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AI Driven Autonomous Plant Operation for Shell Scotford

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AVEVA

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Also, in this presentation we may refer to Shell's "Net Carbon Footprint" or "Net Carbon Intensity", which include Shell's carbon emissions from the production of our energy products, our suppliers' carbon emissions in supplying energy for that production and our customers' carbon emissions associated with their use of the energy products we sell. Shell only controls its own emissions. The use of the term Shell's "Net Carbon Footprint" or "Net Carbon Intensity" are for convenience only and not intended to suggest these emissions are those of Shell plc or its subsidiaries.

Shell's net-Zero Emissions Target

Shell's operating plan, outlook and budgets are forecasted for a ten-year period and are updated every year. They reflect the current economic environment and what we can reasonably expect to see over the next ten years. Accordingly, they reflect our Scope 1, Scope 2 and Net Carbon Footprint (NCF) targets over the next ten years. However, Shell's operating plans cannot reflect our 2050 net-zero emissions target and 2035 NCF target, as these targets are currently outside our planning period. In the future, as society moves towards net-zero emissions, we expect Shell's operating plans to reflect this movement. However, if society is not net zero in 2050, as of today, there would be significant risk that Shell may not meet this target.

Forward Looking Non-GAAP measures

This presentation may contain certain forward-looking non-GAAP measures such as cash capital expenditure and divestments. We are unable to provide a reconciliation of these forward-looking Non-GAAP measures to the most comparable GAAP financial measures because certain information needed to reconcile those Non-GAAP measures to the most comparable GAAP financial measures is dependent on future events some of which are outside the control of Shell, such as oil and gas prices, interest rates and exchange rates. Moreover, estimating such GAAP measures with the required precision necessary to provide a meaningful reconciliation is extremely difficult and could not be accomplished without unreasonable effort. Non-GAAP measures in respect of future periods which cannot be reconciled to the most comparable GAAP financial measure are calculated in a manner which is consistent with the accounting policies applied in Shell plc's consolidated financial statements.

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Speaker Introduction

Donald Dalawampu, Project Lead, Digital and Business Transformation:

Donald is the lead for Shell Scotford's proof-of-concept that tested the feasibility of implementing AI into Process Control. He has 17 years of downstream oil industry experience, spending the last decade contributing significantly to the growth and transformation of the company's assets as a Business Improvement and Engineering Lead. He earned his Chemical Engineering degree from the University of the Philippines, and Project Management Qualification from the Association for Project Management. He is passionate about exploring new solutions to solve complex problems and drive continuous improvement.

Celine Thomerson, Principal Consultant, Simulation Delivery:

Celine is the technical lead on the Scotford MEG Simulator project, logging over 700 hours working with MEG operators and operations engineer. Over the last 15 years, she has completed more than a dozen simulation project, provided training for panel operators and been a panel operator herself. The simulation projects include both engineering studies and operator training simulators. She earned BS and MS degrees in Chemical Engineering from the University of Houston.

Dr. David Smith Principal AI Engineer, AI Center of Excellence, United Kingdom:

Dr. Smith is a Chartered Mechanical Engineer and holds a Ph.D. in Fluid Mechanics from Imperial College London. Spending the first half of his career in industry mainly with EPC companies, he leads design, development, and commissioning of Power Plant processes and combustion systems. Moving to AVEVA, Dr. Smith joined the AI Center of Excellence where his main activities are the integration of AI technologies with AVEVA's first principles simulation products for asset management and autonomous operations.

1

Background

Shell Explores Using AI in Controls

Shell Energy and Chemicals Park Scotford

- The Shell Energy and Chemicals Park Scotford, located 40 kilometers northeast of Edmonton, Alberta, Canada, consists of a bitumen upgrader, oil refinery, chemicals plant and a carbon capture and storage (CCS) facility. It is one of North America’s most efficient, modern and integrated hydrocarbon processing sites, converting oil sands bitumen into finished, marketable products.
- The Shell Scotford Chemicals Plant uses byproducts from the adjacent Shell Scotford Refinery to help manufacture styrene monomer and ethylene glycol. The plant has two units – the styrene plant and the glycol plant. The Shell Scotford Chemical Plant products are shipped by pipeline, rail cars and truck to be marketed and sold across North America.
- The Glycol product is primarily sold to customers in North America for use in making products such as plastic drinking bottles and antifreeze.

Shell’s Transformation Building Blocks

- Shell has been exploring the use of digitalization and AI to support the Powering Progress Strategy to accelerate transition of our businesses to net-zero emissions while creating more value to our shareholders, customers, and wider society.
- We are actively working on a range of digital technologies to improve safety and efficiency, as well as facilitate the energy transition.
- One of these building blocks involves creating a number of small semi-autonomous applications.
  - To aid not only during steady-state, but more so during upsets

A series of small, semi-autonomous applications that help operators mitigate abnormal situations ‘the best way every time’, such as during start ups and shut downs, with minimal human intervention.

Opportunity

Current Condition

Typical process control systems struggle to effectively mitigate plant upsets and emergencies or in general, manage transient conditions.

Gap

The conventional control methods lack the ability to respond quickly to sudden disturbances in the process.

Opportunity

Test the feasibility of implementing an AI application/agent into Shell Scotford's process control system and allow the agent to perform higher level / complex decisions in managing different 'upset/transition' scenarios.

