Setting the Standard for Automation™

Improving the Availability of Lift Stations through Optimized Redundant / Backup Control

Standards

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Presenters

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- Jacob Moser is a member of ISA and an instrumentation specialist for CDM. BSEET from DeVry University in Columbus Ohio. 13 years of experience in I&C design, panel design, PLC programming, SCADA configuration, instrumentation calibration and maintenance in the water/wastewater and manufacturing industries.

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Definitions

- **Reliability**
- **Availability**
- Mean Time Between Failures (MTBF)
- Mean Time Till Failure (MTTF).
- Transient Voltage and Surge Suppression (TVSS) .
- Programmable Logic Controller (PLC) or Process Automation Controller (PAC)
- Uninterruptable Power Supply (UPS)
- **Sanitary Sewer Overflow (SSO)**
- **Combined Sewer Overflow (CSO)**
- Underwriters Laboratories (UL)
- **Technischer Uberwachungs-Verein (TUV)**
- National Fire Protection Association (NFPA)
- National Electrical Manufacturers Association (NEMA)

Backup and redundancy practices study.

– A survey based study of 90 cities developed by the EPA between 1979 and 1980 revealed:

  – “Seven of the top 10 limiting factors that limit the performance of WWTPs were related to improper design and noted that one of the major problem areas was **lack of flexibility of unit processes**”.

  – “Based on these results, treatment facilities re-evaluated design practices and began to implement equipment redundancy”

Results of two U.S. Environmental Protection Agency (EPA) surveys in 1979 and 1980 of over 90 wastewater treatment plants (WWTPs)

Backup and redundancy practices study.

- A similar survey over 46 cities in 2001-2002, developed by the **Water environment Foundation** published under "**Efficient Redundancy Design Practices** *WERF Report published in February of 2003). :*
  - *Results*
    - "**Equipment redundancy** is **practiced** in the design and operation of water and wastewater treatment plants to **improve reliability** through the provision of standby equipment or processes that **reduce the risk of failure** in order to **meet water quality regulations** or guidelines."
  - Example
    - **Orange County Utilities (OCU)** reports: "This level **of redundancy is cost effective** at OCU **because their operating costs have stabilized in the last 3 years**, even though reclaimed water production has increased."

WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

Backup and redundancy practices study.

- Efficient Redundancy Design Practices *WERF Report published in February of 2003).*
  - *Recommendations:*
    - "**Accomplish** documentation of **realistic approach's to redundancy guidelines** that have practical goals having in considerations high-, medium-, and low-cost options, or short- and long-term projects."
    - "Develop a "**how-to implement redundancy design practices**"
    - "**Examine the effective use of redundant instrumentation** and automation, which can have a significant impact on design and operation. **Study how it can be used to reduce capital costs** or eliminate plant expansions and reduce operations and maintenance costs".

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Lift Station

- Sewage pumping stations, or lift stations, are typically designed so that one pump or a set of pumps will handle normal peak flow conditions.
  - Pumping redundancy is built into the system so that in the event that any one pump is out of service, the remaining pump or pumps will handle the designed flow.
  - The storage volume of the wet well between the 'pump on' and 'pump off' settings is designed to minimize pump starts and stops, but is not enough retention time as to allow the sewage in the wet well to go septic.
  - Due to the environmental impact of overflows, lift station pumping must be reliable and continuous including the ability to respond to varying flow demands.

Redundancy and Backup implementation in Lift Station.

- Besides redundant pumps, common redundant equipment that can be found in lift stations are:
  - Backup Generation.
  - Redundant or backup Control.
  - Backup Instrumentation.
  - Backup Telemetry or Auto dialers
  - UPS.
  - Redundant Power Supplies.

Mitigating Component Failures

The 3 Biggest Influences on Component Reliability ….

Temperature

Corrosion

Transient Voltages and Surges

The following guidelines address these killers of electronic components …

Mitigating Component Failures

Use the Components for Their Intended Purpose

Voltage – Current Capacity

Do Not Exceed the Environmental Limits of the Components

Temperature – Moisture – Dirty Environment

Mount the Components Properly

Air Flow – Proper Orientation – Securely Fastened

Corrosion Control

Corrosion Control – Sealing Conduit and Panel Entries – Enclosure Type

Transient Voltage and Surge Suppression

Proper Grounding – TVSS Devices

Mitigating Component Failures

Reliability in Instrumentation and Control states that it has been determined that the increase in failure rate of semiconductors, for every 10 degree Celsius increase in temperature, is 1.2 to 2.0 times the established failure rate.

