Lecture 8: Operation and maintenance of water distribution system
Monitoring of System Performance With SCADA Systems

- Most water utilities now use some form of **Supervisory Control And Data Acquisition (SCADA)** systems in their daily operations.

- A SCADA system is a collection of field instrumentation, communications systems, and hardware and software systems that permit a system's behavior to be monitored and controlled, typically from a remote site.

*Flow measuring device*
The purpose of the field instrumentation is to collect information on the state of the hydraulic system. Such instrumentation may include:

- **Programmable Logic Controllers (PLC)**: typically were used to provide some type of localized control.

- **Remote Terminal Units (RTU)**: were used to collect field data and to send these data to a central computer.

- liquid-level switches,

These devices are capable of measuring and recording system indexes, such as pressure, flows, or tank water levels. In some cases, these devices are capable of providing localized control in the event of a communications failure.

Another common feature of SCADA systems involves alarm recording. When a storage tank overflows, the system continues to operate. Therefore, the SCADA system sounds an alarm indicating a problem with the tank.

Some SCADA systems even have the ability to telephone specified individuals, such as the director of operations, and notify them of an alarm condition.
SCADA operation Example

We have a computer screen in front of us that we use to view the status of the distribution system and its components.

we can cause the SCADA system to display current water levels in each elevated or ground-storage tank. Because some systems use touch screens, we might even be able to touch a tank on the screen and the SCADA system would draw a chart showing the water levels in the tank for the past 24 h.

Suppose that during our shift, we notice that the water level in a particular tank falls below half full. We know from experience that whenever water levels in this particular tank fall below half full, pressures in some parts of the pressure zone served by the tank are unacceptably low.

So from our control panel, we place a booster station into service by pressing the "On" button for this pump station. In short order, we can see that the tank water level has begun to rise and, as a result, the pressures in the pressure zone are kept within acceptable levels.

Data Archiving: SCADA systems offer data retrieval features that allow historical information describing the performance of the system to be displayed.
Network Operation

Consumer’s requirements will not be satisfied in a poorly operated network even if it has been well designed and constructed.

Common Network problems:
- Increase leakage due to high operating pressure
- Turbidity caused by long retention times
- Frequent change of flow direction
- Inadequate supply due to low pressure

This all additionally influences exploitation costs, maintenance requirements and may deteriorate the water quality.
Monitoring

Pressure and flow variation

- Pressure drop due to pipe burst

water quality parameters

- Need to change operation regime
- Need for necessary maintenance

Pressure and flow meters have to be installed in:
- All supplying points
- booster stations
- Junctions
- extreme elevation
- Pressure reducing valves
- The system ends

The sampling is usually done when:
- extreme pressure and flows
- interaction between water quality and pipe material
- soil conditions
- repair of the network
- illegal and inappropriate connections
- Other risks of contamination
A network is reliable if it can permanently perform in accordance with design criteria.

Due to unforeseen events in reality, this is never the case.

Network reliability is the probability of guaranteed minimum quantity, supplied at any (irregular) situation.

Failure of pumping station or main transmission line is considered as calamity, which will affect larger number of consumers and in most cases during more than 24 hours.
Reliability

\[ R = 1 - \frac{Q_o - Q_f}{Q_0} \]

Where

\( Q_f \) = available demand in the system after the failure.
\( Q_0 \) = the original demand
Pipe breakage is the most difficult to prevent. The bursts occur more often at smaller pipes and service connections.

The relation between the number of bursts and the pipe diameter.
Technical provisions

The following technical provisions help to increase the network reliability:

- Parallel pipes, pipes in loop
- Pumps operate with more units
- Alternative source of water
- Proper valve locations
- Pumping stations and storage connected with more than one pipe to the system
- Bypass pipes around the pump stations and storage, etc.
Unaccounted – For Water (UFW) and Leakage

Unaccounted – for water UFW: The difference between water quantity charged and the supplied amount.

Leakage: The difference between the supplied quantity and the amount of water passing actually through the consumer’s tap.

There are two usual ways of expressing the unaccounted- for water:
- As percentage of (annual) water production
- As specific value, in m$^3$/h per m length of the network.

Important notes: The total cost due to leakage includes not only the wasted water BUT also the cost of energy required for additional pumping.
Leak Detection Methods

Acoustic (sound) method

Tracer techniques (N\textsubscript{2}O)

leak noise correlator
Network Maintenance

Reactive maintenance

Preventive maintenance

Repair of something already happened

Preventive maintenance can extend the economical lifetime of the system, and therefore is a must; only the level can be different.
Maintenance and Rehabilitation Problems

Many water systems are old yet perform adequately. However, a number of factors at work might lead to failure if left unchecked. Some of the primary factors are:

**Normal wear:** Most moving components will wear out over time. Distribution systems have few moving parts and thus are not extremely susceptible to wear. Pumps are the components most likely to face wear problems. Depending on the type of pump, routine maintenance can maximize the life and maintain the efficiency of pumps. The moving parts in control valves also need frequent routine maintenance to continue functioning adequately.

**Corrosion:** Many distribution system components are made of metal, and, on contact with an electrolyte, metal tends to corrode. Metal pipes and tanks are the most obvious example of this type of problem. Corrosion also can attack reinforcing wire in concrete structures, and corrosion on valve stems and bolt threads can render these items inoperable. Corrosion is often the root cause of other problems as well: It leads to loss of metal, weakening of the component, and ultimately to failure. The by-products of the corrosion process accumulate on pipe walls and cause reduced carrying capacity and lower pressure. Corrosion also can contribute to poor water quality.
**Unforeseen loads:** Some distribution facilities fail because the load placed on them exceeds the load for which they were designed. Pipes broken by excessive surge pressure or external loads may have been designed correctly at the time they were installed; however, any component (e.g., pipes, pumps) can simply become too small when water demands increase over time.

**Poor manufacture and installation:** Even if an item is designed properly, it may be manufactured or installed incorrectly. A common cause of pipe breaks is poor bedding and backfill. Tank corrosion is accelerated by poor coating. A misaligned pump will fail quickly. Utilities that work with reputable suppliers and contractors have well-prepared contract documents, and quality inspections reduce the risk of poor installation.
Repair Versus Replacement

One approach to quantifying the need for replacement is use of a critical pipe break rate called $J^*$. If a pipe breaks at a higher rate than $J^*$, it is a candidate for replacement. If it breaks at a lower rate, it is less expensive to continue to repair breaks in the pipe:

$$J^* = \frac{[(KrC_r - C_d)e^{-bT} - C_wQ_0]}{C_b}$$

where

$J^*$ = critical break rate (breaks/yr/km),
$K = 1000$ (in case of metric units),
r = discount rate (i.e., 0.04 not 4 percent),
$C_r =$ cost to replace pipe ($/m$),
b = rate of increase of breakage (fraction),
$T =$ planning time horizon (yr),
$C_w =$ cost of leakage ($/ML$),
$Q_0 =$ leakage rate, (ML/ km/yr)
$C_b =$ cost of a break ($/break$), and
$C_d =$ cost of leak detection and repair ($/Km$).
At night: during longer retention time (release of corrosion product)
Relining or pipe replacement is required

At day time: high flow (re-suspension of the sediments)
Flushing is required
Planning of Maintenance

Set Standards of service

Compile information on the network

Hydraulic analysis for present and future demands

Assess current levels of services (Current performance)

Diagnose causes of service deficiencies

Assess current pipe condition

Assess current operating cost

Forecast future condition, level of service cost

Perform economic analysis of feasible options

Choose “best” options and schedule work