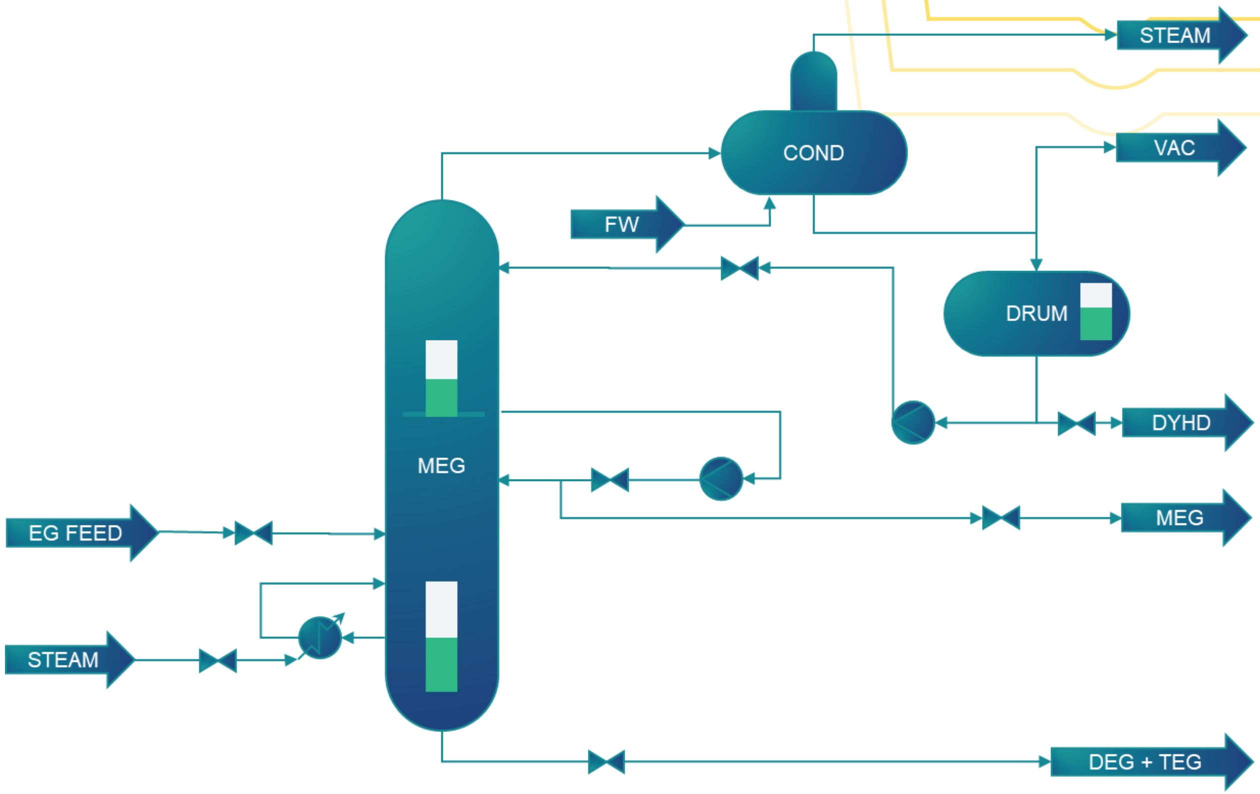
2

Test Problem

Shell Scotford MEG Total Reflux

MEG Plant ‘Total Reflux’

- Shell Scotford ethylene glycol unit comprises a series of columns which separate Mono, Di and Tetra Ethylene Glycol (MEG, DEG and TEG) from the feed mixture.
- During plant upsets, causing an interruption to the incoming feed, these columns need to enter a stable total reflux operation mode, maintaining the appropriate heat input to the inventory in readiness for the later re-introduction of feed.
- If the columns are allowed to slump this can cause considerable lost time to bring them back into a condition for feed re-introduction. All of these actions are currently performed manually by operators.



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AI's Main Goal:

Establish a stable Total Reflux Operation of the MEG column following a trip from the upstream.

WHILE...

Managing all the upsets that may be encountered during the period.

MEG Plant 'Total Reflux'

1 Upstream upset

2 Hibernate column

Maintain Levels

Keep vacpac pressure < limit

Adjust reflux flow to 60% of steady state flow

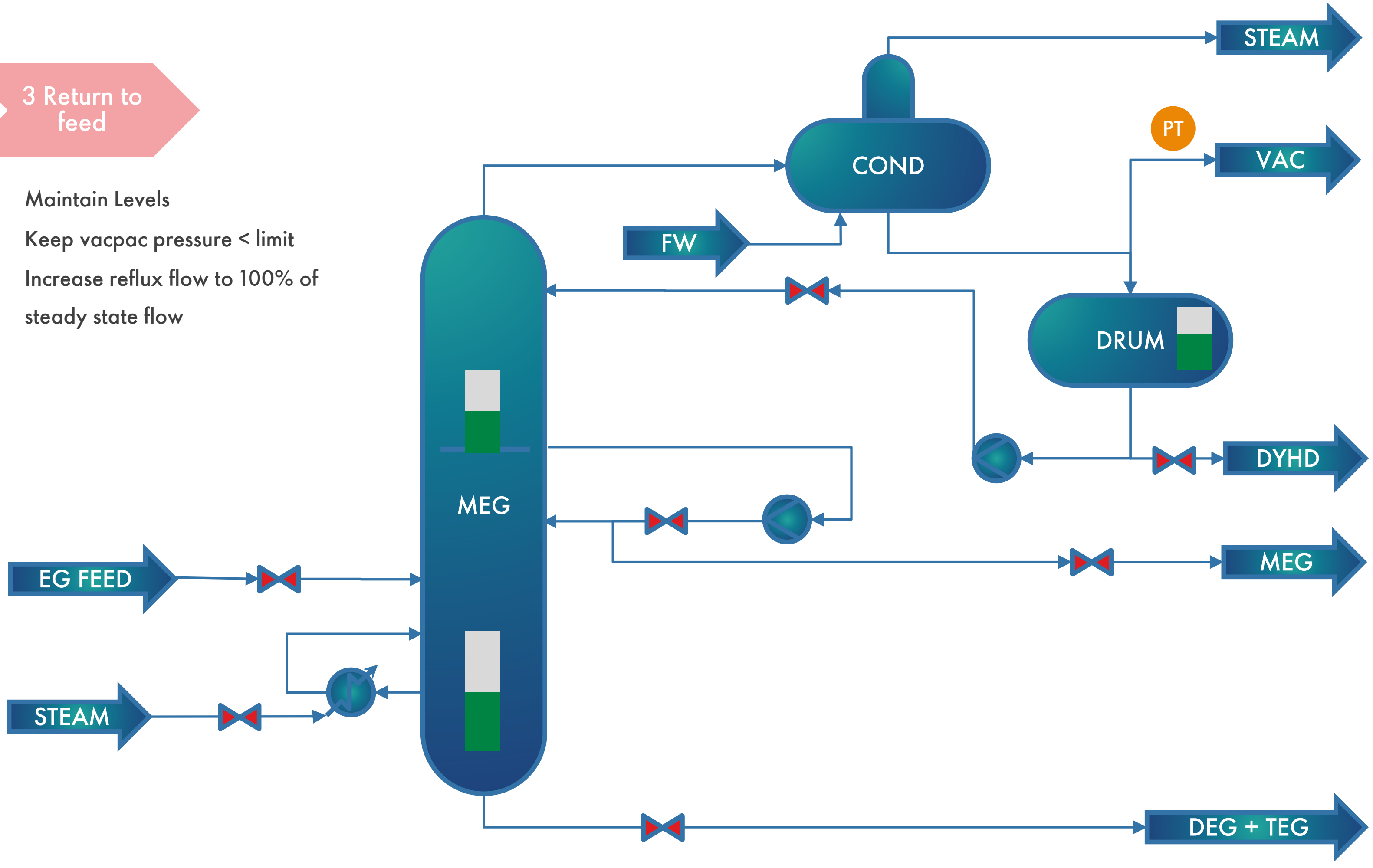
3 Return to feed

Maintain Levels

Keep vacpac pressure < limit

Increase reflux flow to 100% of steady state flow

Objective is to manage hibernation of the column in total reflux state. This means we want to manage the heat input to the reboilers and reflux rates to stabilise and hibernate the column and then restart the column once feed is available to be reintroduced.