Example:
A semiconductor has an established failure rate of 15/1,000,000 hours at 30 degrees Celsius, if the temperature is increased to 55 degrees Celsius and you assume a multiplier of 1.6 per 10 degrees Celsius(mid way through the established range) the failure rate increases to 48.6/1,000,000 hours. That is a 324% increase in the failure rate of a component just due to temperature.

Redundancy and Backup implementation in Lift Station.

- Most Common causes of system failures.
  - Backup generator failures.
    - Battery Failure **(The single most frequent service call for generator failure is battery failure)**
    - Low Coolant Level Alarms/ Shutdown.
    - Low Coolant Temp Alarms.
    - Leaks – Oil, Fuel, or Coolant
    - Controls Not in Auto.
    - Engine Ran Out of Fuel
    - High Fuel Level Alarm
    - Breaker Trip Not Related to the Generator

Redundancy and Backup implementation in Lift Station.

- Redundant or Backup Control failures.
  - Common point of failure
    - Failure of Power supply (UPS)
    - Failure Remote I/O Network.
    - Electromagnetic Discharge.
  - Backup or Redundant Controller not in standby.
  - Borders condition not tested.

- Backup Instrumentation failures.
  - Electromagnetic Discharge.
  - Instrumentation readability not considered as design criteria.
  - Lack of maintenance.
  - Lack of calibration.

Redundancy and Backup implementation in Lift Station.

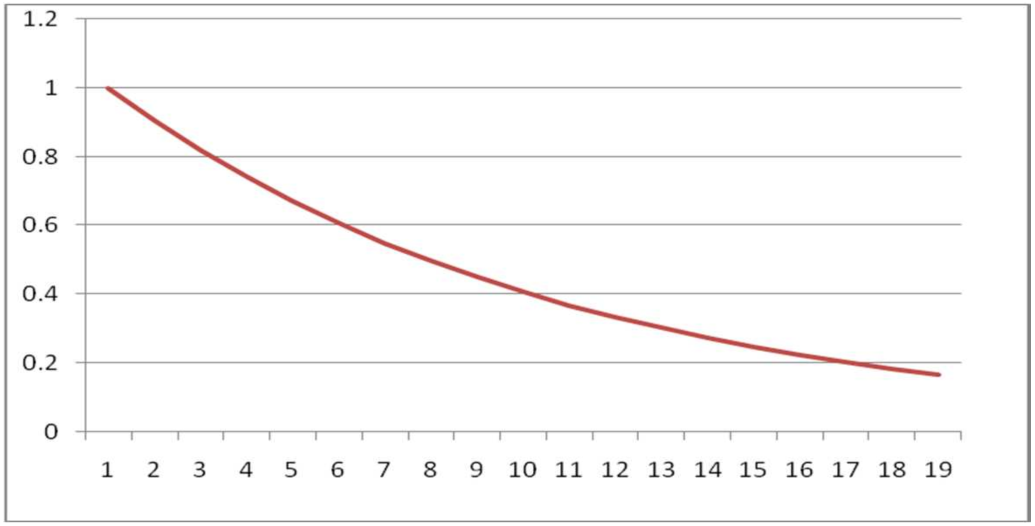
- Backup Telemetry (Auto dialers).
  - Common point of failure
    - Failure of Power supply
    - Electromagnetic Discharge.
    - Single Ethernet Switch Fail.
  - Atmospheric conditions.
  - Operational conditions
    - Temperature
    - Humidity.
- UPS and Redundant Power Supply Failure.
  - Battery failures.
  - Operational conditions
    - Temperature
    - Humidity.

Diagnostic And Periodic Testing To Improve The Availability Of Backup Systems

Reliability: can be defined as "the ability of an item to perform a required function specified by its intended purpose, under stated conditions during a given period of time".

