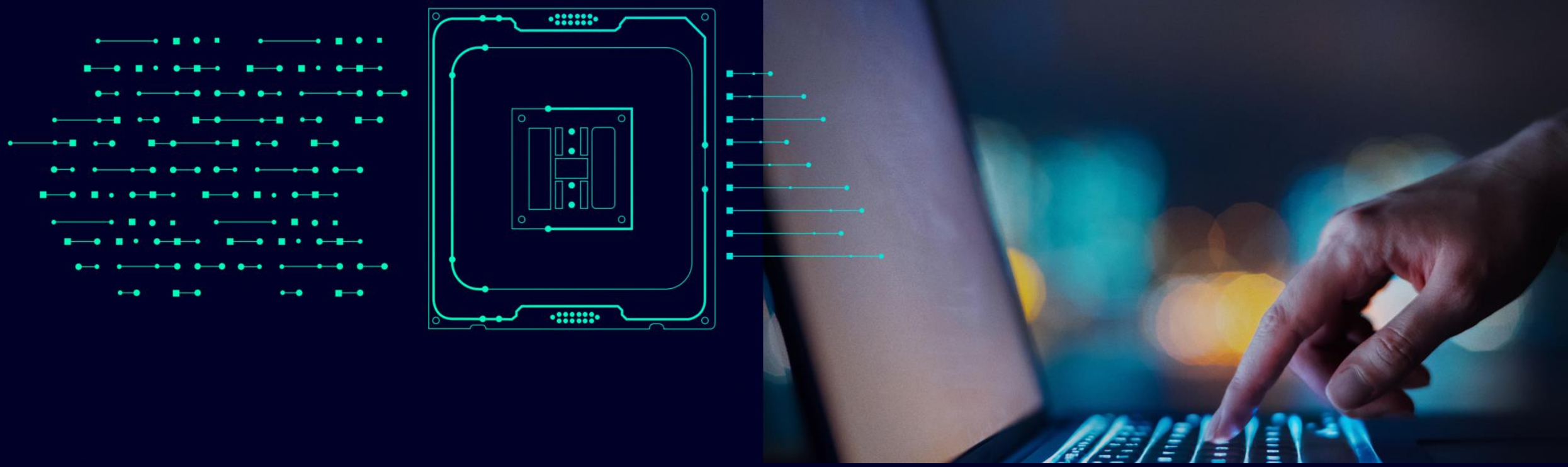


Capitalizing on new economic opportunities through flexible operation using Advanced Process Control

