The purpose of this SAMPLE document is to show in the public domain LIUTAIO's point of view about

DIFFERENCE BETWEEN APC AND COMPLEX CONTROL

this document is developed by:

LIUTAIO
"PROCESS CONTROL SERVICES"

For preparing this SAMPLE document, examples of industrial processes and typical process data was used in combination with

LIUTAIO experience.

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2. Abbreviations

Refer to sample document: 0118H10SD01 Abbreviations

3. Glossary

Refer to sample document: 0118H15SD02 Glossary

4. References

[1] **LIUTAIO** – Process Control Services
0118H10SD01 Abbreviations - Sample Document
Rev.01

[2] **LIUTAIO** – Process Control Services
0118H15SD02 Glossary - Sample Document
Rev.01

[3] CARLOS RAMÍREZ, MARCELO RUIZ, CARLOS LAGO, MARTÍN UGARTE and CARLOS RUIZ
FLUIDIZED CATALYTIC CRACKING UNIT ADVANCED CONTROL
Paper presented at the 1st Mercosur Process Engineering Congress (ENPROMER 97), Bahía Blanca, Argentina, September 1997.

5. Introduction

"APC" stands for "Advanced Process Control".

APC refers to the functionality beyond the typical Proportional-Integral-Derivative controller (PID), to improve plant performance, product yield; reduce energy consumption; increase capacity; improve product quality and consistency; reduce product giveaway; and reduce environmental emissions.

"Complex Control" also refers to the functionality beyond the typical "Proportional-Integral-Derivative" controller (PID), looking to keep the plant operation at a pre-defined operation condition, maintaining "Stable Plant Operation" against plant upsets and operation mode changes.

From previous paragraphs it is understood that APC works on an "Stable Plant Operation", and "Complex Control" keeps the "Stable Plant Operation".

This document will describe further APC and "Complex Control", and next items of comparison will be listed and explained.

The term "Supervisory Control" or "Basic/Regulatory control" **WILL NOT** be explained in this document. They correspond to a lower level control category, and they shall be explained in a separate document.

6. "Advanced Process Control" (APC) outline

APC is a control technology which relies on the idea of generating values for commanding manipulated process variables as solutions of an on-line (real-time) optimization problem. This problem is built based on a process model and process measurements (which provide the feedback, and, optionally, feed forward), process constraints and sometimes inferred hydrocarbon qualities, analyzers or LAB data inputs. Refer to Figure 1 for an APC sketch.

The on-line (real-time) plant optimization problem is structured as follows:

Plant Model:	A linear dynamic model of the plant, built based on on-line plant dynamic test data collection.
Objective Function (OF):	Lead to APC solution to minimize, maximize, or keep constant the plant objective which can refer to a local profit (money), reduce losses, operational performance, purges flows, feed flow, operation variables, better utility allocation, etc., or combination of all these ones.
Operation Constraints:	APC include operation constraints to provide realistic solutions that will keep plant operation within design limits, like maximum/minimum flow, temperature, pressure, composition, etc.

