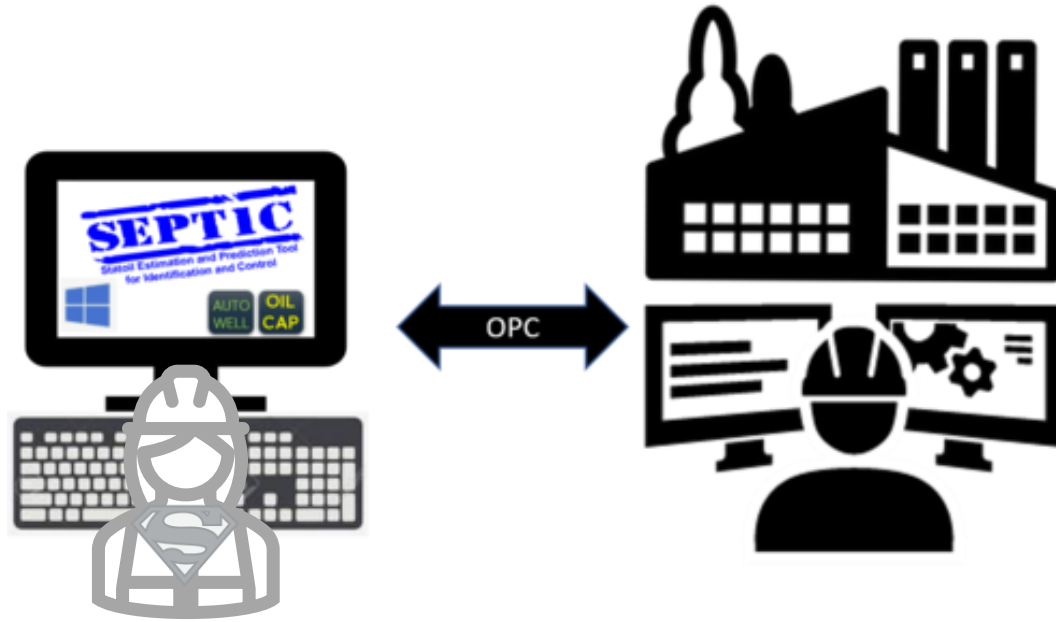




Model Predictive Control in Equinor

NTNU, 17.11.2023

Pål Kittilsen

SEPTIC Delivery Team

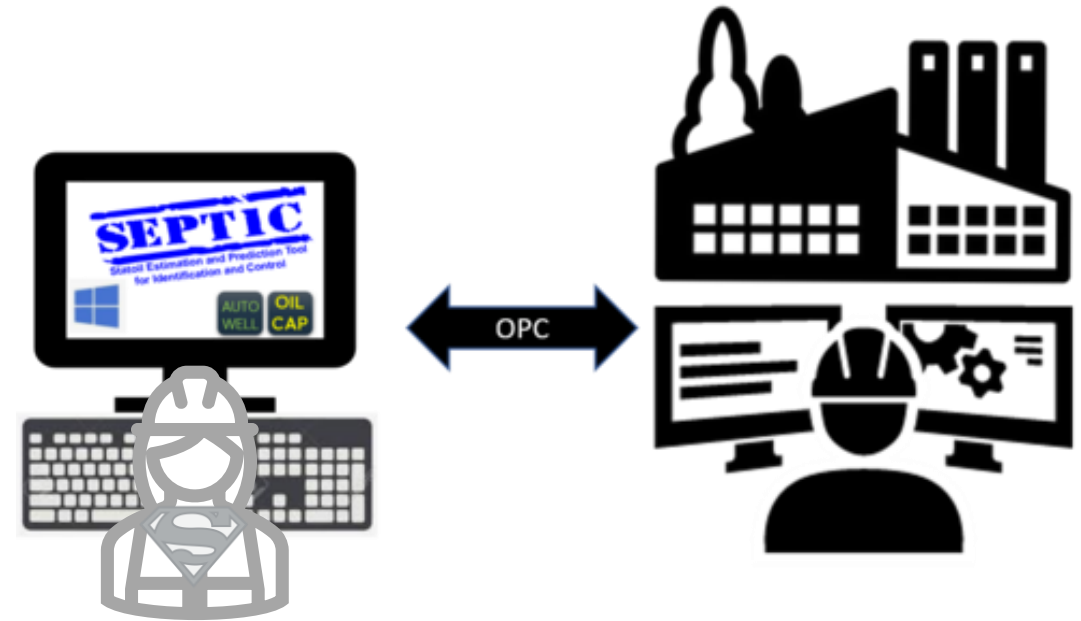
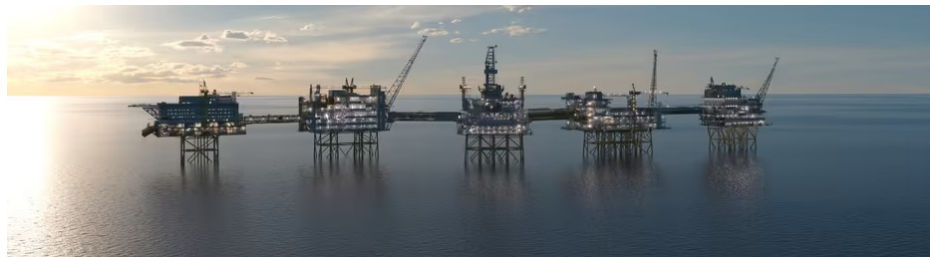
Equinor, Trondheim



