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CHAPTER 14

AUTOMATION OF WATER SUPPLY SYSTEM

14.1 INTRODUCTION

Water supply is a basic necessity for people, the gap between demand and supply is growing day by day. This imposes the need to practice optimum utilization of water through use of information technology at source, treatment, transmission & distribution till it reaches the consumer end. This implies continuous supervision of the water supply process in order to allow any problem that could appear to be isolated, analyzed and resolved, and at the same time, to maintain normal functioning parameters to the best possible level. Proper solutions imply effective point / stagewise monitoring with automation architectures including: a supervision and control system for the real time sensing of various parameters, programmable logic controllers-based control system with basic functions (communication, adjusting, measuring, etc.) libraries, communication systems, standard interfaces or dedicated ones connected with sensors, electrical drive elements, measuring devices, etc.

The informatics systems present the possibility of monitoring, analyzing and processing the data, leading to an optimum functioning of the stage as well as the entire water supply system. This Chapter presents a philosophy of automation system for the monitoring, control, and predictive analysis of the process parameters in the water supply system for efficient energy usage, reduction of water losses and optimum administration of the water supply system.

14.2 PURPOSE AND OBJECTIVE

Application of new technology and “smart (real time process parameter measurement)” devices is well established in all type of works for sustainable services, including water supply networks. Remote and online monitoring is one of the easiest ways to control flow and pressure among other water related process parameters in water supply networks. In order to reduce losses in the network, online monitoring and controlling is more than a necessity. Water loss reduction is one of the biggest challenges today in the water supply system.

Using automatic and electronic devices will help monitoring, controlling leakages in the Water Supply Systems. The application of these new technologies in water supply system eliminates not only water wastage but also provides continuous water flow at pre determined pressure range. The methodology involves automation with minimum human intervention leading to effective and efficient network distribution, cost effectiveness and maintaining safe drinking water quality parameters.

Combination of sensors, automation systems and cloud-based Internet of Things (IoT) system will also be the most appropriate to provide a comprehensive and robust ‘Smart Online Water Management System’.

Application of sensors

The objective of sensor-based monitoring is not only to monitor Key Performance Indicators viz., flow, pressure, leaks, residual chlorine, etc. but also ensure early detection of faults/ deviations from set routines, quick response, minimum service delivery outage, minimum water loss, optimise efficiency and monitor the quantity and quality on sustainable basis. The additional advantage of this data would be to analyse the demand pattern of the user groups over time and use this information for demand management at appropriate level, minimise non-revenue water, ensure proper management and effective operation and maintenance of water supply systems in the ULBs.

14.2.1 Instruments & Control Systems

Instrumentation and control refer to the analysis, measurement, and control of process variables using process control instruments and software tools through an automatic control system. Some of the more common process variables measured in a water distribution system includes flow, pressure, level, chemical dosage, water quality, energy and temperature. Instrumentation should be selected, installed, commissioned, and maintained properly ensuring the data that it can give is invaluable to the water management authority / body.

The control system may be manual or automatic or a combination thereof. Regardless, the system should be designed to promote energy efficiency, conserve water, and reduce waste while meeting the treated water quality standards and demands under all anticipated conditions.

14.2.2 Industrial Internet of Things (IoT) System

Huge advancements in computing, storage, networking and sensor technologies over last decade or so has given rise to Internet of Things (IoT).

At high level, IoT is a network of interrelated intelligent devices, computers, machines, and objects that are capable of transferring data without requiring human-to-human or human-to-computer interaction. The application of IoT in 'Industrial' use cases refers more specifically to interconnected control systems, sensors, instruments, industrial assets, computers and people. IoT enables intelligent industrial operations using advances data analytics resulting in transformational business outcomes. The scale and span of IoT can be massive, easily resulting in deployments reaching into the thousands, if not tens of thousands of individual endpoints. When properly utilized and optimized, it can be one of the largest enablers for smart systems.

IoT Architecture

As depicted in Figure 14.1, there are 3 tiers in an IoT system – Edge, Platform and Enterprise Application.

Edge Tier: comprises of multiple Edge Gateways. These gateways collect data from sensors, PLCs and other automation systems and send to platform tier.

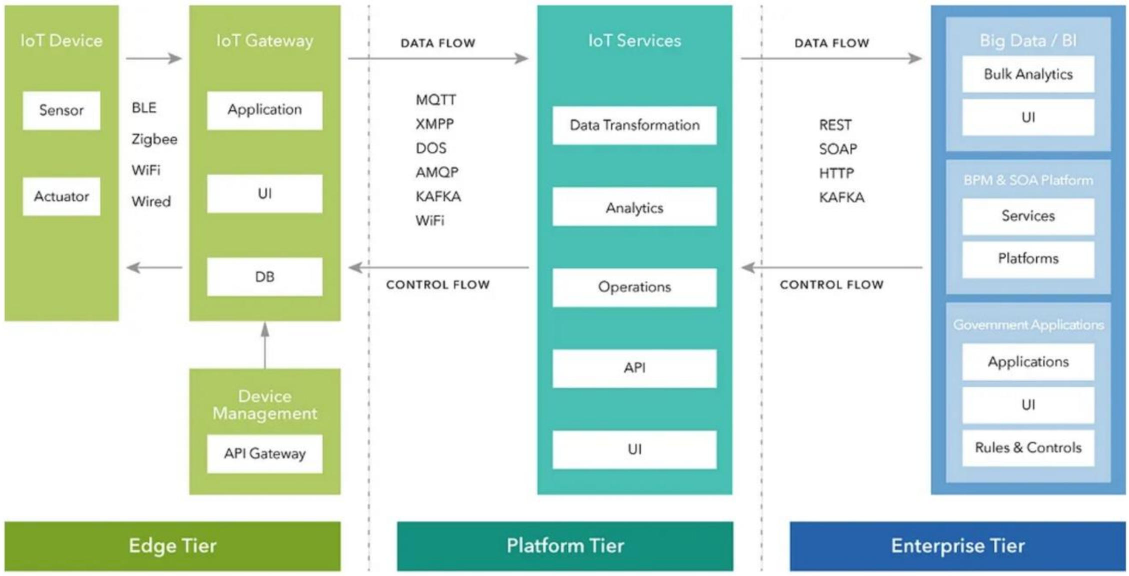


Figure 14.1: Industrial Internet Reference Architecture by https://medium.com/@wiprodigital

Platform Tier: This typically resides in cloud or some sort of Internet / intranet. Uses web server or similar infrastructure. It provides foundational services to Edge Tier and Enterprise Tier. Some services provided by platform are data processing and storage, stream analytics engine, alarm and alerts module, AI/ML engine among others.

Enterprise / Application Tier: This tier resides on top of the platform and shares platform services and data storage. It has the application for a specific requirement, e.g. CMS. It provides user interface and application specific analytics, dashboards, reports. It runs real time analytics on the data and gives actionable alerts to users.

Industrial control systems like SCADA and DCS are suitable for time critical (microseconds latency) primary control of a process. In water distribution domain, WTP is an example of such a process. For other components like pumping station, ESR, FCV time critical control is not required. Control logic of such components may be based on data from other parts of the network in addition to the component being controlled. Thus, an IoT System where data from all parts of network is processed is suitable for non-time critical control.

In short, IoT working on top of automation systems and integrated with technologies like AI/ML is an ideal **Digital Platform** for the distributed Water Management System.

To ensure every drop of water gets meaningfully utilized, India must embark on the journey to Digitalize Water Distribution. The “beginning” of the transition to a centrally monitored Water Supply Distribution and Management System is the most important. It involves-

a. The monitoring and control requirements of the existing system
b. Understanding how available instruments / technology along with Control systems can be used to achieve a real time monitoring and control
c. Understanding the upgradations that needed in the existing water supply system and
d. Working on a cost effective final solution for the utility

14.3 AUTOMATION AT VARIOUS COMPONENTS OF WATER SUPPLY SYSTEM

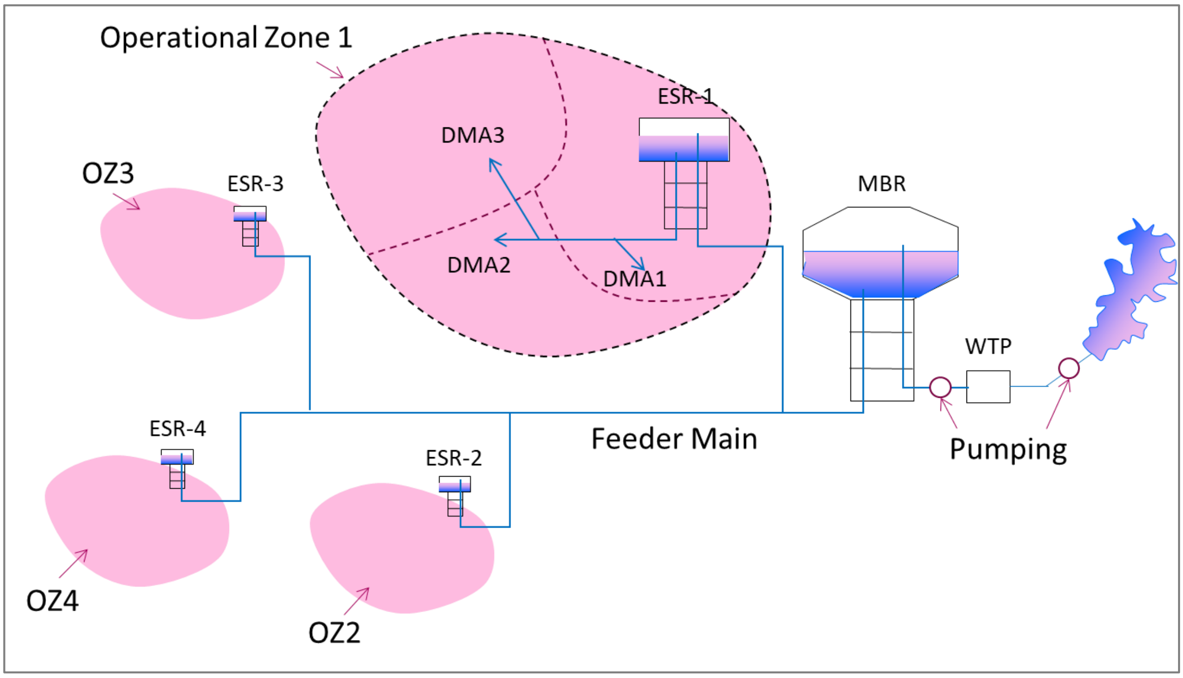


Figure 14.2: Typical water supply scheme

A typical water supply scheme is shown in Figure 14.2. The following components of a water supply system can be considered for the purpose of automation, real-time monitoring, and centralised control.

1) Water Pumping Systems
2) Water Treatment Plants (WTP)
3) ESR / MBR / GSR
4) Key points in Distribution System

14.3.1 Water Pumping Systems

As shown in Figure 14.2, pumping is generally required from source to water treatment plant (WTP) and again from WTP to clear water Master Balancing Reservoir (MBR).

The water pumping systems can and need to be monitored for the parameter such as water level, pressure, incoming and outgoing flow, energy consumed by the pumping systems, water, quality parameters among others.

The components of water pumping systems including valves for priming, pumps and pump delivery / outlet header / distribution valves need to be controlled on the basis of the local feedback received from sensors measuring the above variables. In addition to the pre-set /decided logic of operations which cater to the load / area for water supply being handled by the individual pump house in conjunction with the treatment plant / pumping system etc feeding it.

Monitoring and control using SCADA.

(i) Monitoring: Monitoring location and parameters are shown in Table 14.1.

Table 14.1: Monitoring location and parameters

Location	Parameter	Method	Per
River Source	Level	Ultrasonic / Radar Level Sensor	Take Off Point
Pump House	Level	Ultrasonic / Radar Level Sensor	Underground Reservoir
	Flow	Electromagnetic Flowmeter	Individual Delivery of the Pump
	Flow	Electromagnetic Flowmeter	Common Header from the Pump House
	Energy	Electronic Energy Meter	Common LT / HT Line to the Pump House
	Energy	Electronic Energy Meter	LT / HT Line feeding the individual Pumps at Pump House

(ii) Control: Control location and parameters are shown in Table 14.2.

Table 14.2: Monitoring location and parameters

Location	Parameter	Method	Per
River Source	Flow	Electric Actuated Gate / Valves	Off Take Point
Pump House	Priming System	Electric Actuated Valves / Solenoid valves	Pump at Inlet line
	Flow	Electric Actuated Gate / Valves	Individual Delivery of the Pump
	Flow	Electric Actuated Gate / Valves	Common Header from the Pump House

"Per" : suggests the location of installation,
All parameters must be available as 4-20mA inputs to the monitoring and control system in real time for proper management of system.

14.3.2 Water Treatment Plants (WTP)

All water supply system will involve raw water being picked up from a source (river / check dam / canal etc.). The source is generally a distance away from the town or the city which is being fed by the water supply system.

The water could be pumped or fed by gravity from the source to water treatment plant. It is at the water treatment plant that the water is clarified, filtered, disinfected and provided via multiple / single pipeline to the area of interest.

The following table provides a List of parameters that can be considered for the purpose of real-time and Scada base monitoring.

A typical water treatment plant would comprise of the following subsystems or their equivalents

a. Aerator
b. Flash Mixer
c. Alum/ PAC Dosing
d. Clarifier
e. Filter Beds
f. Back Wash System
g. Backwash Water Recirculation System
h. Chlorine Dosing
i. Pure Water Pumping System

In manual systems, all equipment at the WTP, process operations, backwash sequences, chemical dosing pumps are manually adjusted and handled by the respective operators. In the case of an automatic system, equipment is started and stopped by the control system, with chemical feed rates and pump rates adjusted automatically to maintain the system levels, discharge pressures, etc. This may allow unattended /minimally attended plant operation, but requires a control system, with associated maintenance.

(i) Monitoring: The parameters to be monitored at each stage shall be considered as shown in Table 14.3.

Table 14.3: Monitoring location and parameters

Location	Parameter	Method	Per
Aerator	Flow	Electromagnetic Flowmeter	Aerator Inlet
Flash Mixer	Water Quality: pH & Turbidity	Online Sensors	Per Flash Mixer
Alum / PAC Dosing	Flowmeter of Alum/ PAC	Electromagnetic Flowmeter	Per Dosing Pump
Clarifier	Water Quality: pH & Turbidity	Online Sensors	Per Clarifier Outlet
Filter Beds	Level	Ultrasonic Level Sensor	Filter Bed (multiple in case of multiple outlets in filter bed)
	Pressure	Differential Pressure Sensor	Filter Bed
Back Wash System	Level	Ultrasonic Level Sensor	ESR
	Pressure	Pressure Transmitter	At inlet line to the Filter Bed
Backwash Water Recirculation System	Level	Ultrasonic Level Sensor	Recirculation Sump
	Pressure	Pressure Transmitter	At outlet line from the pumping system

Location	Parameter	Method	Per
	Flow	Electromagnetic Flowmeter	At inlet to the recirculation sump / recirculation line to the pre clarifier stage
Chlorine Dosing System	Residual Chlorine	Online Sensors	Per Pure Water UGR
Pure Water Pumping System	Pressure	Pressure Transmitter	At outlet line from the pumping system
	Level	Ultrasonic Level Sensor	Sump
	Flow	Electromagnetic Flowmeter	At outlet line from the pumping system

(ii) Control: The parameters to be controlled at each stage are shown in Table 14.4.

Table 14.4: Monitoring location and parameters

Location	Parameter	Method	Per
Aerator		PLC based flow monitoring local panel	
Flash Mixer	Mixer Operations	PLC controlled local panel	Per Flash Mixer
Alum / PAC Dosing	Flow of Alum/ PAC	PLC controlled local panel operating Dosing Pump	Per Dosing Pump
Clarifier	Clarifier Operations	PLC controlled local panel	Per Clarifier
Filter Beds	Filter Bed Operations of Regular, Backwash and Drain Modes	PLC controlled local panel	Filter Bed
	Flow	Electric Actuated Gate / Valves	Individual Inlet/ Outlet/ Backwash and Drain of the Filter Bed
Back Wash System	Priming System	Electric Actuated Valves / Solenoid valves	Pump at Inlet line
	Flow	Electric Actuated Gate / Valves	Individual Delivery of the Pump
	Pressure	Pressure Transmitter	At outlet line from the pumping system
	Flow	Electromagnetic Flowmeter	At inlet to the recirculation sump / recirculation line to the pre clarifier stage
Chlorine Dosing System	Residual Chlorine	Online Sensors	Per Pure Water UGR

Location	Parameter	Method	Per
Pure Water Pumping System	Pressure	Pressure Transmitter	At outlet line from the pumping system
	Level	Ultrasonic Level Sensor	Sump
	Flow	Electromagnetic Flowmeter	At outlet line from the pumping system

14.3.3 ESR / MBR / GSR

The ESR/ MBR / GSR systems need to be monitored for the parameters such as water level, pressure, incoming and outgoing flow, water quality parameters among others. A typical inlet and outlet arrangement at service reservoir is shown in Figure 14.3. This arrangement is only for a sump/ clear water reservoir pumping water to the ESR. However, for a gravity/ pumping main supplying water to multi ESRs, the pressure gauge as shown in Figure 14.3 will be replaced by a pressure transmitter which will be connected to RTU. In addition to this, the on/ off sluice/ butterfly valve shall be replaced by the dual solenoid FCV.

Inlet Arrangement: On the inlet pipe of the ESR, the arrangement should be isolation valve followed by the bulk meter and then by the electric actuator operated sluice/ butterfly valve and one pressure gauge/ pressure transmitter.