When a constant failure rate is assumed (which is valid during the useful life of a device)

- $R(t) = e^{-\lambda t}$
- $F(t) = 1 - e^{-\lambda t}$



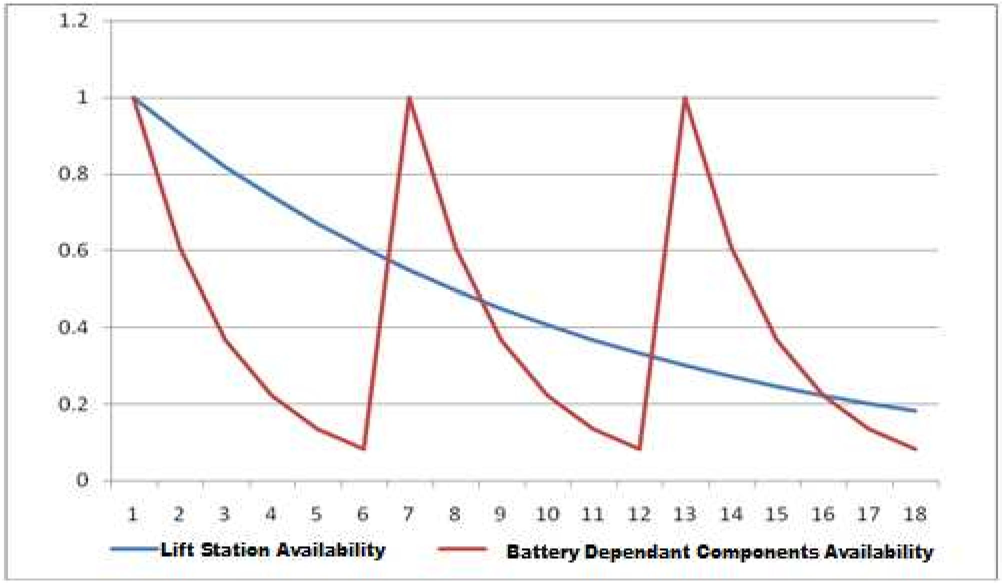
- *Mean Time To Failure (MTTF)*-. Defined as the "expected value" of the random variable *Time To Fail, T.* MTTF = 1/ λ
- Availability: refers to the probability of finding an item in an operational state at a given time".

Diagnostic And Periodic Testing To Improve The Availability Of Backup Systems

- Steady State Availability- Assuming a constant repair rate. The probability models can be solved for "steady state" or average probability of successful operation.

- A = MTTF/(MTTF + MTTR)

- U = MTTR/(MTTF + MTTR)



- Mean Time To Restore (MTTR) : Include both diagnostic detection time and actual repair time.

Diagnostic And Periodic Testing To Improve The Availability Of Backup Systems

- Backup systems by nature are low demand Applications, with a restore rate that is not constant. For failures not detected until a periodic inspection and test, the restore rate is zero until the time of the test. If it is discovered the system is operating successfully, then the probability of failure is set to zero.

- “In practice we define at TUV[2] a test as a diagnostic test if it fulfils the following three criteria:
  - 1. I**t is carried out automatically** (without human interaction) and frequently (related to the process safety time considering the hardware fault tolerance) by the system software and/or hardware;

  - 2. **The test is used to find failures that can prevent the safety (Backup)** function from being available.

  - 3. **The system automatically acts upon the results of the test**”

2. TUV Technischer Überwachungsverein (German: Technical Monitoring Association)

Diagnostic and Periodic Testing on the Reliability of Backup or redundant Systems.