Johan Sverdrup Feltsenter

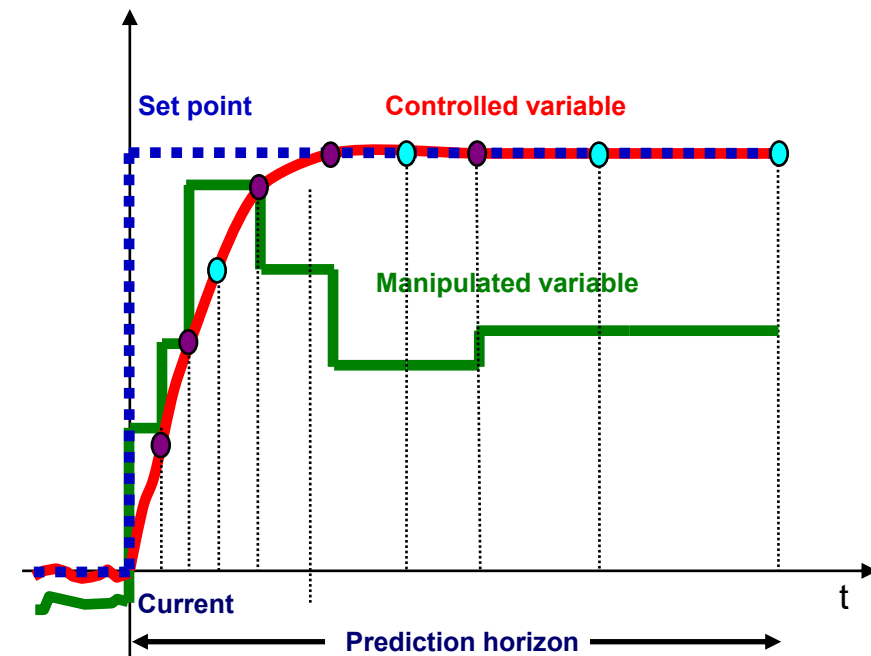
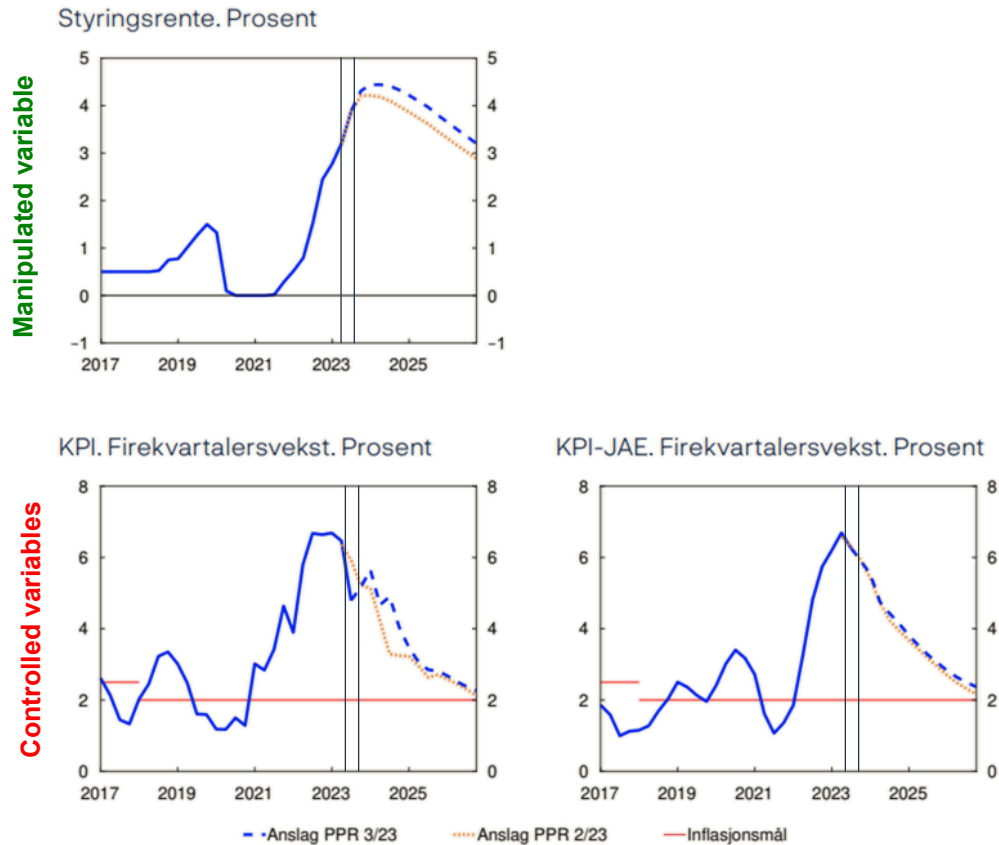
Contents

- Model Predictive Control (MPC)
 - What is it?
 - Formulation in SEPTIC
- Model Predictive Control in Equinor
 - Locations
 - When to use SEPTIC
 - Typical SEPTIC applications
- Demo: SEPTIC at Johan Sverdrup



What is Model Predictive Control?

