<Ind> <Rev>

Technical Information

TI 36J06D10-01E

ADVANCED PROCESS
CONTROL SOLUTIONS

Exasmoc

YOKOGAWA

Yokogawa Electric Corporation
2-9-32, Nakacho, Musashino-shi, Tokyo, 180-8750 Japan
Tel.: 81-422-52-6323 Fax.: 81-422-52-5994

TI 36J06D10-01E

1st Edition Oct. 2001

Blank Page

ADVANCED PROCESS CONTROL SOLUTIONS
Exasmoc

TI 36J06D10-01E

CONTENTS

Glossary 1

1. General Introduction to MVC and MPC 1-1
   - 1.1 What is a Multi Variable Controller (MVC)? 1-1
   - 1.2 Why is a Multi Variable Model Predictive Optimising Controller necessary? 1-2
     - 1.2.1 Objectives of Multi Variable Controllers 1-4
   - 1.3 Brief Introduction to Model Predictive Control Techniques 1-5
2. Product Concept 2-1
   - 2.1 What does an APC do? 2-1
   - 2.2 Benefits of Implementing APC 2-2
   - 2.3 Points to consider while selecting an APC 2-5
   - 2.4 Exasmoc's Answers 2-6
3. Product Overview 3-1
   - 3.1 System Description 3-2
4. System Configuration and Integration 4-1
   - 4.1 System Integration 4-2
   - 4.2 System Integration with other DCS 4-6
5. Features of AIDA 5-1
   - 5.1 Advanced Identification and Analysis (AIDA) 5-1
     - 5.1.1 General Technical Description 5-1
     - 5.1.2 Features of AIDA Modelling Package 5-1
     - 5.1.3 Advantages of using AIDA Modeling Package 5-2
       - 5.1.3.1 Model Structure 5-2
     - 5.1.4 Demonstration of power and flexibility of AIDA 5-3
6. Features of Exasmoc 6-1
   - 6.1 Some common terminology 6-1
   - 6.2 Features of Exasmoc Optimising Controller 6-2
   - 6.3 Advantages of using Exasmoc 6-3
   - 6.4 Advanced Features of Exasmoc Controllers 6-9

7. Project Execution Steps 7-1

8. Examples of APC Implementation 8-1

8.1 Benefits of APC in a Crude Unit 8-2

8.2 Benefits of APC in Fluidised Catalytic Cracking Unit 8-4

Glossary

APC	**A**dvanced **P**rocess **C**ontrol
AIDA	**A**dvanced **Id**entification and **A**nalysis
MVC	**M**ulti **V**ariable **C**ontroller
MPC	**M**odel **P**redictive **C**ontroller
SMOC	**S**hell **M**ulti variable **O**ptimizing **C**ontroller
Exasmoc	On-line SMOC
POV	**P**rocess **O**utput **V**ariable
MV	**M**anipulated **V**ariable
DV	**D**isturbance **V**ariable
CV	**C**ontrolled **V**ariable
SISO	**S**ingle **I**nput **S**ingle **O**utput
MIMO	**M**ultiple **I**nput **M**ultiple **O**utput
BRC	**B**ase **R**egulatory **C**ontrol
ERC	**E**nhanced **R**egulatory **C**ontrol
EV	**E**conomic **V**ariable
ESV	**E**conomic **S**et **V**alue
PCTP	**P**rocess **C**ontrol **T**echnology **P**ackage
FIR	**F**inite **I**mpulse **R**esponse
PRBS	**P**seudo **R**andom **B**inary **S**equence
RQE	**R**obust **Q**uality **E**stimator
PCT	**P**ressure **C**ompensated **T**emperature
ZCTL	**Z** **C**olumn **T**ray **L**oading
OPC	**O**LE for **P**rocess **C**ontrol
LP	**L**inear **P**rogramming
QP	**Q**uadratic **P**rogramming

Blank Page

1. General Introduction to MVC and MPC

1.1 What is a Multi Variable Controller (MVC)?

Most process controllers perform a familiar drill -- measure the variable of interest, decide if its value is acceptable, apply a corrective effort if necessary, and repeat. Industrial controllers generally make their decisions according to the ubiquitous proportional, integral, derivative (PID) algorithm that relies on a single sensor for measurement and a single actuator for corrective action. This single-variable-control routine works very well for a variety of control problems with process variables that can be manipulated independently. Fig 1-1 is a schematic representation of a single input, single output system.

