Applying Resilience Modelling Tools to the Design of Membrane Plants for Pathogen Removal

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Introduction

- Resilience is a system's ability to maintain routine function even under unexpected circumstances.
- It is an essential factor in ensuring continuous process throughput whilst remaining compliant with strict water discharge guidelines.
- Resilience modelling tools have been widely used in the Petrochemical, Oil and Gas, and Aviation industries to model process reliability and safety over the last 15 years.
- No standard resilience modelling method has been developed for the water treatment industry.

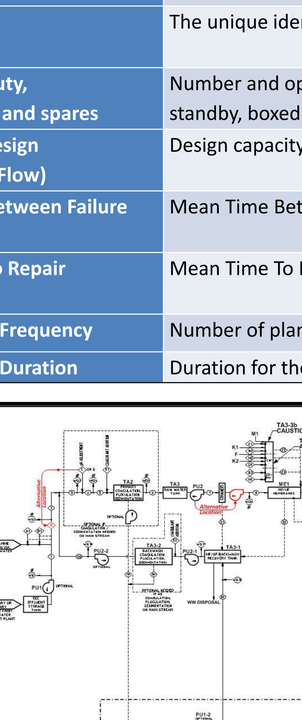
Objectives

- Establish a mechanical resilience model for water recycling systems.
- Quantify process resilience and predict process equipment failure using resilience model.
- Develop "What-if" scenarios for resilience model's sensitivity analysis tests.