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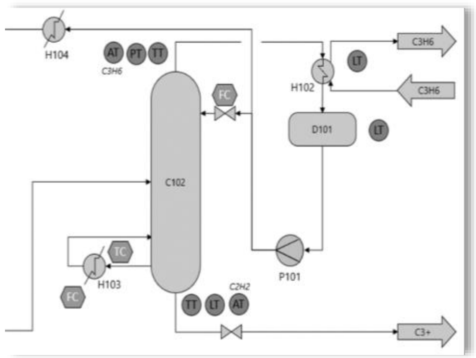
Solution

Reinforcement Learning for Autonomous Operation

Reinforcement Learning for Autonomous Operations



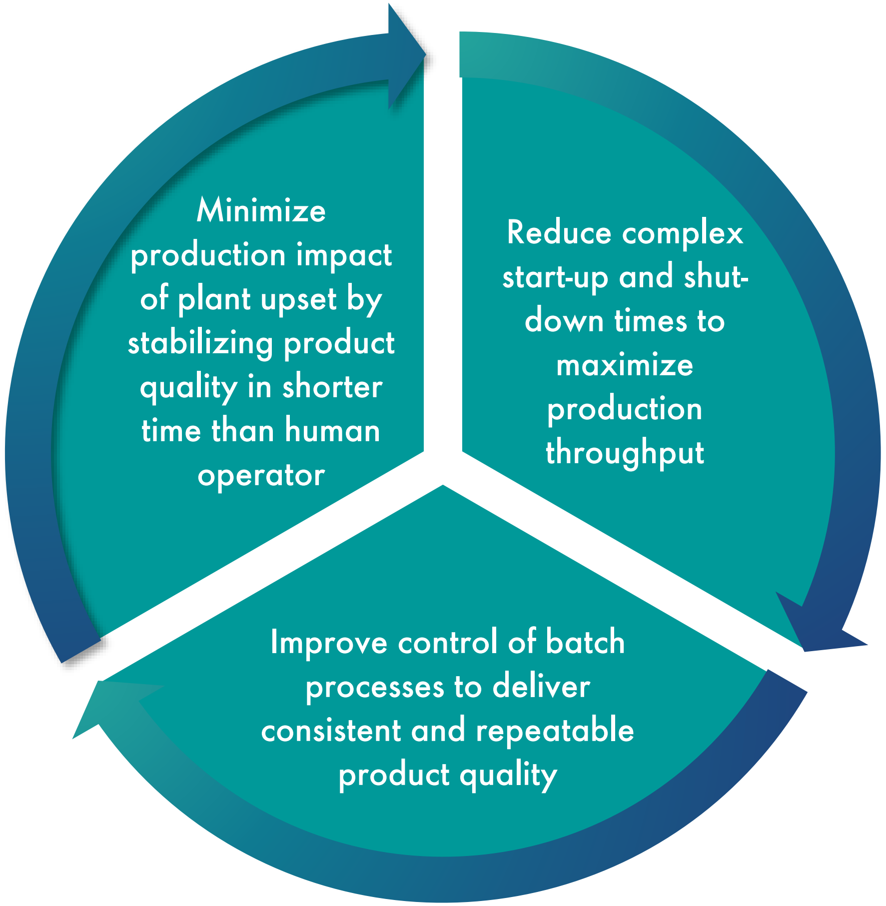
AVEVA™ Dynamic Simulation

+

Reinforcement Learning Toolchain

=

Trained DRL Algorithm: the 'Brain'



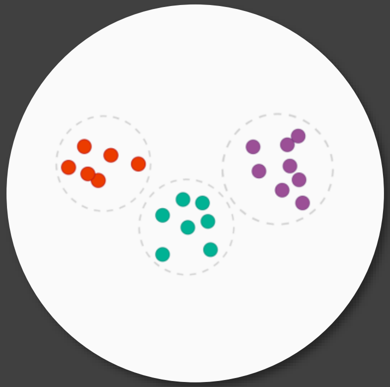
Autonomous Operations for Process Plant

Reinforcement Learning for Autonomous Operations

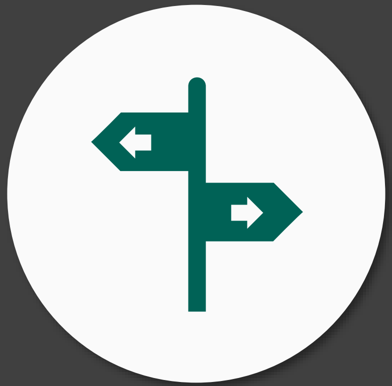
Is this A or B?

How much
– or –
How many?

Is this weird?



How is this organized?

