring data as well as plant data are available in various approved table format according to quarry set in the WMS.

The SCADA software is built in Historian so quick trend or configured trend of all plant, process parameters are available i9n viewer machines as well in the entire network. The WMS is at Centre of the software system which interact with HMI, field equipment also interact with World Wide Web (WWW) through web server and public IP.

Some preapproved configured water monitoring quarry based data in tabular format is available through password protected web page, which are accessible anywhere any place through internet.

The system is also activated with GIS and SMS server such that the system is synchronized with world standard time and WMS can generate mobile alert through SMS to the operation and maintenance engineer during any undesired event in the plant or process.

The Central SCADA Room is situated in the first floor of filter House where all local RTUs through optical fiber and remote RTUs through wireless radios are integrated through a three layer smart network switch and fire wall. The firewall is used to save the important database of SCADA server from external hacking. Firewall also prevents unauthorized access or to get information from SCADA through network. The HMI server collects field raw data and displays those data in various interacting graphical pages. HMI serer also sends those field data to the data base server which logs data in its memory. The HMI server with data base server can generate customized report, as for example residual chlorine status of all 15 Over head reservoirs and treatment plant or water level status of 15 overhead reservoirs.

A CISCO security management system is also implemented to save system from external cyber threat. Air conditioning system works day and night to control environmental temperature and humidity of the control room. This will keep the system healthy and protect the system from mal-functioning. There is a redundant web server installed to broadcast all consolidated report generated by the data server. The web server is broadcasting plant and OHR data through lease Internet facility through BSNL service provider.

The website of Mongol Pandey water treatment plant has dynamic web pages which are Java enabled. Through this dynamic pages, online SCADA can be viewed at anywhere any place by any remote computer through Internet. The wireless backbone created between Mongol Pandey water treatment plant with Booster Station-1 and Booster Station-2 through Smart Cognitive Radio fitted on the self-supported towers.

At OHR site, Radio transmitters are mounted over the OHR top dome. All the radio transmitters are mounted with maintaining line of sight. The voice over IP telephony (VOIP) systems are also established between water treatment plant, Booster Stations and OHRs. All plant operators can talk each other can manage centrally from the control room of the treatment plant through this VOIP system.

Figure 8 depicts the distribution of water supply through pipe lines under North 24 Pgs W/S having distributed SCADA facilities. IoT network were established using Smart cognitive radios installed at the OHR roof tops and self-supported

Fig. 8 IoT network in north 24 Pgs Arsenic area water supply scheme

towers communicating each other through powerful wireless backbone. A typical installation of communication radio and self-supported tower (Base Station) at Naksa, N24 pgs, WB (Booster Station-2) is shown in Fig. 9.

The wireless network used point to point to multi point Topologies. The Radio uses NLOS urban coverage with OFDM technologies 5xGHz extended frequency range and support for 4.9 GHz. It is having +29 dBm aggregated output power and 2 × 2 MIMO with software. The radio uses for data and VOIP for telephonic

Fig. 9 Typical installation of radio base station at Naksa, N24 Pgs

Fig. 10 Typical line of site alignment of SCADA radios

communication uses EION Trust link technologies with user friendly web based GUI. The radio systems are used advanced OFDM and MIMO technologies to deliver breakthrough performance in the unlicensed band. It supports IPV6 and can handle the extreme backhaul loads that originate from today's 4G/LTE based network. MS angle structure based self-supported towers erected at each locations of interest. The height of towers are ranging from 18 to 28 m depends on the sea level height to match line of sight. Figure 10 shows such typical installation of radios and alignment of radio. Table 2 describes hybrid network structures are used in the present water monitoring system.