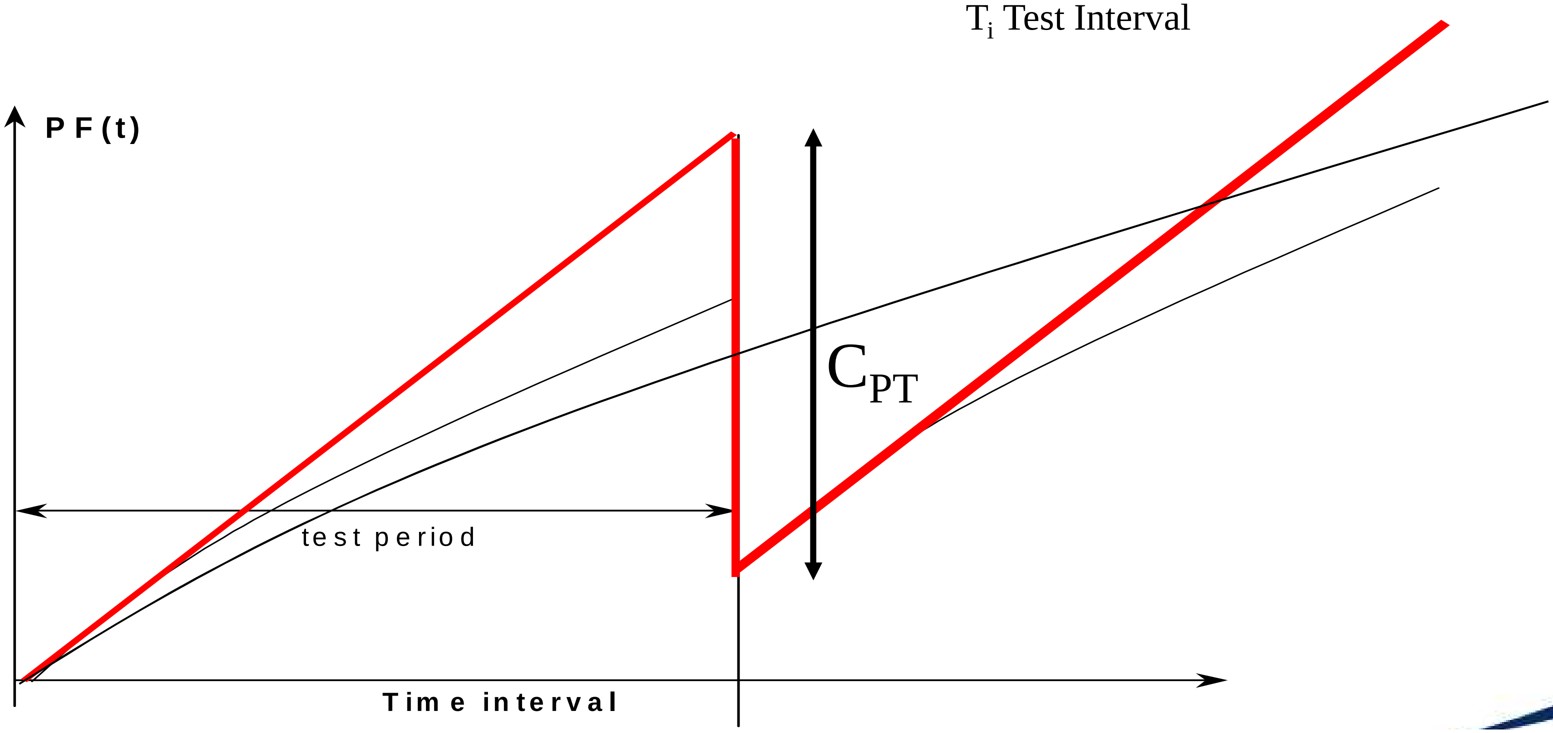
- **The Probability of Failure on Demand is the probability of a given safety instrumented Function (SIF) cannot perform its safety function when is a need it. (This same concept can be applied to redundant or backup systems)**
  - $PFDavg = C_{PT} \lambda T_i / 2 + (1- C_{PT}) \lambda LT / 2$