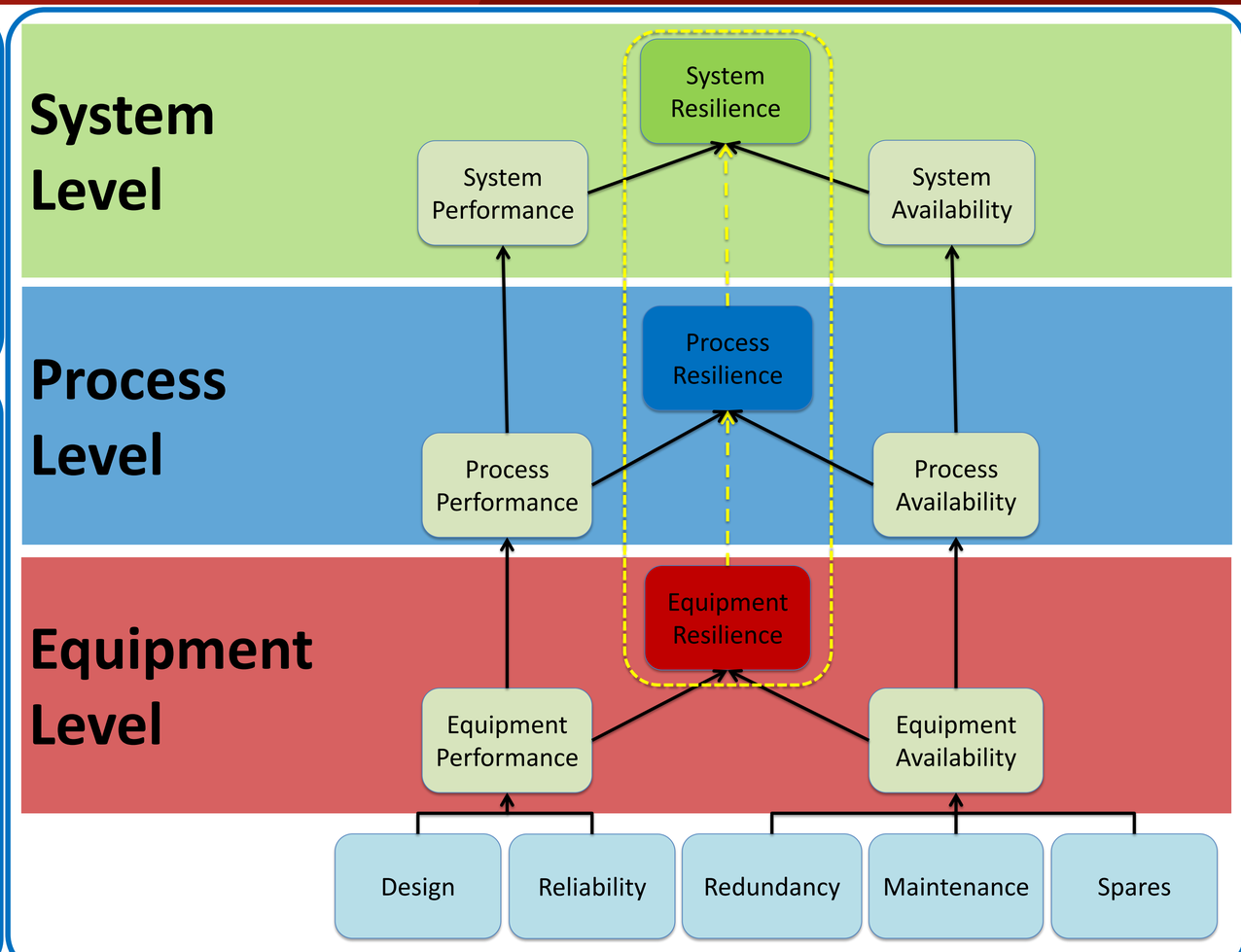
Resilience Model

- Adopting a resilience modelling tool from the Oil and Gas industry, GL Noble Denton's (GLND) OPTAGON Simulation Package was chosen.
- OPTAGON is GLND's Monte Carlo-based Reliability, Availability and Maintainability (RAM) simulation tool which is capable of modelling the performance of asset.
- With user-variated real-time data, OPTAGON is able to accurately predict equipment failure and system resilience.

Asset Resilience



OPTAGON Model

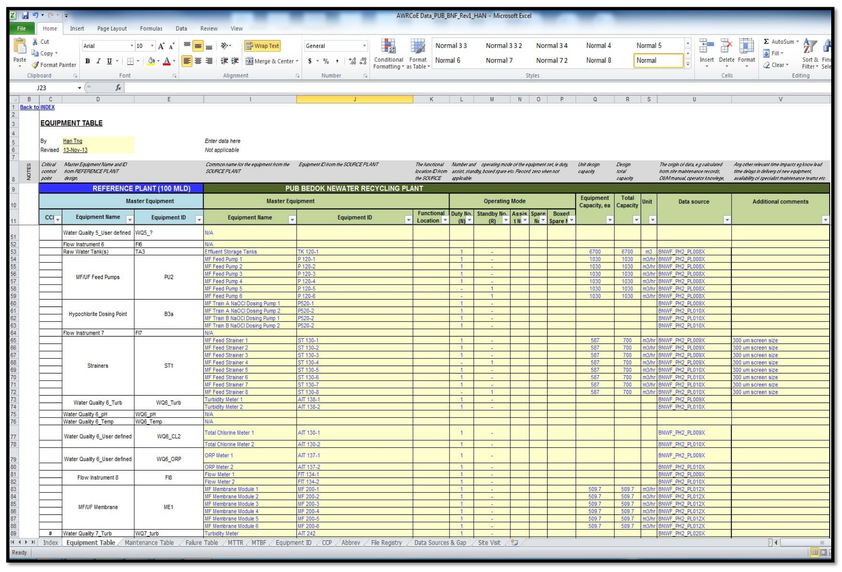


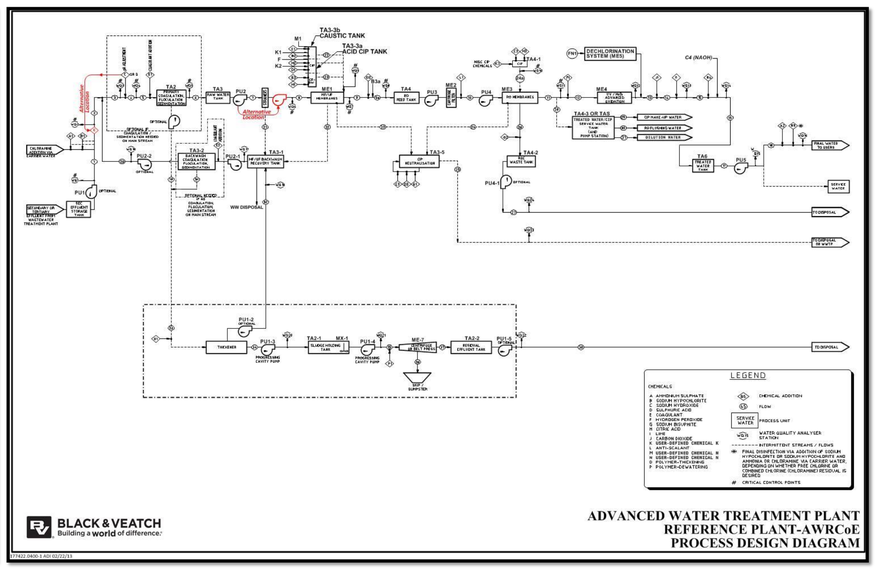
Methodology

Step 1: Data Sourcing and Collection

- Equipment failure and performance data is sourced from 7 water recycling plants worldwide.
- Relevant information is collected from a wide array of data sources.