SIEMENS

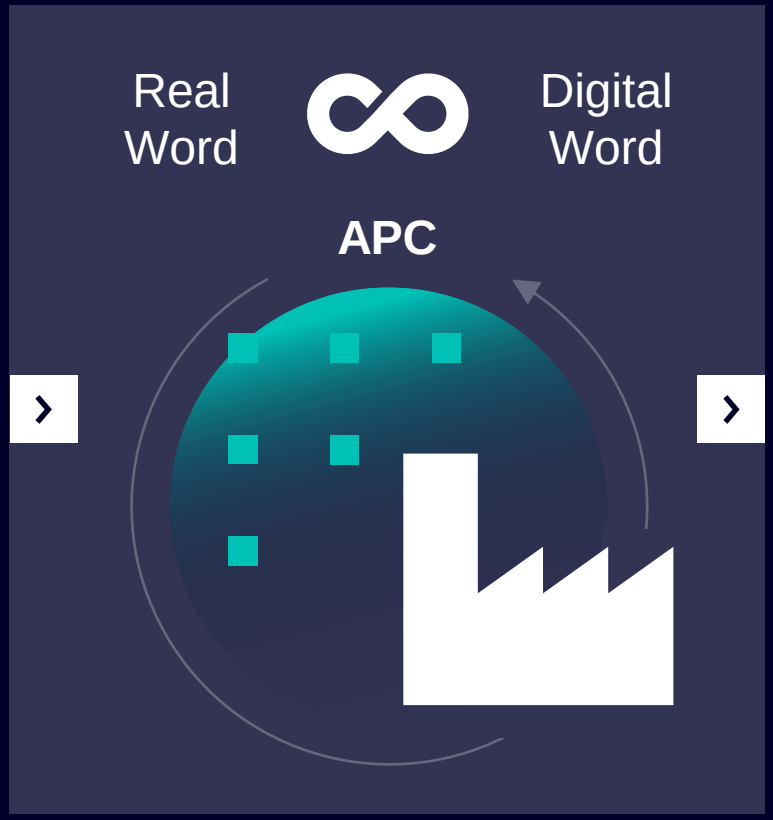
Advanced Process Control

Techniques used in APC

Data Analytics & AI
Use (Gen) AI & data in operation, data-driven production

Modeling & Domain Know-How
Monetize digital twins & domain know-how

Autonomous operation, control & optimization
Use algorithms to operate & optimize



Benefits & KPIs

- Increase throughput
- Increase yield
- Decrease resource consumption
- Autonomous operation
- Decrease disturbances
- Optimal transitions

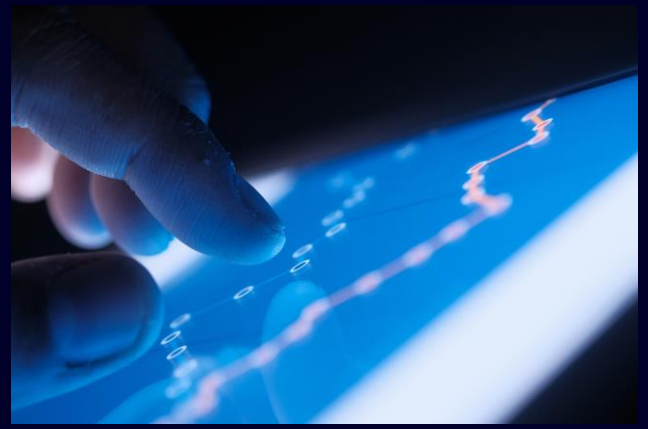
- Typical process operation improvements: **5 – 10 %**
- Typical ROI **< 1 year**

