MPC in Statoil

Stig Strand, specialist MPC

Statoil Research Center 93 →
SINTEF Automatic Control 91-93
Dr. ing 1991: Dynamic Optimisation in State Space Predictive Control Schemes

Process Control – an overview

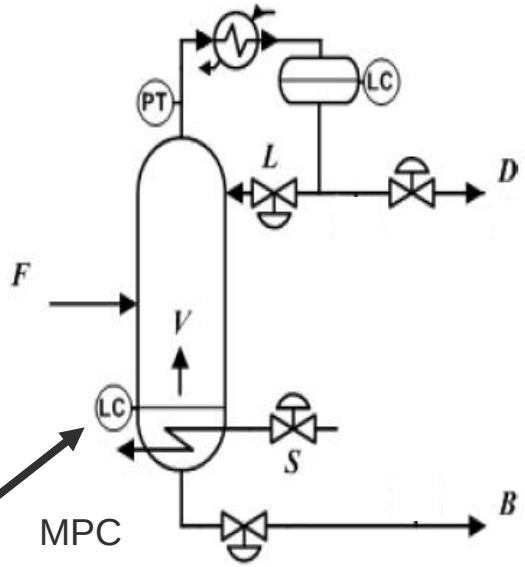
Planning
Scheduling
(days, weeks)

Real Time
Optimisation
(RTO, MPC) (hours)

Supervisory Control
Model based multivariable
control
(MPC) (minutes)

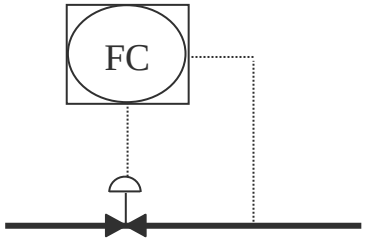
Basic Control (PCS)
(PID, FF,..) (seconds)

MPC/RTO

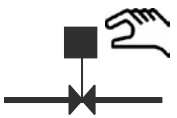


MPC

Basic
Control

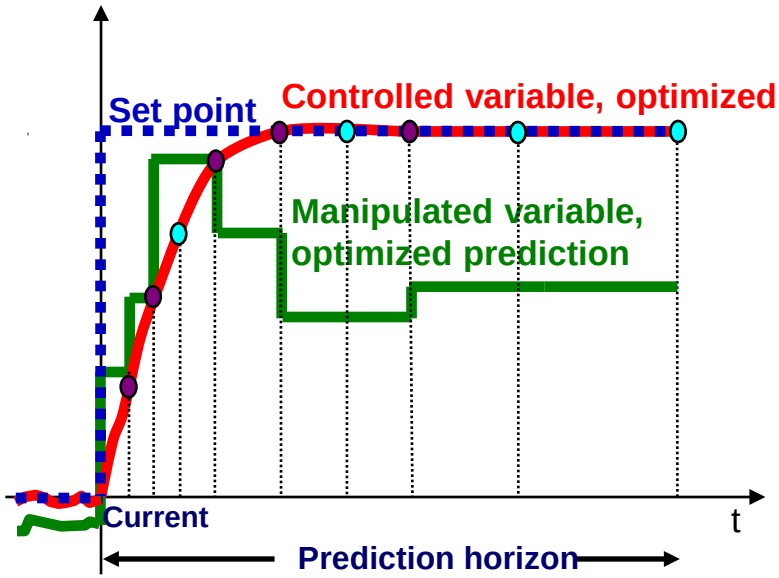


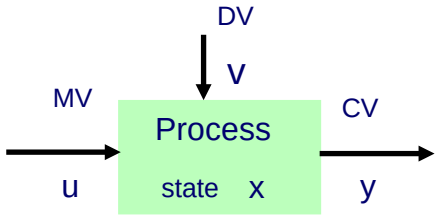
Manual
Control



Statoil

MPC





$$\min_{u} \left[(y - y_{ref})^T Q_y (y - y_{ref}) + (u - u_{iv})^T Q_u (u - u_{iv}) + \Delta u^T P \Delta u \right]$$

$$\dot{x} = f(x,u,v)$$
$$y = g(x,u)$$
$$u_{\min} < u < u_{\max}$$
$$\Delta u_{\min} < \Delta u < \Delta u_{\max}$$
$$y_{\min} < y < y_{\max}$$

$$y = [y_1\, y_2 \ldots y_n]$$
$$u = [u_1\, u_2 \ldots u_k]$$
$$\Delta u = [\Delta u_1\, \Delta u_2 \ldots \Delta u_k]$$
$$\Delta u_i = u_i - u_{i-1}$$