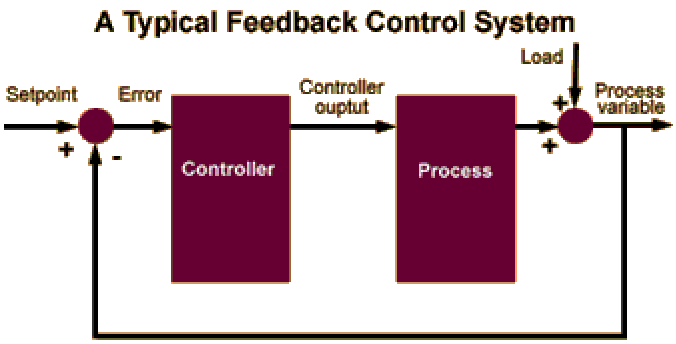


Fig 1-1 A single input single output system

In a process plant, it is only seldom that one encounters a situation where there is a one to one correspondence among manipulated and controlled variables. Given the relations between various interacting variables, constraints, and economic objectives, a multi variable controller is able to choose from several comfortable combinations of variables to manipulate and drive a process to its optimum limit and at the same time achieve the stated economic objectives. By balancing the actions of several actuators that each affect several process variables, a multivariable controller tries to maximize the performance of the process at the lowest possible cost. In a distillation column, for example, there can be several tightly coupled temperatures, pressures, and flow rates that must all be coordinated to maximize the quality of the distilled product.

1.2 Why is a Multi Variable Model Predictive Optimising Controller necessary?

Due to interactive nature of process variables, where change in one affects more than one related variable, it would be ideal to have a controller that is able to combine the operation of a number of single loop controllers. At the same time, this controller should also be able to choose, intelligently, a comfortable selective group of those variables whose manipulation will drive the object variable(s) to its or their optimum targets. Interaction among process variables is a very common situation encountered in many process plants. Often the selection of variables to be driven to their limits and extent of their manipulation is left to the subjective judgement, consequent of experience, of operator-in-charge. The selection is essentially a trade off between variables to be driven to their limits. This is largely because of the complexity of interactions among variables. This judgement, while not wrong from a process or operational viewpoint, may not be in sync with company's objectives or market demands. Every operator recognises the interaction among process variables. However, it is the impracticality of negotiating these variables to maintain an optimum condition at all times that force operator to maintain the variables at a "comfortable" location, away from their constraints. A direct result of this is that the operation is never at its optimum point.

This is where a Multi Variable Controller steps in to perform.

