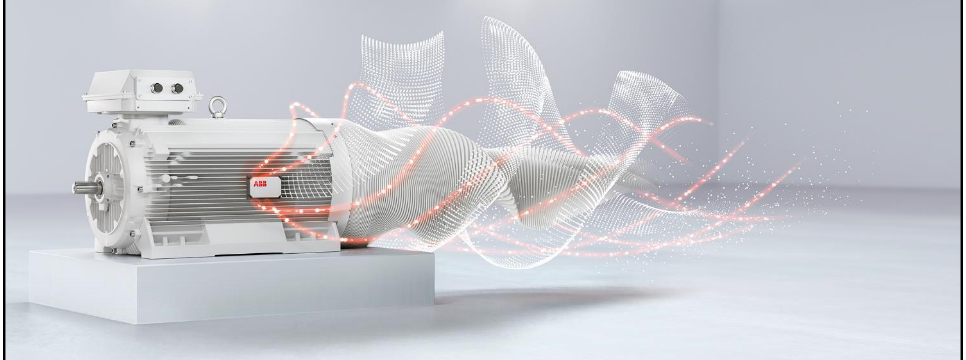


LUCCA, ITALY, 2017-06-12

Future Challenges for Cyber-Physical Systems – An Industrial Perspective

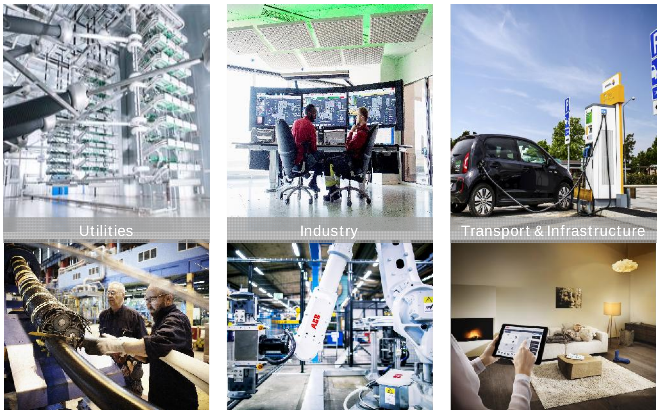
Alf Isaksson, ABB Corporate Research, Västerås, Sweden

Outline

- Facts about ABB
- Future Automation
- MPC still the workhorse?
- Integration of power and automation
- Moving up the value chain
- The modelling complexity
- Future challenges
- Conclusions

This is ABB

"Power and productivity for a better world"



Corporate Research Centers

Close to major customers, universities and ABB's business responsible units

Outline

Facts about ABB

Future Automation

MPC still the workhorse?