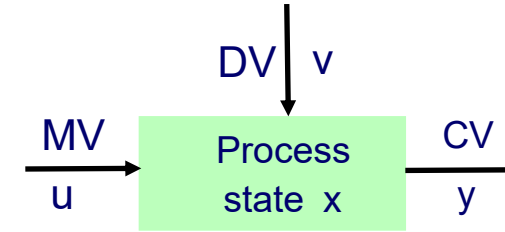
*ChatGPT: Model Predictive Control (MPC) is an advanced control technique used to optimize process control in real-time. It uses a **mathematical model of the process** to predict how the process will behave in the future, and then uses this information to **calculate the optimal control action** that drives the predicted process output as close as possible to the desired reference*



Norges Bank, Pengepolitisk rapport 3|2013, sept 2023

MPC formulation in SEPTIC

$$\min_{\Delta u, \alpha} \left[\text{Controlled variables } (y - y_{ref})^T Q_y (y - y_{ref}) + \text{Manipulated variables } (u - u_{iv})^T Q_u (u - u_{iv}) + \Delta u^T P \Delta u + \alpha^T R \alpha \right] \quad \text{Constraints}$$



SEPTIC

model: $\dot{x} = f(x, u, v) \quad y = g(x, u)$

constraints: $y_{\min} + W\alpha_L \leq y \leq y_{\max} + W\alpha_H \quad \Delta u_{\min} \leq \Delta u \leq \Delta u_{\max} \quad u_{\min} \leq u \leq u_{\max}$
 $\alpha_{L,\min} \leq \alpha_L \leq 0 \quad 0 \leq \alpha_H \leq \alpha_{H,\max} \quad \alpha = [\alpha_L^T \alpha_H^T]^T$

discretization: $u = [u_1 u_2 \dots u_k] \quad \Delta u = [\Delta u_1 \Delta u_2 \dots \Delta u_k] \quad \Delta u_i = u_i - u_{i-1} \quad y = [y_1 y_2 \dots y_n]$

$$J = \frac{1}{2} x^T \cdot H \cdot x + c^T \cdot x$$

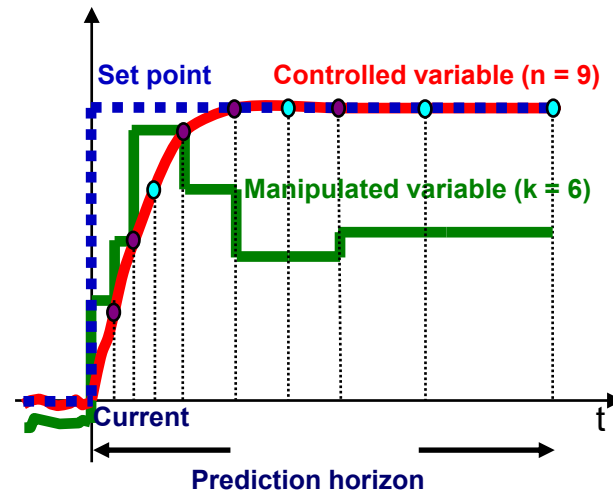
$$C \cdot x + B_{qld} \geq 0$$

$$x - B_L \geq 0$$

$$-x + B_U \geq 0$$

$$B_L = \begin{bmatrix} \Delta u_{\min} \\ \alpha_{L,\min} \\ 0 \end{bmatrix}$$

$$B_U = \begin{bmatrix} \Delta u_{\max} \\ 0 \\ \alpha_{H,\max} \end{bmatrix}$$



Explicit control priorities - solved before the dynamic problem

1. MV rate of change limits
2. MV high/low Limits
3. CV hard constraints ("never" used)
4. CV soft constraints, CV set points, MV ideal values: Priority level 1
5. CV soft constraints, CV set points, MV ideal values: Priority level 2
6. CV soft constraints, CV set points, MV ideal values: Priority level n
7. CV soft constraints, CV set points, MV ideal values: Priority level 99

Sequence of steady-state QP solutions to solve 2 - 7 (or NLP if nonlinear models)

Then a single dynamic QP to meet the adjusted and feasible steady-state goals (or iterated QP if nonlinear models)

- MV blocking → size reduction
- CV evaluation points → size reduction
- CV reference specifications → tuning flexibility set point changes / disturbance rejection
- Soft constraints and priority levels → feasibility and tuning flexibility

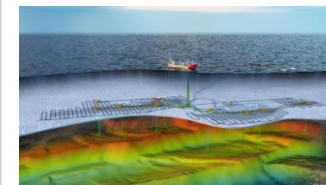
SEPTIC

- Equinor inhouse software for MPC (Model Predictive Control)
- First implementation in 1997
- Available for all Equinor assets
- Typical BC: 1-5% increased production / reduced energy
- ~15 people/~11 full time equivalents with cybernetics/automation/process control background