5 The Monitoring and Visualization of Treatment Process and Water Quality

The goal of the project is to monitor all plant and process parameters including distribution under a single roof. Therefore graphical interface units for each treatment and distribution zones are separated for detail monitoring and designed into graphical pages. There are two home pages, 1st one is home page for water supply scheme through which all different OHRs, Booster station and central treatment plant can be navigated. 2nd home page is for treatment plant only, through which different sections like substation, raw water pump house, clear water pump house,

Table 2 Nature of communication network used

SI no.	Network level	Equipment used	Types of network	Speed
1	Ground level	Monitoring equipment and PLC Base	Flow wise LAN made of ORC and copper	10/100 MBPS (plant)
2	WTP level	SCADA interconnected RTUs	Optical fibre network	100/1000 MBPS (control room)
3	OHR and booster station	Interconnected RTUs	MAN radio operated	1–2 MBPS
4	Connected other WTP	Interconnected SCADA	MAN radio operated	1–2 MBPS
5	Internet	WWW	Internet lease line	2 MBPS raw

filter house, sludge pump house, chemical house, clear water pump house can be navigated. The short description of major SCADA pages are as follows.

5.1 Sub-station Monitoring

The Sub-station has two large transformer dedicated solely for use by treatment plant. One transformer is working and other is stand by. The transformer power rating is 500 KVA. The input supply is dedicated supply of 11 kV, 50 Hz incomer. The transformer output voltage 433 V. The vacuum circuit breaker and air circuit breakers are used to engage and de-engage the transformer from the circuit. Figure 11 is the SCADA page for Sub Station Monitoring. There are various power sensors are installed in the power circuit to monitor all necessary electrical parameters like, Incoming three phase voltages, Power line voltages, load currents, Frequency, Power factor, Quality factor, KVA, KW, KVAR energy consumption and phase voltage.

The substation is built in power protection system using latest micro controller based protection relays, Very good electrical earthing, protective devices are also installed to protect the substation from accidental damage due to lighting discharge. The substation provides power to the different pumping houses, filter beds and all equipment distributed in the plant, lighting systems etc. However SCADA and WMS infrastructure need uninterrupted smooth harmonics free stabilized power therefore separate on line UPS with sufficient power back up is used for individual installations at different houses. The SCADA is also monitoring all parameters related to the health of the UPS supply and records data for future health prediction.

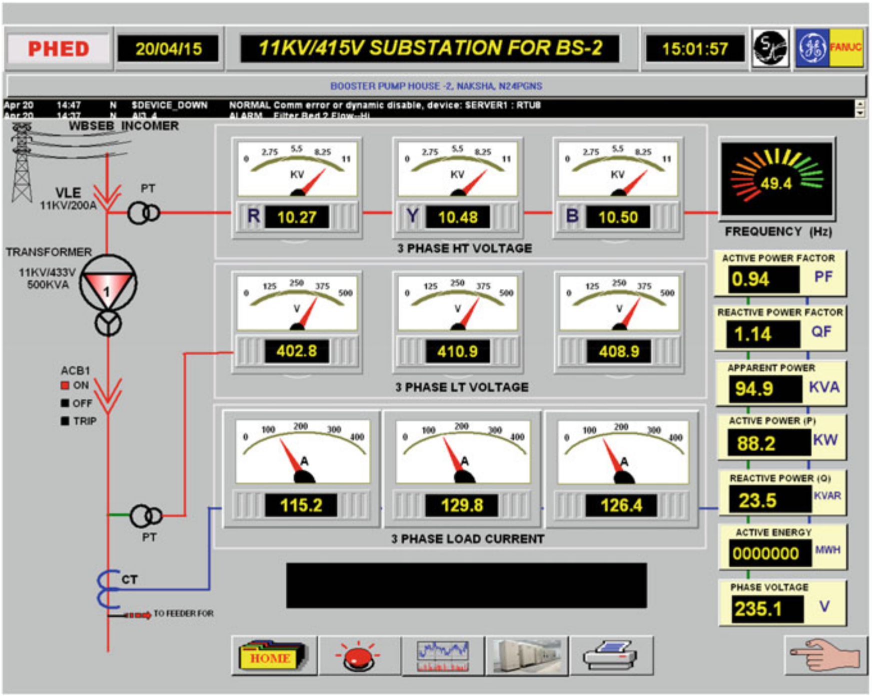


Fig. 11 Typical Substation electrical parameter monitoring

5.2 *Clarifloccculator Zone and Water Quality Online*

The Clariflocculator (Fig. 12) plays a vital in water treatment process. The clariflocculator is a combination of flocculation and clarification in a single tank. It has two concentric tanks where inner tank serves as a flocculation basin and the outer tank as a clarifier. The water enters the floccfulator and motor operated flocculator paddles enhance the flocculation. The water flows rapidly upwards in the clarifier zone.