CV soft constraint:

$y < y_{max} + RP$

$0 <= RP <= RP_{max}$

$w*RP^2$ in objective

- 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

MPC Solver - Control priorities

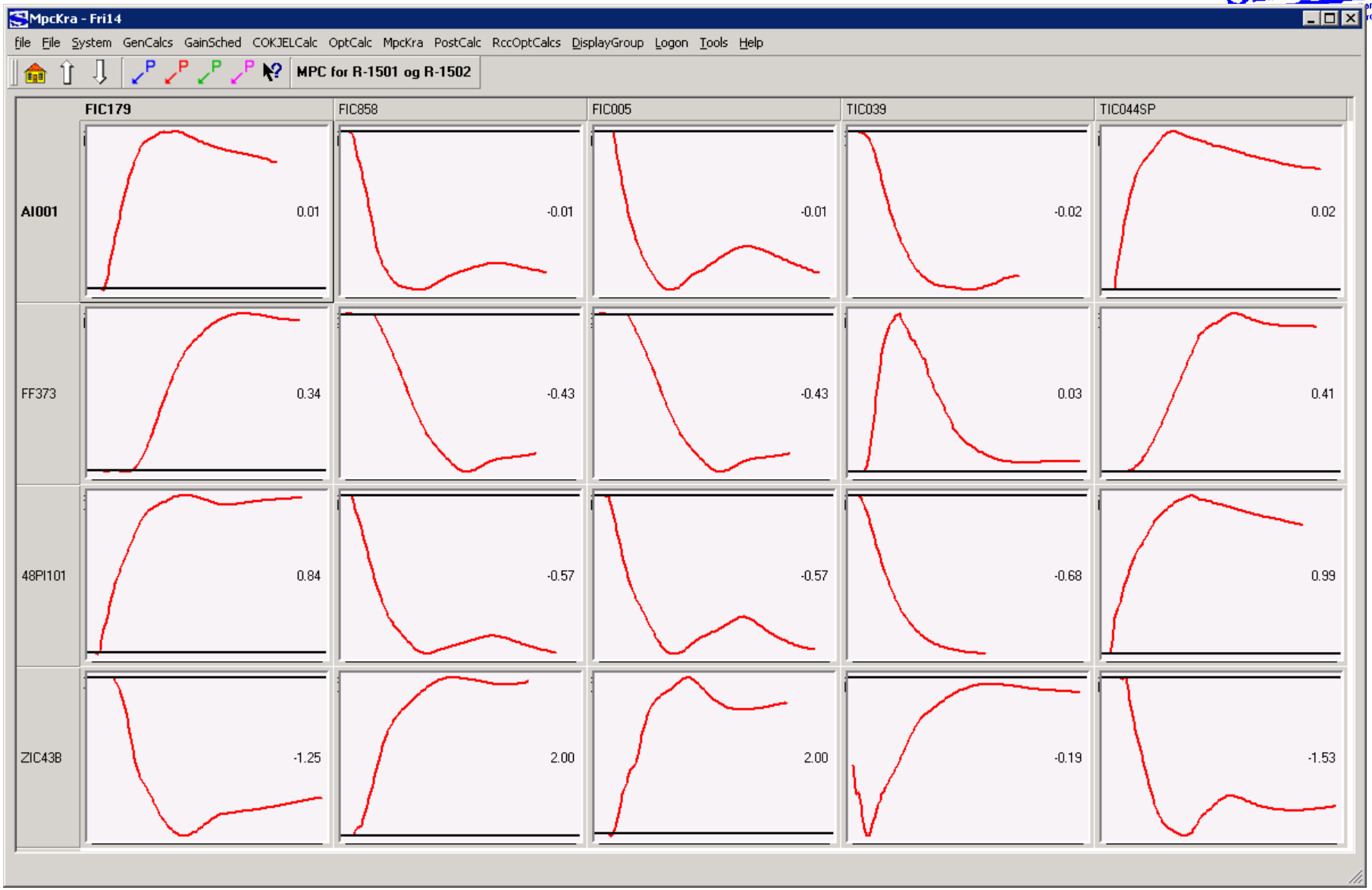
SEPTIC
Statoil Estimation and Prediction Tool for Identification and Control