Integration of power and automation

Moving up the value chain

The modelling complexity

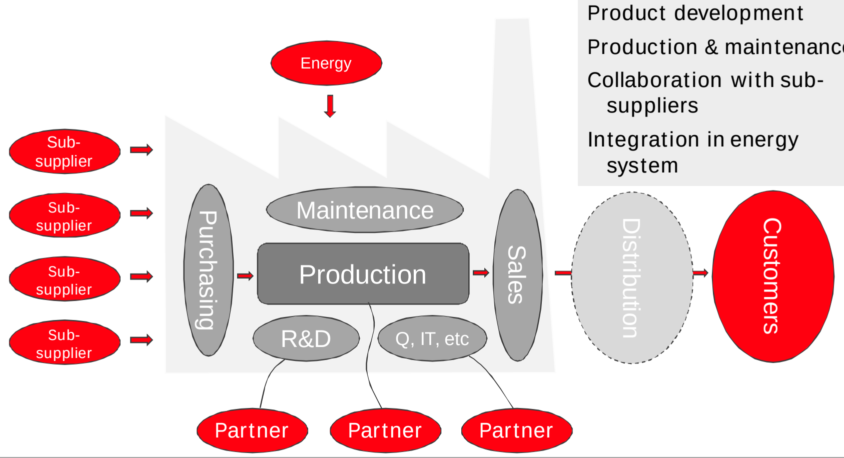
Future challenges

Conclusions

Industrial Digitalization

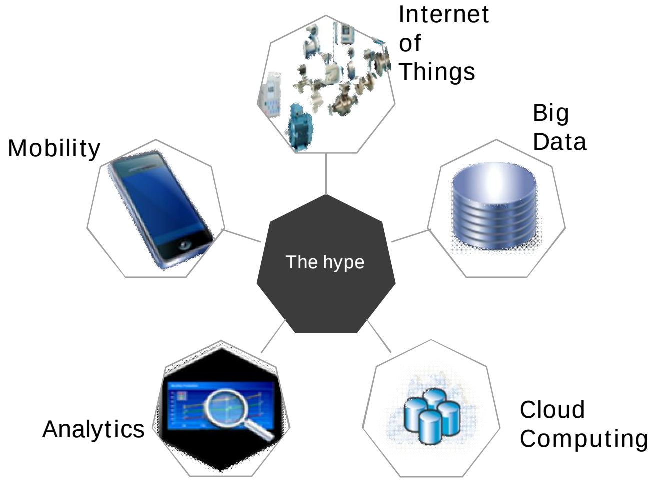
What does that mean?

- Product offering & business models
- Distribution
- Market channels
- Customer contacts
- Product development
- Production & maintenance
- Collaboration with sub-suppliers
- Integration in energy system



Market Trends

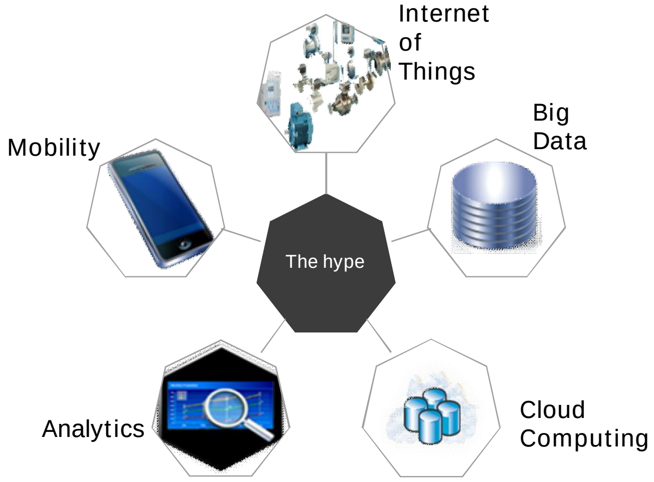
The Five Major Trends that Manufacturers Must Follow