The clarified liquid is discharged over a peripheral launder. The deposited sludge at the bottom of clarified zone is raked by motor operated bridge scraper moved to the central weir from where it is routed to the sludge chamber. Monitoring the health of clariflocculator is very important. The problem is wired cable routing to the clariflocculator system is difficult. As the all machineries are fitted over rotating bridge of the clariflocculator therefore the RTU for monitoring status of clariflocculator is built in wireless.

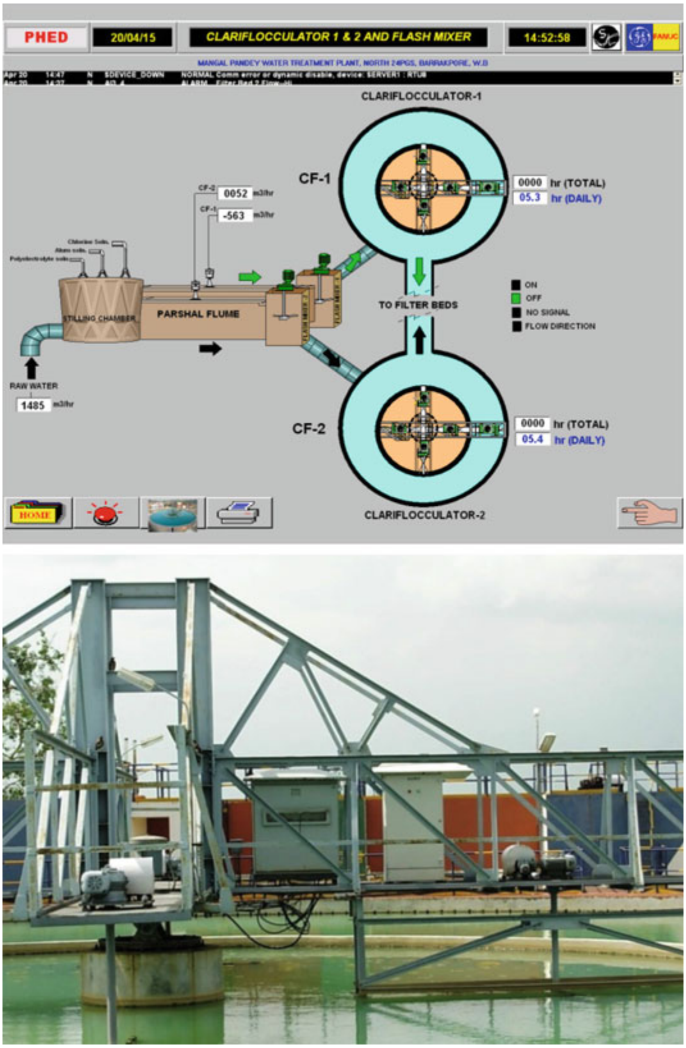


Fig. 12 Clariflocculator monitoring

5.3 Monitoring Fileter Beds and Monitoring Filtration Process

The rapid gravity filter bed is type of filter used in large capacity water filtration system. The filter bed uses relatively coarse sand and other granular media to remove impurities that has been trapped in a floc through flocculation process in a clariflocculator. There are ten filter rapid gravity sand filter beds engaged to filter clarified water to potable drinking water. These filter beds are automatic and