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)

MPC linear models



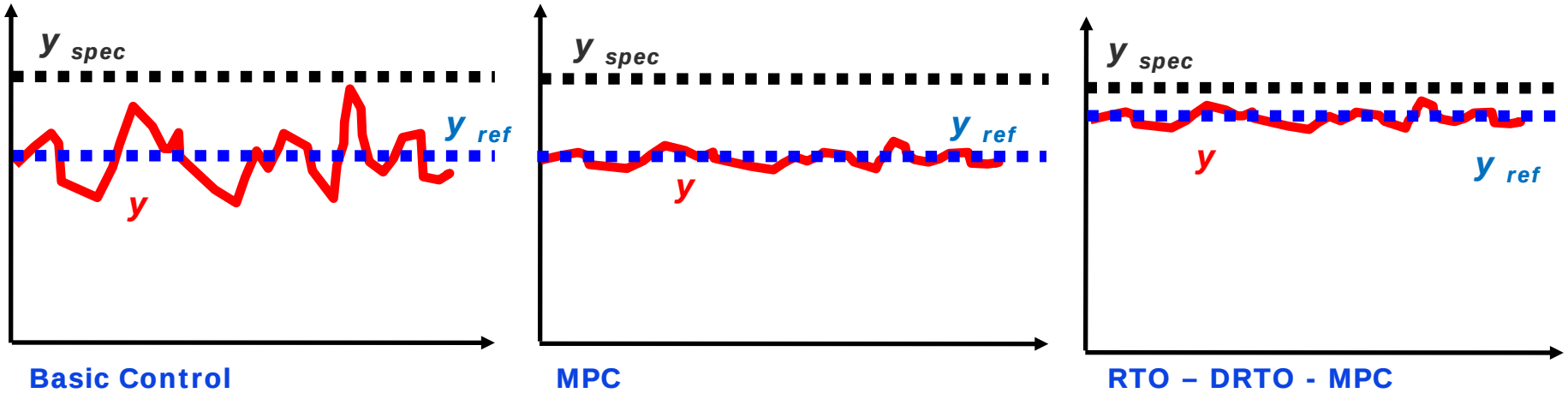
MPC – nonlinear models

SEPTIC
Statoil Estimation and Prediction Tool for Identification and Control

- Open loop response is predicted by non-linear model
  - MV assumption : Interpolation of optimal predictions from last sample
- Linearisation by MV step change
  - One step for each MV blocking parameter (increased transient accuracy)
- QP solver as for experimental models (step response type models)
- Closed loop response is predicted by non-linear model
- Iterate solution until satisfactory convergence

Contributions of MPC

- Flexible, implements decoupling, feedback and feed-forward
- Improved process response to feed variations
- Improved product quality control
- Maximise capacity, maximise profit, reduce cost
- Respect process constraints related to equipment or environment
- Increased process regularity