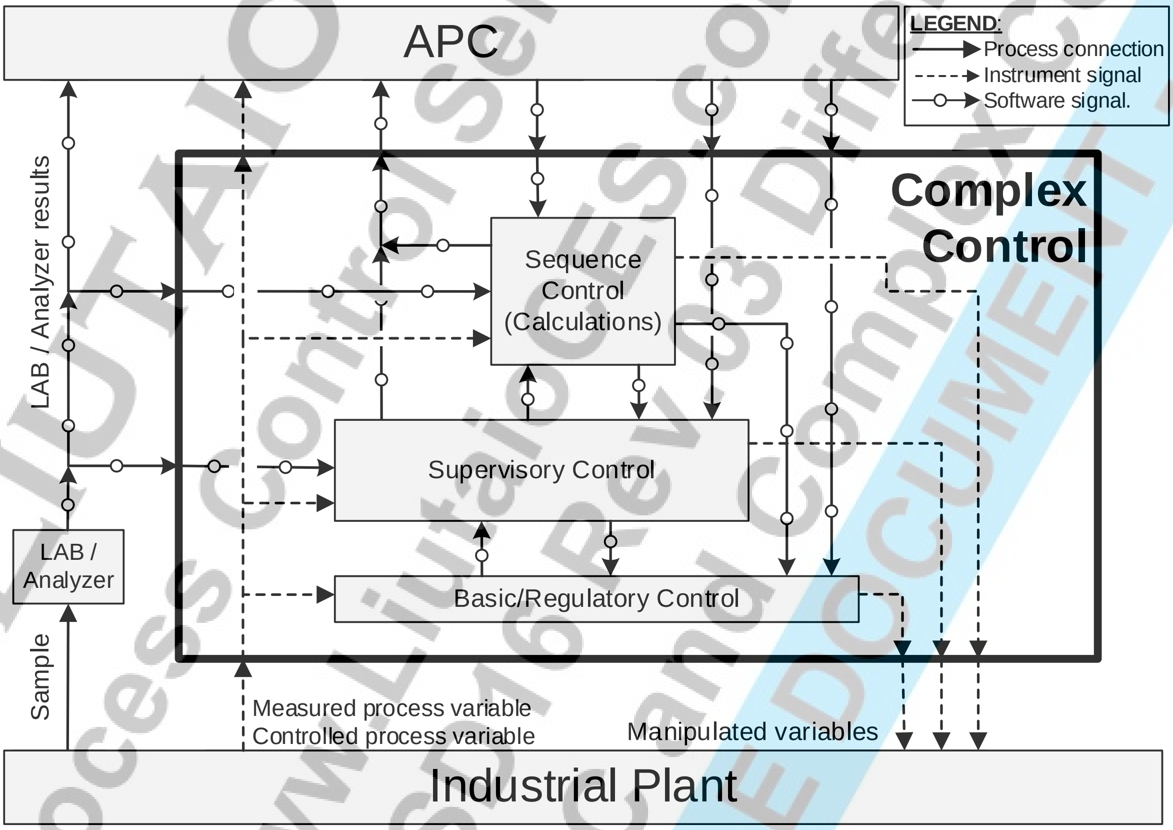
Since APC is supported as the resolution of an optimization problem:

a) The APC sample time (or execution frequency) uses to be every 30 min, or larger.
b) Sequence control is normally **NOT** included, but APC can command sequence.

In the market, APC technology is normally based on:

- “Multivariable Prediction Control” (MPC),
- “Dynamic Matrix Control” (DMC),
- “Linear Programming” (LP), or
- “Non-Linear Programming” (N-LP, Quadratic optimization, etc.).

Figure 1 – Combined APC and “Complex Control” sketch



7. “Complex Control” outline

“Complex Control” is a combined technology that normally is a combination of “Supervisory Control”, “Basic/Regulatory Control” and/or “Sequence Control”.

“Complex Control is located at a lower level below APC. Refer to Figure 1 for a combined APC and “Complex Control” sketch.

As APC, “Complex Control” can handle a plant model and process constraints, but **NOT** an objective function. This means “Complex Control” can keep the plant operation at pre-defined operation condition, maintaining “Stable Plant Operation” against plant upsets and operation mode changes (or setpoint changes).

“Complex Control” sample time (or execution time) can reach in practice up to a minimum of every 100 milliseconds. Normal sample time uses to be every second.

8. Comparison between APC and "Complex Control"

Refer to below section 9 and 10 for APC and "Complex Control" examples, respectively.

Table 1 - Comparison between APC and "Complex Control

No.	Description	APC	Complex Control
	General Comparison		
1	Is "Sequence control" included ?	**No** But can command	Yes
2	Are "Supervisory Control" and "Basic/Regulatory control" included ?	**No** But can command	Yes
3	Is objective function included ?	Yes	No
4	Is plant model included ?	Yes	Possible, if required
5	Can process constraints be handled ?	Yes	Yes
6	Where is APC and "Complex Control" implemented?	Dedicated Server	Separate Server, or DCS, or combination
7	Can implementation be totally embedded in Control/Safeguarding system ?	No	Yes
	Process variables		
8	Direct Command of manipulated variables at the industrial plant	No **(1)**	Yes
9	Direct Command of manipulated variables at "Supervisory", "Basic/Regulatory" and/or "Sequence Control" control levels	Yes	Yes
10	Are command values to manipulated variables ALWAYS within "Operation Constraints" ?	Yes	Yes
11	Does control loop predict future behavior of plant variables ?	Yes	No
12	Handled number of measurement and/or controlled process variables	Unlimited (as required)	Unlimited (as required)
13	Handled number of manipulated variables	Unlimited (as required)	3 to 4 maximum (normally 1 or 2)
14	In case of malfunction of an instrument that provides one measured/controlled variable value, can control continue ?	Yes **(3)**	Yes/No **(4)**
15	"Complex Control" elements that are commanded by APC are normally in CAS, COMP, REMOTE or any other control mode.	Yes	Yes