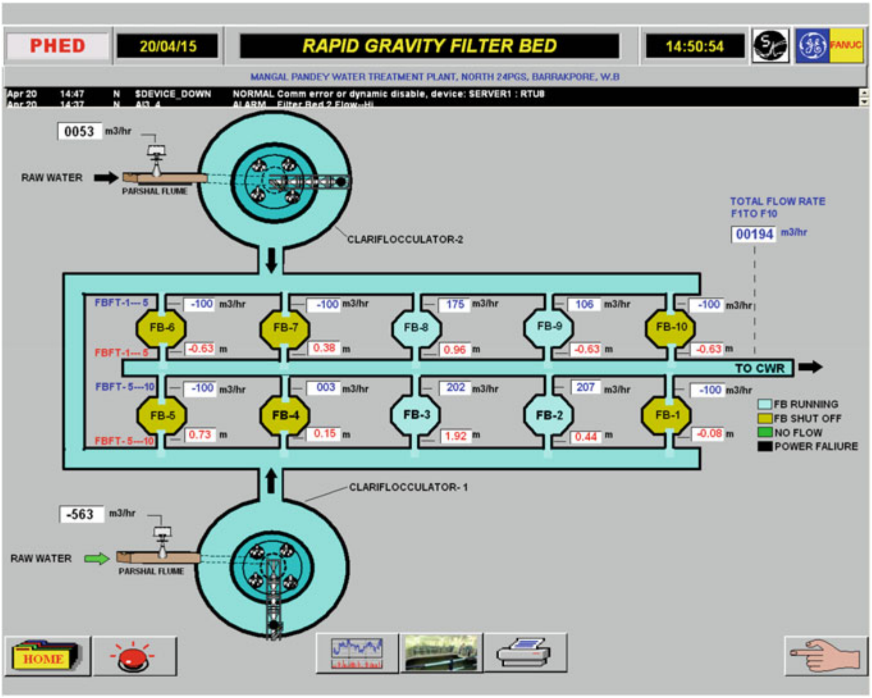


Fig. 13 Filter bed monitoring

pneumatically controlled. There are several sensors for monitoring loss of head in the filter bed, Filter bed out flow and different digital sensors to monitor filter bed through SCADA system.

When loss of head is high above the normal working limit, there is backwash system which activated the cleaning of filter bed through scouring of air from filter bed bottom, which clean the filter bed material thoroughly and increase production. Figure 13 is the GIU page of HMI SCADA through which the operator can monitor all the parameters and can log the values of the parameter with respect of time. The trends of all parameters during filter operation are also available in the central monitoring system. Through this SCADA page one can also monitor the alum chlorine and poly electrolyte dosing during filtration process.

6 Monitoring of Different Pump Houses

6.1 Raw Water Pump House

The raw water is abducted from river Hooghly through three vertical pumps installed at Raw Water Pump house. Two pumps run normally and one kept as stand by. The discharged water from pumps passes through the common header, where a smart pressure transmitter is monitoring raw water discharge pressure. Smart pH transmitter, smart electromagnetic flow meter and online smart turbidity analysers are installed in the pipe line of raw water and connected to the I/O ports of PLC based remote terminal unit. The raw water pump status, working hours of pumps and other online water quality parameters are available in RAW water SCADA page GIU of HMI viewer.

6.2 Clear Water Pump House

The chlorine is added in the form of chlorinated water at two places during water treatment. Pre chlorination at stilling chamber and post chlorination at clear water tank are the normal practise for disinfection process. The filtered water from filter house collected at ground based clear water tank. There are five high speed water pumps are in Clear water pump house. Normally four pumps are operating through common header and one pump is kept as stand by. The pressure transmitter at discharge point measures clear water delivery pressure and one magnetic flow meter is measuring the amount of water flow to the consumer. The SCADA is monitoring the pump operating status, pH value of potable drinking water, turbidity and many more. One ultrasonic water level transmitter is installed at Clear water reservoir to measure water level in the tank. There is a roof top water reservoir for storing filtered water for back wash. The entire backwash process water level in the backwash reservoir are monitoring through clear water SCADA page (Fig. 14).

6.3 Sludge Pump House

A sludge pump house is big underground reservoir where sludge from clarifloc-culator and Filter house are settled and collected through pipe lines. There are two submersible sludge pump and four submersible mixer pumps are installed. Sludge pumps push sludge from the sludge tank to the sludge pond. Here one non-contact ultrasonic level transmitter is measuring sludge level in the tank. The local RTU connected with these physical devices and send data to the SCADA for monitoring and control. The sludge pumps are controlled through SCADA system.