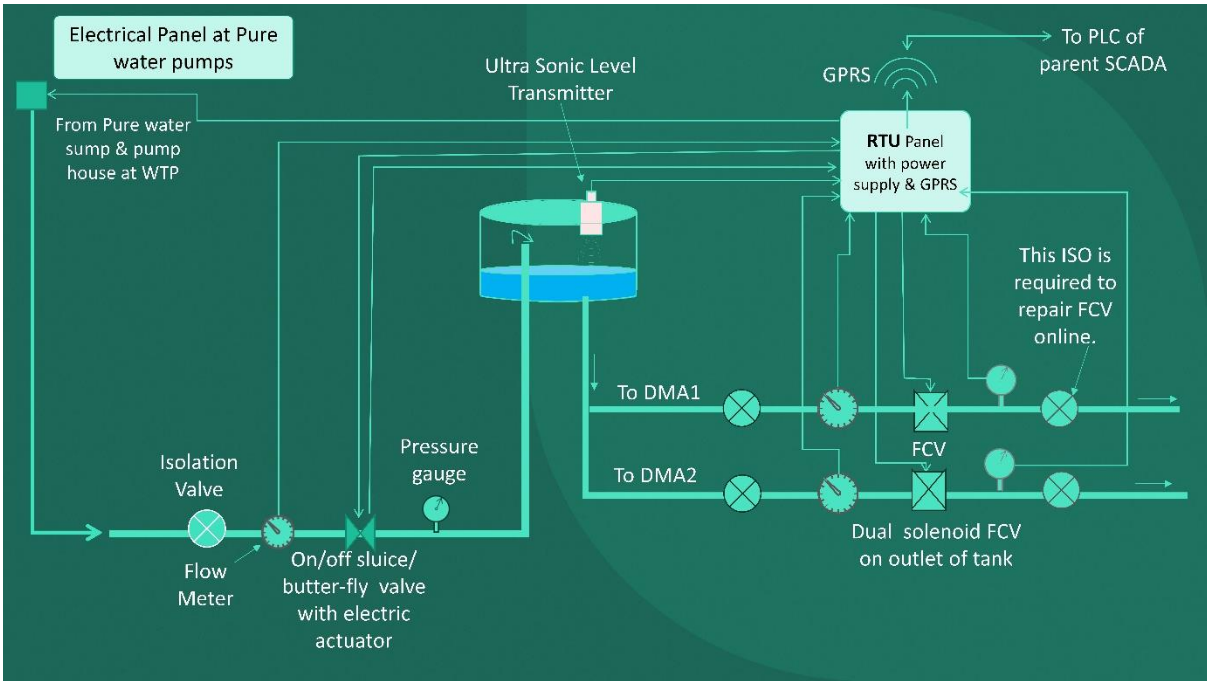


Figure 14.3: Typical inlet and outlet arrangement at service reservoir

The sluice/ butterfly valve shall be open when the water level in the tank is minimum and shall be closed when the water level is maximum.

Outlet Arrangement: From the common outlet of ESR the two branch pipelines are shown in Figure 14.3 supplying water to two DMAs. The sequence of valves is shown in the Figure 14.3.

Why FCV Required: Typical FCV is shown in Figure 14.4. FCVs are used to rationalize (less quantity in non-peak hours and more quantity at peak-hours) distribution of water from ESRs to DMAs. Normally with hydraulic model the design of pipelines is so made that the DMAs to get water as per their demand. However, practically the tank gets empty (on sloppy side) when the flow starts. But with FCV the flow can be regulated in such a way that the water will flow as per the actual demand in the DMA and there will be backward pressure available which will help to maintain water level in the service tank.
During pipe breakages or burst in the DMA, the FCV at the entry of DMA can close the flow. Here the pressure transmitter shall send the signal and accordingly, the PLC shall control the FCV through its solenoids.

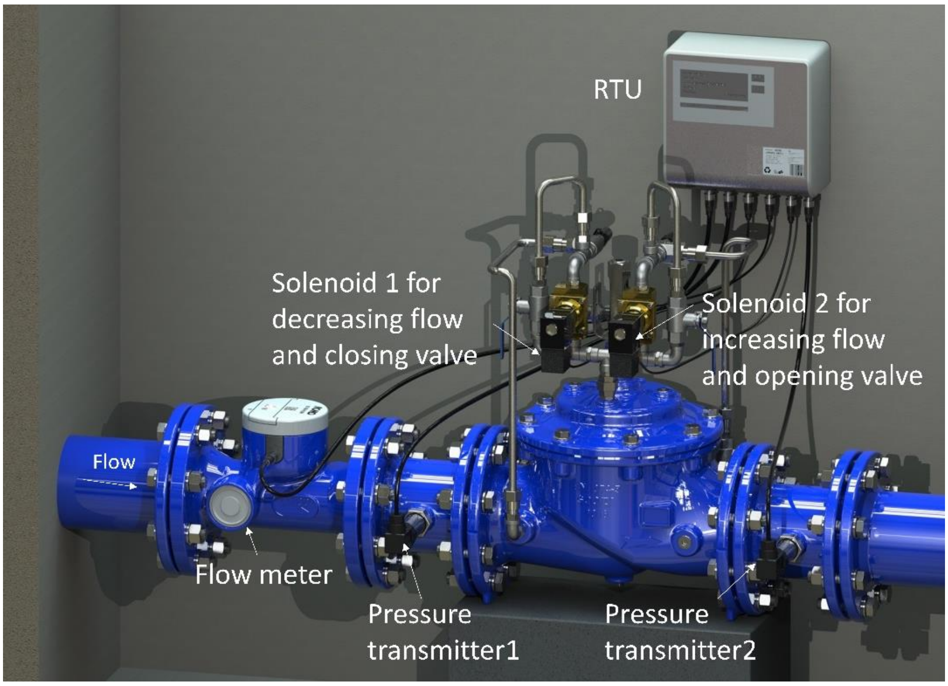


Figure 14.4: Typical FCV with solenoids, RTU, pressure transmitters and flow meter.

When FCV is not Required: In order to maintain the nodal pressure of 21m, if VFD pup is installed on the outlet of the ESR, then FCV may not be necessary.

The ESR/ MBR / GSR systems need to be controlled including valves for priming pumps and pump delivery / outlet header / distribution valves. This needs to be controlled on the basis of the local feedback received in addition to the pre-set logic of operations which cater to the further water supply system (distribution etc.) being handled by the individual pump house in conjunction with the treatment plant / pumping system etc.

Monitoring and control by IoT System

(i)Monitoring: The parameters to be monitored are shown in Table 14.5.

Table 14.5: Monitoring location and parameters

Location	Parameter	Method	Per
Elevated Service Reservoir	Level	Ultrasonic / Radar Level Sensor	Reservoir
Pump House	Level	Ultrasonic / Radar Level Sensor	Underground Reservoir
	Flow	Electromagnetic Flowmeter	Individual Delivery of the Pump
	Pressure	Pressure Transmitter	Individual Delivery of the Pump
	Flow	Electromagnetic Flowmeter	Common Header from the Pump House
	Pressure	Pressure Transmitter	Common Delivery of the Pumps
	Energy	Electronic Energy Meter	Common LT / HT Line to the Pump House
	Energy	Electronic Energy Meter	LT / HT Line feeding the individual Pumps at Pump House

(ii) Control: The parameters to be controlled are shown in Table 14.6.

Table 14.6: Monitoring location and parameters

Location	Parameter	Method	Per
ES Reservoir / UG Reservoir	Flow	Electric Actuated Gate / Valves	Inlet, Bypass & Outlet
Pump House	Priming System	Electric Actuated Valves / Solenoid valves	Pump at Inlet line
	Flow	Electric Actuated Gate / Valves	Individual Delivery of the Pump
	Flow	Electric Actuated Gate / Valves	Common Header from the Pump House

"Per" : suggests the location of installation,

All parameters must be available as 4-20mA inputs to the monitoring and control system in real time for proper management of system.

14.3.4 Key points in Distribution System

In addition to the above systems / subsystems, every water supply distribution system has some key notes where it is important to measure various parameters such as pressure, flow, water quality to ascertain that the water supply system is working within normal and allowed limits. Such key locations are at the entry of each DMA and the strategic spots such as highest and lowest ground elevations and farthest node in the operational zones. It becomes key to be able to get these feedbacks from predefined locations as they are litmus test for the proper functioning of the overall system.

Over a period of time these key points may lose / gain importance for parameter measurement in the overall water supply system.
In addition to the pre-identified key points as the water supply system expands and evolved over time, there may be a requirement to add oblique reduce key points in the water distribution set up.

The following sections deal with a broad outlook on the requirement of parameter monitoring in the various subsystems and gives an insight into what may be considered by the various utilities/ boards of corporations for incorporation in their individual water supply system.

Despite best efforts, it may be found. There are certain components which need to be discounted and certain components that may be additionally required to be added, for the purpose of obtaining optimal and comprehensive monitoring and control systems.

(i)Monitoring: The parameters to be monitored are shown in Table 14.7.

Table 14.7: Monitoring location and parameters

Location	Parameter	Method	Per
	Flow	Electromagnetic Flowmeter	Key Point
Entry of DMA	Flow, pressure	Ultrasonic	
Strategic points such as highest and lowest elevations and farthest node in operational zone	Flow, pressure		
	Pressure	Pressure Transmitter	Key Point
	Ph, Turbidity	Water Quality Analyser	Certain Key Point

(i) Control : The parameters to be controlled are shown in Table 14.8.

Table 14.8: Controlling parameters

Location	Parameter	Method	Per
	Flow	Electric Actuated Gate / Valves	Key Point

"Per" : suggests the location of installation,

All parameters must be available as 4-20mA inputs to the monitoring and control system in real time for proper management of system.

The control systems and all the above subsystems would comprise of PLC / RTU based control panels with accessories and relevant switchgear as per the system requirement that can be programmed to operate the control systems in a pre-programmed fashion. In addition, as required and as per site conditions, the PLC /RTU panels will have the capability to provide localised communication on technologies such as OFC, ethernet, wireless CAN, and on wireless technologies like GPRS, satellite communication, LoRaWAN, etc. The control and monitoring elements should further be enabled to communicate the status of their individual locations to an IoT based centralised monitoring and control centre bracket CMS that enables the water.

The control and monitoring elements should further be enabled to communicate the status of their individual locations to an IoT based centralised monitoring and control centre (CMS) that enables the water supply system to be monitored from one single location for the entire state / city / town.

Note : The above suggested monitoring and control elements that can be considered while designing Water System is non-exhaustive and needs to be adapted to suit the requirements of an individual water supply system. It must be noted that care has to be taken to ensure comprehensiveness of monitoring and control to deliver substantial, measurable and actionable inputs for the water supply department to actually effect improvement in water supply, reduction in NRW.

Controls and instrumentation should be planned as per the projected requirement viz. appropriate plant size, complexity and number of staff and their skills for each plant. To achieve this, the designer should develop a control philosophy that will enable the plant staff to effectively monitor and control the plant and major equipment, the water supply system.

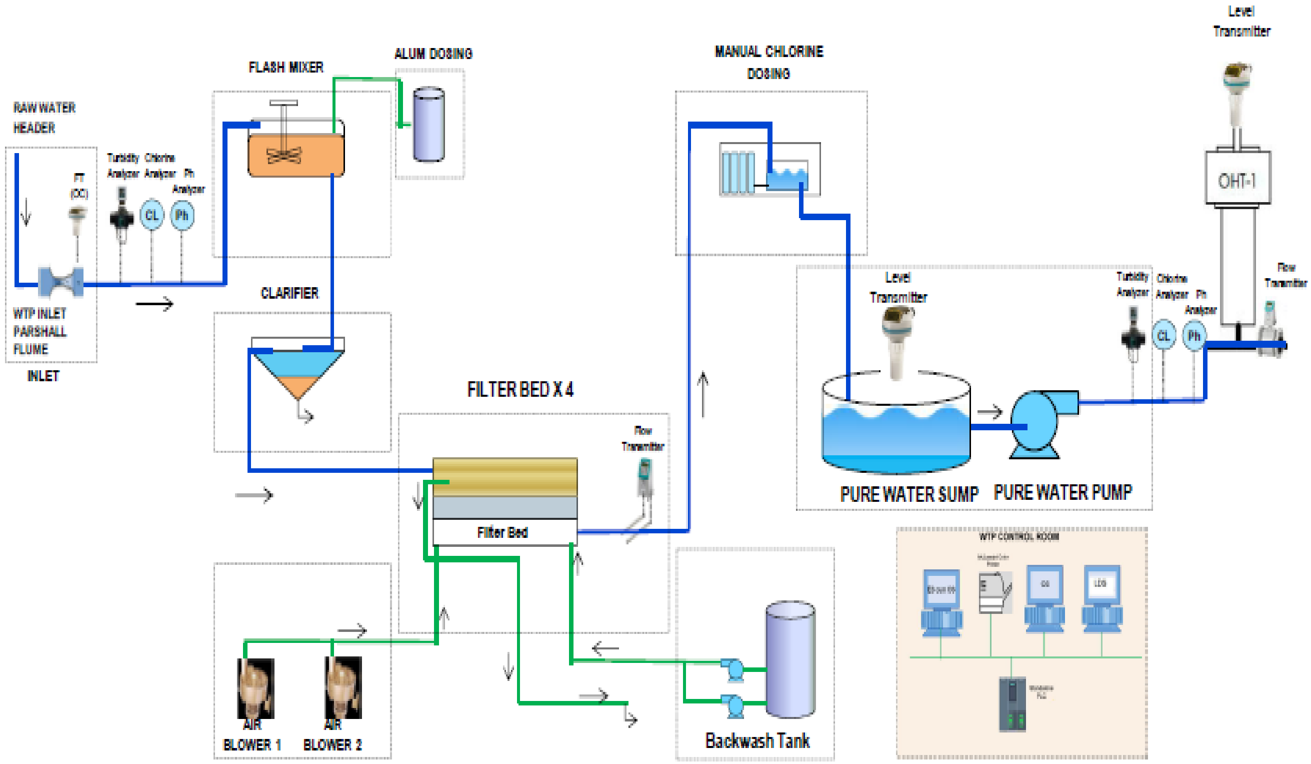


Figure 14.4: C&I scheme for WTP

14.3 SENSOR SYSTEMS

14.3.1 Mechanical

Mechanical system is a system operated by machine or machinery. It is controlled by physical forces. This system can be used to measure, record, and trend variations in process parameters, such as pressure, flow, or temperature. In most cases, the instrument will convert mechanical displacement or movement of its sensor into a corresponding proportional movement of a pen or gauge.

Control of mechanical systems involves using

(i) Sensors to monitor:

1. the input
2. the mechanisms in the process part of the system
3. the output motion and force

(ii) Feeding the information to:

1. analogue or digital displays so that a human operator may act on the information; and/or
2. controlling devices that act on the input and/or process parts of the system to achieve a desired output

14.3.2 Pneumatic

A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic components are resistant to continuous loads and maintenance-free over their entire service life. They are very easy to install and are cheaper than comparable electrical solutions, particularly when implementing complete system solutions. Pneumatic components also have benefits when it comes to safety. Compressed air continues to be available even during a power failure. An air reservoir is always available along with a compressor for generation and preparation purposes. Apart from end-position sensing and monitoring the compressed air supply, it doesn't need to be monitored and checked. It follows the "fit and forget" principle.

Pneumatic actuators only require electricity for the control and generation of compressed air; the movement itself is triggered by the compressed air. Whereas electric actuators require gearboxes, which are responsible for most of the power losses as well as electrical heat losses, pneumatic actuators act directly on the shut-off device. They only require a piston and drive shaft to convert the "linear" compressed air force into a swivel motion.

Since pneumatic actuators are overload-proof and a higher actuation force can be achieved very simply by increasing the pressure, it is often possible to use smaller sizes with a lower weight than would be the case for electric actuators. Provided the tubing has zero leakage and the units are precisely dimensioned, the resulting solutions are energy-efficient.

The disadvantages of pneumatic instruments are:

(i) Sensitivity to vibration, temperature changes, mounting position, and the like affect calibration accuracy to a much greater extent for pneumatic instruments than electronic instruments.

(ii) Compressed air is an expensive tool, much more expensive per watt-hour equivalent than electricity, which makes the operational cost of pneumatic instruments much higher than the electronic one.

(iii) One of the properties of pressurized air is like it always occupy the empty space and the air pressure is maintained in hard work. Therefore, we need a seal so that air does not leak. Seal leakage can cause energy loss. Pneumatic equipment should be equipped with airtight equipment so that compressed air leaks in the system can be minimized.

(iv) Pneumatic using open system, meaning that the air that has been used will be thrown out of the system, the air comes out loud and noisy so will cause noise, especially on the exhaust tract. The fix is to put a silencer on each dump line.

(v) The installation cost of pneumatic instruments can also be quite high, given the need for special pipes (stainless steel, copper, or resistant plastic) to transport supply air and pneumatic signals to distant locations. The volume of air tubes used to transmit pneumatic signals across distances acts as a low pass filter, naturally dampening the response of the instrument and, therefore, reducing its ability to respond quickly to changing process conditions.

(vi) Pneumatic instruments cannot be made “smart” as electronic instruments either.

14.3.3 Electrical

Electrical Instrumentation is about the design, realisation and use of electric or electronic systems for the measurement of electrical and non-electrical quantities. Strongly related fields are measurement science and data acquisition. A control system that uses an electric current; either direct current (DC) or current shuttle (AC) as a source of supply. Electrical systems require:

(i) Electricity (DC) or (AC)
(ii) Input elements (switches, sensors, transducer, valves, electronic components, etc.)
(iii) Output elements (motor, lights, etc.)
(iv) Extension cable

This system of instrumentation and control is simple and widely used.