June 15, 2017 | Slide 7

Market Trends

The Five Major Trends that Manufacturers Must Follow



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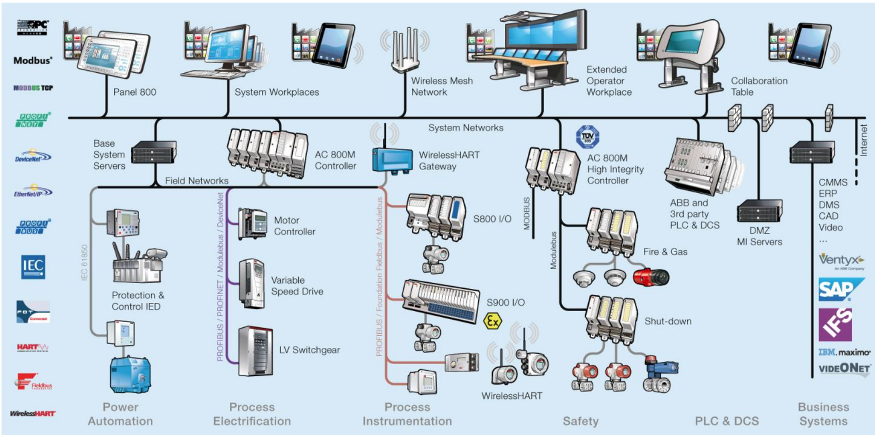
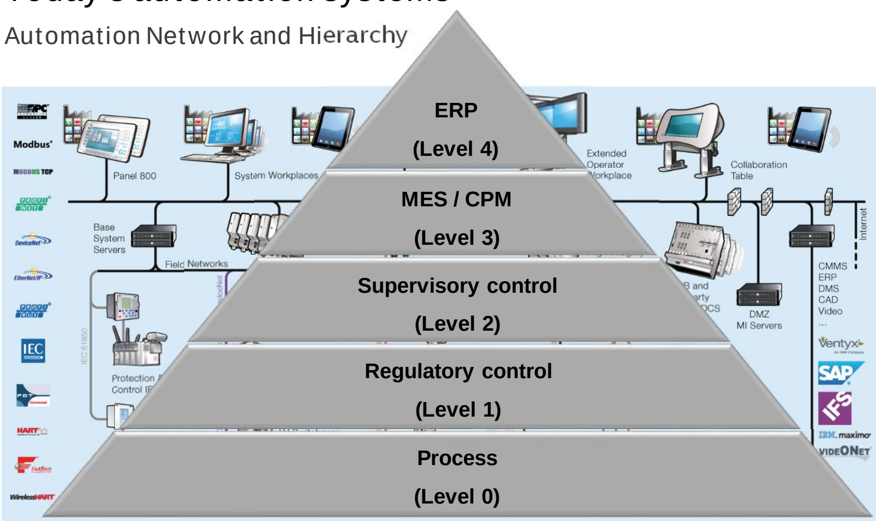
Today’s automation systems

Automation Network and Hierarchy



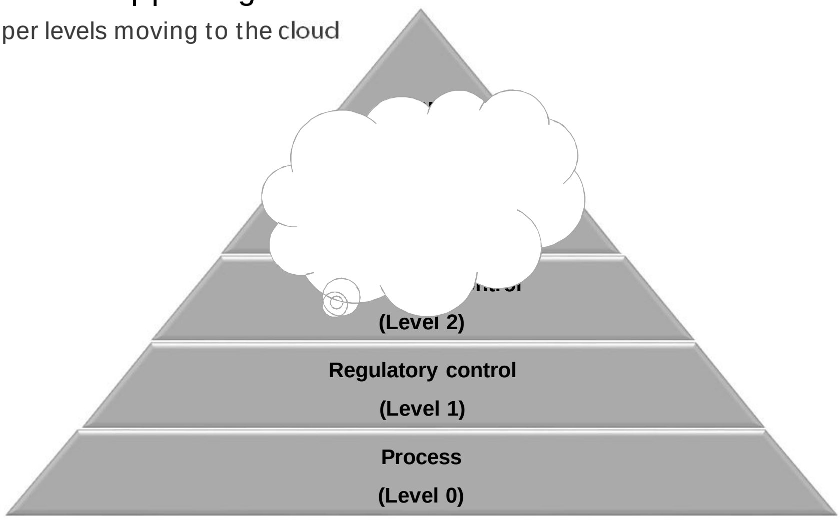
Today’s automation systems

Automation Network and Hierarchy



What is happening next?

Upper levels moving to the cloud



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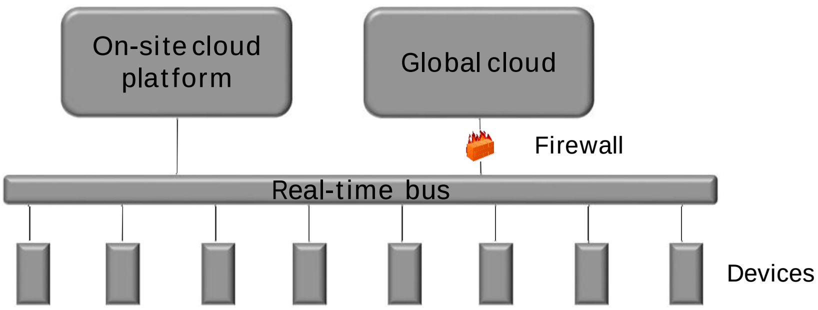
Future automation system architecture