7 Monitoring of Chemical House and Compressure Room

The chemical house of treatment plant is responsible feeding coagulant to raw water and making chlorinated water for pre and post chlorination. There are two poly electrolyte storage tank with mixer and three alum solution tanks with mixer driven

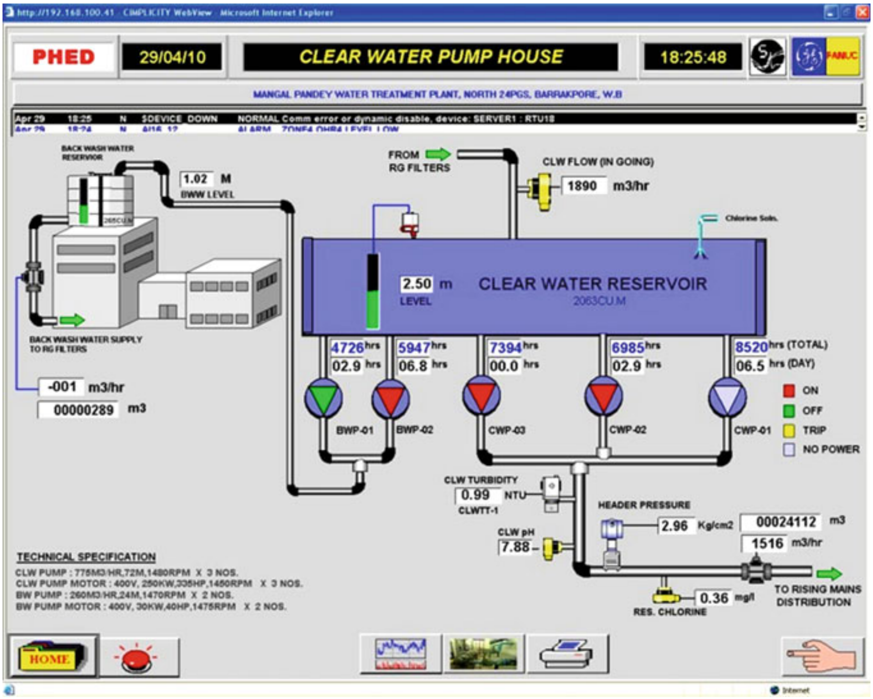


Fig. 14 Clear water pumps house monitoring

electrically. There are six dosing pumps for dosing the coagulant to the raw water. Four pumps out of which six are running for the purpose and rest are kept hot stand by. The chlorination unit mix chlorine gas with water and feed to the clear water tank and raw water at Parshal flume water channel. Here SCADA monitors (Fig. 15) the dosing pump, mixer motors and chlorination unit as well as residual chlorine analyser on line in real time basis. The SCADA also monitors the working status of Compressor and blowers.

8 Monitoring Water Overhead Reservoirs

This project has 16 nos. overhead reservoirs which are distributed throughout the action area of the water supply scheme. There are two Booster stations are working in between two points of water mains such that booster station re-boost the water to the distribution keeping water pressure sufficient to reach overhead reservoir.

We monitor residual chlorine level in Over Head Reservoir and also monitor incoming water flow out going water flow and water level in the OHR. Electromagnetic Flow meters are used for water flow measurement. The ultrasonic