14.3.4 Electropneumatic

Electro-pneumatic control consists of electrical control systems operating pneumatic power systems. In this solenoid valves are used as interface between the electrical and pneumatic systems. Devices like limit switches and proximity sensors are used as feedback elements. Electro Pneumatic control integrates pneumatic and electrical technologies, is more widely used for large applications. In Electro Pneumatics, the signal medium is the electrical signal either AC or DC source is used. Working medium is compressed air. Operating voltages from around 12 V to 220 Volts are often used. The final control valve is activated by solenoid actuation.

The resetting of the valve is either by spring [single Solenoid] or using another solenoid [Double solenoid Valve] . More often the valve actuation/reset is achieved by pilot assisted solenoid actuation to reduce the size and cost of the valve Control of Electro Pneumatic system which is carried out either using combination of Relays and Contactors or with the help of Programmable Logic Controllers [PLC]. A Relay is often is used to convert signal input from sensors and switches to number of output signals [either normally closed or normally open]. Signal processing can be easily achieved using relay and contactor combinations A Programmable Logic Controller can be conveniently used to obtain the out puts as per the required logic, time delay and sequential operation. Finally, the output signals are supplied to the solenoids activating the final control valves which control the movement of various cylinders. The greatest advantage of electro pneumatics is the integration of various types of proximity sensors [electrical] and PLC for very effective control. As the signal speed with electrical signal, can be much higher, cycle time can be reduced, and signal can be conveyed over long distances.

In Electro pneumatic controls, mainly three important steps are involved:

(i) Signal input devices -Signal generation such as switches and contactor, Various types of contact and proximity sensors
(ii) Signal Processing – Use of combination of Contactors of Relay or using Programmable Logic Controllers
(iii) Signal Outputs – Out puts obtained after processing are used for activation of solenoids, indicators or audible alarms

Seven basic electrical devices commonly used in the control of fluid power systems are

(i) Manually actuated push button switches
(ii) Limit switches
(iii) Pressure switches
(iv) Solenoids
(v) Relays
(vi) Timers
(vii) Temperature switches

Other devices used in electro pneumatics are

(i) Proximity sensors
(ii) Electric counters

The greatest advantage of electropneumatic is the integration of various types of proximity sensors [electrical] and PLC for very effective control. As the signal speed with electrical signal, can be much higher, cycle time can be reduced and signal can be conveyed over long distances.

14.3.5 Hydropneumatics

The hydro-pneumatic system provides water automatically at defined pressure & quantities at many locations from single pumping system. This system operates on variety of differential pressures. It operates automatically by sensing the pressure within the preset pressure range. Hydro-pneumatic systems are used to supply water at designed pressure & quantity from a single source.

14.3.6 Method of Control

The key characteristic of control is to interfere, to influence or to modify the process. This control function or the interference to the process is introduced by an organization of parts (including operators in manual control) that, when connected together is called the Control System. Depending on whether a human body (the operator) is physically involved in the control system, they are divided into Manual Control and Automatic Control (SCADA). Due to its efficiency, accuracy and reliability, automatic control is widely used.

14.3.6.1 Manual

Manual Control system is an open loop control system. This type of system needs an external effort to adjust and correct the errors. Manual control System is less reliable. Manual controls are applicable when judgment and discretion are required. Additionally, manual controls can be used to monitor automated controls. Additional risks arise with the use of manual controls as they can be more easily overridden, susceptible to human error, and are inherently less consistent than automated controls.

14.3.6.2 SCADA

SCADA stands for "Supervisory Control and Data Acquisition". SCADA is a type of process control system architecture that uses computers, networked data communications and graphical Human Machine Interfaces (HMIs) to enable a high-level process supervisory management and control.

SCADA is a collection of hardware and software components. Plant floor devices such as pumps, valves, and transmitters transfer real-time data to processors such as Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs). That data is then disseminated to various devices within the network such as Human Machine Interface terminals or HMI's, servers, and computers. Images of these processes are presented to operators for various types of interaction.

Generally, SCADA is done by relying on simple indicators such as lamps, analogue meters, or alarms. Along with the development of computer technology, the computer becomes an important component used in designing SCADA. However, an IoT System is more suitable for web-based monitoring and control for several reasons. These reasons are elaborated in next sections.

In SCADA system, HMI is used as a display of connecting SCADA system between man and machine. HMI displays data to the operator and provides the input medium used to control the process by the operator. Human Machine Interface is used as an intermediary between man and machine. Without using HMI, the process of supervision and control will be more difficult and require more time.

The hardware components likely consist of pumps and motors, valves, switches, and transmitters. These components will communicate with a processor which in turn, will allow the components to be viewed, graphically, on the SCADA system.

Pictorially, this hardware presentation may be as simple as flat lines that represent pipes, simple graphic representations of valves, and motors that may change colour according to current status such as opened or closed for valves and running or stopped for the motors. Typically, the layout of the graphics would be similar to what may be seen on Process/Piping and Instrumentation Diagrams or P&ID's. These drawings would show the piping layout with pipe sizes. The location of instruments, valves, motors, etc within the piping, as well as symbols indicating what signals will be passed to and from the processors in the system. A group of graphical screens are created that would contain all pertinent information that an operator may need to interact with and control the water treatment system.

14.3.6.3 SCADA and IoT Comparison in relation to Water Distribution Systems

Main characteristics of Water Distribution Systems are:

1. Large areas coverage with seamless and very low-cost connectivity
2. Large data crunching
3. Real time monitoring and data analytics
4. Historical data context
5. Making data available to other systems

Thus, an Internet of Things (IoT) platform with a Water Distribution Application is more suitable compared to SCADA. In such a distributed system each device, each node and each facility needs to be stitched together and these will be very large numbers. SCADA is suitable for control of a plant (e.g. water treatment plant) but not for distribution systems.

Total cost of ownership of the systems for very large installations will be very important consideration. Comparison of SCADA and IoT is shown in Table 14.9.

Table 14.9: Comparison of SCADA and IoT

SN	IoT / Digital Platform	SCADA
1.	Designed for web-based monitoring of multiple devices / processes	Designed for primary control of a process
2.	A web-based system suitable for cloud deployment	A standalone system with web interface
3.	ISA-95 level 3 system. Can connect to SCADA for data collection	ISA-95 level 2 system
4.	Main focus is various value-added features using collected data. Has capability of control functions like start / stop pump or open/close valve etc. Latency is in seconds / minutes depending on network latency	Main focus is operations and real time control. Time critical controls with milliseconds latency are possible
5.	Multi-user system with different user roles and elaborate access right allocation	Multi-user system. Access rights allocation is limited
6.	Used by all user levels up to management	Mainly used by plant operators, engineers and supervisors
7.	Core features are dashboards, reports and analytics on data collected directly from plant / process. Also, notifications to users for real time actions	Core features are monitoring and control of plant / process
8.	Distribution of reports via email	
9.	Can be integrated with other enterprise systems like billing system, GIS	Difficult to integrate with enterprise systems
10.	Provides mobile interface for seamless access and convenience	

SN	IoT / Digital Platform	SCADA
11.	Seamless access with any browser and users don't need special/ licensed applications	
12.	Alerts and notifications to users over email and SMS	
13.	Benchmarking of performance of devices and systems can be inbuilt	
14.	Integration with AI/ML models	

14.4 DESIGN PRINCIPLES AND PRACTICES

Following are the principles of automatic control system:

(i) **Display system status:** Without sufficient understanding of what an automated system will do, what it's currently doing, or what's been done, users may not trust the system. Explore ways to educate users on what the system will do, and communicate its progress along the way.

(ii) **Support human-computer collaboration**: Some automated experiences will reliably get the desired outcome 100% of the time but others may need minor modifications. Enabling users to fine-tune the system will improve outcomes. Human-computer collaboration is also important when some parts of a process are more suited to a computer whereas others are more appropriate for a human.

(iii) **Allow for human intervention:** When system status and human-collaboration are insufficient to produce an optimal outcome, the software should allow users to stop the process and manually intervene if they see something is wrong.

14.5 LEVEL MEASUREMENT

The level measurement is a measurement of fluid level, the measure of height is called a level, like the fluid level in a tank. The measurement of level is very important in a process, so by doing level measurement we can make sure the process is safe. The level measurement is categorized into the top-down and bottom-up level, the top-down measurement is not susceptible to leakage or it can be considered as less leakage process. The top-down measurement could make a contact with the fluid or sometimes it won't, while the bottom-up type makes contact with the process fluid.

The level measuring instruments are suitable to measure the level of water and it could be done directly or indirectly which would be done according to the application. A level measuring instrument would act as an indicator that shows the level of the water and this information would be carried in the form of AC signals and this is done for the control purpose. The level switches would monitor if the liquid is at a high level or low level according to the set point.

The direct level measurement is an easy process, this measurement is based on physical principles such as fluid motions, floats, and thermal properties there are many types of level measurement under this category and they are slight gas, float operated, dipstick, dip rods, and lead lines. So basically the direct level measurement is by defining the position of the interface, and the density of the measured material is not a constraint.

The indirect level measurement is done by measuring other quantities like volume. So this method measures level by determining some other parameters such as pressure, weight, or temperature.

14.5.1 Essential instruments

i. Ultrasonic Tank Level Sensor

Ultrasonic level sensors measure the distance between the transducer and the surface. Using the time required for an ultrasound pulse to travel from a transducer to the fluid surface and back (TOF). These sensors work without the need to touch the medium being measured. Ultrasonic sensors are ideal for difficult liquids such as wastewater. Ultrasonic level sensors are also ideal for continuous level measurement. While float switches and other sensors are adept at measuring when liquid levels are above or below a certain point. The nature of ultrasonic level measurement is such that levels can be sensed and displayed in real-time.

ii. Hydrostatic level transmitters

These transmitters help in determining fluid contents of a container, by measuring the pressure of the resting body of the fluid within it. The greater the force of liquid, the greater the volume of fluid. The measured static pressure of a liquid is proportional to the height of the liquid. And the static pressure is converted into an electrical signal. The exquisite structure, simple adjustment and flexible installation methods provide convenience to use.

iii. Radar Level Sensors

Radar level transmitter, also called Radar level gauge. Non-contact Continuous level measurement in liquids and solids with free space radar sensors. Non-contacting radar, based on microwave technology, detects only surfaces that reflect energy. These transmitters work on the principle of a radar by using radio wave emissions. Mounted at the top of a tank filled with a liquid. The transmitter sends a radar signal into the liquid, and receives a reflection of the signal. The transmitters then analyze the current fill level of the tank based on the time taken by the transmitted signal to return.

iv. Capacitance Level Transmitter

Capacitance level detectors, also known as Capacitance level transmitter. Capacitance Level Transmitter offers continuous and point level detection in liquids with capacitance probes. These transmitters use liquid stored in a tank or container as a dielectric medium between two or more electrodes. The energy capacity of the capacitor circuit increases when there is more liquid, and decreases if there is less liquid. Measuring the variations in the capacitance value, capacitance level transmitters calculate level of the tank.

v. Float level transmitters

Float level gauge is mainly composed of magnetic float, sensor and transmitter. When the magnetic float ball changes with the liquid level and floats up and down along the catheter. The magnetic steel in the float ball attracts the reed switch at the corresponding position in the sensor. Which changes the total resistance (or voltage) of the sensor. The transmitter then converts the changed resistance (or voltage) signal into a current signal output.

14.6 FLOW MEASUREMENT

Flow meters are devices that can be used to measure the amount of liquid which passes through it. It is an instrument which is used to conduct the flow measurement. Flow meters measure the flow by two methods, some flow meters measure the flow as the amount of the liquid passes through the flowmeter during a period of time. While other flow meters measure the flow by measuring the total amount of fluid that has passed through the flow meter.

Flowmeter consists of devices such as transducer and transmitter; the transducer will sense the fluid that passes through the primary device. The transmitter will receive a signal from the transducer, so the transducer changes this signal into a usable flow signal. So a flow meter can be considered as the combination of these physical devices.

Flow meters can be classified into differential pressure meters, variable area meter, positive displacement meters, magnetic, turbine, ultrasonic and vortex. In differential pressure meters a restriction is used to create a pressure drop. So the flow rate can be determined by measuring the pressure drop across the restriction. In positive displacement meters, the measuring process takes place by precision-fitted rotors as flow measuring elements. The selection of flowmeter depends upon flow conditions and flow range, process conditions like pressure and temperature, and size of pipe.

14.7 FILTER FLOW CONTROL

An operational control system – along with media configuration, underdrain system, and backwash process – is an important consideration because it determines how water flow is controlled through the filter. Four basic types of operational control systems are used in gravity filtration, with some variances from plant to plant.

(i) **Effluent rate of flow:**This type of system controls the rate of treatment through a cell on the filter's discharge. Basic components include a flow-sensing device, rate controller, and modulating valve. A wide variety of flow-sensing devices may be used, including direct reading meter systems and indirect reading systems such as Venturi or orifice plates. The rate control design also varies considerably, depending on the flow-sensing device and modulating valve design. Signals from the flow sensor, rate controller, and valve may be pneumatic, electric, mechanical, or a combination of these.

(ii) **Influent flow splitting:**An influent flow splitting filter system has an adjustable weir positioned at the entrance of each filter cell. The influent weir is the system's main component. A feed pipe or flume common to all filter cells carries the water to the individual weirs. The inlet weirs are adjustable so each can be positioned at the same elevation to obtain uniform flow splitting. Ancillary equipment often includes an influent control valve and an effluent hydraulic control point to maintain a minimum water level in a filter cell. The influent control valve is used to stop incoming flow if the cell needs to be removed from service, such as during a backwash event. The effluent hydraulic control point may consist of a downstream weir or upturned loop in the effluent pipe.

(iii) **Constant level:**This type of filter control uses a level-sensing device in each filter cell to communicate with a control valve in the effluent line. The communication method can take various forms, including mechanical linkage, pneumatic pressure, electrical signal, or a combination of these. A variety of level-controlling devices may be used. The most common is a butterfly valve equipped with an appropriate actuator to position the valve disc. Valve size selection is critical for operation, and selection should be made such that a small change in disc position doesn't drastically change the flow through the valve.

(iv) **Declining rate:**Declining-rate filtration is one of the oldest and simplest methods of filter control. It is used with multiple filter cells – the greater number of cells, the better the performance. The system's main component is the filter media.To limit the maximum rate of filtration through a cell, a flow restriction may be placed in the effluent pipe or, in some special cases, on the influent side. The flow restriction may simply be an orifice plate. This flow restriction is used to limit the initial flow passing through the filter – essentially a speed limit for the filter. A two-position control valve may also be used where the valve is partially closed directly after a backwash to restrict flow of the cleanest cell.

14.7.1 Filter Flow Control Valve

All filters have either five or six valves associated with the filter bay, depending on the type of backwash procedure. The control valves associated with a filter are influent, effluent, drain and backwash. The fifth valve is either an agitator water supply valve or an air valve, depending on whether a surface agitator wash system or an air/water system is used.

In the filtration mode, treated water enters the filter box through influent piping or channel and fills the box. Water flow is down through the media, through the underdrain support system and out through the effluent piping where flow is measured and controlled by a rate-of-flow controller. The rate-or-flow controller is commonly a venturi meter, a flow transmitter and a filter effluent valve. As the loss-of-head across the filter increases, the filter effluent valve must modulate to a more open position to maintain the setpoint of the flow. Filtered water flows through the rate-of-flow-controller to the "clearwell." The filter media used in a filter is commonly thought to trap the suspended materials. However, filtration is a combination of both physical and chemical mechanisms. As water passes through the media, large particles are trapped, and suspended particles become stuck to the surface of the grains of filter media and to other particles previously adsorbed by the media. Filter run time is dependent on how many particles are present in the water supply to the filter, and the initial cleanliness of the filter following the backwash sequence. Run times can vary from as short as 15 hours or less to over 100 hours. In the filtration mode, grains of filter media tend to stick together forming "mudballs" because of sticky floc. Unless backwashing removes this material, mud balls can sink into the media and clog the filter. As the filtration process a progress, the filter media becomes more restrictive to flow, causing an increased head-loss through the media. If allowed to progress too far, negative pressures can be produced in the effluent piping that can cause air binding. A “loss-of-head” transmitter is a transmitter that senses the differential pressure between the head of water in the filter bay and the pressure in the effluent piping. In an automatic backwash system, high loss-of-head is one of the signals used to alarm or start a backwash sequence.

Automatic filter backwash control provides a consistent process of cleaning, and in the case of multimedia filters, proper re-stratification of the media. Air-water backwash control is extremely critical. An automatic backwash control system provides all interlocks to control the pumps, blowers and valves to provide a safe and reliable operation. In some cases, the automatic control system is designed to adjust the backwash flow rate based on temperature or viscosity of the water, and terminate the backwash sequence based on time or the turbidity of the backwash water. In the automatic mode, all sequencing is done by the control system. The backwash procedure is started automatically after the control system receives a high loss-of-head alarm, a high turbidity alarm, or a preset filter run-time has been reached.