APC = Process control & optimization of operation

Advanced Process Control – Market Trends

1. Market Opportunity

- $3.5B market (CAGR >11%)
- Strong growth across all regions



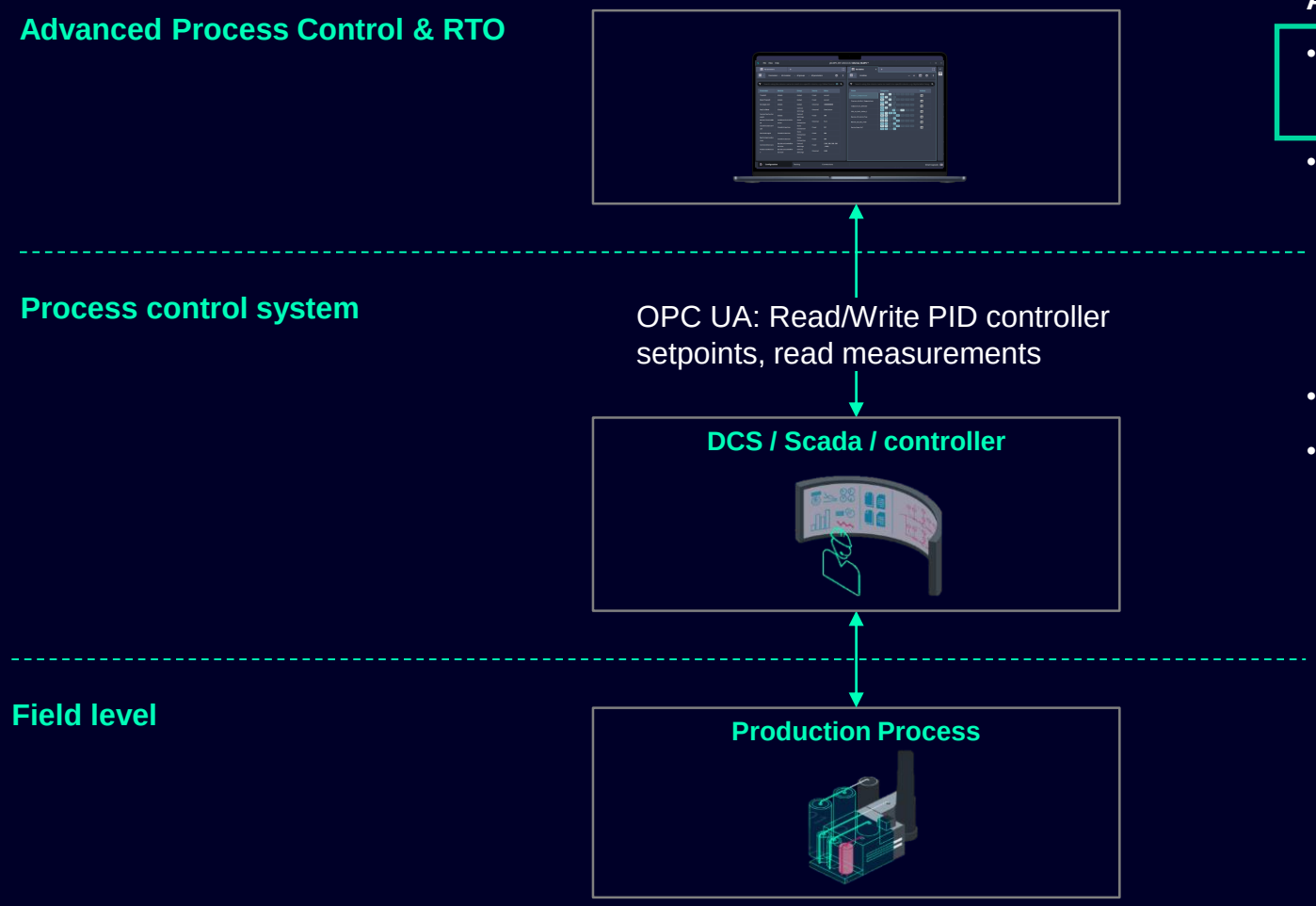
2. Drivers for growth

- Rising and dynamic energy prices
- Stricter sustainability targets
- Technology innovation facilitating use of APC

3. Skills Gap & Workforce Transformation

- Talent shortages create urgent APC demand
- Shift to remote operation
- Update of legacy and proprietary tools, silo data, limited services of existing tools