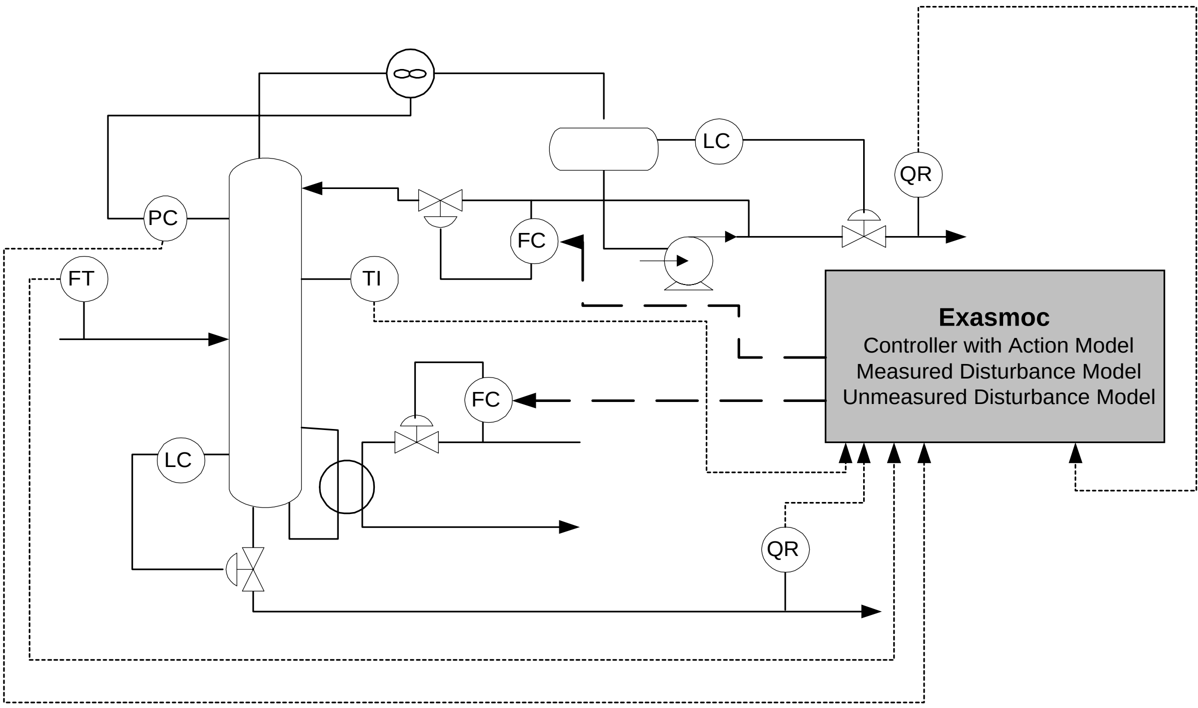


Fig 1-2 Flow scheme of a simple Depropanizer Column using a Multi Variable Model Predictive Controller like Exasmoc.

Fig 1-2 is a schematic of a depropaniser column. In the scheme above, the primary aims are to

- Reduce butane in column overhead
- Prevent slip of propane into butane at bottom

The two concentrations levels at top and bottom are themselves interactive. Further, the two are affected by reflux flow, reboiler steam and variations in feed flow and quality. A block diagram of the process below shows the interactions among process variables.

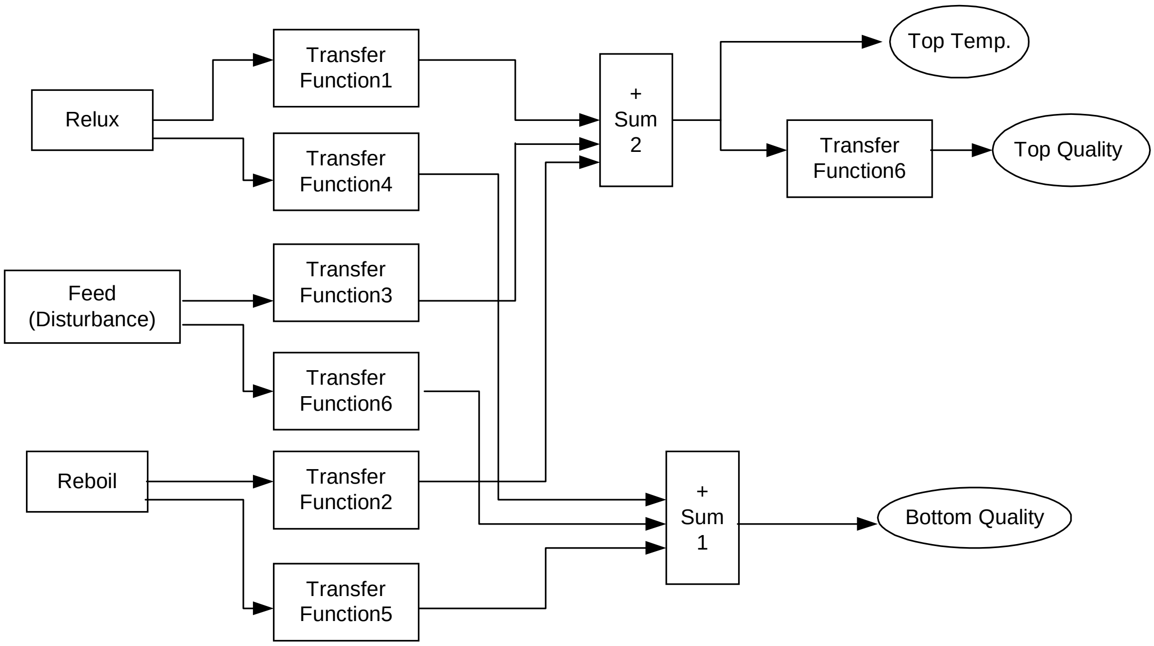


Fig 1-3 Block Diagram of Process

Fig 1-3 is the block diagram of depropaniser column in Fig 1-2. It represents the relationship among the variables in the process.