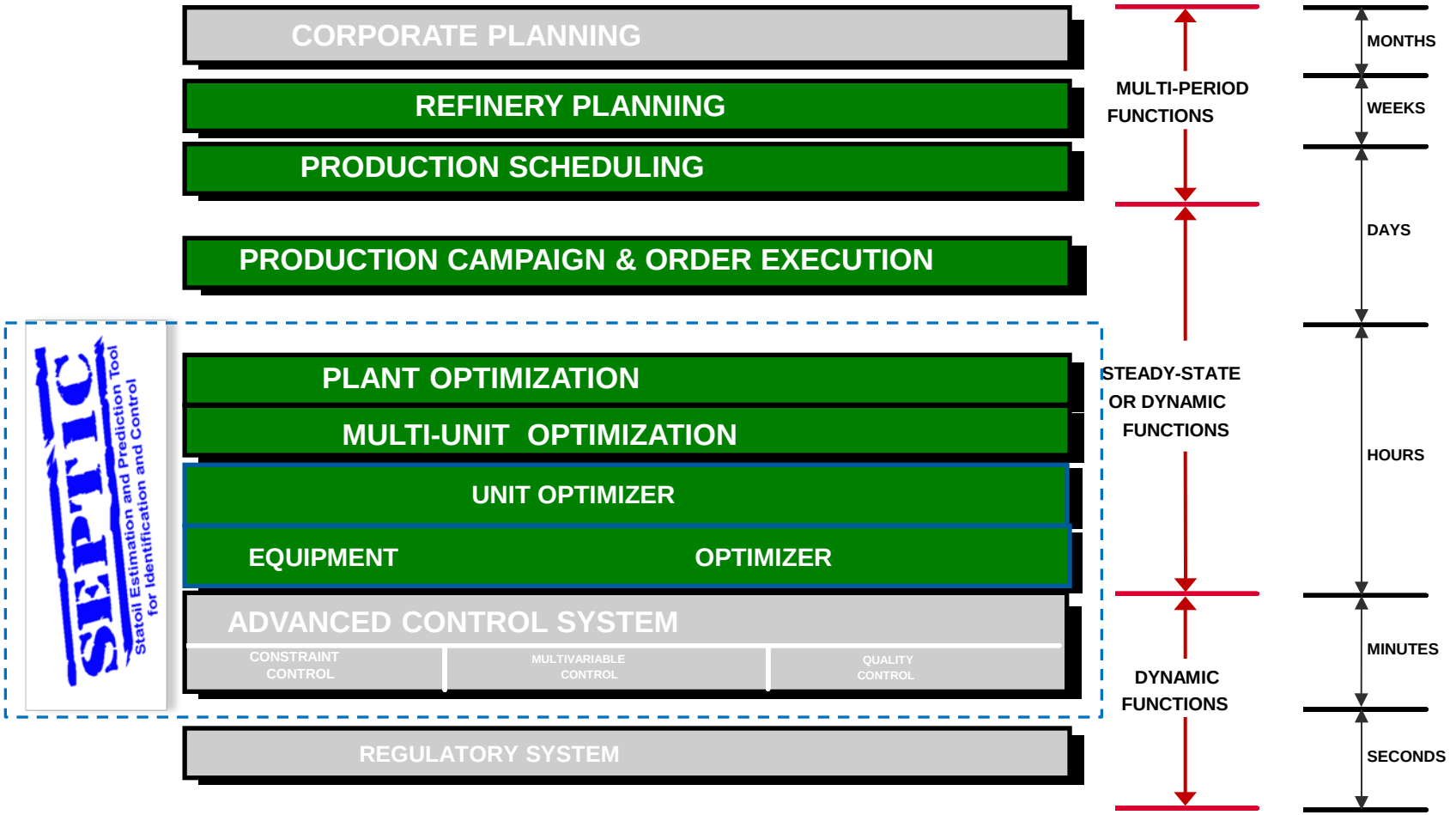


PROCESS CONTROL
”The SEPTIC story”