Typical deployment architecture for APC

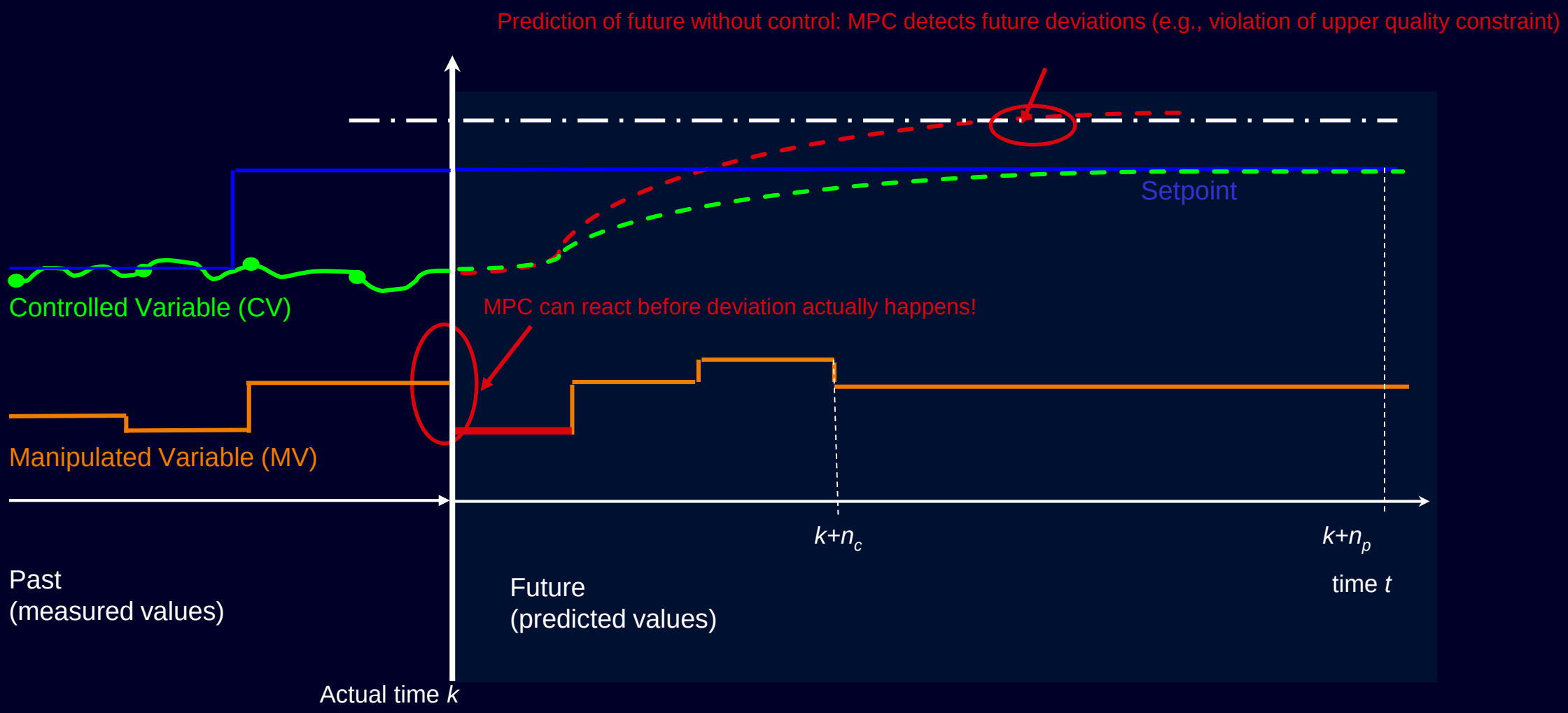


APC: Optimization + control

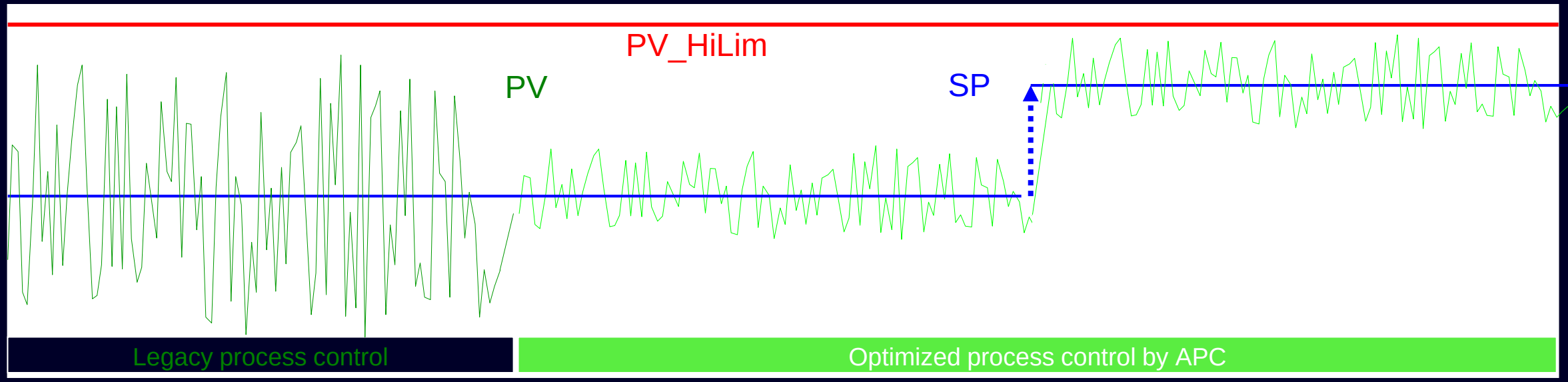
- **MPC**: Keeps the process under control at the specified operating point pushing toward economic constraints
- **RTO:** Specifies the optimal operating point

- **Control system**: base layer control (PID controllers)
- Communication to APC via **OPC**

MPC: Model Predictive Control
Fundamental principle



Exploit the Full Plant Potential by Advanced Process Control



1. Step: improve feedback control
   - Reduced fluctuations (variance)
   - Reduced losses related to fluctuations, e.g. energy consumption
2. Step: smaller variance allows to drive setpoints (↑) closer to critical tolerances, without the risk to hurt them
   - Further, significant cost/energy savings!