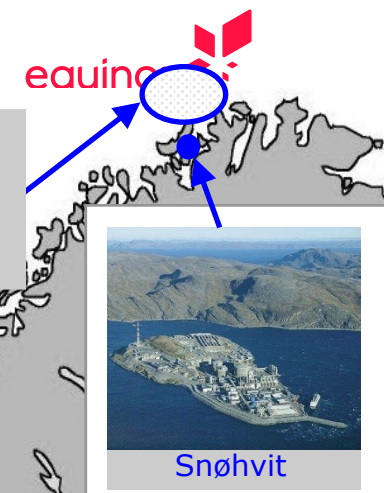
CURRENT USERS PROSPECTS



Åsgard B
Norne
Heidrun
Åsgard A
Kristin/Tyrihans
Aasta Hansteen
Njord



Johan
Castberg



Snøhvit



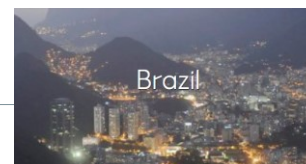
Troll A
Fram-Troll C
Snorre-Vigdis
Breidablikk



Johan Sverdrup
Gudrun
Gina Krog

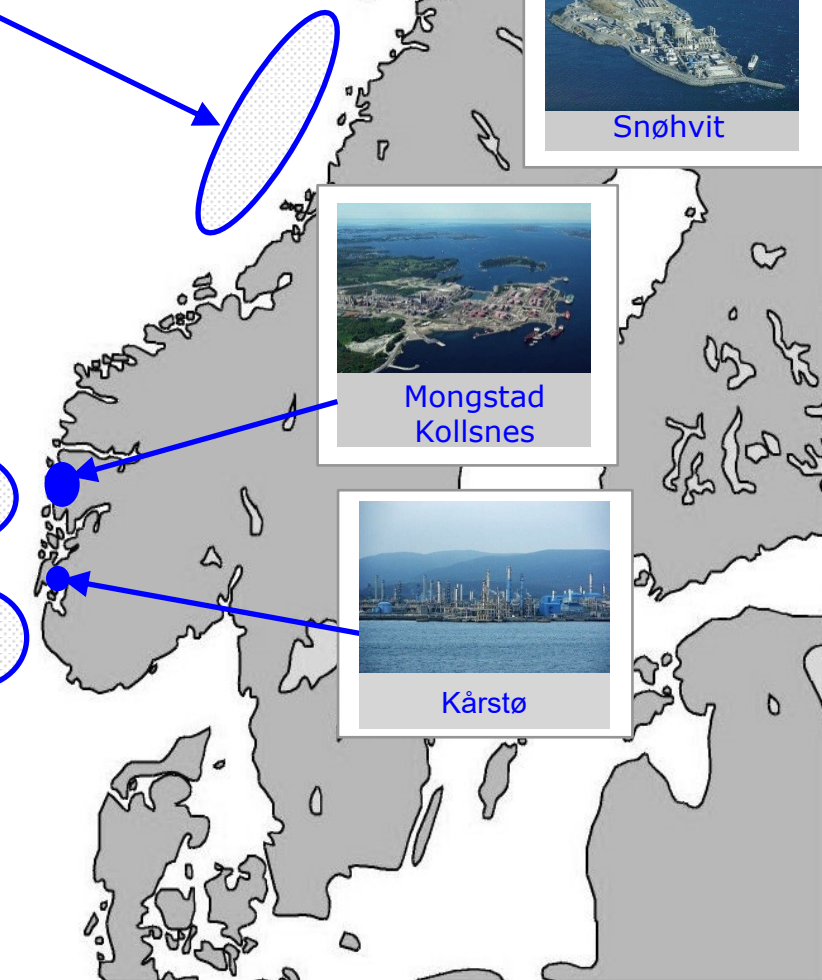


Mariner



Brazil

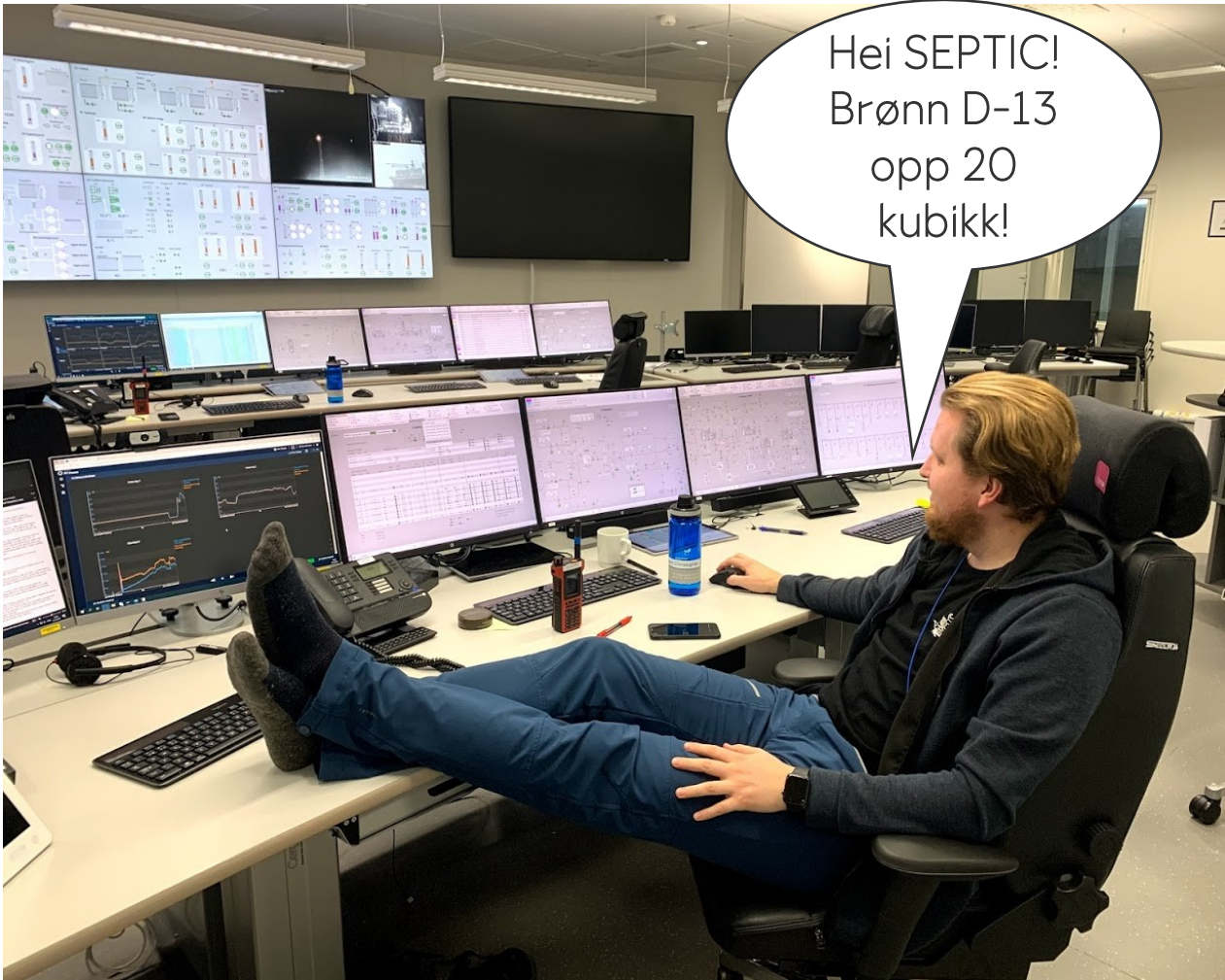
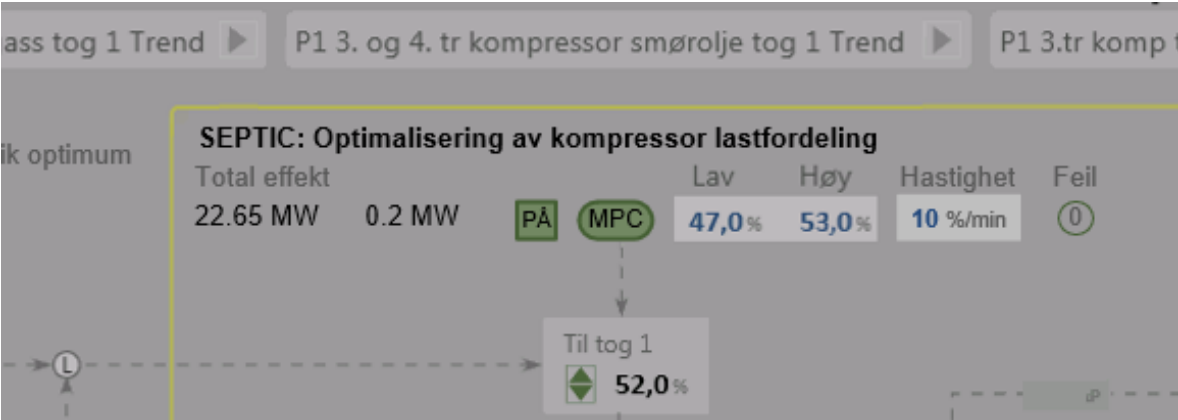
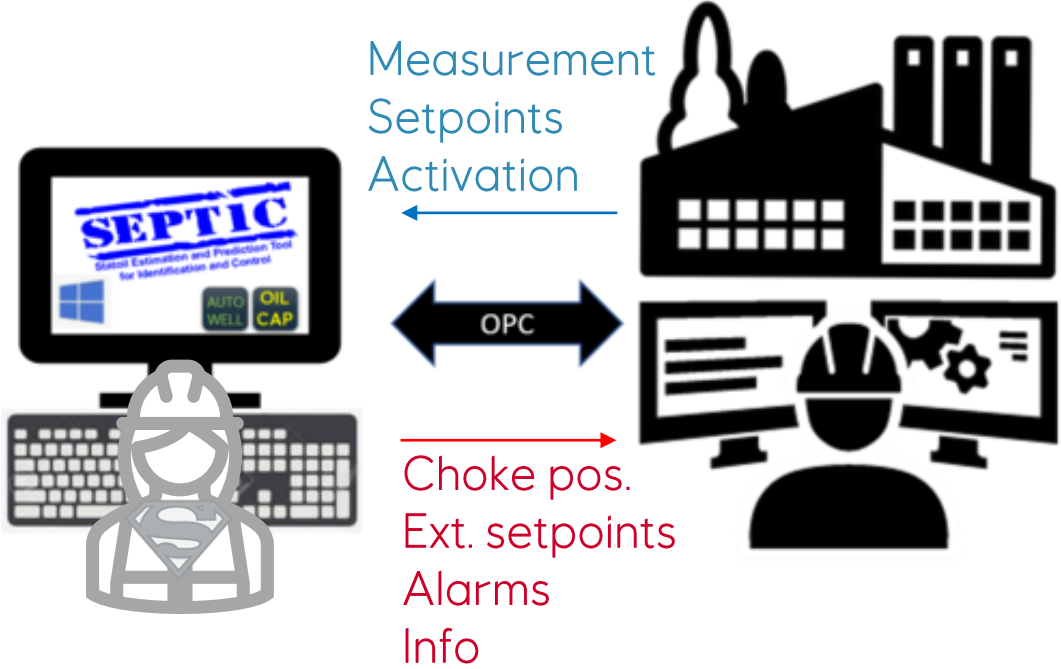
Bacalhau
Peregrino