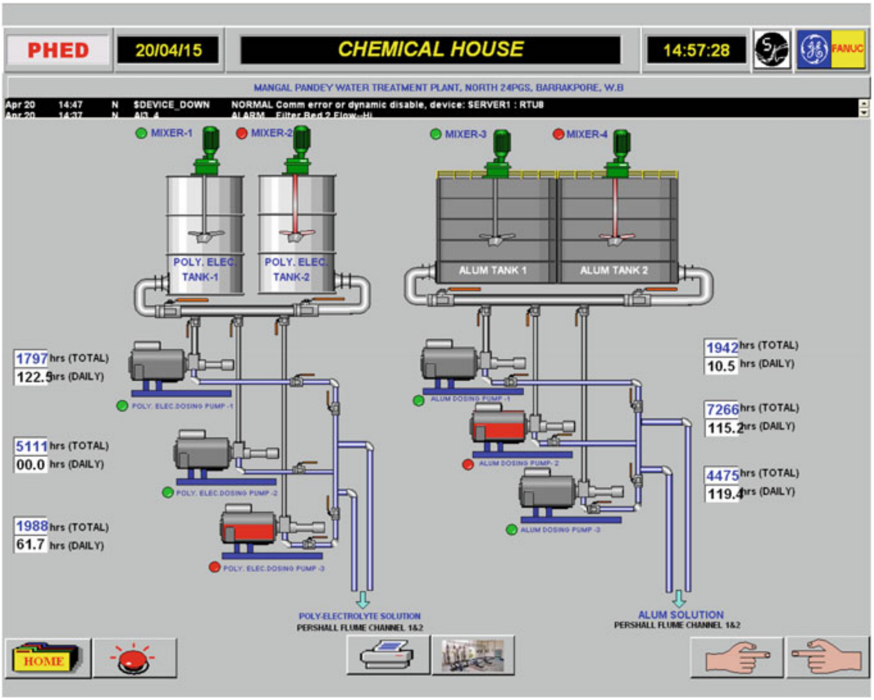


Fig. 15 Chemical house status monitoring

level transmitters are used for OHR water level measurement. The SCADA pages for individual OHRs are created for monitoring centrally. A sample SCADA page of one OHR zone is shown in Fig. 16.

9 Future Water Monitoring Through Indigenously Developed Sensor

In recent times, with the rapid development of agriculture and industry, the excessive discharge of waste water has led to a massive degradation of the quality water in different parts of the world. This has not only caused numerous death of aquatic life and increased outbreak of water-related diseases but also changing the ecological balance of the world.

There is a need of development of new methods of detection of nutrients and pollutants in water at real-time. The current monitoring techniques used are mainly laboratory based and rely on the results of some chemical reactions. For a long-term real-time application the chemical reaction based detection is undesirable as the performance degrades over time. Moreover, with the new regulations the available

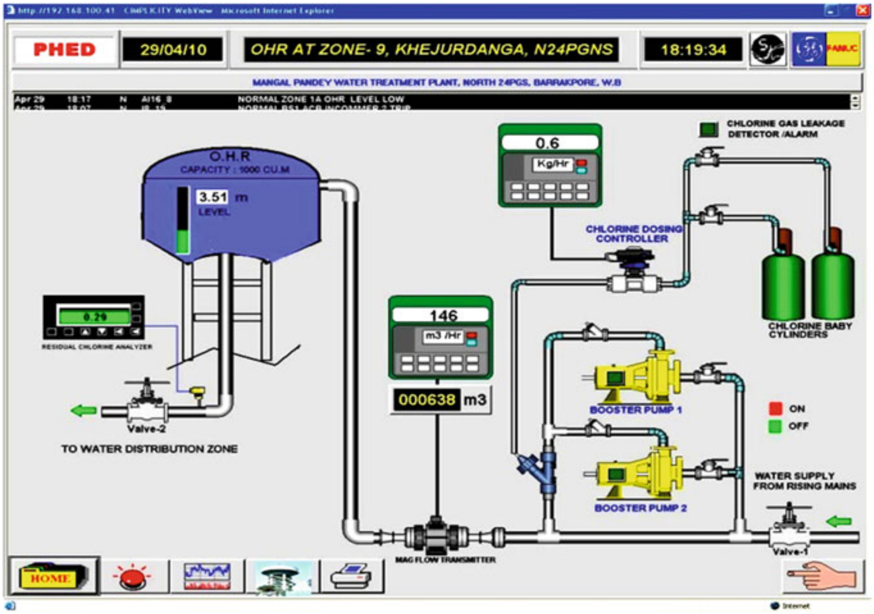


Fig. 16 Remote OHR monitoring

systems may not be suitable in near future to determine the amount of nutrients and pollutants in water relative to allowable levels. Environmental pollution is a huge concern of our society so the emphasis on the monitoring of environment has become very important in recent times. Water is the most important natural resources and getting polluted due to farming, industrial discharge and other reasons. It is very important to monitor water at different points, especially at the different meeting points of rivers and lakes of the country so that a thorough understanding of the relationship between soil, ground and surface water is possible. The continuous monitoring of the constituents of water will enable to determine the sensitivity of the hydrologic system to change of environmental parameters. There is a need of a water monitoring system with wide ranges of water parameters, smart and robust sensors, frequent data input and consequent analysis. This will provide to develop a relationship between water quality and environmental parameters including sources of pollution. This will help to different councils to have a better understanding of the conditions of water and track the sources of pollution.