C_{PT} = Effectiveness of proof test, 0 – 100%

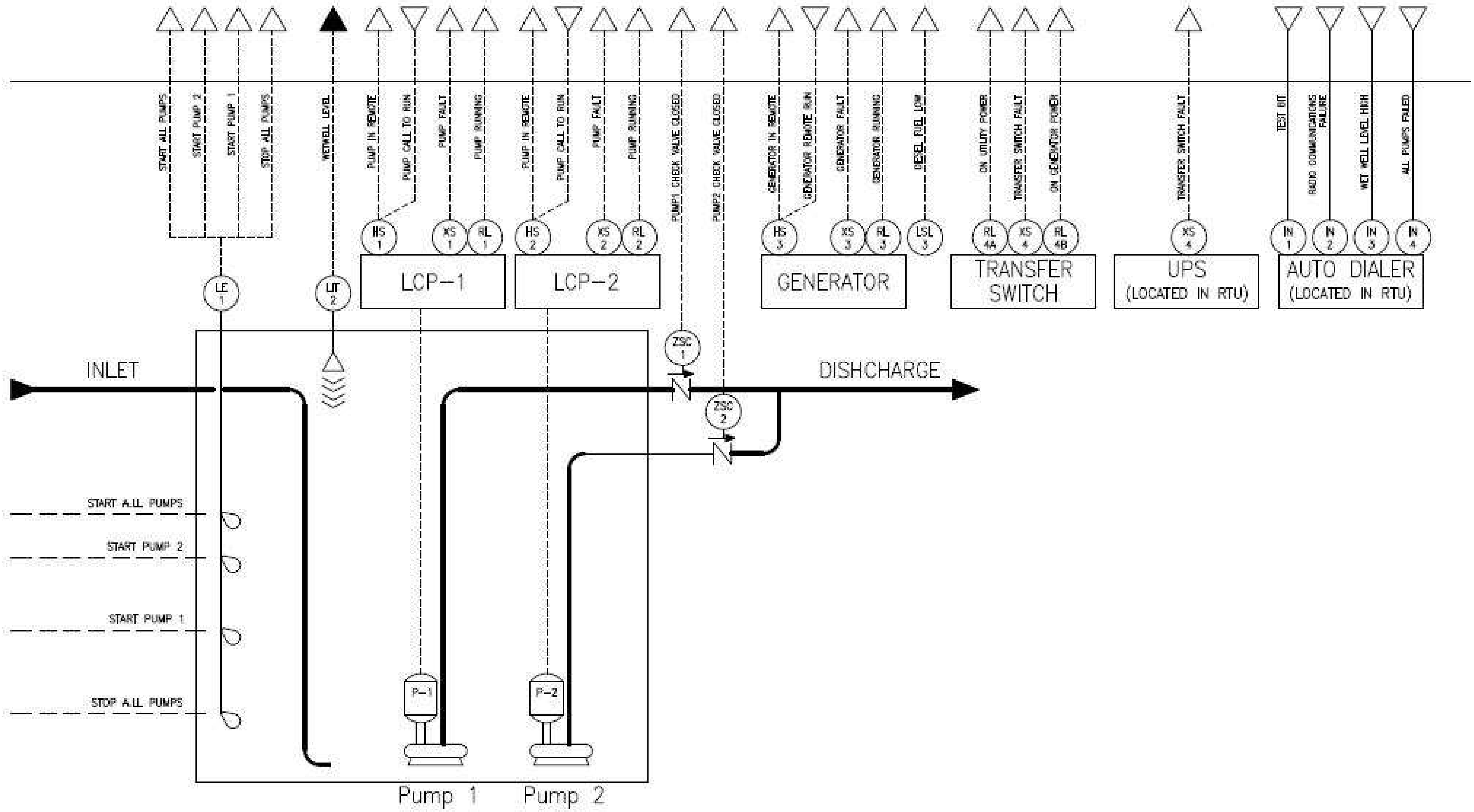
LT = Operational Lifetime of plant

T_i Test Interval

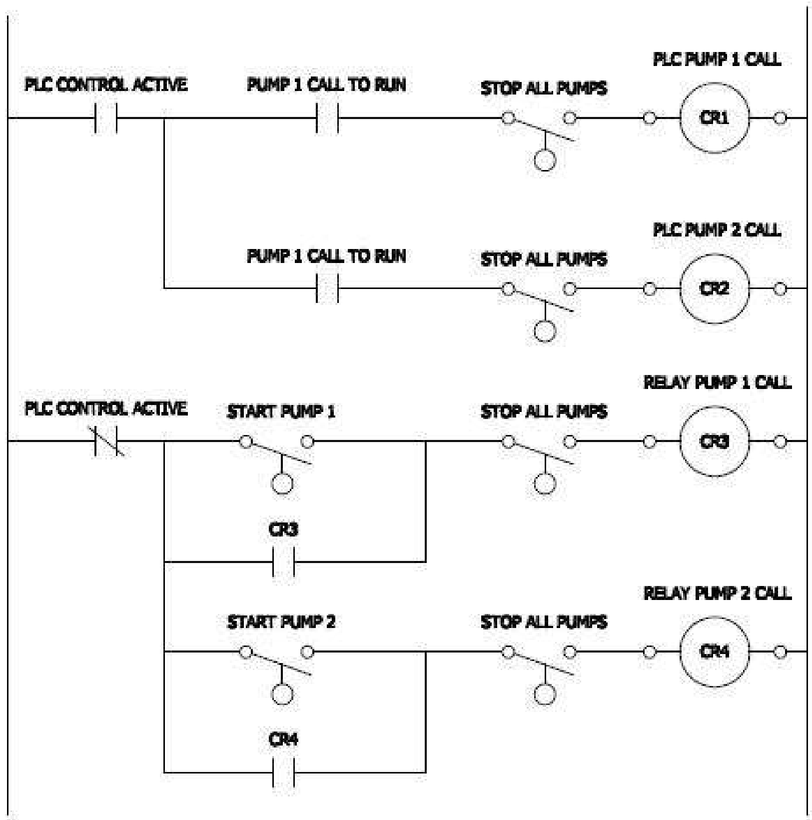
- .