Mongstad
Kollsnes

Kårstø

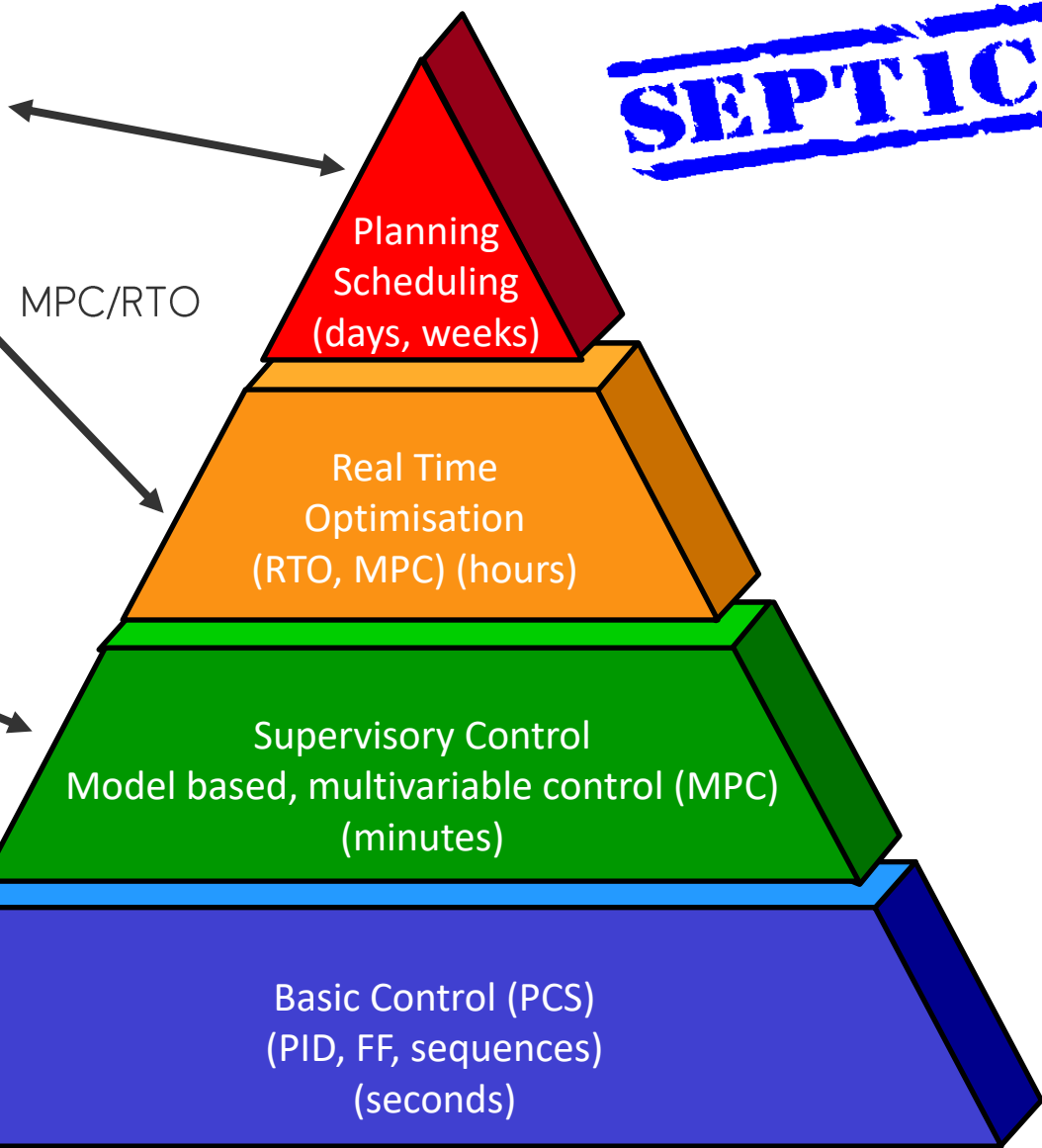
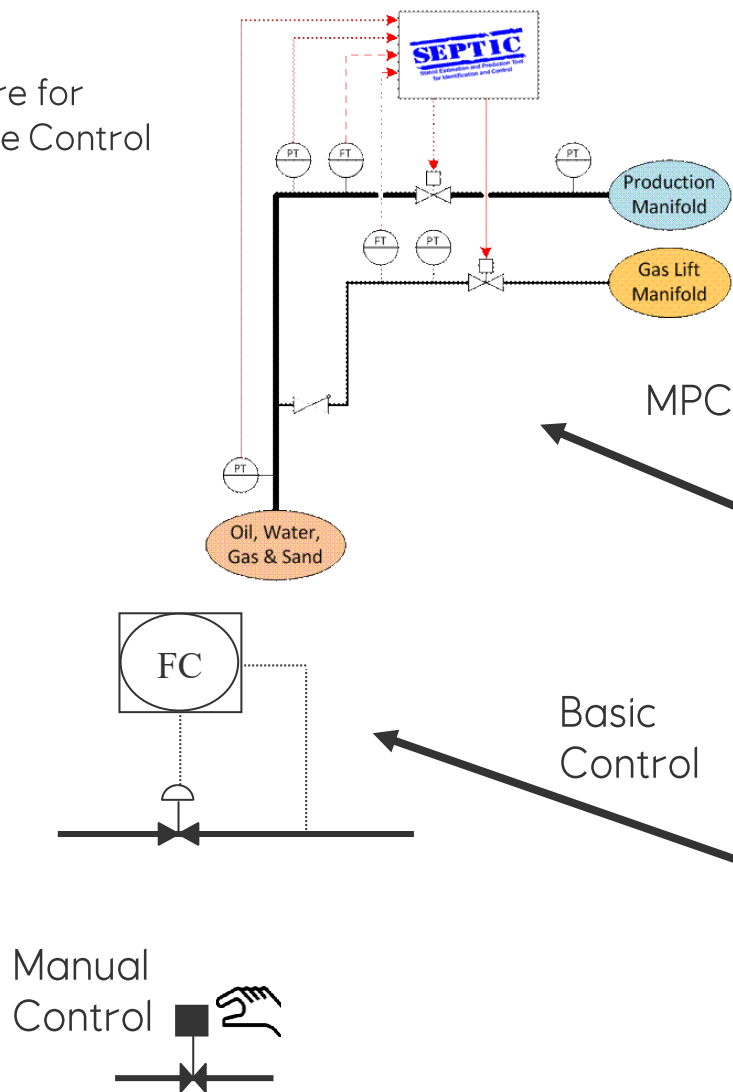
SEPTIC = Program on a server in communication with the control system