No.	Description	APC	Complex Control
16	Can control loop continue operation if a control loop element is "Disconnected" from master command (APC or "Complex control") ? Sometimes this is described as: • In AUTO mode, or • In MANUAL mode, by Console Operator command	Yes/No **(4)**	Yes/No **(4)**
17	Can control loop continue operation if one(1) manipulated variable is "Disconnected" from the control loop command ? Sometimes this is described as: • In AUTO mode, or • In MANUAL mode, by Console Operator command	Yes	Maybe **(6)**
18	Can control loop continue operation when several manipulated variables are "Disconnected" from the control loop command ?	Yes (Advisor mode)	Maybe **(7)**
	Response time		
19	Minimum Sample time (or Maximum execution frequency)	Every 30 min	Every 100 msec **(2)**
20	Can all control loop elements operate at different execution frequencies (different sample times in the same control loop ?	Normally **NO**	Yes
21	Faster control loop time response to plant upsets ?	No	Yes
22	Can keep stable plant operation against plant upsets ?	No	Yes
23	Can control loop smooth change operation condition, or switch to other operation modes ? <u>In other words</u>, Does control loop promote harmonized operation of controlled variables ?	Yes	Yes
	Engage/Disengage with plant operation		
24	Can control loop be IN SERVICE at startup, just after safeguarding is in NORMAL state (Healthy) ?	No	Yes
25	Can control loop be IN SERVICE even when the plant is starting up?	No Automatic disconnection	Maybe **(7)**
26	Plant is tarting up, BUT it is at a minimum feed flow condition, Can control loop be IN SERVICE?	Yes	Maybe **(7)**
27	Can control loop be IN SERVICE even while process constraints are not satisfied, or Unstable condition?	Yes	Yes

No.	Description	APC	Complex Control
28	Can control loop be IN SERVICE when plant is starting up, but plant is within process constraints ? In other words, Can control loop be IN SERVICE when all required process constraints are satisfied ?	Yes	Yes
29	Is integration with safeguarding required on plant shutdown ?	No, just disconnection	No, just disconnection
30	Is integration with safeguarding required to facilitate plant smooth startup after shutdown ?	No **(5)**	Yes
31	Smooth changes in the manipulated variables is achieved by:	Maximum "Speed of Change" limitation in command signals	Application of smooth controller tuning to controllers in control loop, "Speed of Change", or both

NOTE 1 "Manipulated variables" are commanded through "Complex Control", "Supervisory Control", "Basic/Regulatory control" or "Sequence Control".

NOTE 2 Normal sample time uses to be every 1 second.

NOTE 3 If functionality was implemented, APC can continue in case of malfunction of an instrument that provides one measured/controlled variable. Last good value will be used.

NOTE 4 Alternative control modes shall be provided.

NOTE 5 APC is monitoring plant operation and should indicate when it can be activated. Upon activation APC shall start to control plant from current plant operation condition.

NOTE 6 "Complex Control" can operate with one(1) manipulated variable in MANUAL mode, ONLY if this consideration was included in the control loop design.

NOTE 7 Depending on process plant, it can be allowed or not to use "Complex Control" with one(1) or more manipulated variable in MANUAL mode. ONLY if provision was included in the control loop design.