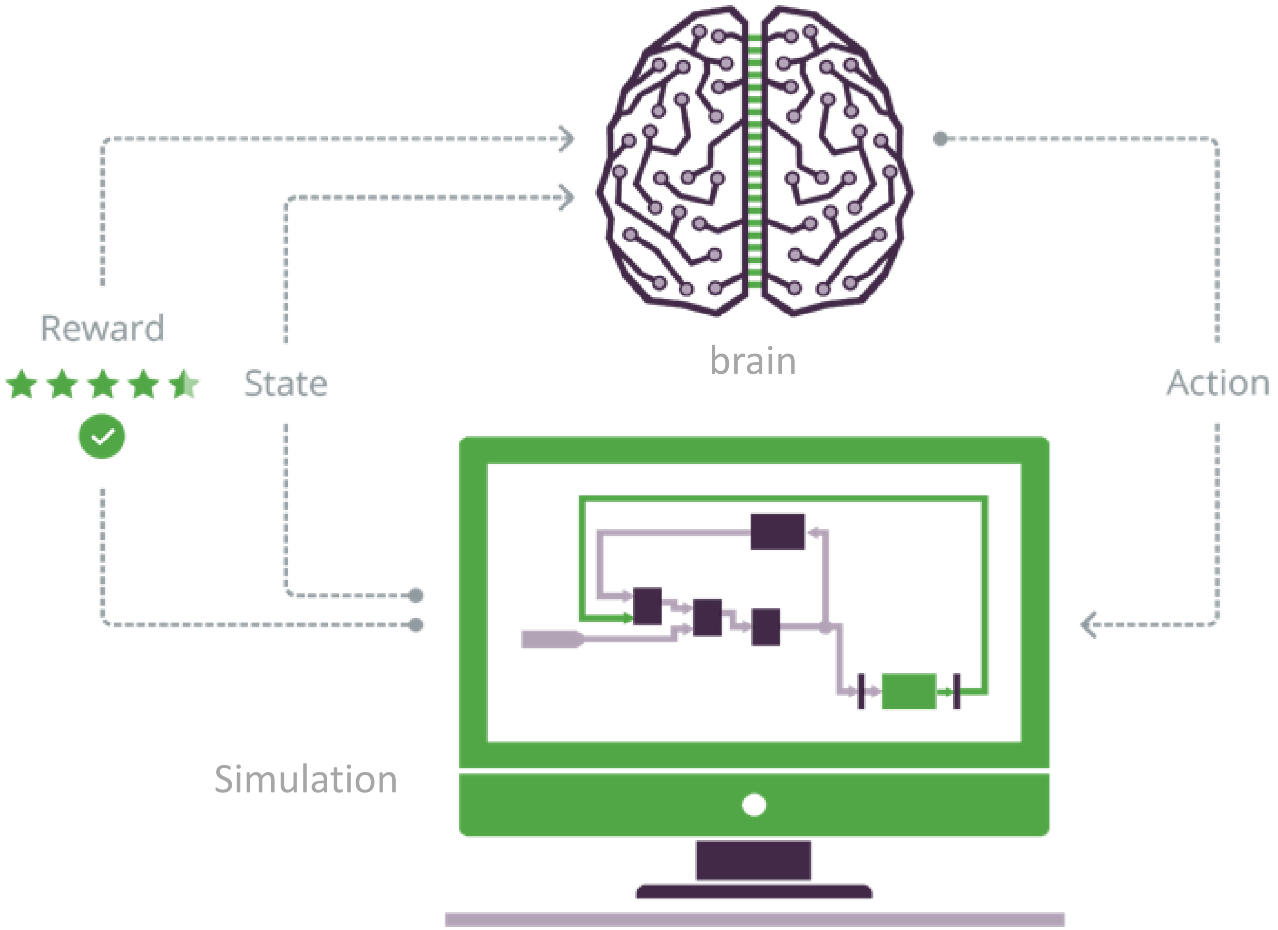


Supervised Learning

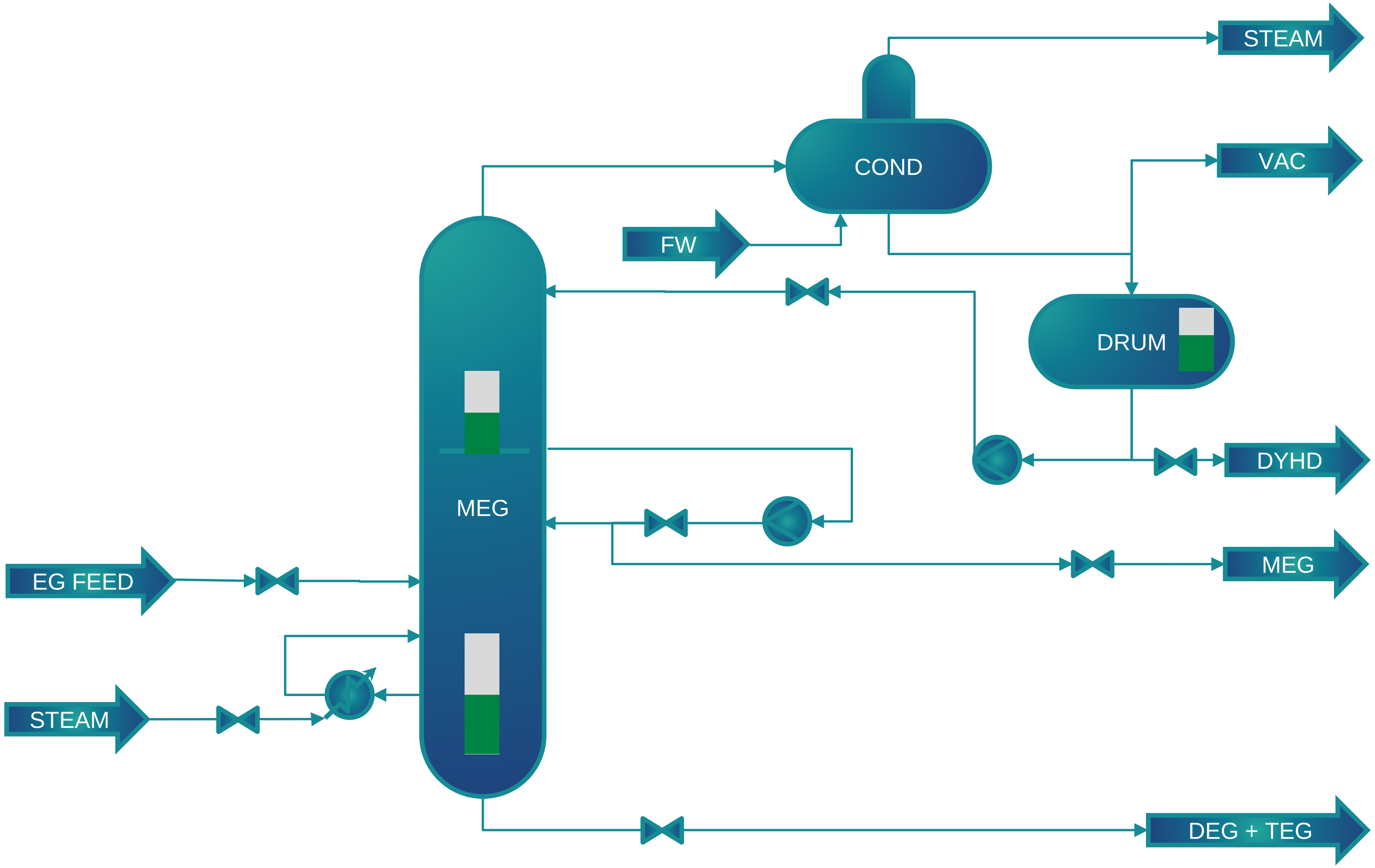
Unsupervised Learning

Reinforcement Learning

Reinforcement Learning for Autonomous Operations



DRL Problem Formulation: States and Actions



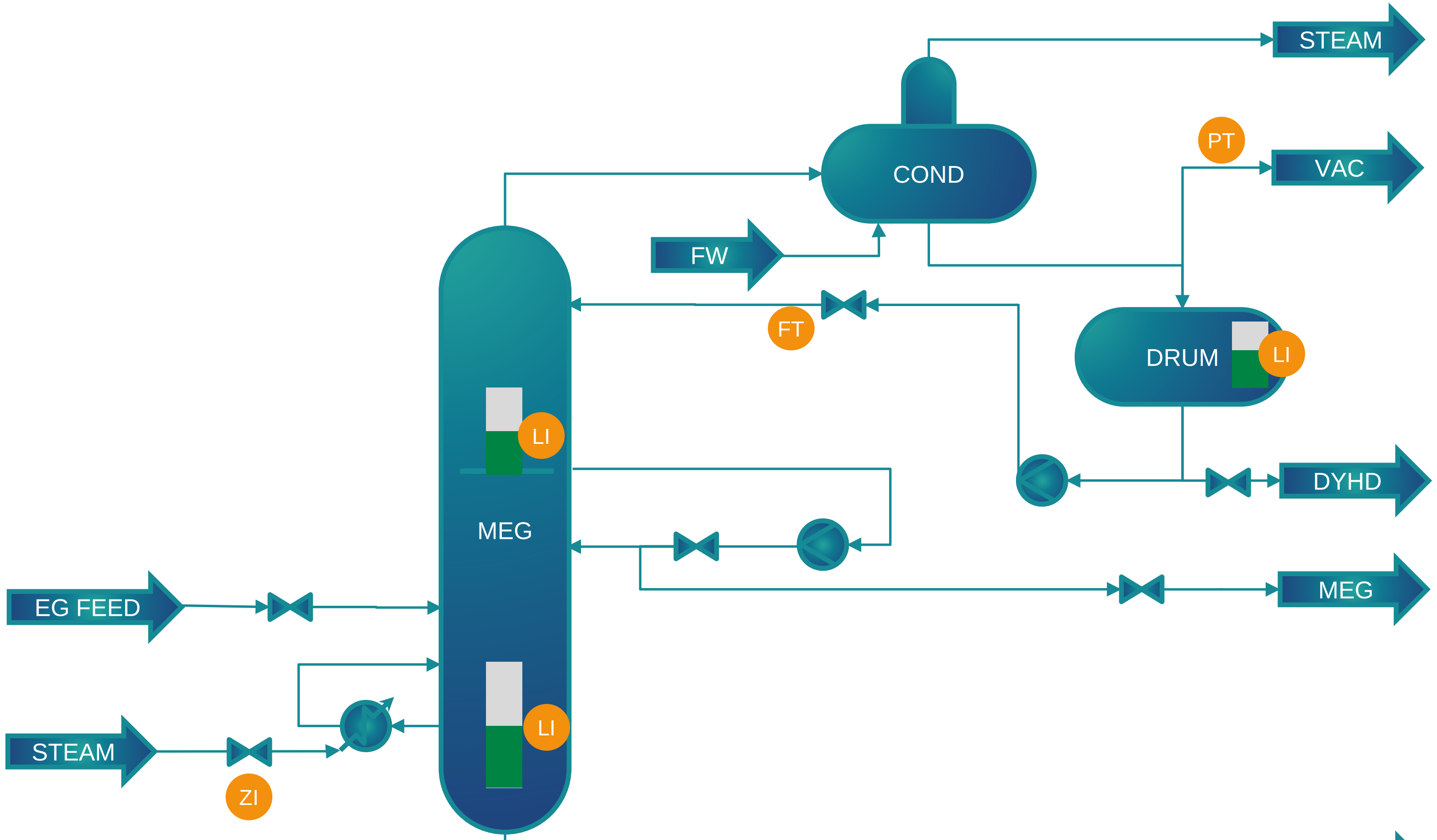
State Space

- LI LT-BOTTOM
- LI LT-DRAWOFF
- LI LT-REFLUX-TANK
- PT PT-VACPAC
- ZI ZT-STEAMVALVE