Process Control – An overview

SEPTIC:

- Inhouse software for Model Predictive Control
- Multivariable
- Constraints
- Non-critical

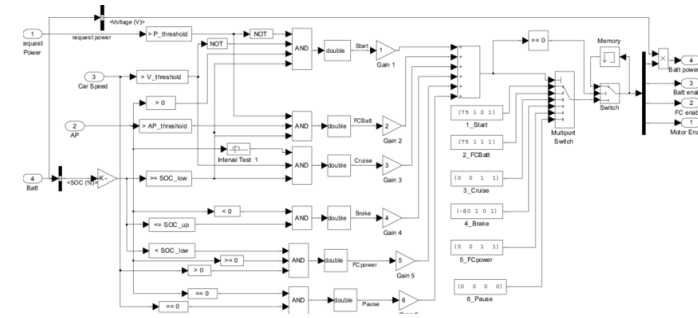


SEPTIC

SEPTIC vs complex control logic



OR



?

Process properties SEPTIC can handle

- **Multivariable:** many to many
- **Constraints:** hard (MVs) and soft (CVs)
- **Nonlinearities:** step chokes, dead band, choke gain, ...
- **Robustify:** good practice to QA «special» measurements
 - Rate estimator/multiphase meters («PC in the loop»)
 - Freeze detect bottom hole pressure gauge
- **Complex logic** (min select, priorities, cascade control, feedforward, varying modes/conditions):
 - Easier to maintain logic in SEPTIC vs SAS
 - SEPTIC engineer support allocated

Considerations

- Simple problems should be solved with simple methods
- SEPTIC server installed already?
- Not safety critical (e.g. safe injection)
- Optimization vs stabilisation

MPC applications

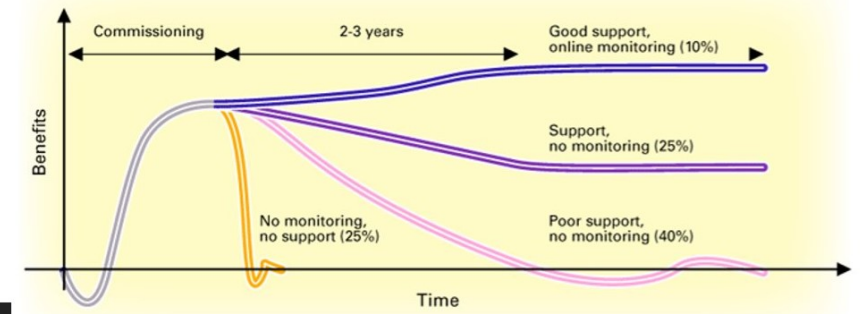
- Oil refining (Mongstad and Kalundborg)
 - Distillation columns
 - Product blending (gasoline, gas oil)
 - Cracking, reforming and hydrotreating
 - Heat exchanger network (RTO)
 - Multi-unit optimisation (RTO/DRT0)
 - Utilities (steam and fuel gas networks)
- Gas processing (Kårstø, Kollsnes, Snøhvit)
 - Distillation
 - Gas quality control
 - Pipeline pressure control
 - Optimisation
- Offshore production
 - Well start-up and target control
 - Extended slug control/surge handling
 - Crude blending
 - Production optimisation
 - Reservoir Pressure Control
 - Compressor load-sharing