Trade-off between edge and cloud



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OPTIMAX® PowerFit

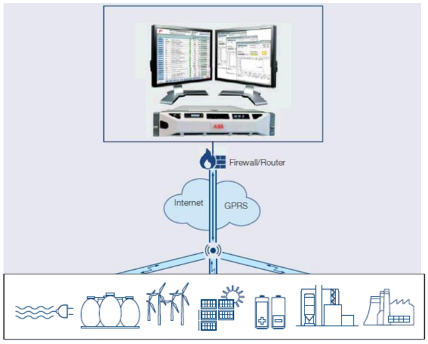
Optimizing control of Virtual Power Pools

Task

- Aggregate many small production units and treat them like one big power plant
- Exploit multiple forms of energy (e.g. el and heat) and storages

Solution

- Build overall plant model (exploiting Modelica multi-physics)
- Formulate optimizing control task as mathematical program
- Online optimization of set points and plant schedules



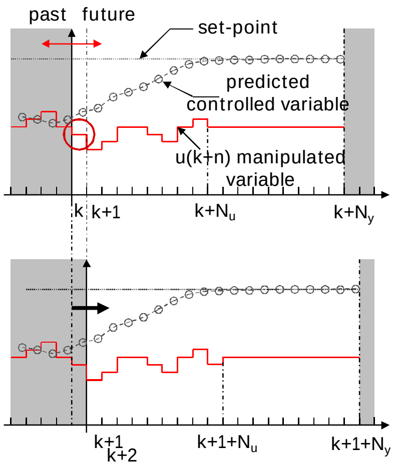
Digitalization enables the interconnection of power generation, consumption, storage and production

Outline

Model Predictive Control

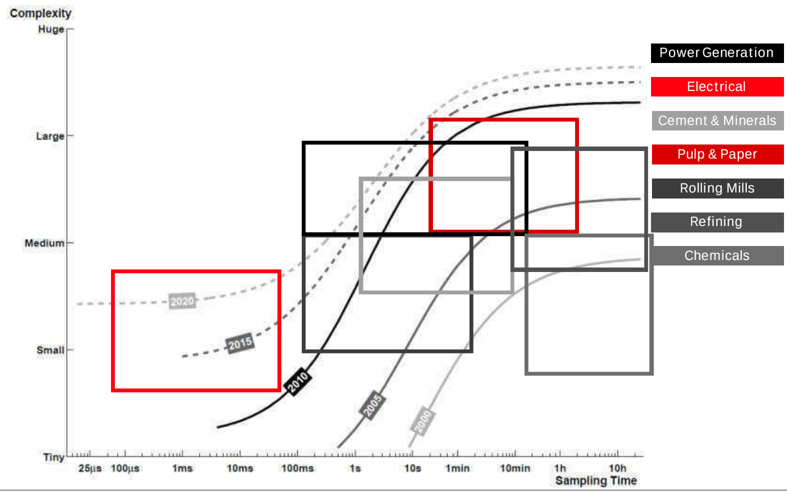
Use model to

- Estimate where you are – state estimation
- Optimize future control signals over a time horizon
- Repeat at next sampling instant
- Shift horizon one step – receding horizon control



Model predictive control: advancing the frontiers

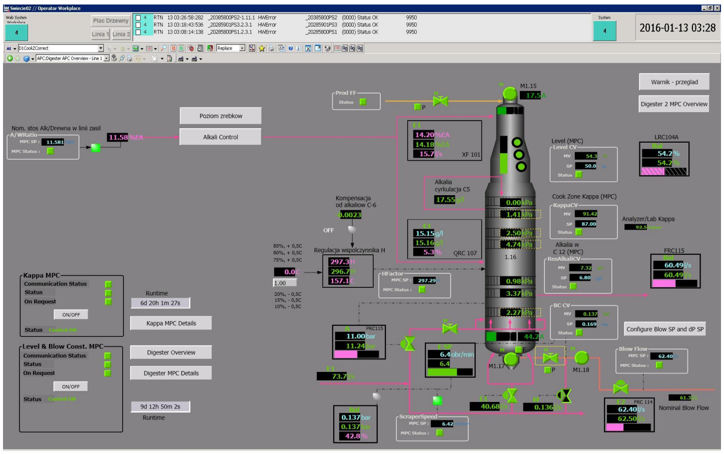
Industry requirements vs available processing power