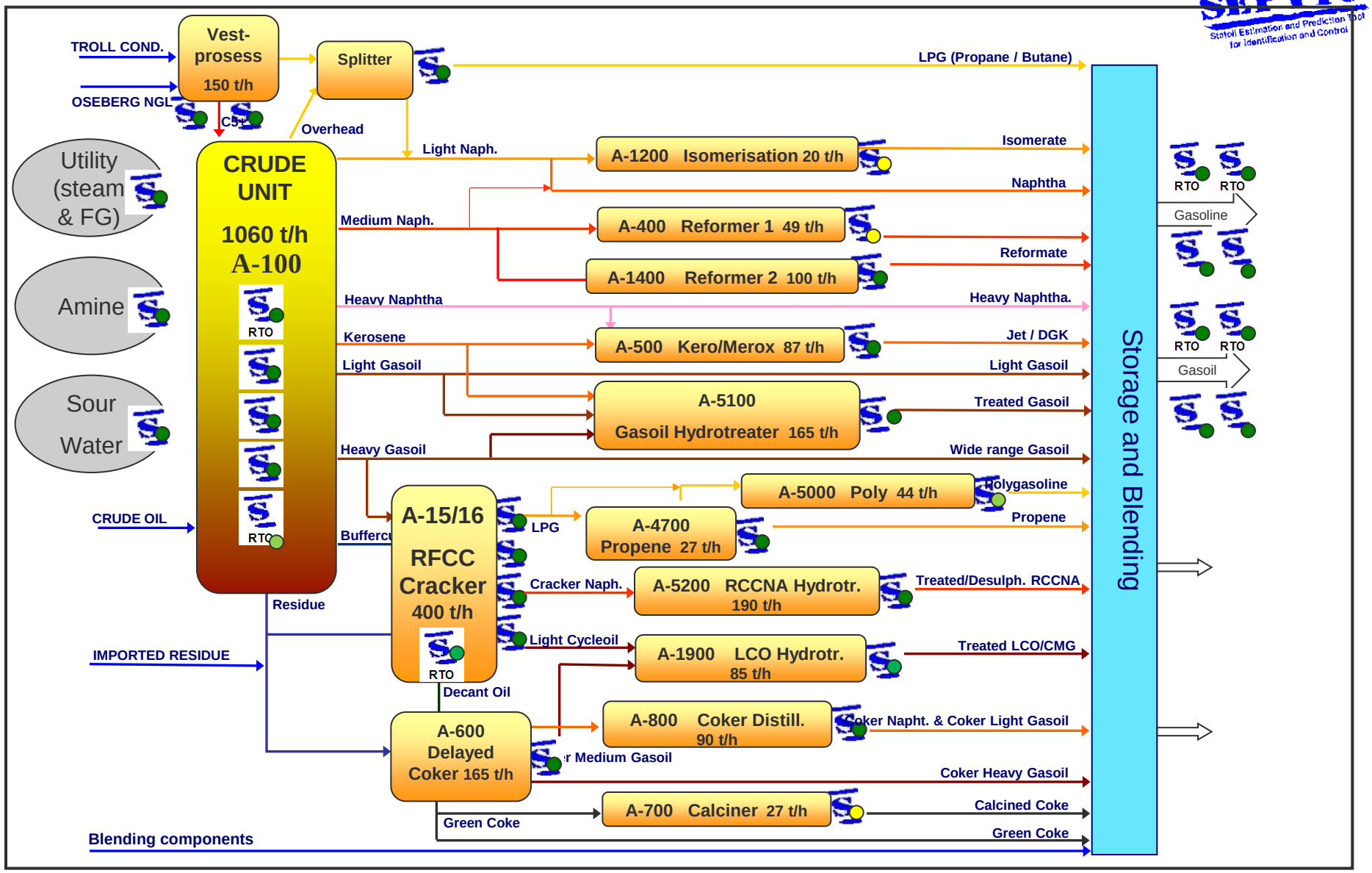
SEPTIC
Statoil Estimation and Prediction Tool for Identification and Control

- The in-house developed SEPTIC MPC tool was established in 1997 and has continuously been improved since then, securing state-of-the-art technology
- The process control group at R&D is responsible for SEPTIC, and works with Statoil customers only
- The philosophy with SEPTIC is to implement MPC applications together with the users, which have resulted in;
  - Flexible and quick installations
  - Cheaper solutions than using external vendors
  - Non-bureaucratic way of work
  - Building in-house competence
- In 2013 there are 90 (+/-) SEPTIC applications installed in Statoil