New opportunities in the APC market

Historically, operating companies have been incentivized to maintain stable operation…

- Energy suppliers valued predictable energy use
- Stable supply chains

How do I ensure my process remains stable at the optimal point when it is complex to operate and faces frequent disturbances?

Now, operating companies are being incentivized, and perhaps will be required, to be more flexible

- Energy suppliers value on-demand flexibility in energy use to ease integration of renewables
- Uncertainty in supply chains means flexibility leads to higher profits

How can I make my process more flexible, such that I can freely increase/decrease production safely to leverage new economic opportunities?

Selected reference
Creating additional value by participating in electricity market

Challenge of large gas producer

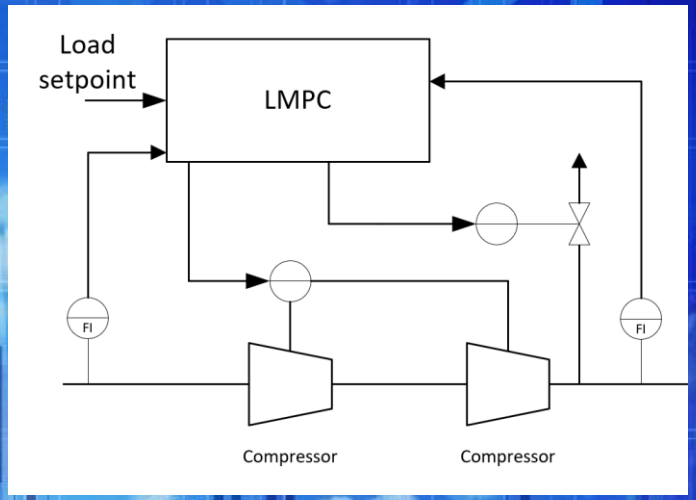
- Dynamically adjusting electricity consumption brings in new revenue
- Changes in electricity consumption disturb process operations
- Flexible operation of compressor trains

Solution: Model predictive controller to maximize benefit without disturbance

- Data acquisition & model identification
- Controller tuning and testing
- Automatic process optimization
- Model predictive controller run 24/7 controlling and optimization the process
- Dashboard for
  - ✓ Monitoring performance
  - ✓ Adjusting process settings

Benefits

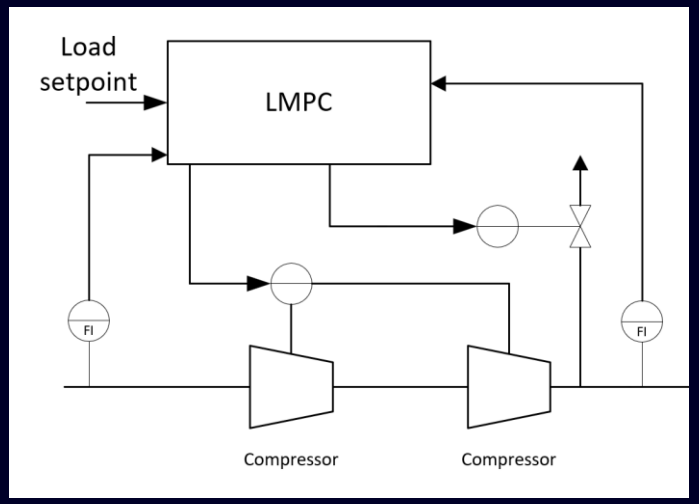
- Reduced OPEX (ROI: 4 month)
- Improved control for existing compressor system
- Model available in engineering environment to test “what-if” scenarios



The control problem

Electrical grid requests energy consumption, load set-point is set accordingly

Ambient air temperature can vary



Blow-off valve (BOV) can be adjusted

Process requires gas, flow set-point is set-accordingly

Downstream pressure can vary

Compressor inlet guide vane (IGV) can be adjusted

Controlled Variables

Manipulated Variables

Disturbance Variables

Why MPC is the right technology?