Case study : Mondi Swiecie, Poland

Digester APC Overview

- Operator overview
- APC display
- Faceplates
- Switch APC and Supervisory mode



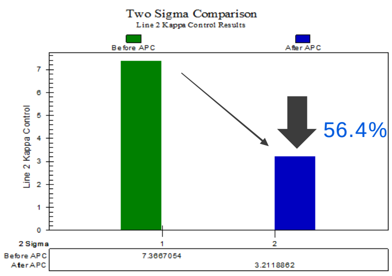
Case study : Mondi Swiecie, Poland

Mid-point Kappa control: Results before & after APC implementation

Performance test run results

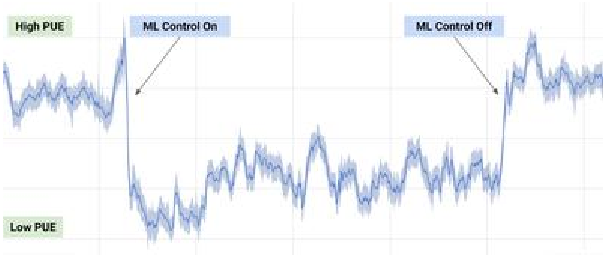
	Blow Kappa			Test Run	
	Average	Upper Lt	Lower Lt	Sigma	% results
Before APC	88.86	89.00	85.00	3.68	36.8%
After APC	87.93	89.00	85.00	1.61	71.4%
Improvements	0.93			2.08	94%
Before APC	**% of data within Limits**				**36.8%**
After APC	**% of Data within Limits**				**71.4%**

Kappa variability reduced by 56.4%



DeepMind AI for Data Center Cooling

Reduces Google Data Centre Cooling Bill by 40%



PUE = Power Usage Effectiveness

 https://deepmind.com/blog,2016-06-20

Outline

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End of Isolated Solutions

Balancing Between Control Systems

Energy availability and pricing (smart grids) — Grid control

Industrial demand-side management

Production Management (P&S, APC, Analytics, …)

Integration of scheduling and control

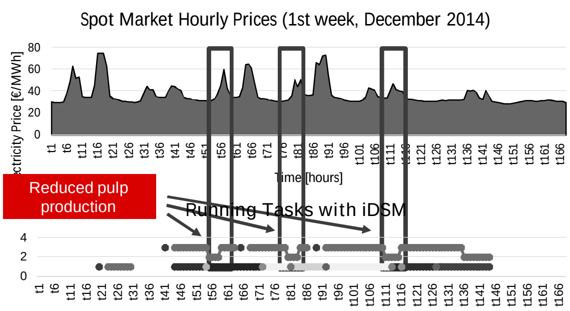
Process variations, e.g. quality, yield, disturbances (DCS) — Process control

Industrial demand side management in pulp & paper

Coordination of production planning and energy management

Mechanical pulp production

- Thermo-mechanical pulp (TMP) production is highly integrated with other parts of paper plant
- Most energy consuming production steps are moved to low cost times
- Paper output of plant is not reduced



Industrial demand side management in pulp & paper

Evaluating market opportunities for thermo mechanical pulping (TMP) mills

Case study with TMP mill

- Real world plant and production data of a Nordic paper mill
- Different scenarios evaluated

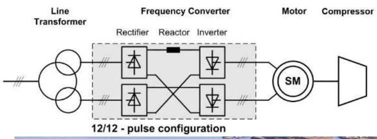
Scenario	Energy cost	Allowed pulp storage levels
S0	No	20%-80%
S1	Yes	20%-80%
S2	Yes	5%-95%

	No. of starts	Savings
S0	8	0%
S1	24	6%
S2	26	5%

	No. of starts	Savings
S0	7	0%
S1	34	4%
S2	33	4%

NMPC for Load Commutated Inverters

Controlling 48 MW at 1kHz sampling rate



Goal

LCIs play an important role in powering electrically-driven compressor stations. Enable LCIs to ride through partial loss of grid voltage.