- FT FT-REFLUX
- FT FT-DRAWOFFRETURN
- FT FT-FEEDFLOW
- PT PT-STEAM

Action Space

- ZC ΔZ-STEAMVALVE
- FC ΔF-REFLUX
- FC ΔF-DRAWOFF

DRL Problem Formulation: Goals



LEVELS:

DRIVE : TARGET

RANGE 40-60%

AVOID : 0%

AVOID : 100%

VACPAC PRESSURE:

AVOID : >35kPaa

REFLUX RATE:

DRIVE :

60% of SS Hibernating

DRIVE :

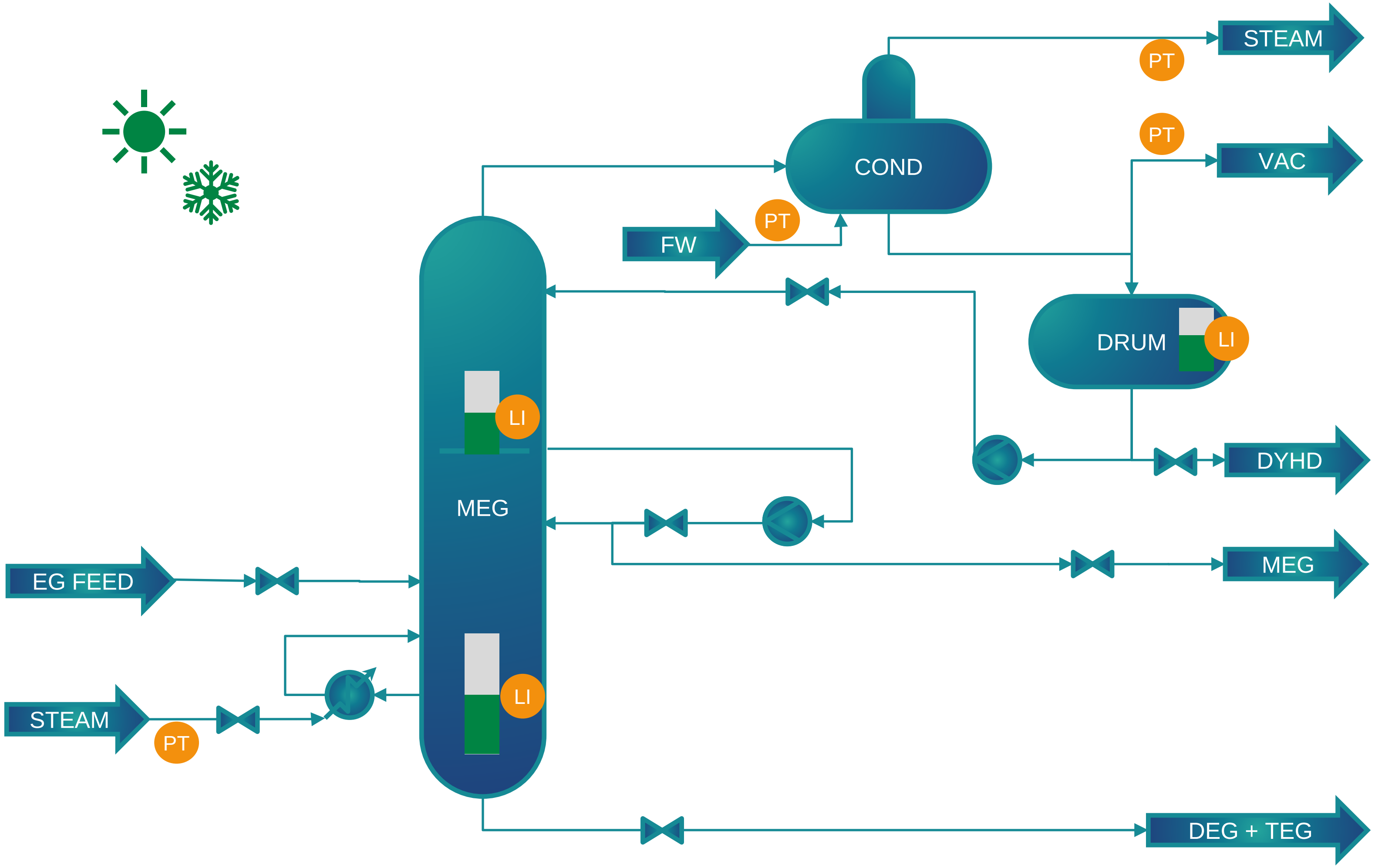
100% of SS Restart

STEAM VALVE:

DRIVE : > 3% open

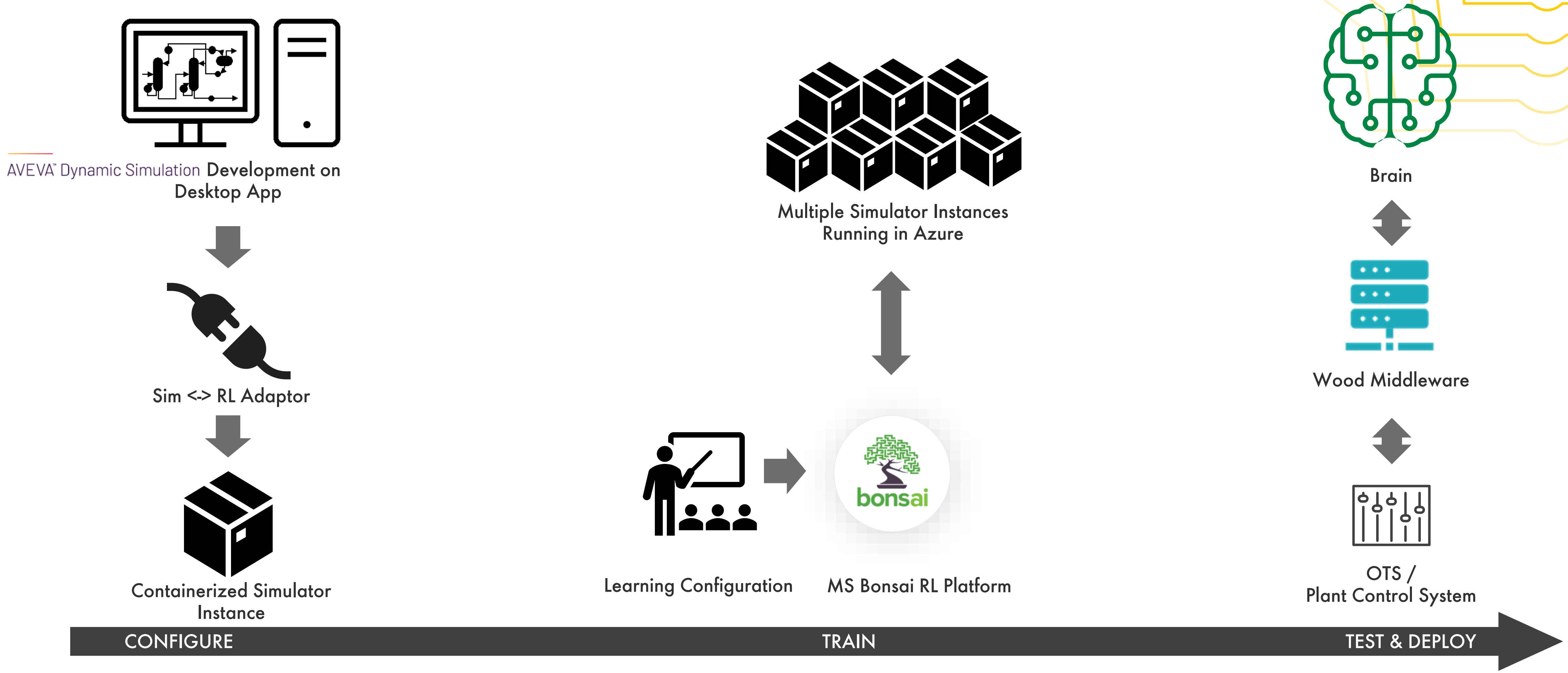
MINIMIZE : <0.5% / minute

DRL Problem Formulation: Lessons



- Inventory: different starting levels for column and reflux tank
- Boiler feedwater disturbance
- Steam systems disturbance
- VAC Pac disturbance
- Ambient conditions
- Feed introduction