Very strong relationship between the MVs and CVs

- → Change in IGV affects both power consumption and gas flow
- → Change in BOV affects both power consumption and gas flow

PID control, by definition, requires the CV to be disturbed off their SP before it can act – but in this case, the PIDs would disturb each other

- → This leads to longer settling times, which may be acceptable for occasional disturbances or gradual ones, but not when disturbances are frequent and can be significant

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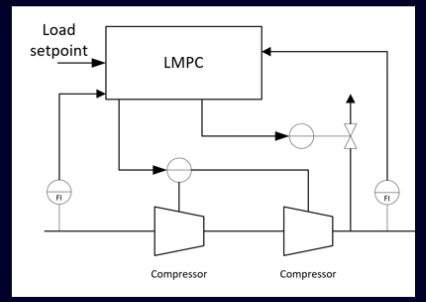
Ambient air temperature can vary



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How do I ensure my process remains stable at the optimal point when it is complex to operate and faces frequent disturbances?

APC has been the go-to technology for this for decades

Now, operating companies are being incentivized, and perhaps will be required, to be more flexible

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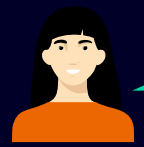
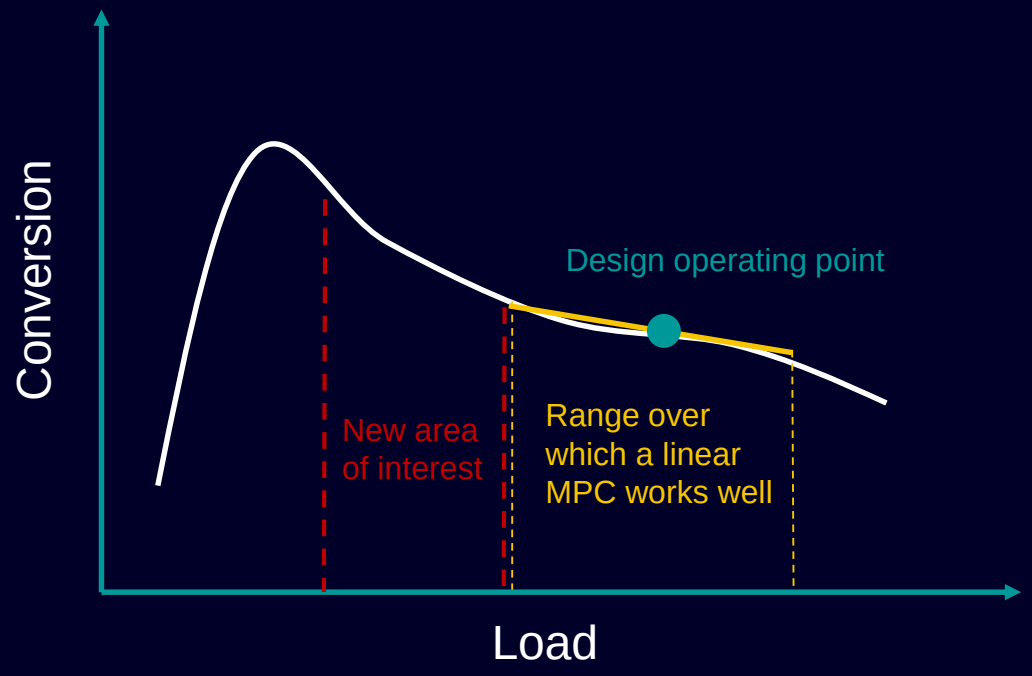
- Uncertainty in supply chains means flexibility leads to higher profits



How can I make my process more flexible, such that I can freely increase/decrease production safely to leverage new economic opportunities?