14.8 RATE OF FLOW OF CHEMICALS

(i) **Liquid Chemical Feed**

The chemical dose rate should be flow paced to the plant flow in the part of the process that the chemical is to be injected into. Two methods are typically used to achieve this: metering pump, or flowmeter and flow control valve on the chemical feed. In metering pump, positive displacement type (diaphragm, peristaltic or progressive cavity) pump should be used. The output of the pump is directly controlled by a 4-20 mA signal from the flow transmitter on the plant flowmeter. On plant shutdown, the flowmeter (usually the raw water flowmeter) will signal the metering pump to stop and a solenoid on the dilution water to close. A load cell or pressure (level) transmitter on the chemical storage tank should provide warning signals when chemical supply is low, and should have alarm and initiate plant shutdown on low-low level. In case of Flow Meter Control, the chemical feed rate is controlled by an in-line flow control valve. A PLC receives a 4-20 mA signal from the flow transmitter on the plant flowmeter. Using this dose rate set point, the controller will look at the flowrate on the chemical feed flow transmitter and signals the in-line flow control valve to a position that will control the feed rate to the established set point. On plant shutdown, the controller will signal the in-line control valve to close. Depending on the range of feed rates, multiple flow meters and control valves may be required. As with the metering pump system, low and low-low level alarms/shut-down should be provided on the chemical storage tank.

(ii) **Dry Chemical Feed**

Dry chemical feed systems typically include a packaged bulk storage combination feeder and mixer. The feeder can be gravimetric or volumetric, and will be controlled by a 4-20 mA signal from the flow transmitter on the plant flowmeter. The chemical feeder discharges to a dissolving tank where it is mixed with plant service water to form a solution (slurry) suitable for dosing. Plant service water flowrate is manually set and monitored by flow indicator. The rate needs to be suitable for the range of anticipated chemical feeds and its solubility; the rate may need to be manually adjusted seasonally. For a specific plant service water flowrate, the variation in chemical feed rate creates a corresponding variation in solution strength fed to the process water. The solution is fed via a hydraulic injector (if into a pipeline under pressure), or directly by gravity into open channels or tanks. On plant shutdown a signal from the raw water flowmeter will call for the dry feeder to stop and a solenoid valve on the plant service water feed to the dissolving tank to close. If an injector is used, a solenoid valve on the plant service water will also close.

14.9 PRESSURE MEASUREMENT

Pressure may be simply indicated on a gauge or transmitted by a transmitter. Pressure gauges are available to read both differential and single-ended pressure. By far the most common measurements are single-ended, although differential gauges are used to read head loss on water and air filters.

(i) Where a pressure gauge is reading a pressure produced by a pump (normally required) the gauge should be protected from vibration by filling it with either silicone liquid or glycerin. Silicone should be used if the ambient temperature will fall below -30°C.

(ii) The range of the gauge should be chosen so that it will normally operate at one-half to twothirds of scale at normal design pressure; the gauge should not be operated full-time near the top end of the scale. This will provide some safety margin on over-pressure as well as prolonging the life of the gauge.

(iii) The gauge should be installed where the lens will not get damaged and where it can be read easily. Choose a gauge with a top-mounted stem where it will be installed near the ceiling so that the dial will read right-side up.

(iv) For water applications (both raw water and treated) a bronze or 316 stainless steel bourdon tube mechanism should be used. For applications on chemical lines, the manufacturer should be consulted for compatibility between the process and the gauge material.

(v) On corrosive liquids and processes containing solids, or where the gauge material is not compatible with the process, an isolating diaphragm should be used between the process sense line and the gauge to protect the gauge.

(vi) A block and bleed valve should be installed between the process and the gauge, or between the process and the diaphragm, to take the gauge out of service.

Pressure transmitters are available to read either differential or single-ended pressures. The single-ended type may read either gauge pressure (the pressure relative to the atmosphere) or absolute pressure (relative to a vacuum). Absolute pressure measurements are not common. Differential measurements are commonly used to determine when a filter needs washing. The range of the transmitter should be chosen so that it will normally operate at one-half to two-thirds of scale at normal design pressure; the transmitter should not be operated full-time near the top end of the scale. This will provide some safety margin on over-pressure as well as prolonging the life of the sense element in the transmitter. For water applications (both raw water and treated) a bronze or 316 stainless steel sensing diaphragm should be used. A block and bleed valve should be used between the process and the transmitter, or between the process and the isolating diaphragm, to take the transmitter out of service, and to facilitate calibration. Where a pressure gauge is not installed on the same line as the transmitter, an integral display should be provided on the transmitter for local indication.

14.10 WATER QUALITY

The Water quality measurement plays a major and crucial role in water treatment and distribution system. In general, the water quality evaluation takes place manually by collecting samples from the field and sent to a laboratory for the result but this way has a delay in the process. This process wastes too much manpower and material resource, and has the limitations of the samples collecting, long-time analyzing, the aging of experiment equipment, results. A set of automatic measuring, storing and display system of water quality helps in resolving the limitations in manual monitoring. A Sensor is an ideal detecting device to solve these problems. It can convert non-power information into electrical signals. It has many special advantages such as good selectivity, high sensitivity, fast response speed and so on.

14.11 WATER QUALITY STANDARDS

Bureau of Indian Standards (BIS), has specified drinking water quality standards in India to provide safe drinking water to the people. It is necessary that drinking water sources should be tested regularly to know whether water is meeting the prescribed standards for drinking or not. If not, then, the extent of contamination/ unacceptability needs to be understood and necessary counter-measures to be taken. Apart from BIS specification for drinking water, there is one more guideline for water quality, brought out by Ministry of Water Resources, Government of India in 2005. This is known as Uniform Protocol for Water Quality Monitoring.

14.12 PROTOCOL FOR SAMPLING

There are many important factors for accurate analysis of the sample. These factors include proper collection of the samples, method of storage and protocol for microbial and chemical analysis, data analysis and interpretation. If any of these steps are carried out with insufficient care, the result will be inaccurate and the entire operation will result in wastage of energy, time and money. The general precautions in the Bureau of Indian Standards i.e., IS-3025/1622 and/or Standard Methods for the Examination of Water & Wastewater- latest edition [Published jointly by American Public Health Association (APHA), and American Society for Testing and Materials (ASTM) shall be referred to for detailed information on sampling and testing procedures. Water treatment and distribution process with sampling points are shown in Figure 14.5.

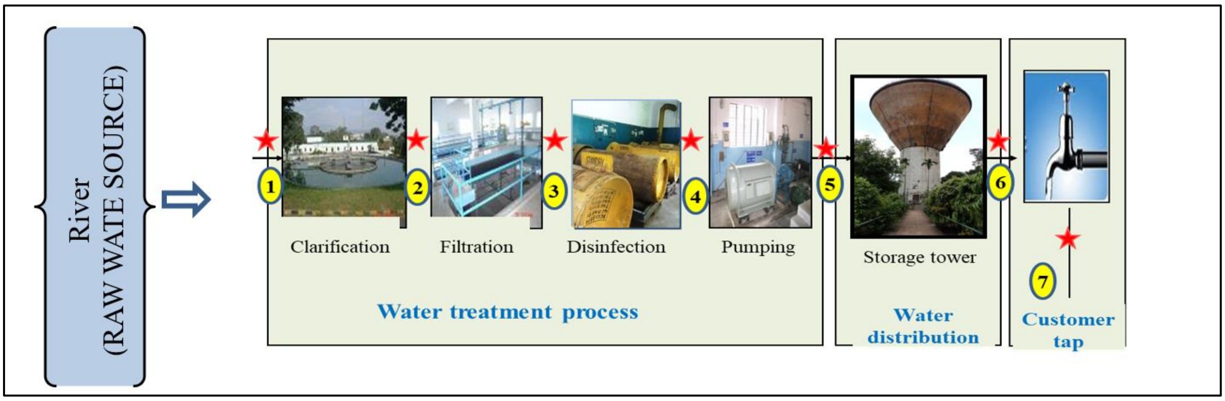


Figure 14.5: Water treatment and distribution process with sampling points

Sampling points and sampling schedule is shown in Table 14.10.

Table 14.10: Sampling points and sampling schedule

Sampling points	Sampling Schedule	Test Analysis	Critical Parameters for Process efficiency
1	Daily	Jar Test, Turbidity, pH, Color, Coliform, Iron	pH 7.0 – 8.0 , MPN of Coliform/100ml ≤ 160000
2	Daily	Turbidity, pH, Color, Coli form	Turbidity 2 – 6 N.T.U, pH 7.0 – 7.8, Coliform- ≤ 1600
3	Daily	Turbidity, pH, Color, Coliform	Turbidity ≤ 1 N.T.U, pH 7.0-7.6, Color ≤ 5 hazen, Coliform- ≤ 500 CFU , Aluminum ≤ 0.2 mg/l, Iron ≤ 0.3 mg/l
4,5,6 & 7	Daily	Turbidity, Free Chlorine, pH , Color, Coliform, Aluminum, Iron	Turbidity ≤ 1 N.T.U, Free Chlorine 0.7– 0.9 mg/l (WTP), ≥ 0.2 ppm (consumer tap) pH 7.0-7.6, Color ≤ 5 hazen, Coliform- absent, Aluminum ≤ 0.2 mg/l, Iron ≤ 0.3 mg/l

14.13 QUALITY SENSORS

The most widely used water-quality sensors in monitoring installations are temperature, specific conductance, dissolved oxygen (DO), pH, and turbidity. Sensors also are available to measure oxidation-reduction potential, water level, depth, salinity, ammonia, nitrate, chloride, and chlorophyll.

The sensors needed to measure these properties are available as single instruments or in various combinations. A group of sensors configured together commonly is referred to as a sonde, which typically has a single recording unit or electronic data logger to record the output from the multiple sensors.

Types of Monitor Configuration

In general, three types of configurations are used for water-quality monitors:

1) The flow-through monitoring system generally has a pump that delivers water to the sensor(s) mounted in a shelter;
2) The sensors are placed in situ (immersing a field measurement sensor directly into the water); and
3) The self- contained sensor and recording system that requires no external power and is placed in situ. Each configuration has advantages and disadvantages in relation to site location and data-quality objectives.

Instrument Acceptance Criteria

Independent testing to ensure accuracy and reliability is an important part of any quality-assurance program for hydrologic field instrumentation.

As stated in the Water-Resources Division (WRD) Hydrologic Field Instrumentation and Equipment Policy and Guidelines (U.S. Geological Survey WRD Memorandum 95-35, 1995), any program or project that procures an instrument is responsible for ensuring that adequate testing is carried out and that the documented results fully characterize the performance and capabilities of the instrument.

14.14 CONCLUSION

Monitoring water quality is an essential tool for the control of pollutants and pathogens that can cause damage to the environment and human health. However, water quality analysis is usually performed in laboratory environments, often with the use of high-cost equipment and qualified professionals. With the progress of nanotechnology and the advance in engineering materials, several studies have shown, in recent years, the development of technologies aimed at monitoring water quality, with the ability to reduce the costs of analysis and accelerate the achievement of results for management and decision-making.

Thus, new alternative technologies for the main physical (color, temperature, and turbidity), chemical (chlorine, fluorine, phosphorus, metals, nitrogen, dissolved oxygen, pH, and oxidation–reduction potential), and biological (total coliforms, Escherichia coli, algae, and cyanobacteria) water quality parameters are being explored. They are based on optical or electrochemical sensors, etc.However, due to the recent development of these technologies, more robust analyses and evaluations in real conditions are essential to guarantee the precision and repeatability of the methods, especially when it is desirable to compare the values with government regulatory standards.

14.15 OPTIONAL INSTRUMENTATION AND CONTROLS

14.15.1 Level

A level switch can be described as a device that can sense the level of a liquid in a process tank. A level switch is also used to control valves and pumps so that it can maintain the fluid level at a set value and also that it can prevent the tanks from overfilling. So we can see a level switch in measurement and control applications, level switch can indicate the high and low levels in process tanks. There are many level switches and the most common types of level switches are thermal, inductive, ultrasonic, etc.

14.15.2 Flow

Flow switches are used to detect the flow of the fluid, these switches are used to determine if the required flow is available or not. So if the required flow is not available then it could damage the system. There are different types of flow switches and we can choose the flow switches according to the line size.

14.15.3 Pressure Switch Applications

Pressure Switch is a device that monitors pressure and provides an output when a set pressure is reached. The specific pressure that opens and closes the switch is called the set point. Pressure switches are commonly associated with well pumps.

Pressure switches are comprised of several components including an adjustment screw, diaphragm, lever, and contacts. The adjustment screw sets the spring pressure. This can be adjusted to change the on-and-off pressure range that the switch operates at. The standard range of a pressure switch is usually located on the unit itself. It relies on water pressure to do all the work. The change in pressure that activates the switch is provided via the water from the well. The pressure moves up through the diaphragm which presses against a piston and spring, which in turn opens or closes the contacts. Open contacts located within the switch, closes when pressure drops. This completes an electrical circuit, which in turn activates the pump. When the set pressure is reached, this allows the contacts to open again which turns off the pump. It is used to operate as a safety valve, which vents out pressure when the pressure exceeds the upper limit.

14.15.4 Filter Console

Filter control console provides continuous and discrete controls that are necessary for a typical surface or bulk filter in a water treatment plant. This device can be used for stand-alone operation or it can be integrated into a plant-wide SCADA network. The PLC in the system eliminates the need for items such as timers, relays, and PID controllers. It also provides documented configuration that can be adapted by users to suit the unique needs for a given situation.

14.15.5 Clarifier Desludging

The removal of the sludge from the clarifier is through the openings arranged at the widest circumference of the sludge space, and closed by an axially mobile bottom during the separation process. The opening and closing movements of the mobile bottom valve are controlled by a hydraulic control system. The control system associated with the clarifier consists of the mobile bottom valve hydraulically movable in the bowl; the control water feed , the control water valve system with the solenoid and manually controlled valves for automatic and manual control, and the program control system. The control system is operated in normal operation by a preselected desludging program. Any required full desludge operation can be controlled semi- automatically by the valve control cabinet. In the case of current failure or other possible defects, putting the control cabinet or the electrical control valves out of operation, the separation process can be brought to an end by operating the manually-operated valves.

14.16 INSTRUMENT CUM CONTROL PANEL

These panels are useful to monitor and control process parameters like temperature, pressure, flow etc and also to control the power to the final driver like motor pumps, heaters etc. . Various interlocks and safety audio visual alarms are provided through PLCs. Total process simulation can be shown on the mimic. Starters for motors, heaters, pumps are provided in the panel.

14.17 ONLINE MEASUREMENT INSTRUMENTATION

14.17.1 Level Measurement

Whenever water parameters are considered, both water quantity and water quality must be given equal weightage. Instrumentation facilitates the coordination of various water parameters, which are essential for the optimization of water supply & treatment plants. One of the important parameters amongst them is water level measurement, which is carried out at various locations viz water reservoir, inlet chamber, open channel, alum feeding tank, lime tank, filter beds, air vessel, sump well, etc.

This measurement is accomplished in waterworks by following two ways:

A. Direct Method
B. Inferential Method

Direct Method – Their merits, demerits as well as uses are shown in Table 14.11.

Table 14.11: Direct Method of Level measurement

Hook Type Level Indicator	Sight Glass	Float Type Indicator
Advantages		
i. Low cost ii. Simple	i. Inexpensive ii. Corrosion resistive iii. Simple	i. The level can be read at a convenient place ii. Operates over large temperature range iii. Very accurate
Disadvantages		
i. Only local reading ii. Human error may be encountered in reading	i. Only local reading ii. Accuracy and readability depends on the cleanliness of glass and fluid iii. It is fragile	i. They are tailored to tank geometry ii. Requires a certain amount of mechanical equipment
Uses		
i. Inlet channel level	i. Filter bed level ii. Reservoir level iii. Head loss in the filter	i. Filter bed ii. Final water reservoir iii. Sump well iv. Lime tank

Inferential Method – Some specifications of the recent level transmitters as mentioned in

Table 14.12.

Table 14.12: Inferential Method of Level measurement

Hydrostatic Pressure Gauge Type & Pressure Bulb Type	Displacer Level Type	Electrical Method (Capacitance Type)	Ultrasonic
Advantages			
i. Easy maintenance ii. Simple to adjust iii. With pressure, bulb type remote reading possible iv. Reasonably accurate	i. Excellent accuracy ii. Possible at remote places	i. Good accuracy ii. Possible at remote places iii. Very sensitive iv. Suitable for highly corrosive media	i. Good accuracy ii. Possible at remote places iii. Suitable for liquid as well as bulk products
Disadvantages			
i. The instrument must be installed at base reference level for gauge type ii. Pressure bulb type relatively costly	i. Limited range ii. High cost iii. Requires stilling chamber iv. Requires a significant amount of mechanical equipment	i. Affected by dirt & other contaminants ii. Affected by temperature	i. Affected by foam ii. Not suitable for high temperature & pressure
Uses			
i. Delivery head of the pump (pressure gauge type) ii. Clear or raw water reservoir iii. Sump level	i. Clear water reservoir ii. Raw water reservoir	i. Raw water reservoir ii. Clear water reservoir	i. Raw water as well as clear water level i.e. inlet channel sump level etc. ii. Lime tank iii. Sludge level

14.17.2 Pressure Measurement

In the water supply network pressure, parameter plays a very important role to get sufficient water to the consumers. Similarly, in flow measurement by differential pressure type flow meter, differential pressure measurement across the primary element is the main physical parameter to interlink with flowing fluid. This pressure or differential pressure measurement is accomplished with the help of following methods in water works:

A. Manometers
B. Elastic Pressure Transducer
C. Electrical Pressure Transducer

The advantages and disadvantages of the instrument of pressure measurement normally used in waterworks are given below:

A. **Manometers:** Types of Manometers are shown in Table 14.13.

Table 14.13: Types of Manometers

U Tube Manometers	Well Type Manometers	Inclined Manometers
Advantages		
i. Simplest ii. Low cost	i. Zero reference setting is possible ii. Low cost	i. More sensitive ii. Low cost
Disadvantages		
i. No fixed reference ii. Large & bulky iii. Need for levelling iv. No over range protection	i. Accuracy inferior to U tube manometer ii. Large & bulky iii. Need for levelling iv. No over range protection	i. Large & bulky ii. Need for levelling iii. No over range protection
Uses		
i. For measurement of differential pressure in D.P. type flow meter & calibration of D.P. type transducers	i. For calibration of D.P. type flow meters & measurement of differential pressure in D.P. type flow meter	i. For measurement of very small pressure differences

B. **Elastic Pressure Transducer:** Commonly used are-

Bourdon tube type pressure gauge:

Advantages

(i) Low Cost
(ii) Simple construction
(iii) Time tested in applications
(iv) Availability in a wide range
(v) Adaptability to electronic instruments
(vi) High accuracy in relation to cost

Disadvantages

(i) Low spring gradient below 3 kg/cm^2
(ii) Susceptibility to shock and vibration
(iii) Susceptibility to hysteresis
(iv) Accuracy in terms of full-scale deflection

Uses

(i) Pump delivery & suction
(ii) Water supply distribution network
(iii) Air receivers
(iv) Chlorinators
(v) Pump cooling water

C. Electrical Pressure Transducer

In this category following types are there:

(i) Strain gauge pressure transducer

(ii) Potentiometric pressure transducer
(iii) Capacitive pressure transducer
(iv) Variable reluctance pressure transducer
(v) Piezo electric pressure transducer

The advantages & disadvantages of electrical pressure transducers commonly used in water works are as shown in Table 14.14.