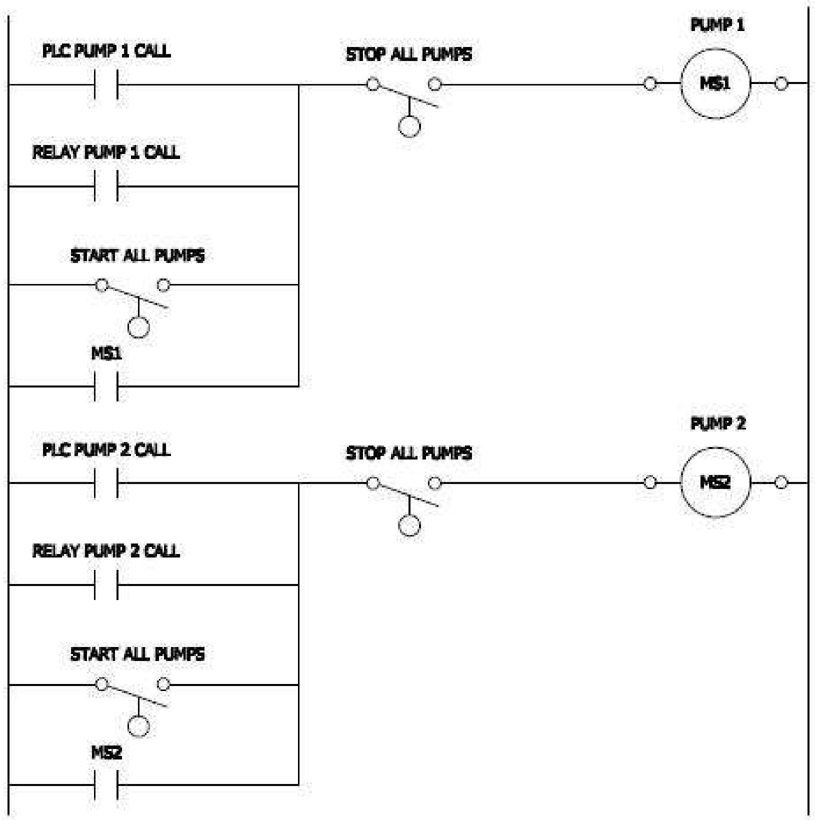


Examples Of Automatic Testing

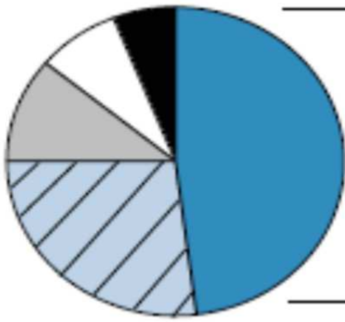


Examples Of Automatic Testing





Marginal investment of implementing test routines for Redundant or backup system versus cost associate with SSO or CSO



Causes of SSO Events	Percent
Blockages	48%
Wet weather and I/I	26%
Mechanical or power failures	11%
Line breaks	10%
Miscellaneous	5%
Total	**100%**

Report to Congress, Impacts and Control of CSOs and SSOs. Publisher: EPA 833-R-04-001. Publish Date: August 2004.

It was found that Mechanical or power failures as well as miscellaneous events correspond with the 16% of all electromechanical fails.

But what percentage of these failures may be considered preventable due to lack or failure of the redundant or backup components?.

Marginal investment of implementing test routines for Redundant or backup system versus cost associate with SSO or CSO

The Michigan Department of Environmental Quality (DEQ), Combined Sewer Overflow (CSO) & Sanitary Sewer Overflow (SSO) Annual Reports 2006, 2007 and 2008.
Avoidable Failures

These events could be avoided by diagnostic tests followed by corrective actions.

9324	11/14/06	9:30 A	11/14/06	10:30 A	0.0002 Million Gallons	Raw sewage	1025 East Michigan (Lift station near address). Land: Yes, Waterbody: none	The pumps a the 1025 E. Michigan Ave. Lift Station were inadvertently left off during the routine inspection at the station. This caused the wet well to fill up and overflow.
8287	02/16/06	5:30 P	02/19/06	9:00 A	0.0006 Million Gallons	Raw sewage	PS-3, 12023 Woodland Park Dr. (PS-3). Land: None entered, Waterbody: Groundwater *** PS-4, 12311 Abbott Street (PS-4). Land: None entered, Waterbody: Groundwater *** PS-3A, Dream Isle Drive (PS-3A). Land: None entered, Waterbody: Groundwater	Power failure at lift stations, PS-4, PS-3, PS-3A, due to ice storm. Emergency generator did not operate properly.
8925	07/22/06	6:00 P	07/23/06	12:00 P	0.000005 Million Gallons	Raw sewage	PS-6, 11804 4 Mile Road, Murray Lake (Manhole lid). Land: Area around manhole lid, Waterbody: None entered	Dialer not reset after power outage. Pumps tripped and no notification was sent.
7945	02/08/06	7:00 P	02/08/06	7:35 P	0.000015 Million Gallons	Raw sewage	625 West Union Street (Plant Lift Station). Land: None entered, Waterbody: Paw Paw River	Plant lift station level transducer failure.
7946	02/09/06	8:50 A	02/09/06	9:40 A	0.0001 Million Gallons	Raw sewage	625 West Union Street (Plant Lift Station). Land: None entered, Waterbody: Paw Paw River	Failure of high level alarm float and level transducer.