Data Element	Element Description	Source Documentation
	Plant Level	
Process configuration/Design	Overall process design diagram/information of plant.	Engineering drawings and operational documents (P&ID, PFD, O&M Manuals)
System Compliance Constraints	Plant quality compliance thresholds.	Compliance related documentation, Alarm thresholds
	Equipment Level	
Equipment name	The common name for the equipment set	Asset Register, equipment data sheets, Engineering drawings and operational documents such as P&ID, PFD, O&M Manuals
Equipment ID	The unique identifier for the equipment	Asset Register, equipment data sheets, Engineering drawings and operational documents such as P&ID, PFD, O&M Manuals
Number of, duty, redundancies and spares	Number and operating mode of the equipment set, ie duty, assist, standby, boxed spare etc.	Engineering drawings and operational documents such as P&ID, PFD, O&M Manuals, layout drawings
Equipment Design Capacity (i.e. Flow)	Design capacity of the equipment in terms of primary flow (m3/h).	Equipment data sheets, OEM documentation, Historic flow monitoring data (avg), and Process Flow Diagrams
Mean Time Between Failure (MTBF)	Mean Time Between Fail (MTBF) for each failure mode if identified.	Equipment failure rates, site maintenance records from CMMS. Ideally records provided should cover full operating period.
Mean Time To Repair (MTTR)	Mean Time To Repair (MTTR) for each failure mode if identified.	Site maintenance records from CMMS, replacement lead time from suppliers, and maintenance regime documentation.
Maintenance Frequency	Number of planned maintenance activities per year	O&M Manuals
Maintenance Duration	Duration for the planned maintenance.	O&M Manuals





Step 2: Data Analysis and Mapping

- Cataloged equipment data is sorted and mapped according to process equipment specified in the model (Reference Plant).
- Equipment arranged with design and operational capacities based on functional location.
- Operation & Maintenance (O&M) Manuals provide vital information on equipment availability.
- MTBF and MTTR are also calculated if not previously provided.
- Equipment criticality is determined based on failure and maintenance data.

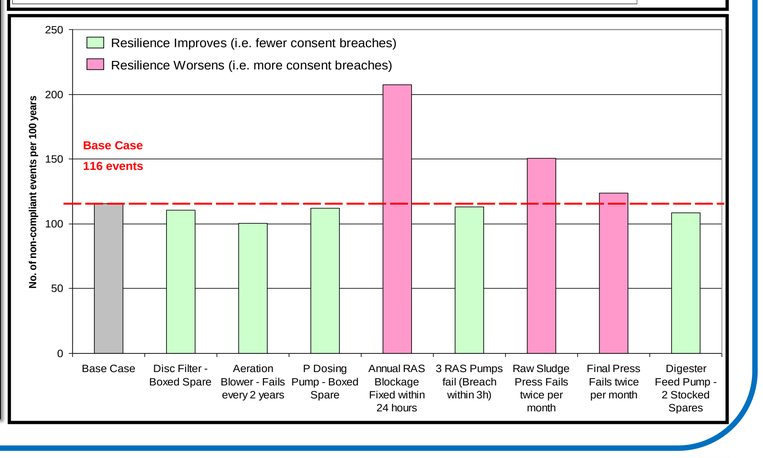
Step 3: Resilience Modelling & Sensitivity Analysis

- Mapped data becomes input variables for OPTAGON to model asset's mechanical resilience.
- Monte Carlo simulations of 10,000 realisations ensure confidence of modelling results.
- Results also demonstrate equipment interdependency.
- Modelling results would quantify the asset's overall reliability and resilience.
- Sensitivity analysis would further highlight which input variable would have the greatest impact on the system.
- "What-if" scenarios would test the robustness of the reference plant and aid with process optimisation.

Resilience = f (Availability, Performance)

Availability = f (Reliability, Maintainability)

Risk = f (Likelihood, Consequence)



Conclusion

- OPTAGON can model complex water recycling systems with high level of accuracy and consistency.
- Modelling results would be able to quantify asset resilience, criticality and risk.
- Resilience modelling can predict and improve asset performance throughout asset's lifespan.
- Sensitivity analysis would support asset management decisions and aid in efficiency and profitability.
- Reference model can also be used to provide insight to specific failure modes and resulting effects.

Acknowledgements

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