Table 14.14: Advantages & Disadvantages of Electrical Pressure Transducers

Potentiometric Transducer	Capacitive Pressure Transducer	Variable Reluctance Type
Advantages		
i. Widely used in Industry as these are simpler and less expensive ii. Easy compatibility with the requirement	i. Short response time ii. Vibration-proof iii. Extremely sensitive iv. It can measure static as well as dynamic changes	i. Excellent linearly ii. Good repeatability iii. Low hysteresis iv. High sensitivity
Disadvantages		
i. Finite resolution ii. Wear out early iii. Noise signal is generated	i. Sensitivity changes with temperature	i. Relatively large size ii. More nos. of components iii. More maintenance
Uses		
i. Where less accuracy is required	i. Distribution network ii. In process instrumentation	i. Distribution network ii. In process instrumentation

14.17.3 Calibration of Pressure Measuring Instruments

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressure. All instruments tend to drift from their last setting. This is because springs stretch, electronic components undergo slight changes on the atomic level, and other working parts sag, bend or lose their elasticity.

The calibration procedure includes zero, span, and linearity adjustments. The pressure is varied with the help of a pneumatic calibrator so as to give desired pressures to the instrument. The settings are carried out on the instrument for zero and span adjustment on the basis of applied pressures. For carrying out linearity setting various pressures between zero and maximum range of the instruments are applied and adjusted the output of the measuring instrument with the help of controls provided in the instrument.

In the case of pressure gauges, the calibration is carried out by means of dead weight tester.

In absence of a pneumatic calibrator, the air can be supplied to the instrument with proper pressure regulator, and pressure is measured with the help of a manometer so as to calibrate the instrument.

The calibration should be checked every 3, 6 or 12 months depending upon the use and accuracy expected, as per the manufacturer's recommendation and latest ISO standards.

Maintenance of pressure instruments is essential for their proper working and accurate reading. It also improves the life and reliability of the instruments.

14.17.4 Radar Level Transmitters

They provide a non-contact type of level measurement in case of liquids in a metal tank. They make use of EM i.e. electromagnetic waves usually in the microwave X-band range which is near about 10 GHz. Hence, they can be also known as microwave level measurement devices. However, there are some differences between radar and microwave types. They are:

(i) Power levels in the case of radar systems are about 0.01 mW/cm^2 whereas, in the case of microwave systems, these levels range from 0.1 to 5 mW/cm^2
(ii) Microwaves can work at higher energy levels; hence they are competent enough to endure extra coating as compared to radar level detectors

A radar level detector (Table 14.15) includes:

(i) A transmitter with an inbuilt solid-state oscillator
(ii) A radar antenna
(iii) A receiver along with a signal processor and an operator interface

The operation of all radar level detectors involves sending microwave beams emitted by a sensor to the surface of the liquid in a tank. The electromagnetic waves after hitting the fluid's surface return back to the sensor which is mounted at the top of the tank or vessel. The time taken by the signal to return back i.e. Time of Flight (TOF) is then determined to measure the level of fluid in the tank.

Table 14.15: Radar Level Transmitter

Radar – Microwave type level transmitter	**Service: Raw Water (Non-Contact Type)**
Transmitter	
Type	Microwave level measurement
Principle	Pulse Time of Flight
Output	4-20 mA HART Current
Housing	Die-Cast Aluminium
Electromagnetic compatibility	Interference Immunity to EN 61326, Annex A (Industrial) and NAMUR
Ingress protection	IP65 / IP 66 / IP 67
Accuracy	±3 mm
Area classification	Non-Hazardous
Display	4-line LCD Display. Menu guided operation. Display of Envelope Curve.
Configuration	Using the keypad on display
Sensor	
Range	Liquids 0 to 5m and 0 to 10m depending on Tank size

Radar – Microwave type level transmitter	**Service: Raw Water (Non-Contact Type)**
Temperature range	-40°C ... +80°C
Max pressure	3 bar abs
Materials	Sensor: PVDF Seal: EPDM
Antenna seal	FKM Viton
Process connection	Threaded or universal flange dependent on model selection
Degree of protection	IP65

In water works, various treatment processes are carried out to supply potable water. The parameters of the water which are normally used for monitoring are as follows:

(i) Turbidity
(ii) pH
(iii) Residual Chlorine

These parameters are monitored either by means of on-line instruments or by analytical laboratory instruments or both. Their relative advantages and disadvantages are as follows:

14.17.4.1 Turbidity Meter

Table 14.16: Advantages and Disadvantages of Turbidity Meter

Online	**Laboratory Type**
Advantages	
i. Turbidity continuously monitored ii. Can be hooked up for automation iii. Can be set for giving an alarm if minimum and maximum limits of turbidity are exceeded. iv. Human error in sampling is eliminated	i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
Disadvantages	
i. High cost ii. High maintenance is required iii. Periodical calibration is required iv. It is not portable	i. Does not monitor continuously ii. Human error may encounter iii. Low accuracy
Maintenance	
i. Clean chamber &lense with fresh water ii. Microprocessor based instrument has a self-calibration facility which is useful for periodical calibration iii. Clean sources of light	i. Clean sampling tube with fresh water ii. Bulb, standard sample tubes and lense should be cleaned with soft cotton iii. Calibrate before carrying out the measurement iv. Calibrate with standard samples of 100 NTU, 10 NTU & 1 NTU or calibrate with formazin standard solution

14.17.4.2 Typical Specification for Online Measurement of Turbidity

Online sensor (Table 14.17) based on Nephelometric 90 degree scattering light method as per ISO 7027. The sensor must be an easy plug and play with digital communication based on inductive energy transfer with IP68 rating suitable for measuring range 0 to 9999 FNU /NTU with an accuracy of <2% of measured value or 0.1 FNU/NTU. The sensor shall store on-board all the calibration data and other diagnostic information. The sensor must have provision to store at least 5 user calibration points. The offered transmitter shall be 4 wire digital with the possibility of connecting multiple sensor inputs for additional parameters – referred to as multichannel /multi parameter type. The transmitter shall be suitable for outdoor installation with IP66/67 rating.

Table 14.17: Online Turbidity Meter

Turbidity Measurement	
Transmitter	
Type	Turbidity and suspended solids transmitter
Principle	Nephelometric measuring principle 90° NIR scattered light according to ISO EN 27027
Output	4-20 mA HART current
Supply voltage	100 / 115 / 230 V AC +10 / –15%, 48 ... 62 Hz ; 24 V AC/DC +20 / –15%
Material	Field Housing: ABS PC Non-corrosive type
Display	LC display, two lines, with status indicators
Electromagnetic compatibility	interference emission and interference immunity acc. to EN 61326-1:1998
Protection class of field housing	IP 65
Ambient temperature	– 20 to 60 °C
Self-Diagnostic feature	Required
Sensor	
Measurement range	0 – 9999 FNU / 0 - 3000 ppm / 0 – 3.0 g/L
Material	Sensor shaft : PVC / PPS GF40 Optical window : sapphire Cable : TPEO
Max Process temperature	50°C
Max Process pressure	10 bar
Temperature sensor	Integrated NTC temperature sensor
Connection	Fixed cable connection
Ingress protection	IP68
Additional Certifications	Calibration certification
Resolution	0.001 FNU, 0.01 ppm, 0.1 g/l, 0.1%
Measurement error	<2% of meas. value (min. 0.02 FNU)

14.17.4.3 pH Meter

Table 14.18: Advantages and Disadvantages of pH Meter

Online	**Laboratory Type**
Advantages	
i. Continuously monitored ii. Can be hooked up for automation iii. Can be set for giving alarm for specified limits iv. Human error in sampling is eliminated	i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
Disadvantages	

Online	Laboratory Type
i. High cost ii. Periodical calibration is required iii. High maintenance cost (replacement of electrodes) iv. It is not portable	i. Does not monitor continuously ii. Human error may encounter iii. Low accuracy
Maintenance	
i. Clean electrode with soap water or clean with 5% concentrated H_2S0_4 and 6% concentrated H_20_2 ii. Calibrate periodically with a standard solution of pH 4 and pH 7 iii. Replace electrodes if dried up	i. Clean sampling electrode with distilled water ii. Calibrate the instrument with three standards samples i.e. pH 4, pH 7 & pH 9.2 iii. Prepare standard samples from readily available capsules iv. Calibration may last from 4 days to 7 days

14.17.4.4 Typical Specification for Online Measurement of pH

Online pH (Table 14.19) sensor is based on potentiometric measurement using a glass sensor. The sensor shall have digital communication based on inductive energy transfer. The sensor shall have inbuilt memory to store calibration data and other additional diagnostic information. The offered transmitter shall be 4 wire digital with the possibility of connecting multiple sensor inputs for additional parameters – referred to as multichannel /multi parameter type. The transmitter shall be suitable for outdoor installation with IP66/67 rating.

Table 14.19: Online pH Meter

Transmitter	
Type	Glass electrode
Principle	Glass electrode with dirt repellent PTFE diaphragm
Output	4-20 mA HART current
Supply voltage	100 / 115 / 230 V AC +10 / –15%, 48...62 Hz ; 24 V AC/DC +20 /–15%
Material	Field Housing : ABS Polycarbonate non corrosive
Display	LC display, two lines, with status indicators
Electromagnetic compatibility	Interference emission and interference immunity acc. to EN 61326: 1997 / A1: 1998
Protection class of field housing	IP 68
Ambient temperature	–20 ... +60 °C
Diagnostic feature	Required
Sensor	
Measurement range	pH 0 - 14
Material	Glass
Max Process temperature	130°C
Max Process pressure	6bar
Temperature sensor	NTC / Pt100
Connection	Inductive digital connection with Transmitter
Ingres protection	IP68
Additional Certifications	FM, ATEX, CSA
Resolution	pH 0.01, Temp 0.1°C

Measurement Error	± 0.5% of Measuring range

14.17.4.5 Residual Chlorine Meter

Table 14.20: Advantages and Disadvantages of Chlorine Meter

Online	Laboratory Type (Lovibond Type)
Advantages	
i. Continuously monitored ii. Can be hooked up for automation iii. Can be set for giving alarm for specified limits iv. Human error in sampling is eliminated	i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
Disadvantages	
i. High cost ii. Periodical calibration is required iii. High maintenance cost (replacement of membrane) iv. It is not portable v. It requires electricity of battery or solar	i. Does not monitor continuously ii. Human error in sampling may encounter iii. Low accuracy
Maintenance	
i. Clean membrane if it gets clogged ii. If the membrane is damaged replace it with the new one iii. Fill up/ DPD membrane /electrolyte if necessary iv. Calibrate it using Potentiometric electrode	i. Clean tubes with distilled water ii. Calibration is not required as it is a comparator

14.17.4.6 Typical Specification for Online Measurement of Chlorine

Online chlorine analyzer (Table 14.21) is based on Amperometric / membrane-based measurement of active chlorine converted to free chlorine by means of pH compensation. The sensor shall have digital communication based on inductive energy transfer which will withstand moisture, corrosion, and ensures reliable data transmission. Complete measuring system includes chlorine sensor, pH sensor with suitable flow assembly for mounting these sensors along with the transmitter. The offered transmitter must be IP65, Interference emission & immunity as per EN 61326-1:2006.

Table 14.21: Online Chlorine Meter

Transmitter	
Type	Free chlorine
Principle	Amperometric measurement of free chlorine
Output	4-20 mA HART current
Supply voltage	100 / 115 / 230 V AC +10 / –15%, 48 ... 62 Hz ; 24 V AC/DC +20 / –15%
Material	Field housing: ABS PC Fr
Display	LC display, two lines with status indicators
Electromagnetic compatibility	Interference emission and interference immunity acc. to ISO EN 61326: 1997 / A1: 1998
Protection class of field housing	IP 65

Transmitter	
Ambient temperature	-20….+60°C
Sensor	
Measurement range	0.01 – 5ppm free chlorine
Material	Sensor Shaft: PVC
	Membrane: PTFE
	Membrane cap: PBT (GF30); PVDF
Process temperature	+2°C…..+45°C
Max process pressure	1 bar
Temperature sensor	NTC/ Pt100
Connection	Inductive digital connection with transmitter
Ingress protection	IP 68
Resolution	0.01 mg/l
Measurement error	±0.5% of measuring range

14.17.4.7 Total Dissolved Solids/Electrical Conductivity

The amount and composition of TDS in water is linked to the electrical conductivity of the water. As such, of the most effective ways of measuring TDS in water is by measuring the conductivity of the water itself. Electrical, or specific, conductivity of water is directly related to the concentration of dissolved ionized solids in the water. Ions from the dissolved solids in water create the ability for that water to conduct an electric current, which can be measured using a conventional conductivity meter or TDS meter.

14.17.4.8 Typical specification for online measurement of TDS/EC

Conductivity measurements are used routinely in several applications as a fast, inexpensive and reliable way of measuring ionic content in a solution. The measurement of product conductivity is a typical way to monitor and continuously trend the performance of water purification systems. Ions from the dissolved solids create the ability for water to conduct an electrical current, which is measured by the online TDS analyzer, and immediately displayed as sodium chloride ppm or mg/L or µS/cm conductivity.

Online Conductivity/TDS Analyzer having the specification to measure analyze and control conductivity, TDS and Temperature

(i) 3 programmable on/off relays: 2 for conductivity and 1 for temperature.
(ii) Accepts 2-wire or 4-wire conductivity cells for K=0.1, K=1 and K=10 cell constants for improved flexibility and accuracy.
(iii) Displays 3 selectable conductivity and TDS ranges per cell constant for a total of 18 ranges.
(iv) Automatic temperature compensated (ATC) conductivity readings.
(v) Programmable temperature coefficient.
(vi) Simultaneous display of: conductivity, tempera- ture, cell constant, temperature coefficient, relay status and transmitter current mA output.
(vii) Convenient one point calibration and calibration data is stored in memory and is ready for use on power up.

(viii) Standard ¼ DIN size.

(ix) Performs self-diagnostic at power up to ensure proper operation.

14.18 LEAKAGE REDUCTION AND CONTINUITY OF SUPPLY

There are multiple causes for loss of water in transmission pipelines which include leakage, metering errors, public usage such as firefighting, and theft . The most critical route for losses is a leak, as they are considered to contribute an estimated of 70% of water loss in water transmission systems, this value is expected to become higher in undermanaged networks.
The two classes of leak detection system can be defined as follows:

(i) *Static leak detection systems*: are systems that rely on sensors and data collectors that are placed within the water network and on valves and are capable of transmitting periodical data to the network management office. This data can be used to identify, localize, and pinpoint leaks.

(ii) *Dynamic leak detection systems*: are systems that rely on moving leak detection devices to suspected leakage area to perform an investigation. Therefore, they rely initially on suspicion of an existing leak. Another approach is performing regular surveys around cities to identify leaks as soon as possible. Those systems can confirm the existence of leaks and immediately localize and pinpoint them.

The main distinction between the two classes is that static leak detection systems can inform the water network management of the existence of a leak almost immediately, whereas dynamic leak detection systems are required to have information of a leak possibility so that they can be mobilized for investigation. On the other hand, dynamic leak detection systems can pinpoint the exact location of a leak almost immediately under ideal operating conditions, whereas static leak detection systems will provide a location within a certain area and they are also more prone to false alarms. The two classes encompass a wide variety of technologies to provide an accurate leak detection system, but the technologies are not limited to one class. For example, acoustic technologies, specifically noise loggers, can be dynamic and moved from one location to the other periodically or they can be left in the network to detect leaks.
Identification of leakage is performed by a PIC microcontroller to automate the process. Leakage and suction of water are identified by the pattern of water flow rate which is monitored continuously by the processor and if the same goes beyond a predefined threshold level, suitable alarms or annunciators are triggered to notify the leakage or theft. The flow rate is sensed by the signal conditioning unit when the water is passed through the pipeline. The sensor operates under certain pretend value. When there is a in the water flow due to leakage or any pumping of water through motor, it will be detected by the water flow sensor. The signal conditioning unit is used to give the desired input signal of the ADC. The analog signals generated due to variation in the flow of water sensed by the water flow sensor are converted into digital signals using Analog to Digital Convertor (ADC) and this digital signalis given to Microcontroller. This microcontroller enables the transmitter signal for intimate to water supply personnel. At the same time they enable the driver unit to closes the solenoid valve.