Marginal investment of implementing test routines for Redundant or backup system versus cost associate with an overflow

- From 2006 to 2008 an average of 20 overflows(5% of total overflows) were preventable spills.
- Analyzing several emergency response plans issued by different cites the average cost per event was estimated at $6,000 to $12,000.

- Estimated cost of 20 at $9,000 = $180,000.
- Including a Diagnostic and Testing Routine (DTR) as part of the lift station's design, could help to reduce this cost by 50% (level of success of the DTR) to $90,000

Marginal investment of implementing test routines for Redundant or backup system versus cost associate with SSO or CSO

For a collection system consisting of 200 lift stations:

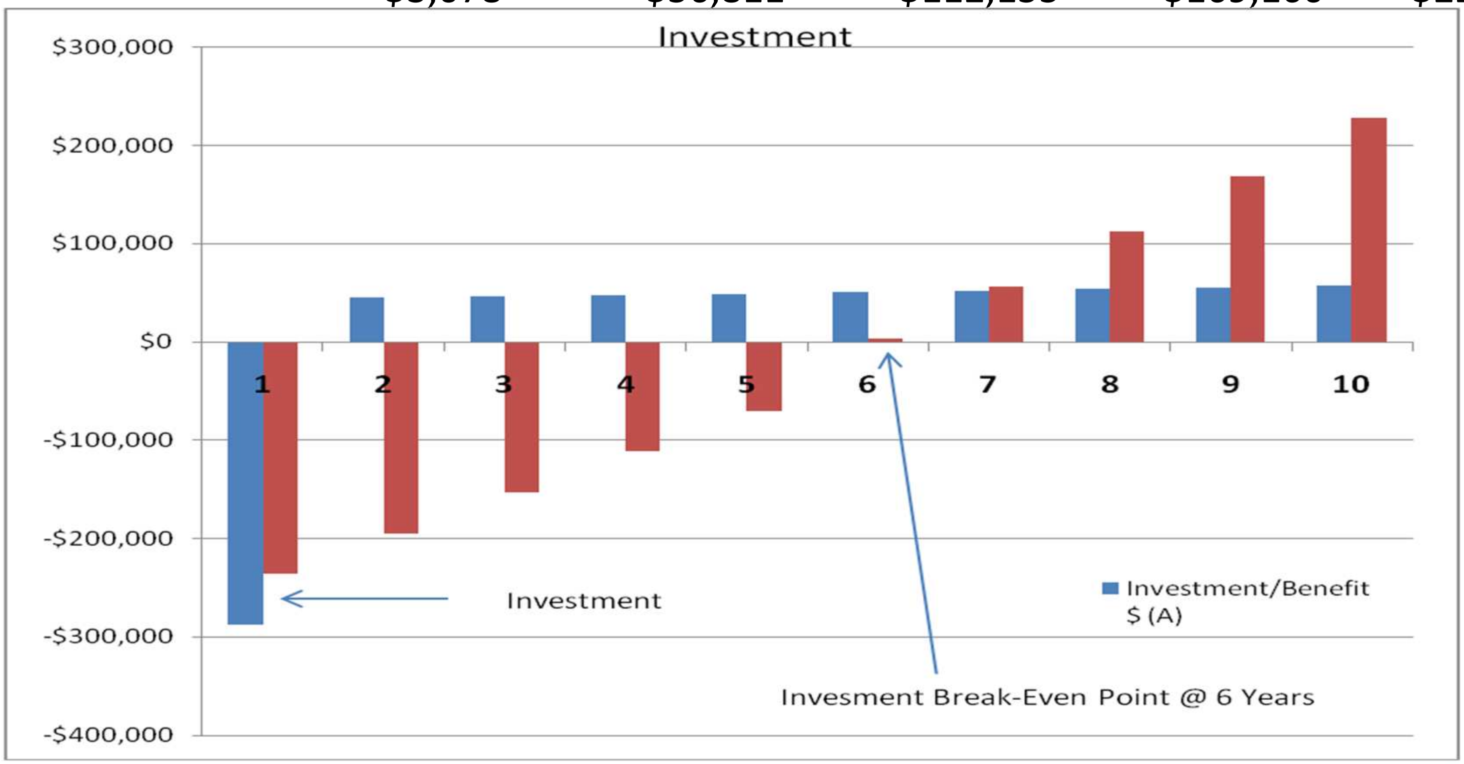
Average amount of Annual avoidable spills	10
Average Clean Up Cost	$ 9,000
Annual avoidable Clean Up Spill Cost	$ 90,000
Success Factor	50%
Annual avoidable clean up Spill Cost* Success Factor	$ 45,000
Investment Details	
Development	$ 48,000
Installation per site	$ 700
Hardware per site	$ 500
Investment per lift station	$ 1,440
Number of Lift Stations	200
Total Investment	$288,000