APC can deliver significant value, but there are limitations…

The paradigm shift in the future of APC

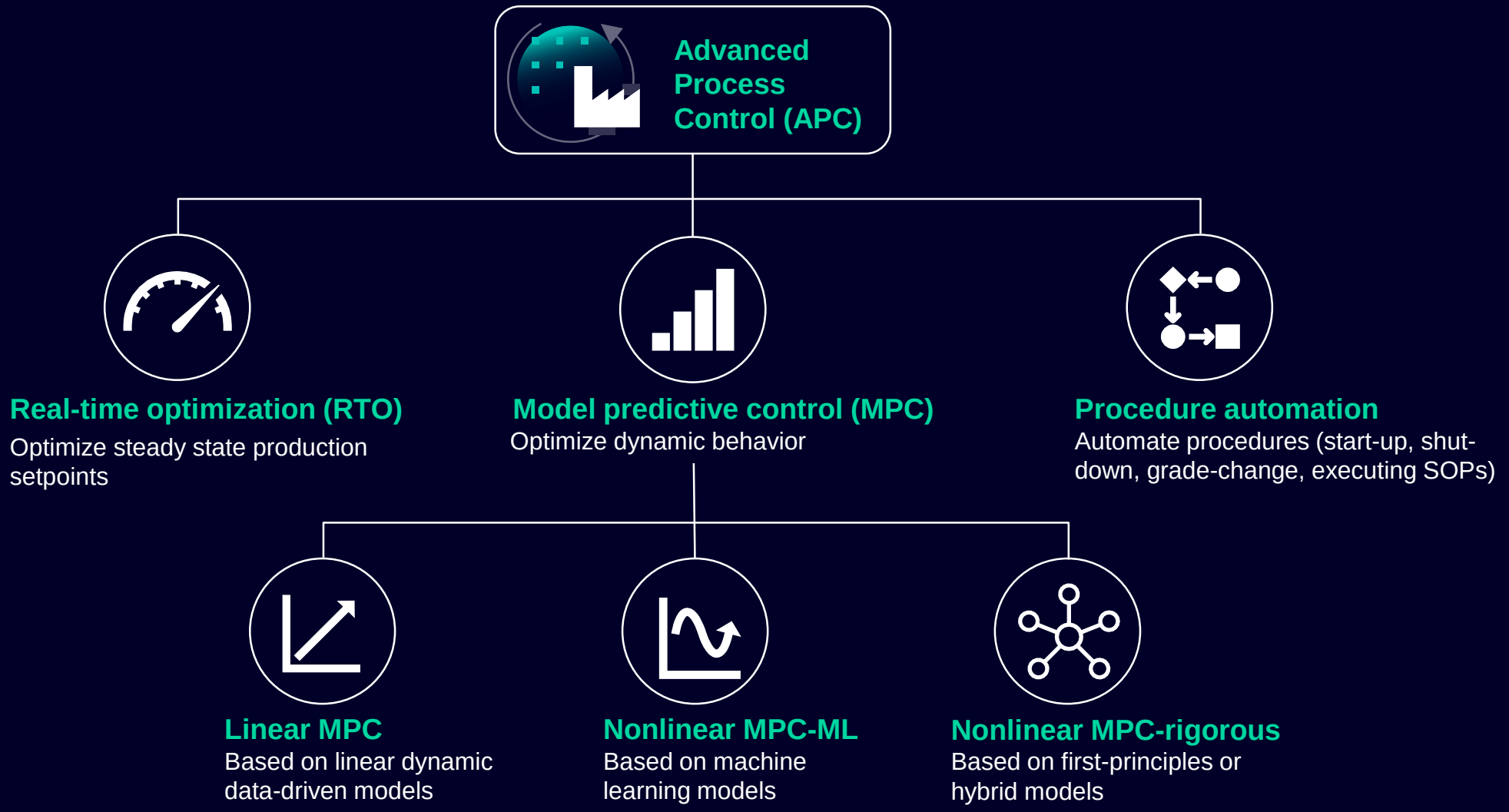


Traditionally, the objective was to stay near "the operating point", so for many applications a linear MPC solves the problem
→ **Keep the plant at this state**

But when flexibility can be monetized, being able to control and optimize beyond this range becomes valuable
→ **Move the plant to the best state continuously**

New equipment designs can significantly improve flexibility, but they require CAPEX investment
APC projects require no CAPEX investment and can still deliver significant value today

Advanced Process Control (APC) – unified approach to APC



SIMATIC Advanced Process Control – A unified suite for APC

https://www.siemens.com/global/en/products/automation/topic-areas/advanced-process-control.html

Planning & Scheduling

✓ Optimization up to fleet level

Site-wide optimization

✓ Real-time optimization
✓ Monitoring (soft-sensor, anomaly detection)

Adaptive control and procedural operation

✓ Linear MPC
❖ Nonlinear MPC (machine learning)
✓ Nonlinear MPC (physics based)
✓ Dynamic real-time optimization
❖ Procedure Automation

Process control systems and base layer control

- Base layer control
- PID controller tuning
- LMPC (embedded)

Field level

Modular & scalable APC suite
Flexible vertical integration
Analysis, development and deployment

Data

Process models

Thank you

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