Solution

- Auto-generated NMPC algorithm (ACADO/qpOASES)
- Running at 1kHz on AC 800PEC

Results

Solution running at a key Statoil/GASSCO sites

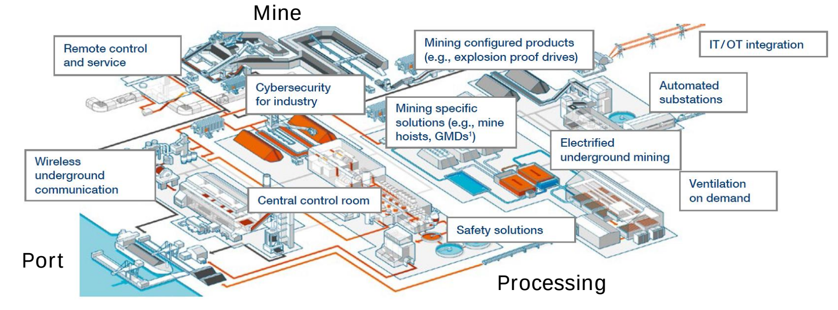
- Two out of six 41.2 MW compressor strings for gas export at Kollsnes
- Three 7.5 MW booster compressors at Kårstø
- First successful ride-through November 2015

Outline

Mining value chain

Mine - Processing - Port

Automation touches every aspect of mining



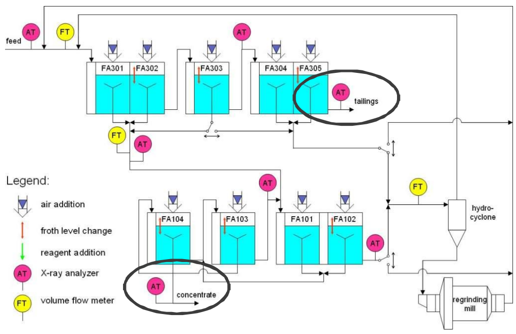
Process optimization of the entire value chain in real-time
Lowest level of automation is in the underground mine

In co-operation with Boliden

Optimization of Flotation Process

Boliden/Garpenberg

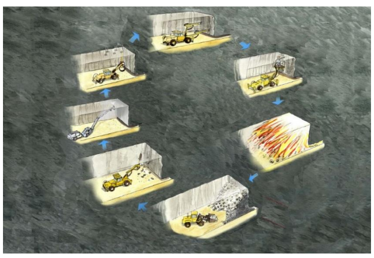
- Boliden stated that the project is impossible!
- MPC + static nonlinear optimization
- Optimize financial output based on dynamic price models
- Increased throughput by 1-2 percent units



Underground mine production

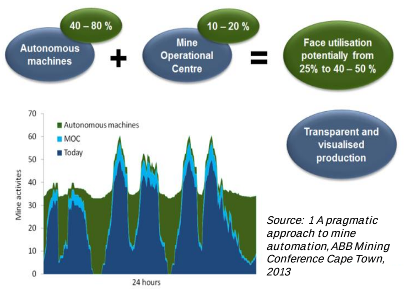
Blast cycle expands the mine

Production cycle



More than 50 operations in a harsh and high risk environment whereof 10% is automated*

Where automation can help



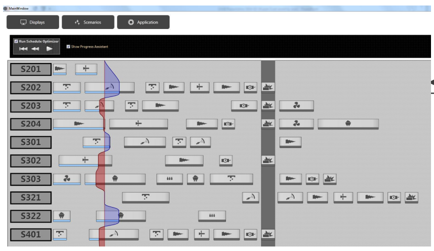
In reach is a significant production increase of 40-50% through automation