14.19 TELEMETRY AND IOT SYSTEMS

IoT and telemetry work in tandem to provide a combination of data acquisition, analysis, storage, and reporting. Additionally, IoT systems allow operators to monitor and control system command functions from a remote location. It's a powerful blend of hardware and software technologies that improve efficiency, cost, and productivity. IoT is a web-based platform for real time monitoring and analytics of geographically distributed systems. Telemetry is a technology which allows the remote measurement and also reporting of information of interest to the system designer.

Geographical Information System (GIS)

The Geographic Information System (GIS) is a software system with which location-based mapping and characterization of the geographic features can be integrated into a Decision Support System (DSS) for planning, execution, and management of any spatial both the manmade and natural features. Geographical Information System will play an important role in mapping, monitoring and operation of water supply schemes under AMRUT on IoT based sensors. The areas in which the GIS can be used in the water supply system from planning till operation and management monitoring are mentioned below:

i.) Mapping of Surface and Ground Water Sources and Infrastructure including mapping of IoT sensors;

ii.) Water resources availability estimation and determining carrying capacity through GIS;

iii.) Water budgeting and audit at different levels of hierarchy;

iv.) Planning of Water supply infrastructure up to home;

v.) Management of System (Resources, Assets, Functionary);

vi.) Use in day-to-day effective maintenance management by locating the areas for trouble shooting in pipe network and infrastructure through GIS based simulated hydraulic models;

vii.) Real time monitoring of Services using IoT based sensors and analytical tools with GIS linkage for water quantity, quality, operations, and Maintenance. Dissemination of information to beneficiaries/ public and system management group;

viii.) GIS based Consumer Relations Management (CRM) using Geo- spatial database of consumers and using several electronic media like mobile, e-mails, social media etc;

ix.) Monitoring of the CRM and grievance redressals in relation to KRAs of concerned official;

x.) Nation, State, ULB level Visualization of Status of Services through GIS enabled Dashboards in the map form;

xi.) Decision Support System (DSS) development on daily and seasons basis for policy makers. In the present context of IoT sensors-based monitoring in AMRUT

GIS for mapping and Geo-coding of water supply schemes, its sources, geographical boundaries of beneficiary areas, IoT based sensors deployed for the scheme for monitoring, areas under influence of a sensor. This shall after analytics shall display visually on the GIS map-based dashboards about the quantity and quality of water supply in an area under the influence of Geo-coded sensor.

The data from Geo-coded ground water level measurement sensors and its GIS based analysis will have to be projected on the maps as dashboard for use of water scarcity management measures and decision support system for the different Administrative Units.

Development of modules for use of the Geo-spatial IoT sensor based available data for effective operations management of individual water supply system by mapping the entire transmission and distribution network and using GIS based simulated hydraulic models with real time flow and pressure data inputs through sensors.

14.19.1 Telemetry

Telemetry is the automatic recording and transmission of data from remote or inaccessible sources to an IT system in a different location for monitoring and analysis. Telemetry data may be relayed (Figure 14.6) using radio, infrared, ultrasonic, GSM, satellite or cable, depending on the application.

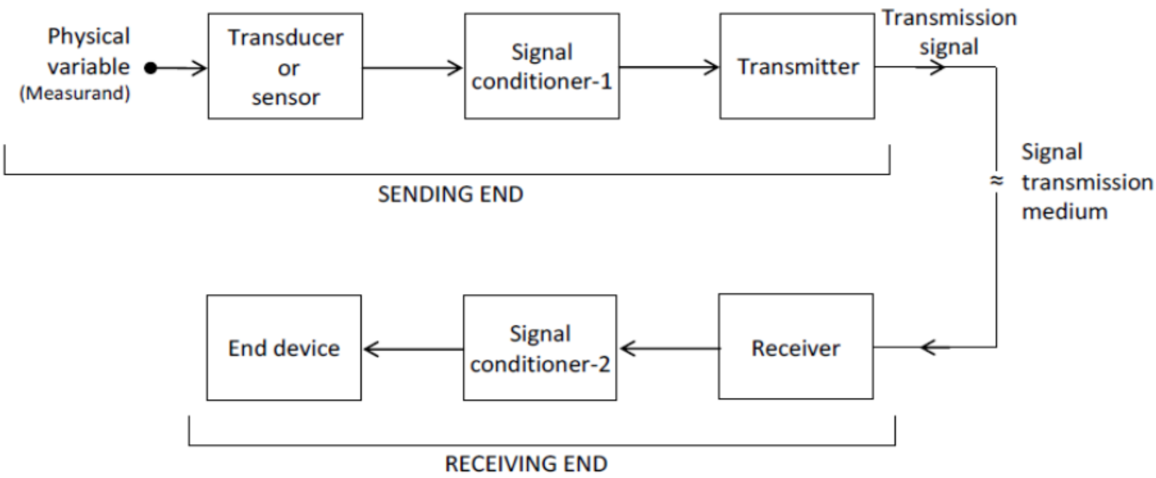


Figure 14.6: Block schematic of basic telemetry system

A high-level solution has to be described as shown in Figure 14.7.

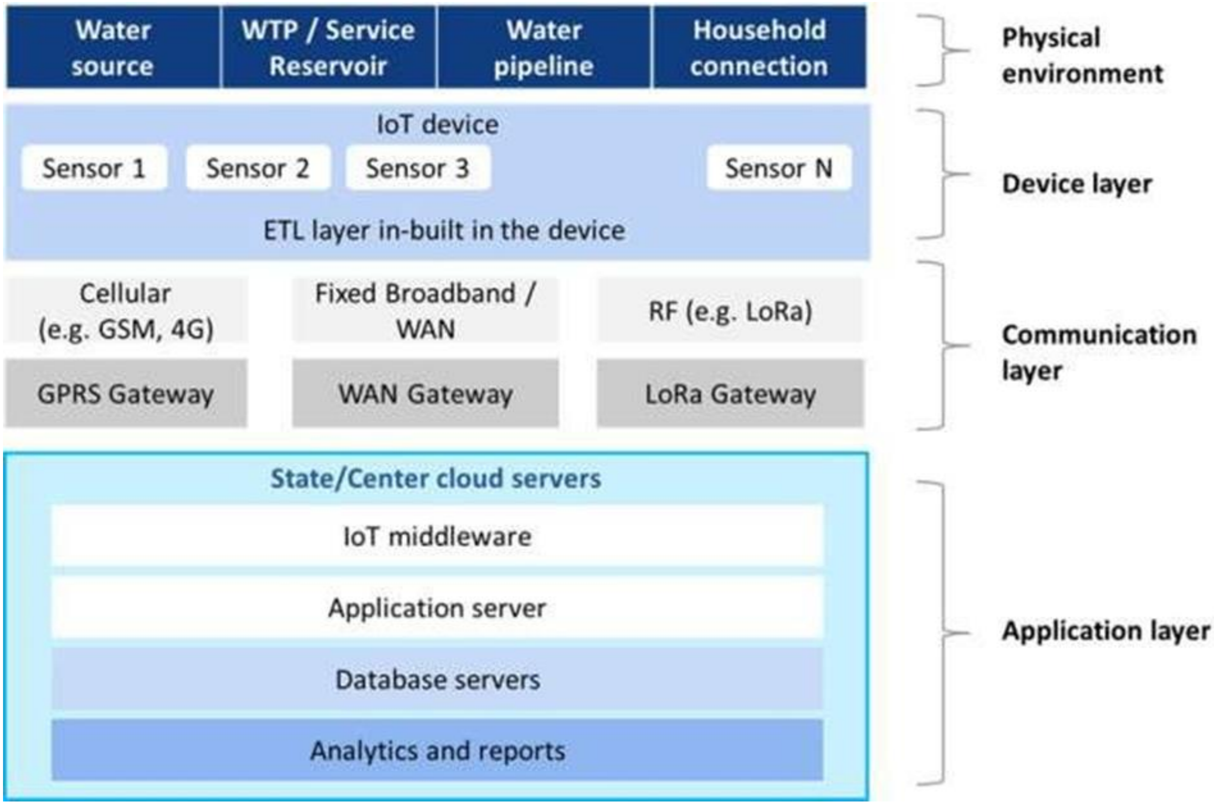


Figure 14.7: Block schematic of basic telemetry system

Networking and communication standards

The solution design should adhere to open standards and be technology neutral. It can use a variety of networking technologies as per local conditions and availability of services, such as fixed broadband / Wi-Fi, local area RF (e.g., Lo Ra), and/ or cellular technologies (2G/3G/4G/5G & NB-IoT). The communications to cloud can be done via several IoT compatible and specialized protocols

14.19.1.1 Data for collection by Telemetry

Telemetry works through sensors at the remote source which measures physical (such as pressure or temperature) or electrical (such as current or voltage) data. This is converted to electrical voltages that are combined with timing data. They form a data stream that is transmitted over a wireless medium, wired or a combination of both.

14.19.1.2 Processing data from Telemetry

At the remote receiver, the stream is disaggregated and the original data displayed or processed based on the user's specifications.

14.20 CLOUD BASED IOT SYSTEM

As elaborated in earlier sections, IoT systems are Enterprise Systems that utilize latest technologies like internet, cloud, AI/ML amongst others. In these systems, the system's infrastructural cost is reduced by implementing IoT through cloud computing. Maintaining as well as integrating these systems is easy compared with others.

In real-time, the condition of these systems can be reported through cloud computing. Therefore, the implementation of algorithms like intricate control can be done that are frequently used on usual PLCs. Here are some key features of cloud-based IoT systems explained in Figure 14.8.

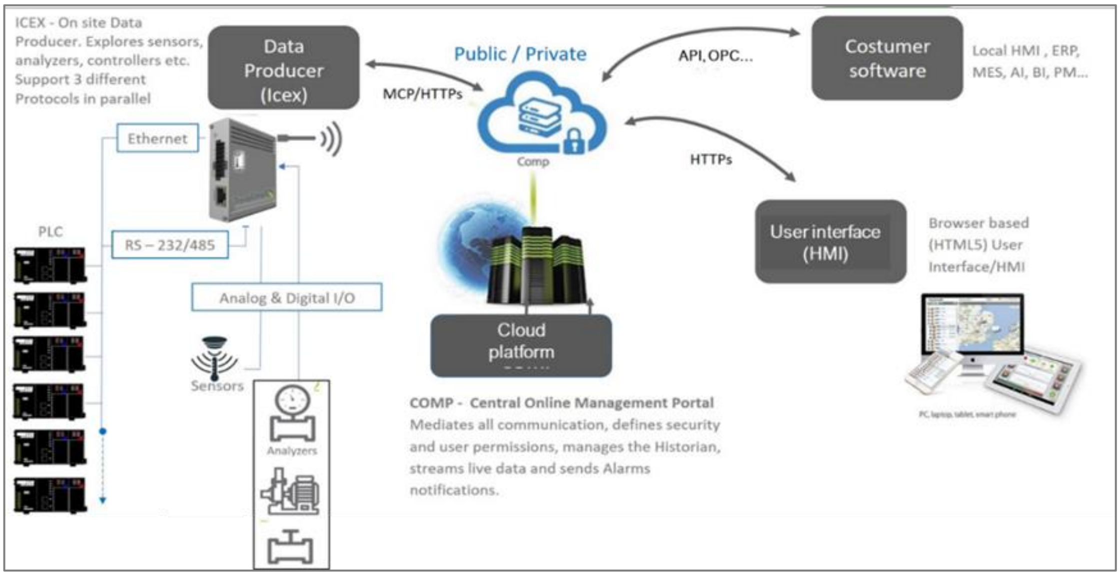


Figure 14.8: Cloud-based IoT systems

1. Cloud-based architecture: A cloud-based IoT system uses cloud computing technologies to store and process data, rather than relying on local servers. This allows for scalability and flexibility, as well as cost savings since companies don't need to invest in expensive hardware and maintenance.

2. Communication protocols: Cloud-based IoT systems use a variety of communication protocols to connect to sensors, controllers, and other devices. These may include OPC UA, MQTT, and others such as MCP propriety protocol.

3. Security: With the increasing use of cloud technologies in industrial settings, security is a top priority. Cloud-based IoT systems use a variety of security measures to protect data and systems from cyber threats, such as firewalls, encryption, and access control.

4. Analytics: Cloud-based IoT systems can leverage the power of cloud-based analytics to provide real-time insights into operation processes. This can include predictive maintenance, anomaly detection, energy management and other machine learning algorithms.

5. Mobility: Cloud-based IoT systems can be accessed securely from anywhere, using any device with an internet connection. This allows operators and managers to monitor and control processes and assets from anywhere in the world.

Cloud based IoT comparing to legacy SCADA.

There are several reasons why cloud-based IoT systems are considered better, more secure, and more open for the future than legacy SCADA solutions.

1. Security: Cloud-based IoT systems have better security measures in place compared to legacy SCADA solutions. The cloud service providers invest heavily in securing their systems, implementing strict access controls, encryption, and monitoring to prevent unauthorized access and data breaches.

2. Scalability: Cloud-based IoT systems are highly scalable and can easily accommodate changes in the number of devices or users. They can also handle a larger volume of data and processing requirements, making them suitable for larger and more complex systems.

3. Accessibility: Cloud-based IoT systems provide remote access to the data and control systems, allowing operators to monitor and control the system from anywhere in the world with an internet connection.

4. Interoperability: Cloud-based IoT systems are built with open standards and protocols that make them more interoperable with other systems and technologies. This makes it easier to integrate them with other systems, such as IoT devices, AI, and machine learning algorithms.

5. Cost-effectiveness: Cloud-based IoT systems are more cost-effective than legacy SCADA solutions as they require less hardware and software investment. Also, maintenance and support costs are significantly lower as the cloud service provider takes care of most of the maintenance and updates.

Interfacing IoT with GIS

IoT system can interface with a geographic information system (GIS) to provide location-based data and visualization. Here are some examples of how IoT can interface with GIS:

1. Asset Management: to provide a map-based view of assets, such as equipment and infrastructure. This can enable more efficient asset management, such as tracking maintenance activities, optimizing routes, and identifying areas for improvement.

2. Real-Time Monitoring: to display real-time monitoring data on a map. This can provide a visual representation of the data, making it easier to identify trends, patterns, and anomalies.

3. Incident Management: to provide a map-based view of incidents, such as alarms, faults, and other events. This can enable faster response times and improve incident management.

4. Environmental Monitoring: to monitor environmental factors, such as air quality, water quality, and weather patterns. This can enable more proactive environmental management, such as identifying potential hazards and mitigating risks.

By interfacing with GIS, IoT system can provide a powerful tool for managing and optimizing processes. This can enable more efficient decision-making, reduce costs, and improve overall system performance. Details of facility, control type etc are shown in Table 14.22.

Table 14.22: Details of facility, control type etc.

Facility	Control Type	Control Parameters	Control Mode	Source
Pump / Pump Station	Pressure Control	Discharge Pressure	Local / Remote	Automation Program
	Level Control	Discharge Reservoir/Tower Level	Local / Remote	Automation Program
	Time Control	Day Time	Local	Automation Program
	Power Consumption Optimization	Demand,Pumps Characteristics,Network Topology, Power Tariffs	Remote	Optimization Algorithm
Puimp - Variable Speed Drive	Speed Control	Diacharge Flow/Pressure	Local	VFD setup
Controlled Valve	Status Control	Status	Local / Remote	Automation Program
Pressure Reducing Valve (DMA,PMA)	Fixed Pressure	Discharge Pressure	Local	Controller
	2 points Pressure	Discharge Pressure , Time	Local	PLC / Valve Pilot
	Dynamic Pressure	Discharge Pressure , Time/Flow	Local / Remote	PLC / Valve Pilot
Flow Control Valve	Fixed Flow	Discharge Flow	Local	Controller
Storage : Resrvooir/Tank valve	Level Control	Water Level	Local	PLC / Controller

14.21 SMART WATER MANAGEMENT

General: Smart water management is the use of data and technology to optimize water usage, reduce waste, and improve overall efficiency. IoT systems can play a critical role in smart water management by providing real-time monitoring and control of water systems. Here are some examples of how a cloud-based IoT system can be used for smart water management:

1. Real-time Monitoring: A cloud-based IoT system can monitor water systems in real-time, including water quality, flow rates, pressure, and other key metrics. This can provide

valuable insights into system performance and enable early detection of issues before they become significant problems.

2. Leak Detection & NRW: A cloud-based IoT system can detect leaks and Non-Revenue Water (NRW) issues in water systems by monitoring and compering pressure changes and flow rates. This can enable quick identification and repair of leaks, reducing water waste and minimizing damage to infrastructure.

3. Energy Management: A cloud-based IoT system can monitor energy usage in water systems, optimizing energy consumption and reducing energy costs.

4. Remote Control: A cloud-based IoT system can provide remote control of water systems, enabling operators to adjust system settings, turn pumps on or off, and monitor performance from anywhere with a secured internet connection.

14.22 DISTRICT METERING AREAS (DMA) OR SUB-DMA MONITORING AND CONTROL

A District Metered Area (DMA) is a sub zone within operational zone of a water distribution network that can be hydraulically isolated and for which water consumption is measured using water meters. Bulk flow metres are installed at the entry points of the DMAs, and all user connections are properly metered for recording the consumption.

The main purpose of DMA is to identify and prioritize leak identification and repair program by computing NRW values. Another important purpose of DMA is to rationally distribute the water according to the needs with equal pressure. A typical hydraulically discrete single DMA is shown in Figure 14.9.