Planning and control layers in oil refining



Mongstad Refinery – Septic MPC & RTO



Notation: Running Application | Implementation ongoing | Future Application

Statoil

SEPTIC applications Mongstad 2014

Area	Unit	App	Scope	#of MV	#of CV	Description
A1	A-0100	MPCSPLT	MPC	16	24	Nahta stabilizer and 2 LNA/MNA splitters
A1	A-0100	MPCFVRM	MPC	12	29	Crude feed & preflash control
A1	A-0100	HEXOPT	RTO	8	11	Crude feed heat exchanger optimization
A1	A-0100	PasBal	MPC	7	9	Crude heaters pass balancing
A1	A-0100	ESTT101	CALC	-	-	Calc app for soft sensors crude unit
A1	A-1100	MPCNGL	MPC	10	9	2 paralell LPG/Naphta splitters, Vestprosess pipeline feed
A1	**A-0100**	**MPCT101**	**MPC**	**31**	**42**	**Crude atm distillation, jet fuel unit and gasoil hydrotrea**
A1	A-1100	MPCLPG	MPC	10	11	C3/C4 splitters Vestprosess
A2	A-0600	MPCT601	MPC	8	5	Delayed cocker fractionator
A2	A-0800	MPCDES	MPC	4	4	Delayed coker overhead hydrotreating and destillation
B1	A-1500	ESTB1	CALC	-	-	Calc app for cat cracker
B1	**A-1500**	**RCCOPT**	**RTO**	**10**	**21**	**Optimizer cat cracker**
B1	A-1500	MpcKra	MPC	11	19	Cat cracker reactor and regenerator control
B1	A-1500	MpcDes	MPC	12	11	Cat cracker main fractionater control
B1	A-1600	MPCBUT	MPC	4	5	Cat cracker LPG/Naphta splitter
B1	A-1600	MpcAbs	MPC	5	8	Cat cracker fuel gas/heavier splitcontrol
B2	**A-1900**	**A-1900**	**MPC**	**12**	**19**	**LCO hydrotreating**
B2	**A-4000**	**A-4000**	**MPC**	**14**	**15**	**2 parallell amine regenerator control with foaming con**
B2	**A-4300**	**T-4352**	**MPC**	**3**	**5**	**Sour water stripper control**
B2	A-4700	MpcPro	MPC	4	5	Cat cracker LPG C3/C4 splitter
B2	**A-5000**	**A-5000**	**MPC**	**40**	**46**	**Cat cracker Butene polymerization unit**
B2	A-5200	A-5200	MPC	4	12	Cat cracker naphta hydrotreating
B3	A-1400	MPC_R-1400	MPC	6	22	Cat reforming control
B3	**A-21/25**	**MPC-SG2500**	**MPC**	**7**	**8**	**Steam & Fuel gas network control**
YA	**A-6200**	**LUCBBL1**	**MPC**	**10**	**21**	**Gasoline blender #1 lineup capasity control**
YA	**A-6200**	**LUCBBL2**	**MPC**	**10**	**21**	**Gasoline blender #2 lineup capasity control**
YA	**A-6500**	**LUCGOB1**	**MPC**	**10**	**19**	**Gasoil blender #1 lineup capasity control**
YA	**A-6500**	**LUCGOB2**	**MPC**	**9**	**18**	**Gasoil blender #2 lineup capasity control**
YA	A-6200	MPCBBL1	RTO	11	31	Gasoline blender #1 product quality control
YA	A-6200	MPCBBL2	RTO	11	31	Gasoline blender #2 product quality control
YA	A-6500	MPCGOB1	RTO	10	24	Gasoil blender #1 product quality control
YA	A-6500	MPCGOB2	RTO	10	24	Gasoil blender #2 product quality control
		Grand Total:		**319**	**529**	

Comments or questions?

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