A variation in feed quality will change bottom composition sooner than it will affect top product. Once the controller senses the change in bottom quality, it will immediately calculate the changes to be made to reflux and reboiler steam flow rates to drive bottom quality to the set target. While arriving at the step values for reflux and steam flow rates that will drive bottom quality, the controller also takes cognizance of the effect of feed disturbance, reflux and steam flow on top quality. This way, top quality is kept under control.

If the controls were single loop controllers, one each for top quality and bottom quality, the column will swing because of interacting effects of change in steam flow and reflux flow on bottom and top qualities.

A multivariable control system can also take into account the cost of applying each control effort and the potential cost of not applying the correct control effort. Costs can include not only financial considerations, such as energy spent vs energy saved, but safety and health factors as well.

Once the basic aim of maintaining quality is achieved, the focus can be shifted to achieving economic targets. It is possible to set a constraint (of the more expensive product in cheaper product) thereby minimising loss of the more expensive product. While forcing the controller towards realizing this goal it can also be asked to look into the possibility of reducing reflux flow and reboil duties. All three goals set for the controller are dependent on one another. Yet, because it is a multi variable controller that has already been taught the effect of changing one variable on related variables, it keeps a check of the variables at each move.

1.2.1 Objectives of Multi Variable Controllers

We have just seen what the various tasks a multi variable controller needs to perform as a minimum. These are

- Prevent violation of input and output constraints
- Drive controlled variables to their steady state optimal values
- Drive manipulated variables to their steady state optimal values
- Prevent excessive movement of manipulated variables
- Push plant to optimal operation

1.3 Brief Introduction to Model Predictive Control Techniques

In order to drive a process to its operating target, we have to know how the process or plant will respond to each step change. A behavioural pattern of the process is therefore necessary to predict "Process status" for each change. This pattern is represented by a mathematical equation and is known as the "process model". Using this model, the controller makes a decision in real time the extent of move required for a manipulated variable that will move the process as close as possible to a reference trajectory. This is done at each control step and for the entire horizon. It is this predictive nature of the controller that enables it handle constraints, feed forward and allows us to incorporate abilities to handle noise etc.

Model Predictive Control algorithms are algorithms that compute a sequence of manipulated variable adjustments in order to optimise future behaviour of a plant. It uses a model to evaluate how control strategies will affect the future behaviour. It can deal with explicit constraints. After finding a good strategy, MPC pursues a strategy for one control step and then reevaluates its strategy based on plant's response. Simultaneously, it copes with amplitude constraints on inputs, outputs and states.

It is in effect a controller having a process response model inside, which enables it to predict the optimum manipulating output to get the desired process response. With this information, the controller drives a manipulated variable into steps that will ultimately drive a controlled variable to its target. All the while it checks for constraints, both on manipulated and controlled variables and any other that the operator may choose to define and specify.