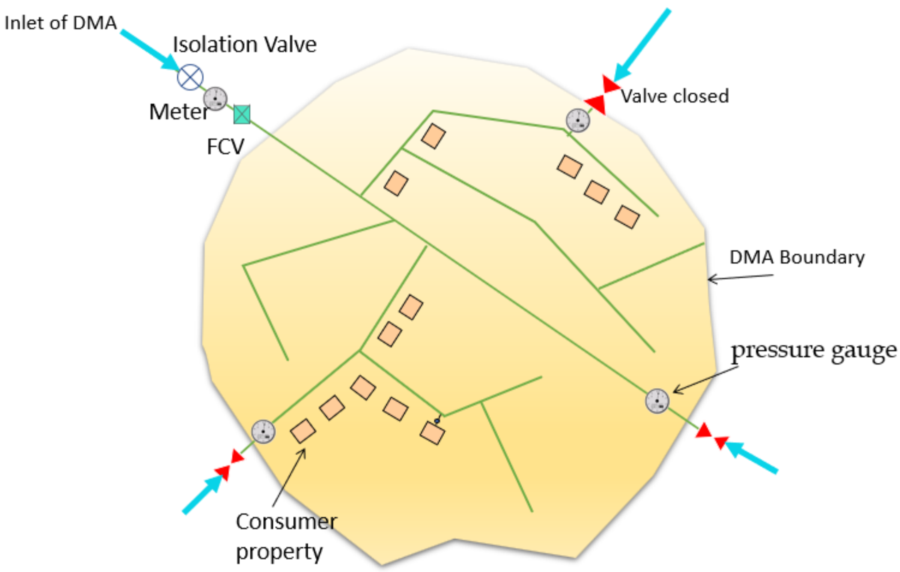


Figure 14.9: Typical hydraulically discrete single DMA

The isolation valve, meter and the Flow Control Valve (FCV) at the entry point of DMA should be connected to the SCADA/ IoT.

The RTU Panel shall be installed with GSM-GPRS-LTE-NB LTE unit to transfer the field process and non-process parameters to the cloud server or centralized monitoring and control center or web - mobile based information retrieval system. Process Parameters include:

- Real Time - Upstream - Downstream - Pressure
- Real Time - Flow rate
- Real Time - Flow Quantity
- Real Time - Pressure - Flow Control - OPEN/CLOSE
- Real Time - Pressure - Flow - Proportional Control

Monitoring DMA inflows and pressures is used for calculation of:

- System Input Volume (SIV).
- Minimum Night Flow (MNF).
- Supply pressure at inlet point and at Critical and Average pressure point of the DMA.
- Online bottom-up Water Balance including Leakage, Water Demand estimation.
- Detection of bursts events
- Water Loss Performance Indicators: including leakage per service connections/per length of pipes, and the Infrastructure Leakage Index (ILI).

DMA Operation may be controlled for:

- Setting supply pressure at DMA inlet point
- Controlling isolating valves to control supply in case of failure or shortage or to manage supply for Sub-DMAs in case of intermittent supply.

This information is used to score DMAs based on their situation, set targets and prioritize activities.

Pressure Control

Pressure reduction is highly efficient in reducing and controlling leakage. Pressure is usually modulated by installation of Pressure Reducing Valve (PRV) at the DM inlet chamber to control the downstream pressure.

Three PRV control types are enabled:

1. Fixed Pressure Control: PRV is set to control one fixed downstream pressure.

2. 2-point control: PRV setpoint changes between day and nighttime.

3. Dynamic Pressure Control: Downstream pressure is controlled according to Flow, Time or Pressure at remote point, typically the DMA Critical Point.

14.23 USE OF INFORMATION TECHNOLOGY (IT) & IT ENABLED SERVICES (ITES)

Information technology (IT) & IT Enabled Services (ITES) has the potential to help improve water supplies and address the systemic problems faced by the water sector. IT has great potential to provide timely information on the level of services delivered and the performance of service providers. Although snapshot baseline maps of water supplies can be created with mobile phones or GPS units, these maps often do not track core issues over time. Applied appropriately to monitoring, IT can do more to trace these issues over time and allow previous data points to be updated easily. A second use of IT is providing data management tools in areas and improving the quality of monitoring information so that it is taken seriously. Accuracy requires reviewing and validating information during data collection and reducing data entry errors. With IT, data can be checked by an expert in a utility's office even as surveys are being conducted in the field. Data do not need to be transcribed if they are entered into a phone during data collection. Validated data improve the ability of stakeholders to learn and adapt to new challenges. Additionally, data collected by different agencies can be shared for cross-validation and coordination. If the data are known to be accurate, broken infrastructure can be fixed in a timely manner, sector regulations can be enforced, and external support can be provided when necessary. Finally, the implementation of IT can lower the costs of existing monitoring activities by speeding up data collection, management and analysis while reducing travel distances and costs. The cost of Internet access, phones, computers, and software is decreasing dramatically while the benefits continuously improve.

ITES, is defined as outsourcing of processes that can be enabled with information technology and covers diverse areas like revenue claims processing, legal databases, content development, payrolls, logistics management, GIS (Geographical Information System), web services etc. Information Technology that enables the process by improving the quality of service is IT enabled services. The most important aspect is the value addition of IT enabled service. The value addition could be in the form of Customer relationship management, improved database, speedy complaint redressal, etc. This radically reduces costs and improves service standards.

14.24 APPLICATION OF INTERNET OF THINGS (IOT) & ARTIFICIAL INTELLIGENCE (AI)

The Internet of Things (IoT) is a dynamic wireless network infrastructure that integrates various communication technologies and solutions to enable the interaction between people and things/objects. This remarkable technology opens opportunities for the development of distinct applications for the cities. For instance, in the context of water management, the use of IoT allows for monitoring and controlling water supply systems in real-time.

IoT systems are fourth-generation systems. In these systems, the system's infrastructural cost is reduced by implementing IoT through cloud computing. Maintaining as well as integrating these systems is easy as compared with others. In real-time, the condition of these systems can be reported through cloud computing. Therefore, the implementation of algorithms like intricate control can be done that are frequently used on usual PLCs.

Artificial intelligence (AI) comprises "a branch of computer science dealing with the simulation of intelligent behaviour in computers." In the context of delivering efficient water supply, AI or machine learning is mainly applied to decision-making tasks: how water utilities can maximize information and data available to make better decisions while enhancing service delivery; optimizing capital investment; and reducing operating costs, including social and environmental externalities.

AI in water management might come off as a huge revelation but it can change the way we treat and manage water sources around us. AI can make the process of water management easier with data analytics, regression models, and algorithms. These cutting-edge technologies help in building efficient water systems and networks. AI can be used to build water plants and to get the status of water resources. Water managers and government bodies can use AI to build a smart water system that can build efficient infrastructure for water management and can adapt to changing conditions. These systems will be cost-effective and sustainable that can optimize all water management solutions and predict potential damages. Physical water leak detection techniques are based on combining special equipment (acoustic sensors, gas tracers, etc.) with human skills. A current trend is to incorporate AI in some of this hardware to replace humans in interpreting the data (water leak noises). With the advances in numerical modelling of the hydraulics of water distribution networks, it is now possible to detect potential leaking pipe sectors through numerical methods, as long as the hydraulic models are fed with a sufficient amount of calibrated field data such as pressure, flow, and node consumptions.

14.25 DIGITAL TWINS

Digital Twin is a technology which creates virtual representation (Figure 14.10) of a water supply system. In other words, Digital Twin creates a virtual replica of the real-world water supply system.

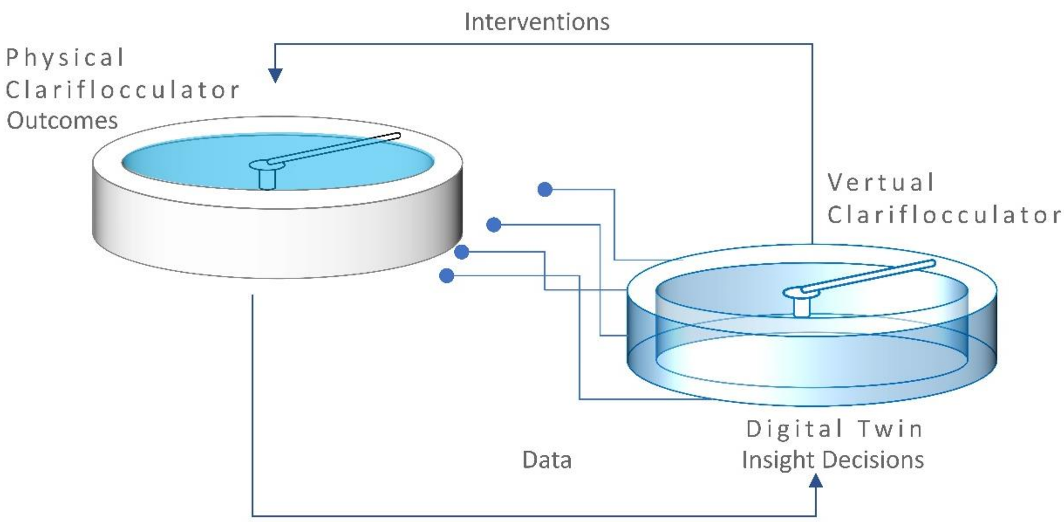


Figure 14.10: Digital twin of Clariflocculator

Digital Twin brings SCADA, GIS, hydraulic modeling, and consumer information into a connected data environment, delivering cost-effective operations strategies in real time.

Objective of Digital Twin

Many times, water supply system of the towns and cities are suddenly hit by 'unexpected' events such as pump failure, pipe burst, low pressures or the failure of ageing assets. On occurrence of such instances, we react only to solve the present issue. The reality is that most such events are not truly 'unexpected'. In many cases they are predictable, we just fail to plan and prepare. Digital twins help us, and above situation no longer remains unpredictable. With real time data and data analytics, digital twin makes predictive analysis. For example, the flow and pressure in pipelines are continuously shown on the screen in real time with 95% confidential ratio. If we observe a sudden dip into the pressure, we can immediately know that there is a burst or heavy leakage in the system.

Benefits of Going Digital

Virtual representation of water supply system of a city using digital twin spans its lifecycle. It is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making. It serves as system simulation, integration, testing, monitoring, and maintenance.

The performance data of the real world of city's water supply system is taken to the virtual reality where the performance data is processed and continuously made available to the system's manager.

Digital Twin provides an environment using which the utility's engineer can have access to their critical system. On observation from measurements and analytically derived results, he gets performance information of his assets. This would enhanced skills of operations, maintenance, and decision-making.

With real time data and data analytics, digital twin makes predictive analysis. During O&M, if a city witnesses any problem due to pipe breakages, bursts, leakages etc., then Digital Twin immediately alarms the utility and guides to take corrective measures. For example, a sudden dip is observed into real-time pressure, it indicates that there is a burst or heavy leakage in the system. Hence, the ground team can be engaged to address the issue at the site.

Digital Twin Setup

It is needed to configure the digital twin by assigning the data . As shown in Figure 14.11, the information is put in various silos. For example, the shape files are put in the GIS silo, sensors, customers information is put in the silos allotted for them.

Hydraulic model a city is fed to the digital twin software. For that we have to share hydraulic model file and the GIS shape files with the support team of the digital twin. This team feeds the files to cloud platform (Figures 14.12 and 14.13) and the system automatically uploads the file and set up the model.

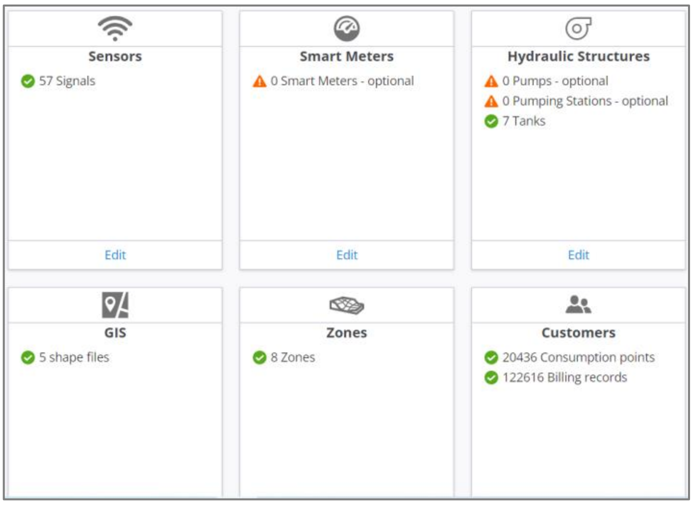


Figure 14.11: Performance data of the real world

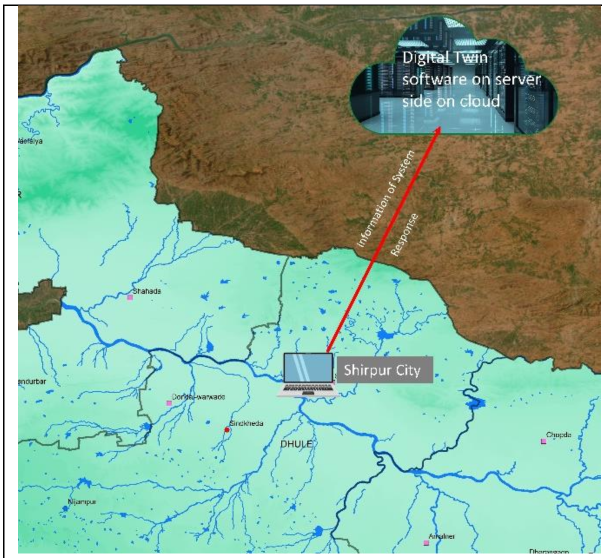


Figure 14.12: Data uploading from city to cloud platform and response

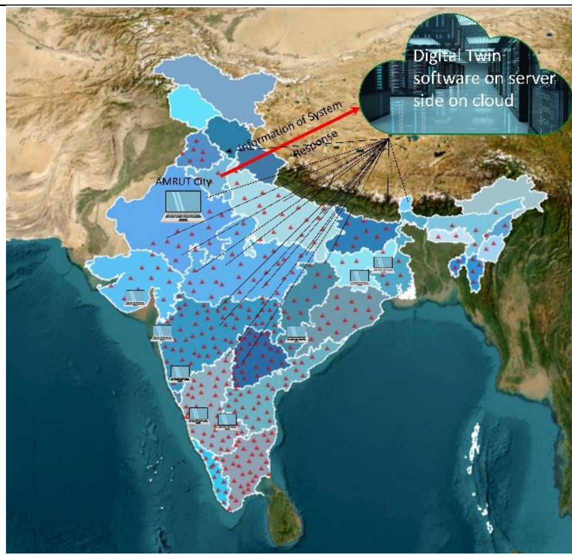


Figure 14.13: Data uploading from 500 AMRUT cities to cloud platform, processing and response.

Working of Digital Twin

The working of digital twin is shown in Figure 14.14.

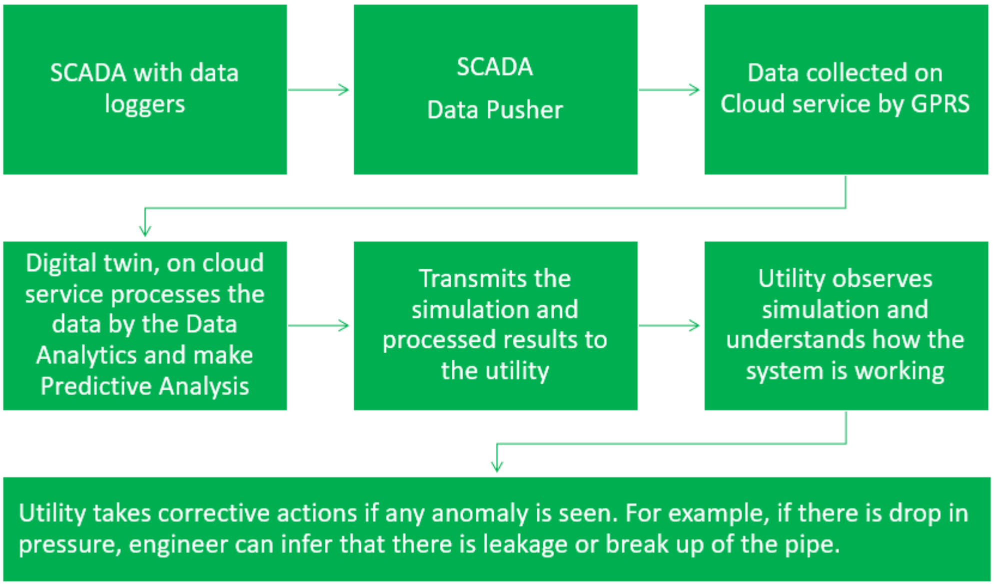
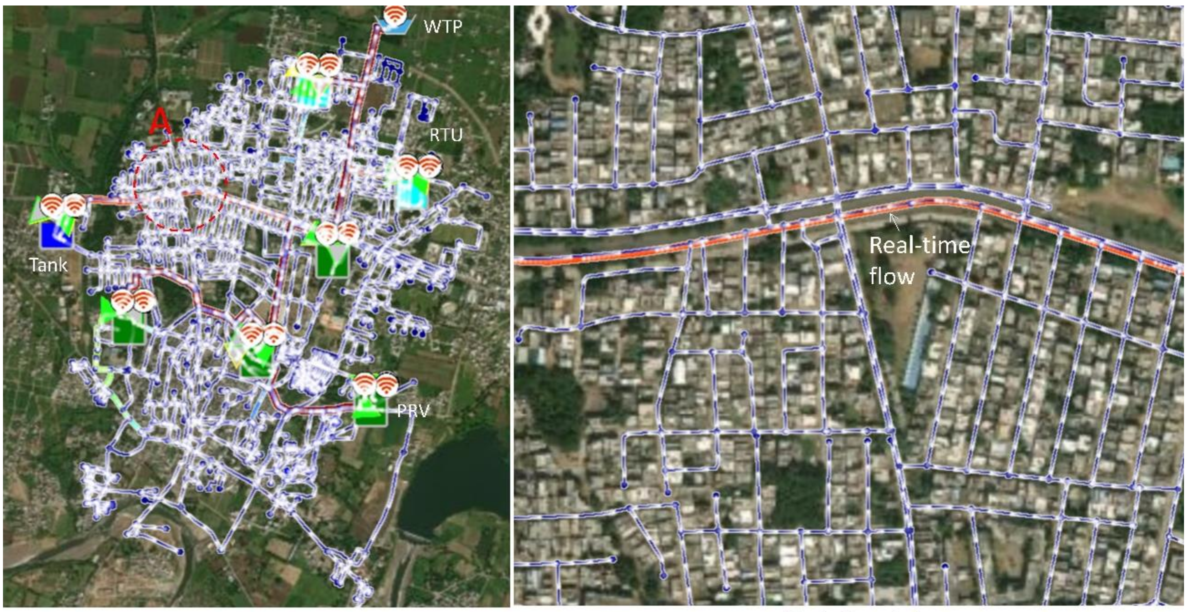


Figure 14.14: Working of digital twin.