For now and future, there is a need of development of an integrated framework of water monitoring system based on smart sensors and sensor network. The complete system may consist of three parts: The first part consists of integration of available sensors and development of smart high-performance of novel sensors. There is a need of development of novel sensors as the available sensors are not suitable for continuous monitoring of water under harsh condition. The second part

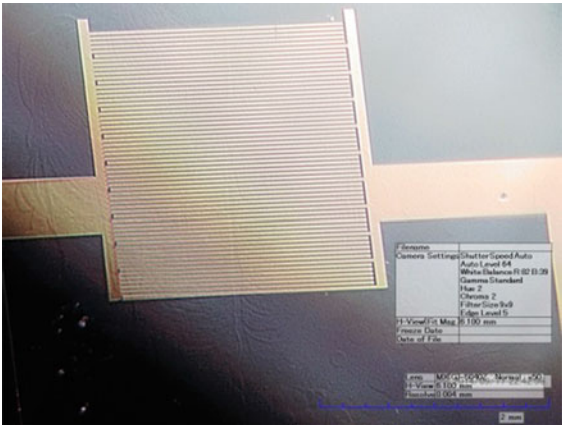


Fig. 17 Interdigital sensor [32]

is the development of combination of energy harvesting techniques such as solar, wind and hydel to obtain energy to supply the sensors for normal operation and communication. The third part is the integration of the sensors to wireless sensor nodes, collection of data, storage and putting the data in a website using Internet of Things techniques. This will provide an easy access to the concerned authority as well as some part of it may be available to general public to know the changes of water parameters over time due to environmental changes.

The water parameters considered are: temperature, humidity, pH, conductance, rain-fall, light-intensity, turbidity, nitrate, phosphate, bio-toxin, BOD, COD, TOC, nitrogen, phosphorus, potassium etc. Novel types of sensors and sensing system will be designed and developed to measure different parameters to qualify and quantify water. The working knowledge of the development of high performance planar electromagnetic sensors to determine the nitrate levels in water as well other parameters may be exploited to develop new sensors [23–37].

Figure 17 shows the interdigital sensor used for detection of contamination in water and Fig. 18 shows the planar electromagnetic sensors developed to detect nitrate contamination in water [23, 30]. The planar electromagnetic sensor consists of interdigital part at the center and surrounded by meander coils at periphery.

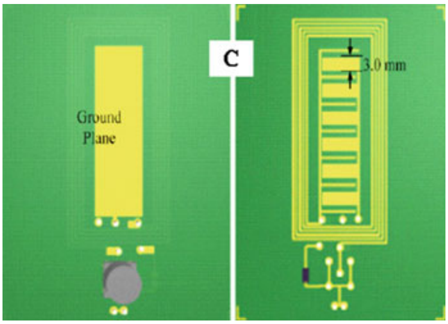


Fig. 18 Planar electromagnetic sensor [25]

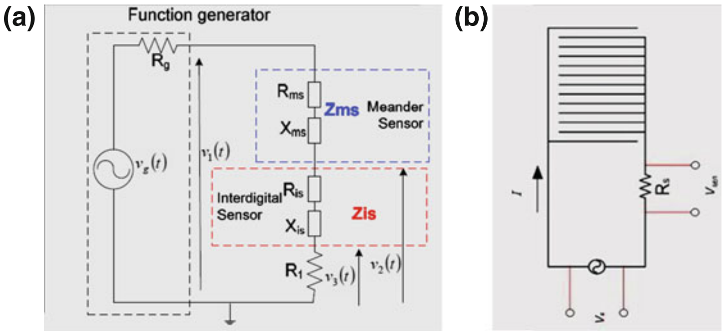


Fig. 19 Meander and interdigital sensing part of planar electromagnetic sensor. **a** Equivalent circuit of meander coil of planar electromagnetic sensor [23]. b. Equivalent circuit of the interdigital sensing part of planar electromagnetic sensor [30]

The meander coil produced magnetic field and the inter-digital produced electric field between the electrodes. An alternating perturbation of required frequency is supplied to the sensor. The produced electromagnetic field extrudes useful information from the sample under test. The impedance of the sensor is measured to determine the level of contamination. Figure 19 shows the equivalent circuit of the planar electromagnetic sensor. The components of impedances are measured for the concentration of contamination levels (Fig. 20)

Using electromagnetic sensor, water from different sources was tested to determine the concentration of sodium nitrate in it. The graph given below in Fig. 21 shows the amount of increase in sensitivity of the nitrate sensor to the increase in the concentration of sodium nitrate. It can be seen from the graph that the sensitivity increases linearly with the increase in the amount of sodium nitrate.