DRL Training

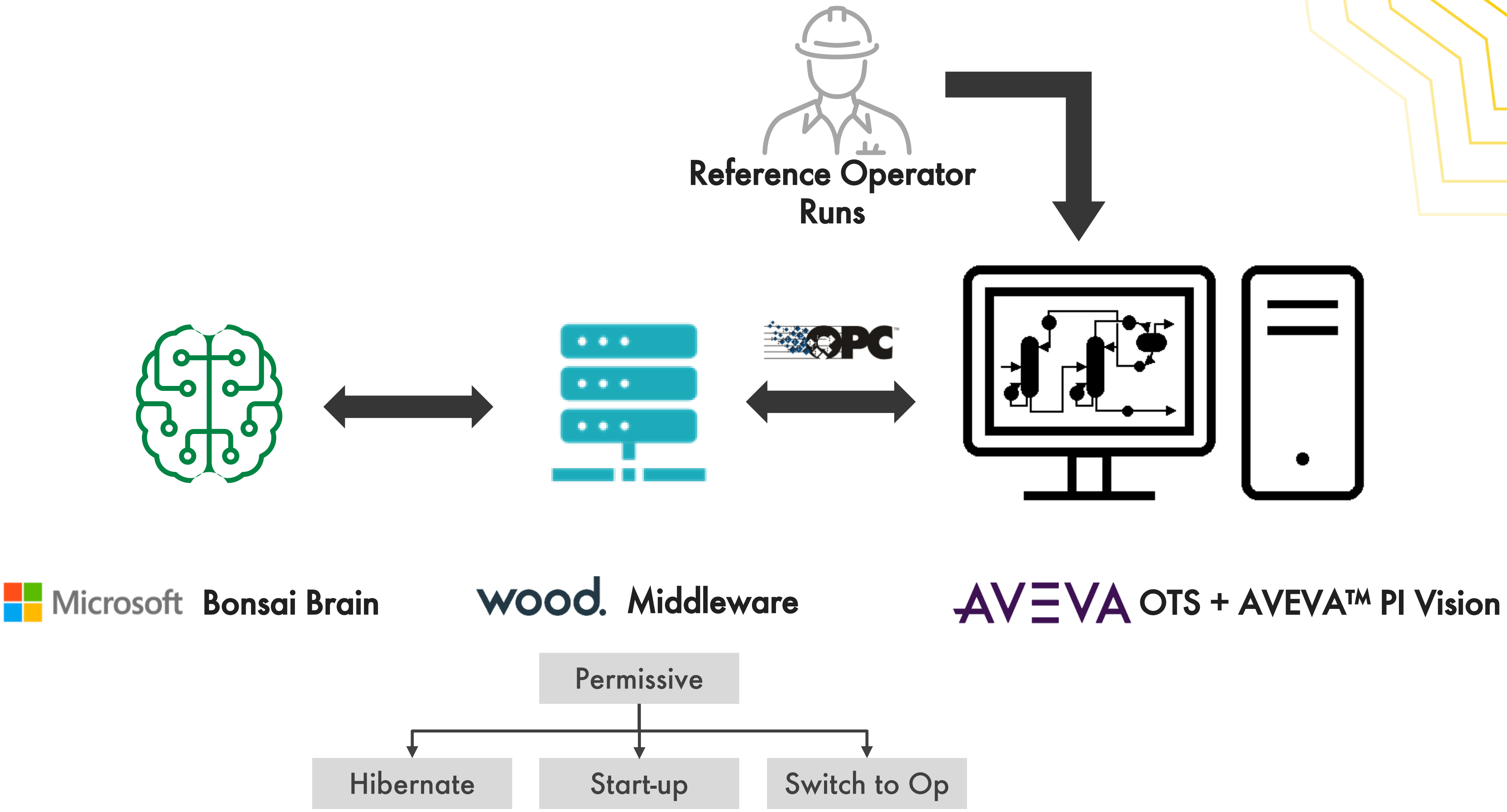


4

Result

AI's Performance vs. Baseline Data Testing using OTS Lite

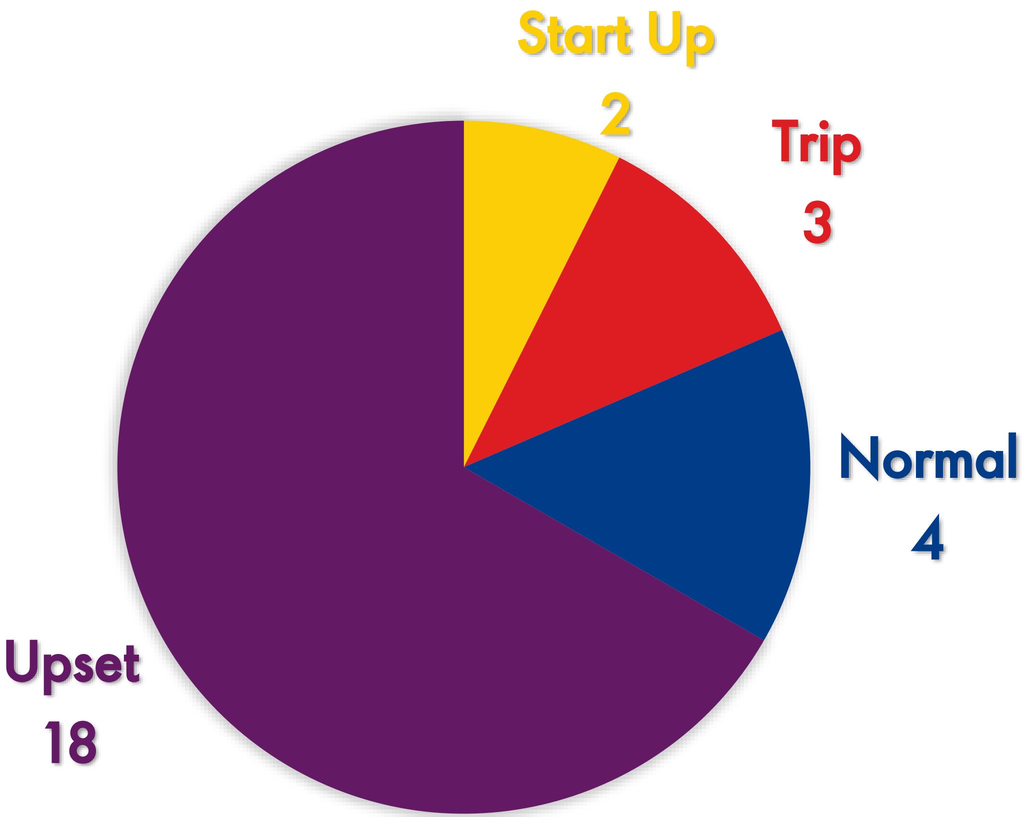
OTS Lite Testing Architecture



Brain Evaluation Testing

Total of 27 Cases Evaluated

- Cold Front
- Steam Supply to Reboiler Dip
- Cooling Water Pump Swap Over
- Cooling Water De-Icing
- Warm Front
- Water leak into Column Feed
- Loss of inventory from Overhead Drum
- Loss of inventory from Draw-Off tray
- Loss of Inventory from Bottom level
- Dip in Overhead Condenser Pressure
- Air leak into Vacuum Column
- Trouble in the Vacuum system

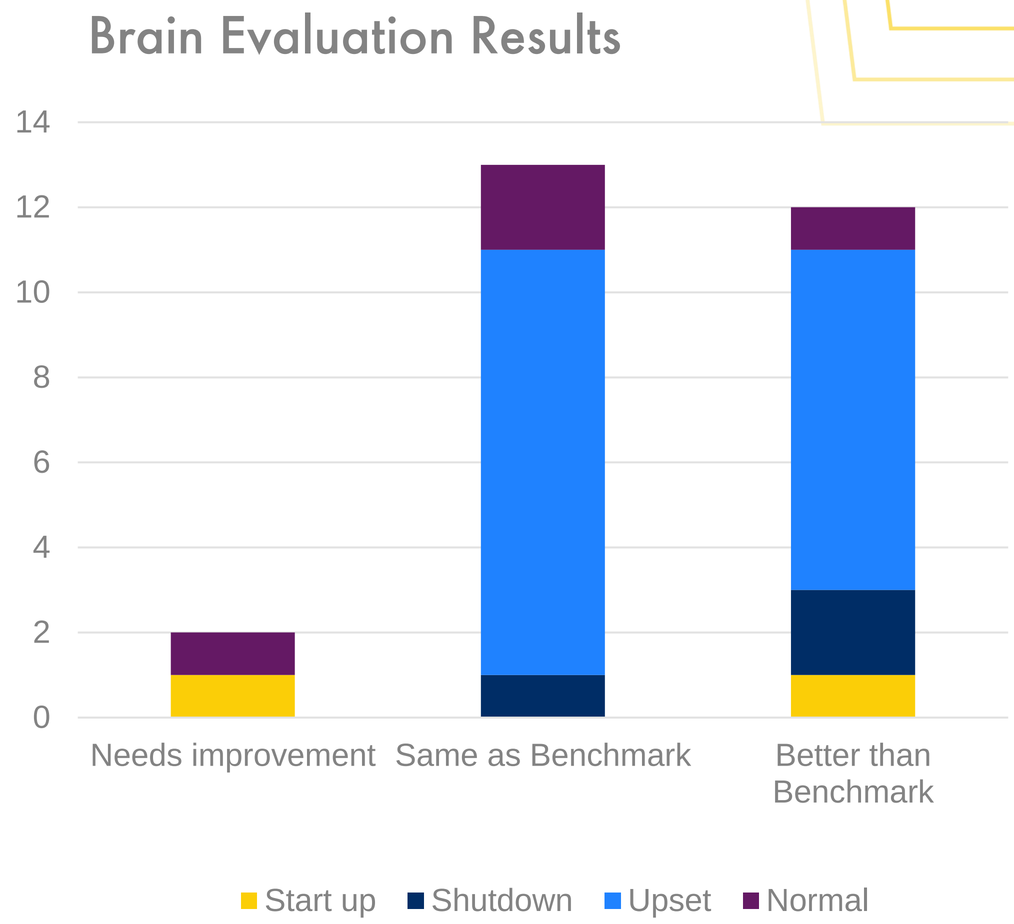


- Initial Fill from tankage after turnaround
- Run for an extended time period
- Transition from Hibernate to Ready for Feed
- Transition from ready for feed to Hibernate Mode