Working of digital twin starts after the SCADA. SCADA generates the data. Data pusher is inserted into the PLC of the SCADA which sends the data to cloud service. This data is accessed by the digital twin software on cloud.

Real Time Simulation of the network: Once the digital twin is configurated, Digital Twin shows the sensors in network, pipes, service tanks and valves etc. It shows the real time animation of flow through pipes as shown in Figure 14.15.



Details at A

Figure 14.15: Real-time Simulation of flow in network

On configuration, the Digital Twin shows the machine learned forecast and real time results with statistical data, data analytics and predictive analysis.

Water Audit

For real time water audit the customer's information is fed into the silo (Figure 14.11) earmarked for customers. The software installed on server of the cloud platform makes data analytics and computes system inflow, consumption and losses and the NRW is computed. The results are shown in Water Balance table which is shown in Figure 14.16.

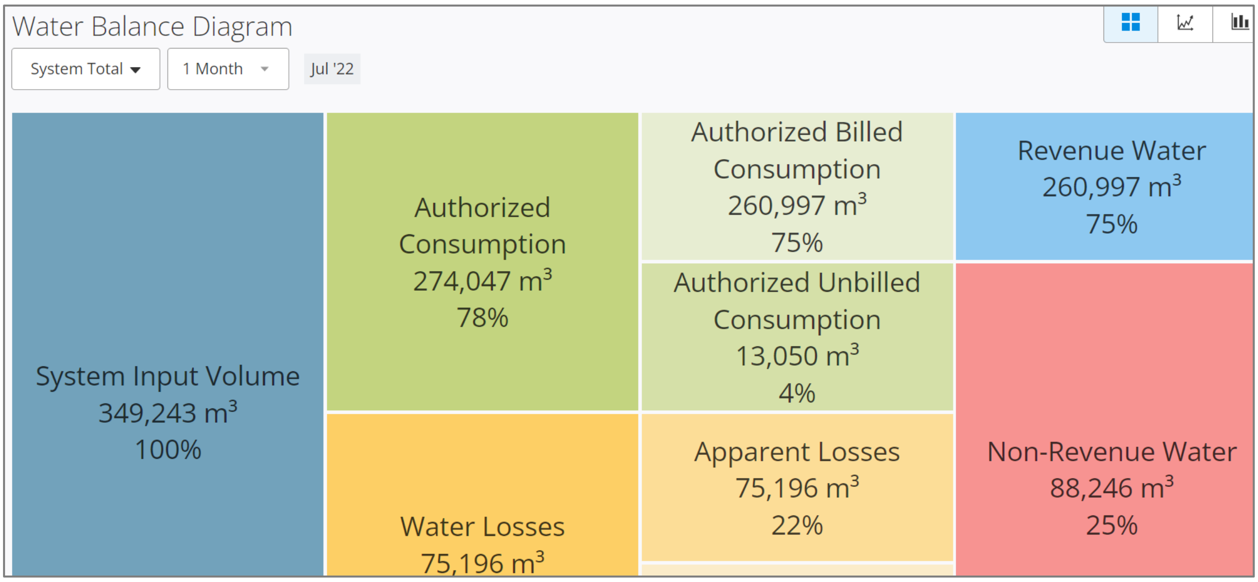


Figure 14.16: Results of water audit of the city

Digital Twin produces the water balance series for different months, its graphs are shown in Figure 14.17.

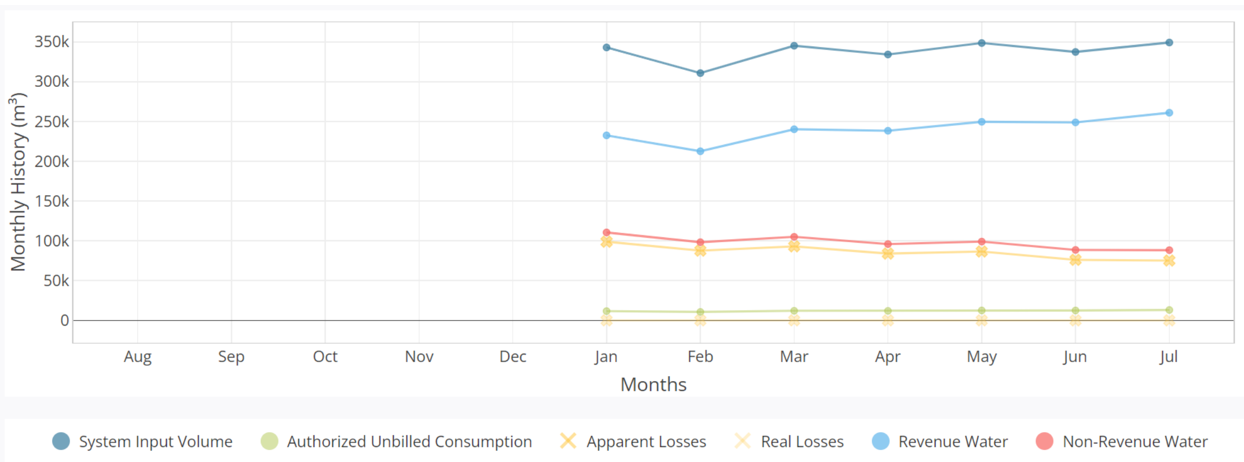


Figure 14.17: Results of water balance series for different months

Digital Twin also produces water balance bar charts for various operational zones of the system as shown in Figure 14.18.

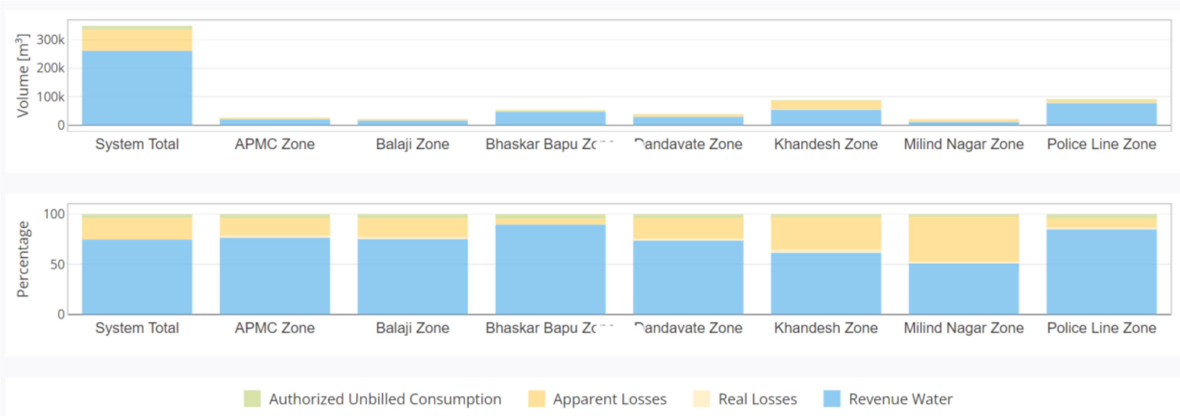


Figure 14.18: Results of water balance bar charts

Digital Twin also generates minimum net night flow (MNF) values of the system as shown in Figure 14.19.

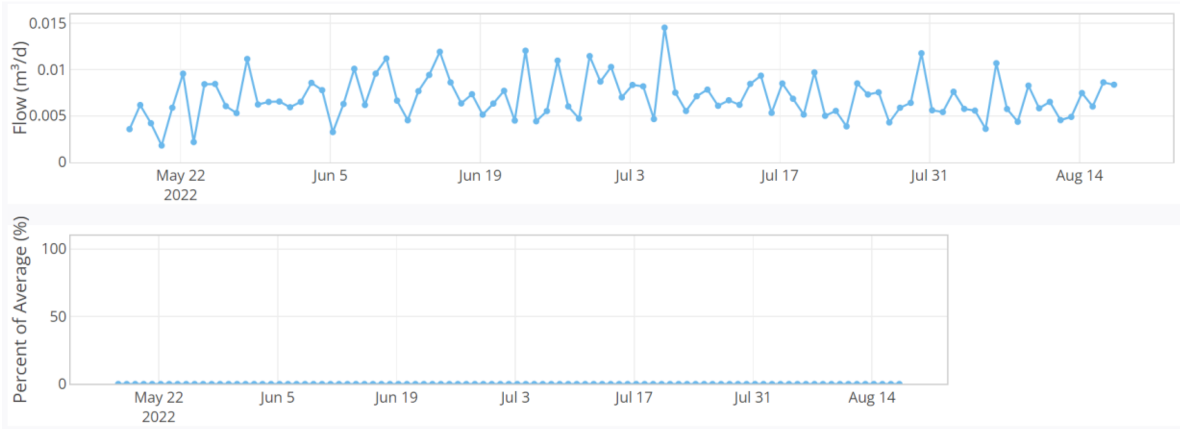


Figure 14.19: Results of minimum net night flow (MNF) of the system

Actionable Insights for the Entire Utility

It shall integrate combined data spread across multiple systems with the power of real-time analysis. The Digital twin shall connect all data sources and create a continuous, consistent digital representation of your operated assets. The solution's browser-based portal shall provide an easy framework to visualize and communicate with stakeholders from any device. It shall be possible that entire team can quickly identify system inefficiencies and anomalous events, track system performance over time, make more-informed decisions, and drive high-quality, consistent, and cost-effective service levels immediately as well as in the future.

Moving Beyond SCADA Results

The features allows to readily monitor various parameters at any point in the system. The Digital twin visualizes current data in the context of historical trends. Thematic displays provide visual cues on the normal operating ranges as well as indicate when recorded data points are outside of normal operation.

With The Digital twin, it shall be possible to investigate the real-time performance for each asset using an embedded hydraulic model that is continually updated with boundary conditions from sensors. Any parameter that can be computed with the hydraulic model can therefore be simulated and monitored in real time without the need to separately open, set up, and run hydraulic modeling software. This enables graphical indication of current pressure, velocity, and other characteristics for every asset in the system, providing instant detection of areas in need of intervention to improve service levels or minimize potential issues.

Proactive Network Management

The Digital Twin can compute up to one week of demand forecasts for each sensor or district metered area by combining machine learning algorithms with advanced data analytics. Zone demand forecasts, along with other initial conditions from other sensors, can also be used as boundary conditions for the model runs, empowering more reliable insights and support toward a more proactive system operation.

Identification of- Where Water is Going and at What Cost

The Digital Twin shall help to reduce Non-Revenue Water (NRW) using live water audit calculations. It shall be possible to compare overall production against metering data to estimate how much water was lost, both in quantity and percentage. The application shall perform automated evaluation of nightly minimum flows, enabling identifying the location and quantity of nonrevenue water. This auditing shall be available for individual zones or the entire network, which allows you to detect when a problem occurred or determine the effectiveness of mitigative actions. The features shall also improve energy efficiency by leveraging real-time analyses of each pump and tank, with alerts that tell you when performance is outside of service thresholds.

Early Warning and Emergency Management

Digital Twin shall improve awareness of anomalous network events such as leaks, bursts, and meter failures, contributing to reduced response times and subsequent operational cost reduction. By incorporating a real-time anomaly detection system, The Digital Twin shall automatically trigger alerts whenever real data is outside the expected operational behavior. Volumes lost in each event need to be automatically computed, allowing to manage those events with status updates, category classifications, and comments. The features shall facilitate to evaluate current network performance as well as various *what-if* scenarios when quick decisions are needed due to a fire, pipe break, pump outage, or other time-critical events, and demonstrate the impact of actions to service levels and customers throughout the network.

Connected Data Environment

The Digital Twin shall leverage a connected data environment that provides a cloud-provisioned open framework for collaboration and asset information management throughout the lifecycle of water infrastructure. The connected data environment shall ensure the accuracy and availability of system data at every stage of the asset lifecycle, allowing faster project start-up, streamlined workflows, improved standard adherence, reduced risk, more informed decisions, and increased asset performance.

Water Audit

Digital Twin can make following activities:

- IWA/AWWA Water Balance Diagram – Monthly water audit by pressure zone based on production data from SCADA and customer consumption from billing data.
- Non-Revenue Water (NRW) Analysis - Automatic derivation of real and apparent losses (based on Minimum Nightly Flow analytic))
- NRW Visualization - Graphical comparisons of the water balance components for multiple zones (historical trend series and bar charts)
- NRW key performance indicators (KPIs) - minimum nightly flow (MNF) per connection and ratio between minimum and average flow.

Pump Performance and Energy Management

- Pump Operational Analytics - Individual pump and/or total pump station performance evaluations in terms of best operation point, energy efficiency, and energy cost including comparisons over historical time periods (constant and variable speed pumps)

- Pump Power Cost KPIs – key performance indicators including total pump power cost and pump "inefficiency" cost.

Tanks assessment

- Historical trend Analysis – Comparative trends in tank operation (level, hydraulic grade line, and volume)
- Total Storage Assessment - Real time storage volume assessment
- Alerts - Low- and high-level alert notification

Event Management and Emergency Response

- Intelligent Alerts - Automatic alerts generated for sensors or zones based on user-defined rules and patterns.
- Pipe Break Volume KPI – automatic calculation of pipe break volume using calculated DMA flow volume exceedance above the Pattern prediction.
- Events management – user updatable status, category, and edit workflow comments; Ability to add manual events.
- Operational Event Simulation – Define and analyze impacts of events such as: valve closure/opening, pipe breaks, fires, and pump shutdowns.

Background Real-time Network Simulation

Digital Twin can make following simulations:

1) "Heartbeat" Model – Re-occurring automatic background run of hydraulic model (user defined interval such as 1 hour) using real-time boundary conditions, control overrides, and/or demand overrides from SCADA data derived calculations
2) Map Thematic and Graphical- Display - "heartbeat" modelling results for hydraulic grade line (HGL), pressure, flow, velocity, water quality, and other characteristics displayed in map view and chart views including pre-configured symbology templates and flow direction simulator on map.
3) Hindcast/Forecast Simulation - Real-time model simulation of hindcast (up to 24 hours) with optional control and demand override and forecast (up to 24 hours) based on model's inherent control logic.
4) Trend chart – display SCADA vs. Model simulation results in chart
5) Demand Forecasting - Automatic calculation and adjustment of demand patterns for forecast model simulation
6) Desktop Alternative – ability to upload and download hydraulic model for offline analysis (such as WaterGEMS).
7) Alerts Configuration - Set alerts for anomalous conditions defined based on absolute value or pattern, by individual sensor or zones, duration, and magnitude (absolute value or %); also flag lost signal or repeating values
8) User Configuration – user can incorporate new sensors, pumps, tanks, or zones into the system, configure alerts, routinely add customer billing data, and upload the most up-to-date hydraulic model as needed.
9) User Settings and KPIs - Customizable settings such as production and customer water costs, pressure level of service requirement, pump efficiency, or energy tariff information
10) User Credentials - Manage users and access to cloud application.
11) Global Settings - Customizable definition of thematic displays for all users
12) External Data Connections - Refresh/modify links to external data.
13) Power BI Integration - Integration and visualization of user-customizable reports done in Power BI
14) LoF and CoF Factors - Define the factors that define the Likelihood and Consequence of Failure (LoF and CoF)
15) LoF and CoF Decision Tree -Logic based decision tree interface to easily create simple or more complex LoF and CoF analysis; Create queries across multiple datasets
16) Risk Matrix Scenarios - Combine LOF and COF using a user-defined risk matrix to create various scenarios for analysis and comparison
17) Risk Calculation – automatically performs LoF, CoF and Risk score calculation for each pipe asset
18) Visualization – Tabular and map display of the assets based on low, medium and high risk (or user defined); Side by side comparison of different risk scenarios
19) Capital Plan - Define the performance parameters that can influence capital planning decisions; Define Intervention Plans based on risk and performance.

14.26 CONCLUSION

Implementation of various solution/tools such as sensors, smart meters, advanced communication tools coupled with IoT platforms can bring about real-time data base and information management and thus improving the performance of Urban Local Bodies (ULBs) and water utilities.

Smart technologies are likely to benefit both, the water utilities and the consumers, thus promoting efficient use of water both at the supply and demand side. Besides, it shall improve the credibility of the utilities thus improving revenue collection and reducing non-revenue water (NRW). The ability to monitor water supply & distribution system on a real-time basis shall enable quick identification, prediction and prevention of potential problems such as a burst water main, a slow leak, a clogged drain or a hazardous sewage overflow/contamination. It shall thus ultimately ensure water conservation and reduction in losses and UFWs. Such systems can improve the efficacy of water supply system.

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