9. APC example

Figure 2 – Typical FCC reactor-regenerator arrangement

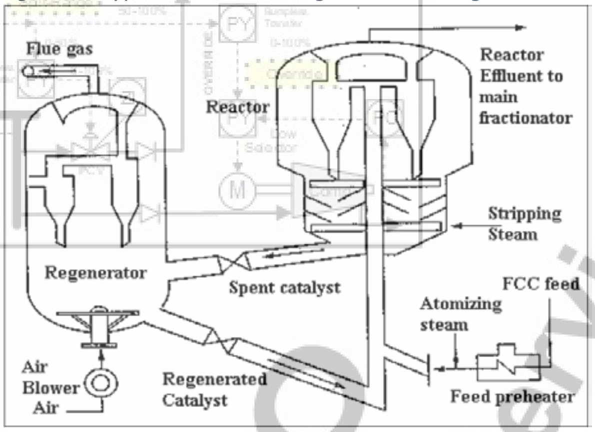


Figure 3 – Typical FCC main fractionator configuration

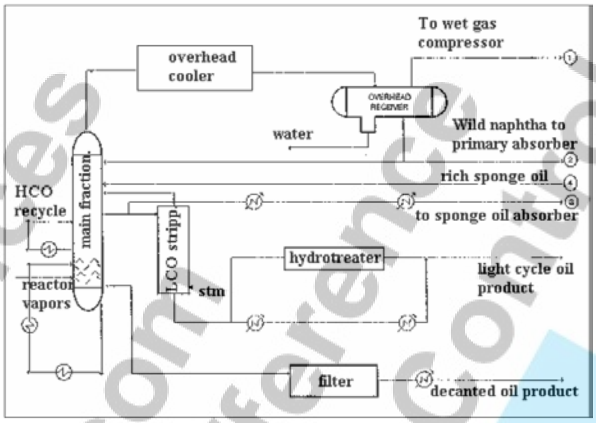
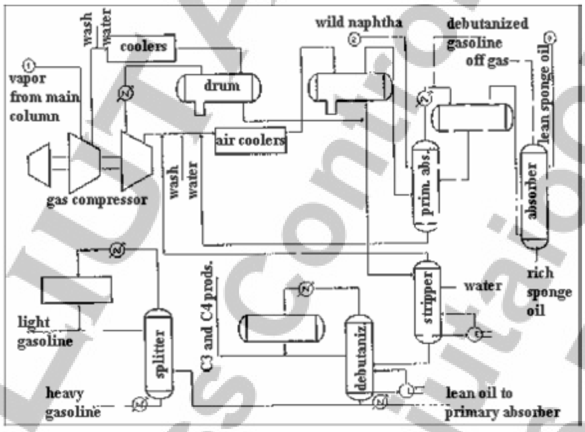


Figure 4 – Typical FCC gas concentration (GASCON) plant configuration



The Fluidized Cracking Catalytic Unit (FCCU) is one of the most important plants of a modern high-conversion refinery. It produces the bulk of high quality naphtha blending components from low quality feeds. Even small improvements in the operation of such units' impact on the overall refinery economics. See reference [3].

APC technology was applied to an FCCU, including the gas concentration plant. Figure 2, Figure 3 and Figure 4 shows general schematics of a typical FCCU.

The APC control structure of the plant consists in three(3) MPC covering the number of manipulated, feedforward and controlled variables that are shown in Table 2.

Table 2 – Number of manipulated, feedforward and controlled variables for a typical MPC implementation in a FCCU

#	Description	Number Manipulated variables	Number Feedforward variables	Number Constraint variables
1	Reactor, Regenerator, Main fractionator	24	14	62
2	Gas Concentration	8	8	19
3	Depropanizer column	4	3	10

From a personal experience in a FCCU like the described above, I want to mention that once the FCCU were in the "Ready To Load" condition (it means all unit within operation constraints):

a) To feed up the unit from ZERO(0.0) to normal operation feed rate, the manual procedure used to take 36-40 hours.
b) The APC implementation allowed to feed up the unit in 8 hours.
c) APC implementation sample time was every 30 min.

10. "Complex Control" example

A single centrifugal compressor is used to rise the pressure from one plant output, before it is fed to another plant.

The single compressor "Complex Control" loop structure consists of:

- Anti-Surge control loop.
- Compressor Load control.
- Integrated compressor Load-Anti-Surge control.

The constraint variables are clearly indicated in compressor sketch in "APPENDIX A".

For this "Complex control" loop implementation, the Compressor's "Startup Sequence" starts and prepares the compressor for operation up to the "Ready To Load" condition (it means all unit within operation constraints), next the Compressor's "Complex Control" loop rises the compressor load up to the required gas discharge pressure.

A separate control loop at the inlet of the downstream plant control the feed flow to that plant.

For this compressor control implementation:

a) Anti-Surge control is executed every 100 msec.
b) The rest of the "Complex Control" loop is executed every 1.0 sec.

Table 3 – Number of manipulated, feedforward and controlled variables for a typical single compressor "Complex Control" loop

#	Description	Number Manipulated variables	Number Feedforward variables	Number Constraint variables
1	Single compressor	2	[redacted]	7

APPENDIX A – Single compressor "Complex Control" loop sketch