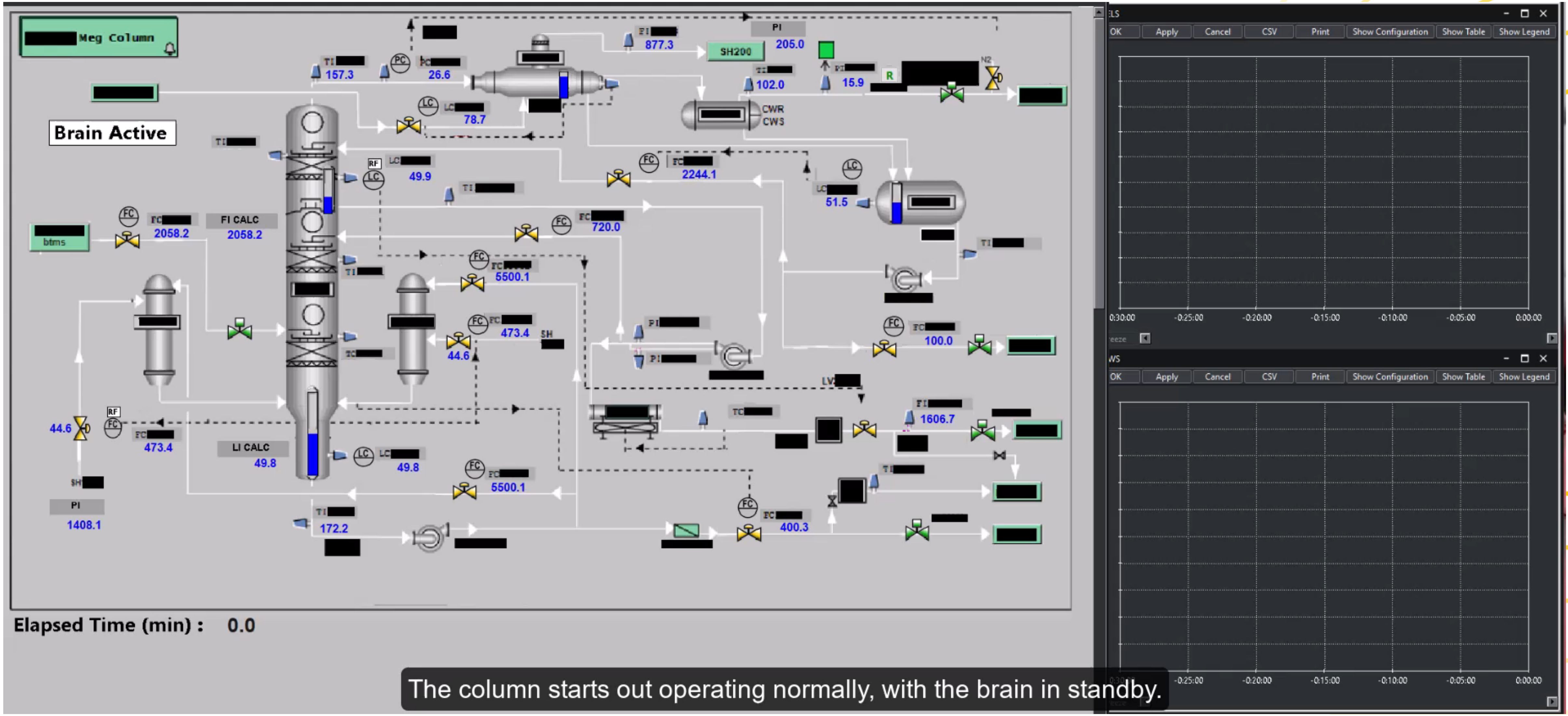
Brain vs Benchmarks Results

For each of the tests the brain evaluated based on the following criteria:

- ✓ Operator Benchmark – Created on the full Operator Training Simulator at site
- ✓ Historian Data from the plant
- ✓ Operator Experience



Shutdown Case – Video



5

Conclusions

What it means for us?

SME Feedback

I did some of the final testing and was very impressed with the response it had to major upsets. In areas that it did well, it performed way better than expected. Throwing very dramatic upsets at it and came out in good shape holding all the levels it was supposed to.

To be able to cut feed into and out of a column with no other intervention was definitely not something I felt was possible by automation. With the right people building and testing, it will be a big asset and common tool someday.

- Experienced Plant Operator for 14 years

SME Feedback

I was involved in the project from the start, and I had my doubts as to how well the "AI brain" would do. The strategy we employed to get the brain to react to every conceivable upset condition from loss of air pressure to upset steam conditions, etc. was crucial for the brain training, which by the way took weeks on each upset scenario.

As it turned out, it was time well spent. When we finally had all the training completed and when we put the brain through the tasks of loss of feed flow to the column, plant trips, etc., it performed well proving that the AI application will work for process distillation columns and other process plant equipment. Just like the APCs before it, AI control will further enhance process operations performance and efficiency.

- MEG Plant Operations SME

CHEMICAL MANUFACTURING | SHELL SCOTFORD CANADA

Shell Scotford Successfully Completes First Steps in Achieving Autonomous Operations

Challenge

- Conventional control methods including PID and APC (Advanced Process Controls) are very useful for maintaining and optimizing steady-state operations. They, however, lack the ability to respond quickly to sudden disturbances or unpredictable situations such as trips and big process upsets leaving operations exposed to process safety risks and margin losses.

Solution

- Developed AI Agent using Deep Reinforcement Learning which was trained to handle multiple transient scenarios using Aveva's Dynamic Simulation of the plant.

Results

- **Trained AI agents were able to manage the controls and bring the plant into a stable condition. This translates to fewer alarms (safer operation), shorter stabilization period (higher uptime/margin), and more energy-efficient operation (~59% lesser steam consumption translating to reduced CO2 footprint).**[1]

[1] Compared to baseline data from 1) actual performance of SMEs and 2) historical process trends.

AVEVA

Key Contributors

AVEVA	Shell	Wood	Microsoft
David Smith	Donald Dalawampu	Jayanth Nair	Jazmia Henry
Celine Thomerson	Gord Grof	Sanmitra Tembe	
Moresh Wankhede	Kim Doucette	Danny Golczynski	
Doug Mills	Peter von Hauff		
	Jasper Stolte		
	Scott McKinny		
	Dean Onushko		

Q&A

Shell Scotford Successfully Completes First Steps in Achieving Autonomous Operations

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