*Source: Final report Zepa, SMIFU Work package 1, Rock Tech Centre, 2011-12-15

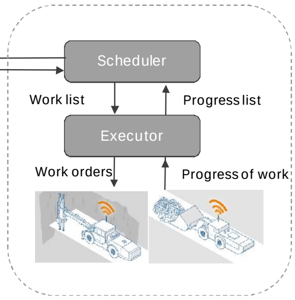
Automated scheduling - MineInsight

Short term scheduling in closed loop

Real-time visualization of actual status and on-line replanning



Monthly production plan
Personell and machine availability
Machine characteristics and distances



Increased weekly blasting by 10% - Increased utilization of machines and faces
A predictive production from the beginning of the value chain

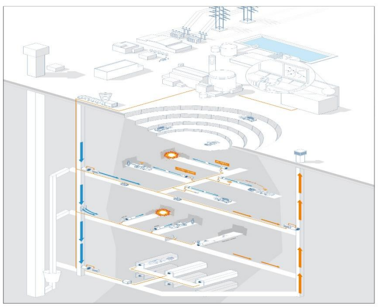
In co-operation with Boliden

ABB

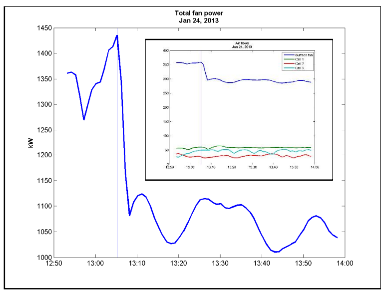
ABB Smart ventilation

Healthy working environment and Energy efficiency

Ventilation where needed



Real-time feedback control



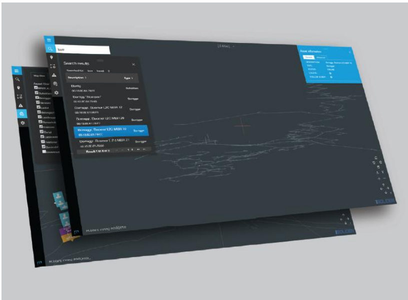
Extended lifetime of existing infrastructure
Energy consumption reduction of 30-50% validated on site

ABB

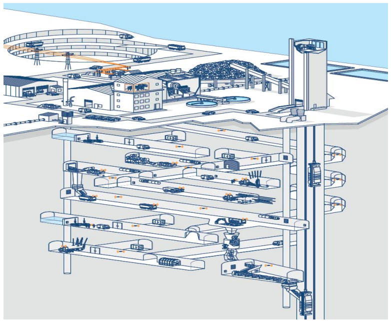
ABB Mine Location Intelligence™

Increased safety and productivity

3D visualization on a map



Connection of people and machines



Enabled by mine wide wireless communication network through WLAN

Outline

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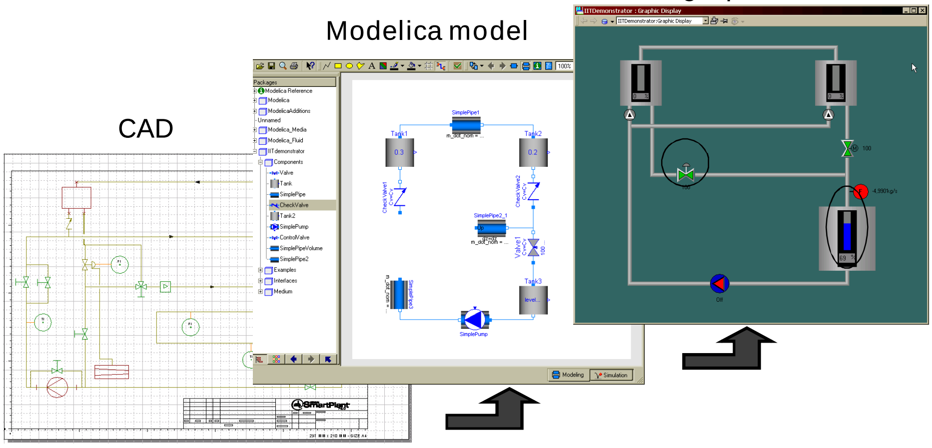
Modelling vision – Automation of automation