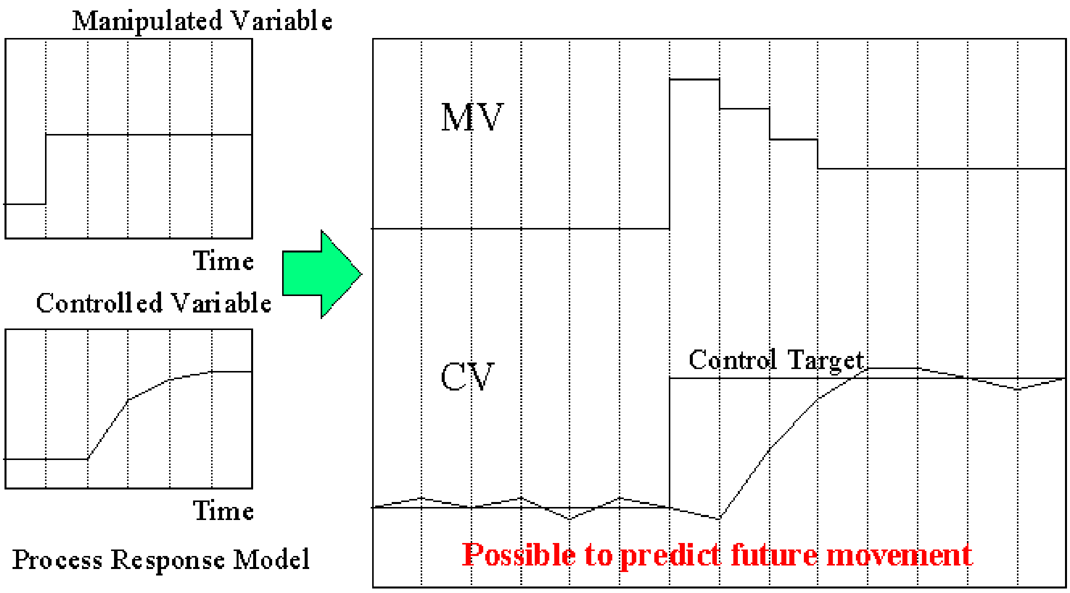


Fig 1-4 Action of a MPC on a controlled variable using a model.

Fig 1-4 shows how a model predictive controller is able to drive a controlled variable to its target by using a process model .A Model Predictive Controller is also able to handle processes with long dead time, inverse or integral response. A feedback mechanism makes it possible for the controller to constantly update its prediction model. It is typically suited to processes where large interactions among controlled and manipulated variables are witnessed. Fig 1-6 shows how a MPC moves a manipulated variable so that the controlled variable moves along a reference trajectory to minimise the error between target and actual value, at each execution step.