How to succeed with SEPTIC over time

- Long term commitment of personnel with plant & process knowledge
- End User Support / Training / Attention
- Solution/Application Support (on running systems)
- Application maintenance/enhancements
- System (SEPTIC) development
- End User Engagement and Involvement

POSSIBLE MPC PERFORMANCE



SEPTIC
Stall Estimation and Prediction Tool
for Identification and Control

OIL&GAS JOURNAL

SPECIAL REPORT: PROCESS CONTROL: Best practice improve control system performance (Oct 2006)

AUTO
WELL

AUTO
SAFE
GAS LIFT

DEDUCTION
TESTING

WEAK
WELLS

LINE
CAP

OIL
CAP

GAS
CAP

AUTO
SAFE
INJECTION

SEPTIC



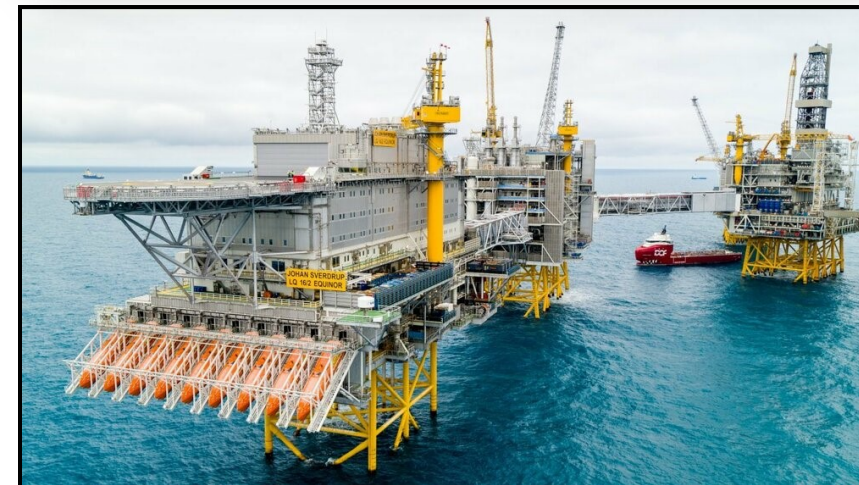
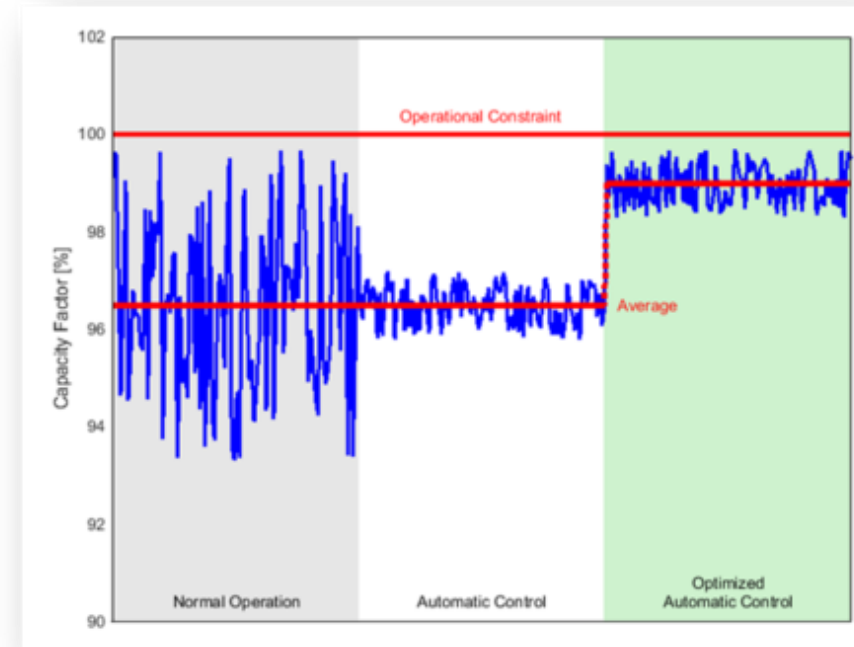
equinor



SEPTIC at Johan Sverdrup

SEPTIC at Johan Sverdrup

- AUTO WELL** Production well control
- OIL CAP** Total oil production control
- TVP** Export oil TVP/RVP (vapor pressure) control
- COMP LOAD** Compressor Load Optimization (lower energy)



Example: SEPTIC for automatic choke control of production well

- Manipulated variables:
 - Production choke position
 - Gas lift choke position
- Controlled variables:
 - Bottom hole pressure
 - Well head pressure
 - Oil/gas flow rate

AUTO
WELL