Automatically generate models for control and optimization from CAD

Process graphics in 800xA

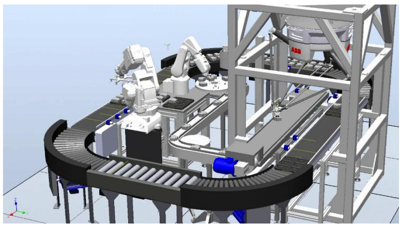
Modelica model

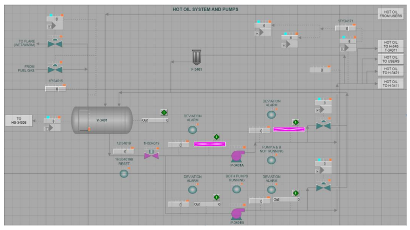
CAD



Virtual commissioning

Commissioning using a (simulated) virtual reality





Manufacturing: Mechanical objects up to cells, lines, incl. 2D or 3D simulation are coupled with automation systems (hardware or software in the loop)

Process automation more difficult due to lack of easily available process models. Currently piloting simulation models derived from P&I diagram to be used for FAT.

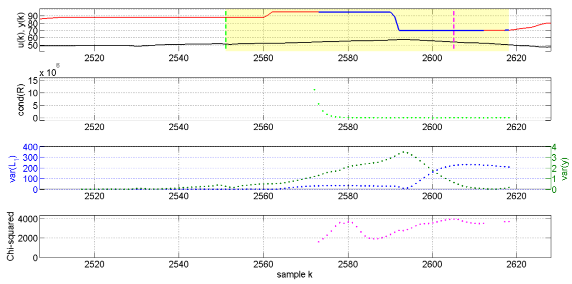
Virtual commissioning

Demo cell at ABB in Gothenburg

Learning models from historic data

Finding intervals that are useful for modelling

- Method available for system identification using input-output data
- Less than 5 % of normal operating data useful for identification
- Can (historic) data be used also for applications learning decision models rather than process models? For example
  - Alarm management
  - Production scheduling
  - Supply-chain optimization



Outline

Future Challenges

Systems Design: Open, Efficient and Easy to Engineer

- How to design future automation systems (of systems)
  - Easier usability of more complex system (Smartphone)
- How to ensure seamless communication and access to data
  - Can we agree on ONE set of standards?
  - How to make systems more open
- How to make the design adaptive to facilitate the dynamic changes in the operating environment
  - Engineering 10 times more complex systems at 10 % of today's effort
- Which functions become redundant / merged?
  - Inheritance vs. innovativeness

Future Challenges

Operations: Less is More – Focus on the Essence

- Which decisions are relevant and necessary?
  - Are there redundant functions?
- Role of an operator in the future
  - How to maximize his/her performance & quality
- Create relevant information from data
  - Easy to get lost with all possibilities
- How to ensure truly collaborative functions
  - Eliminate competition between local targets
- What comes instead of the automation pyramid?
  - Do we end up in another form of hierarchy?
- The 100 % available plant – meaning only planned maintenance stops

ABB

Future Challenges

Modeling and Optimization: Dealing with Complexity

- How to model cross-topics (merge earlier separated ones)
  - How to link models to each other - global awareness
- How to deal with nonlinearities / nonconvexities
  - Do linearization schemes kill the performance
- How to optimize ever growing problems
  - Are there true options to MI(N)LP?
- Collaborative optimization solutions ensuring best performance in all situations
- Balance between Cloud and Edge computing
  - What functions can and will have to be executed locally and what can instead be moved to a local vs global (outside firewall) cloud?

ABB

Outline

Conclusions

Digitalization is Inevitable

Digitalization will have a tremendous impact on control and operations.
Will be future business differentiator and growing academic field.

We (may) see shifts from
- Proprietary to open architectures
- Multivariable control with few in-out to DeepMPC
- Isolated to integrated power and automation systems
- Low level control to optimization of entire value chain
- Manual to automatic generation of models
- Real to virtual commissioning

Acknowledgements

The speaker is grateful to many colleagues, especially within ABB, for discussions and slides.

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