The Nyquist plot is given in Fig. 20 shows that the rate of change of the real part of impedance to the imaginary part of impedance at different frequencies as a function of contamination water from different sources.

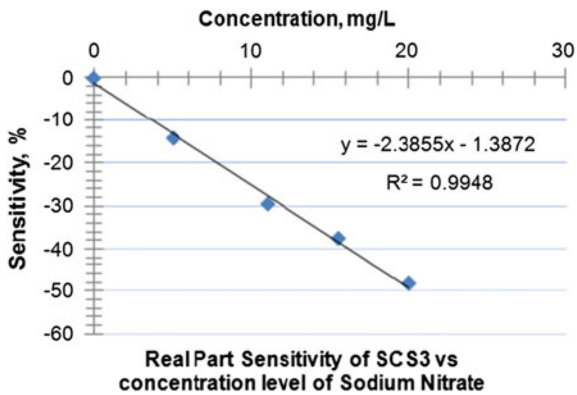
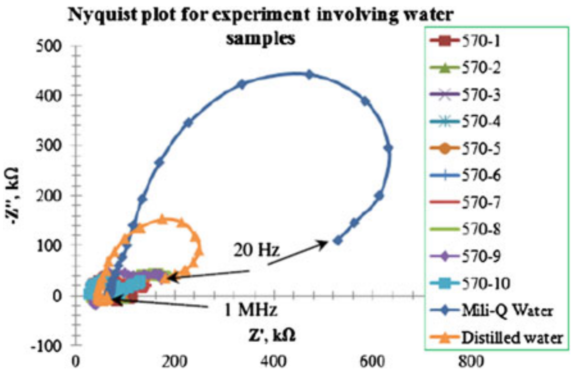


Fig. 20 Sensitivity of SCS3 with sodium nitrate concentration

Fig. 21 The Nyquist plot



The biggest challenge of development of sensors for remote monitoring is the supply of power. Due to the non-availability of electricity, sensors will rely on batteries. The sensors especially the sensor nodes used in wireless sensor network need continuous supply of power.

The battery has limited amount of energy storage which will get depleted with use. This means that the primary or disposable batteries are not the viable option for the sensor nodes. The energy of the batteries should be replenished before it gets completely depleted. This tells that the rechargeable batteries along with some energy harvesting techniques are the only viable options. Energy harvesting is defined as the process of collecting energy from the surrounding environment and converting it into electricity. The energy harvesting techniques are gaining interest as a future next-generation energy source as they have the following advantages:

i. Long lasting operability,
ii. No chemical disposal,
iii. Cost saving,
iv. Maintenance free,
v. No charging points,
vi. Inaccessible sites operability,
vii. Flexibility,
viii. Environmentally friendly,
ix. Applications otherwise impossible.

Though different techniques are explored separately but the amount of energy available from one type of sources may be limited. So it may be a good idea to combine a few sources together to form a hybrid harvesting of energy. In the current project the combination of solar, wind and hydel (stream of river) will be exploited. The sensors will be located at different points distributed over a wide region of monitoring area. The fusion of sensors data are done at the wireless sensor node.

The nodes are connected wirelessly with the central coordinator located at a distant point. The collected data from different nodes are stored in a computer. The data will be analysed and then the useful data are uploaded in a website for remote access.

10 Conclusion

This chapter has detailed need of monitoring water quality and different sensors associated with water quality monitoring. A case study of water treatment plant and details of different sub-system associated with it has been described. There is a need of development of new sensors and extension of real-time monitoring through Internet of Things for monitoring of water quality in current times as well for the future generations.

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