A return on investment analysis of the costs to upgrade all 200 lift stations to add automatic testing, shows that there would be a return of investment in 6 years. This is just using the cleanup costs as the motivator, this doesn't include any fines levied by the EPA which can amount to tens of thousands of dollars for repeated spills, especially if they involve populated areas or waterways.

Marginal cost of implementing test routines for Redundant or backup systems versus cost associate with SSO or CSO

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment/Benefit $ (A)	($288,000)	$45,000	$46,350	$47,741	$49,173
NPV $ (A)	($236,253)	($194,448)	($152,845)	($111,443)	($70,241)

	Year 6	Year 7	Year 8	Year 9	Year 10
Investment/Benefit $ (A)	$50,648	$52,167	$53,732	$55,344	$57,005
NPV $ (A)	$3,078	$56,811	$112,155	$169,160	$227,875



Marginal cost of implementing test routines for Redundant or backup systems versus cost associate with SSO or CSO

These results are theoretical and vary depending on the following factors:

1. Level of success of DTR.
    1. Diagnostic and test coverage.
    2. Diagnostic and test frequency.
2. Marginal cost of DTR project.
    1. Type of technology (PLC, SCADA, Telemetry System)
    2. Level of integration and Reporting.
3. Number or Lift stations. (Economies of Scale)
4. Technology legacy.
5. Discount rate.
6. Operational costs associated with the DTR Task.
7. Inclusion of a DTR as parts of the operations and maintenance procedures.

Marginal cost of implementing test routines for Redundant or backup systems versus cost associate with SSO or CSO

- Summary of benefits.
  - Increase the average availability of the redundant or backup components. Increasing the availability of the overall system.
  - Help to plan corrective maintenance when failure on redundant or backup components are detected.
  - Reduce the uncertainty.
  - To meet regulatory requirements and to reduce operational costs by reducing process-unit downtime.

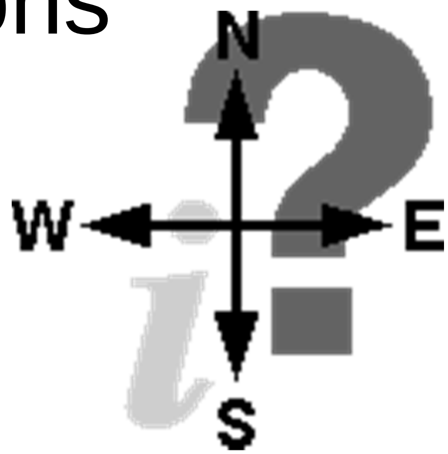
Conclusion

- The specification of redundant or backup components is a common practice in the water/wastewater industry.
- Following the guidelines set forth by UL, NFPA, and TUV, and implementing an automatic testing regime creates a highly available system that can be installed with minimal cost impact.
- It has been proven that diagnostics and testing will decrease the average probability of failing on demand.
- The diagnostic and testing routine can be implemented as a task in a new or upgraded I&C project where the test coverage and frequency may be carefully determined in order maximize the benefits and avoid system upset.

Conclusion

- This study concludes that the marginal cost associated with diagnostic and testing implementation could have a recovery period of approximately 6 years.
- The cost recovery time will depend on several factors such as the level of success of the diagnostics and tests, and the number of facilities and legacy components.
- It is recommended and cost appropriate to implement DTRs and redundant or back up components to the overall system.

Questions



Thanks.