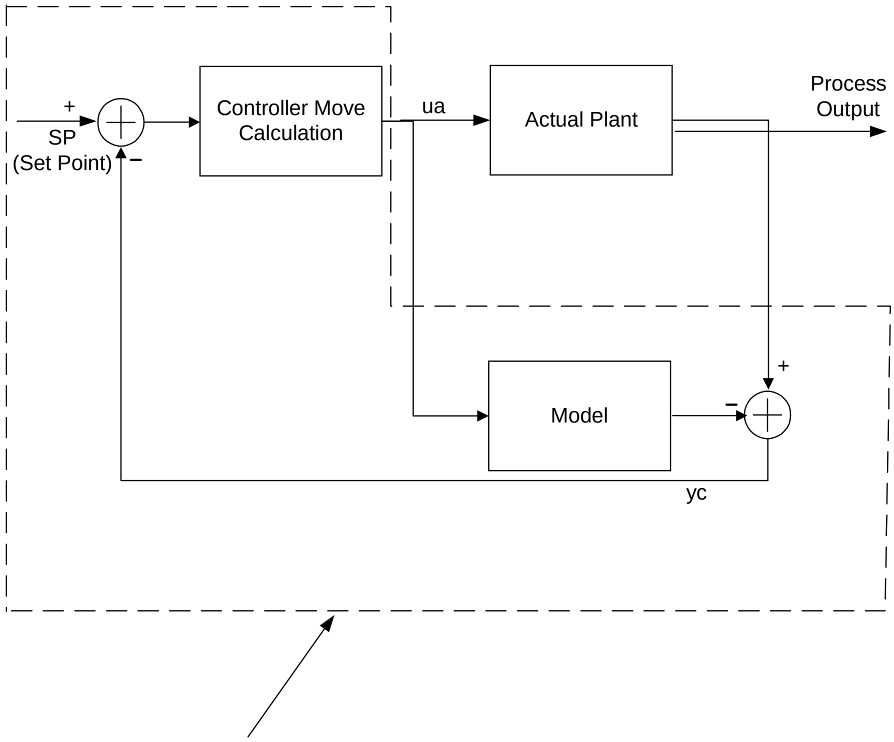


Fig 1-5 Block Diagram of a Model Predictive Controller

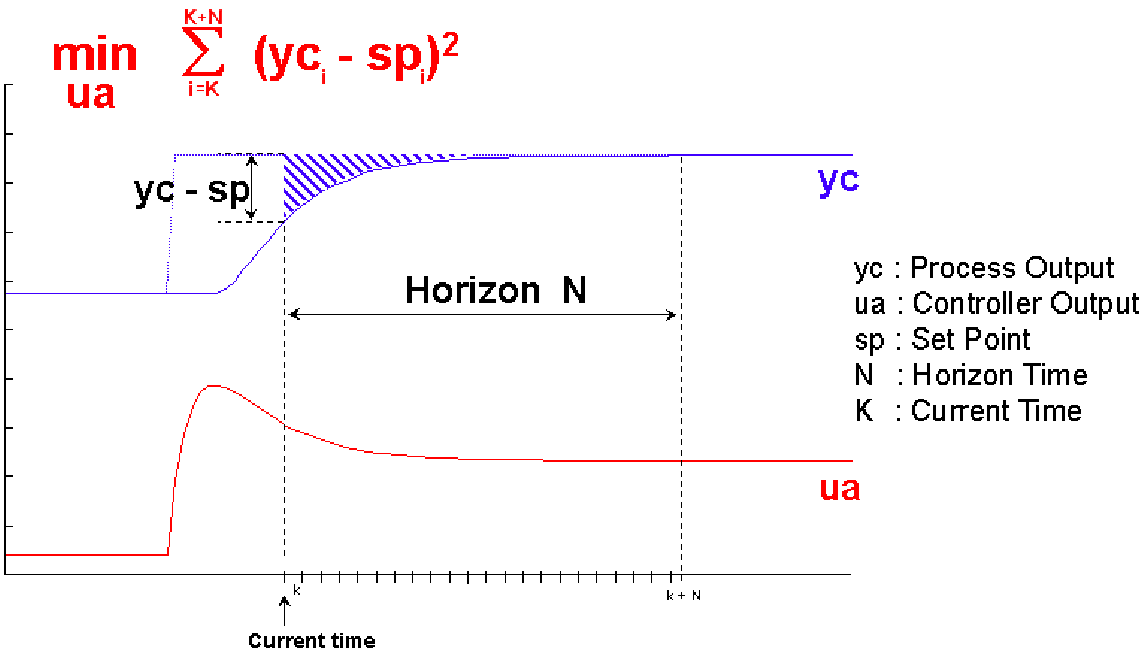


Fig 1-6 Aim of a Model Predictive Controller

2. Product Concept

2.1 What does an APC do?

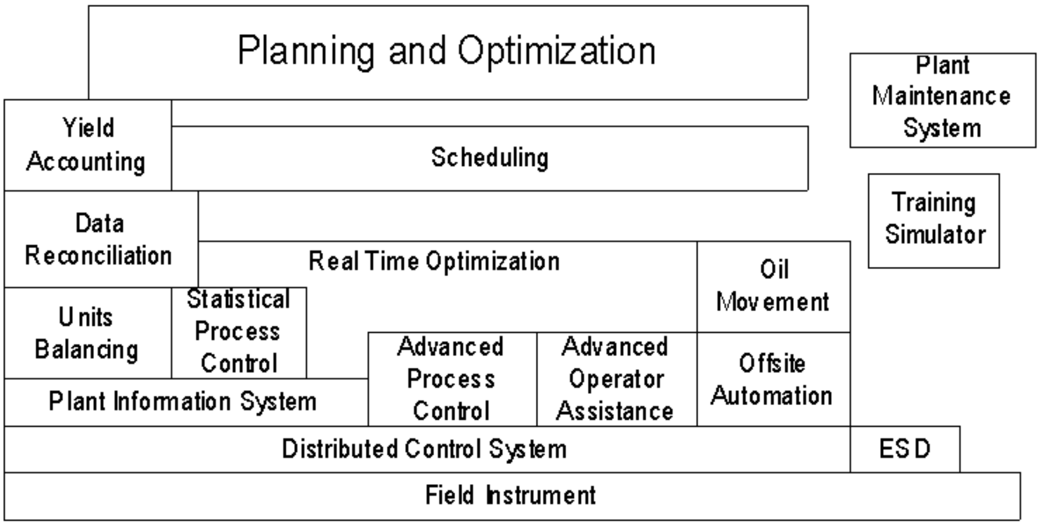


Fig 2-1 Position of Advanced Process Control in a Refinery

Figure 2-1 indicates position of Advanced Process Control (APC) in a refinery-wide set up. An APC is a multi-variable-model-predictive controller that sits above a regulatory control implemented in DCS. In its turn, it receives its set point from a real time optimizer. The tree can be extended upwards up to market forces.

In a hierarchical sense, an APC is a low-level controller. It takes cognisance of ground level realities or constraints and directs basic controllers, already provided, towards an optimum target. The direction or targets can be set by operator or higher level optimisers.

The principal aims of an APC are:

- Drive variables in a process to their optimum targets keeping in mind the interaction among variables.
- Effectively deal with constraints.
- Respond quickly to changes in optimum operating conditions
- Achieve economic objectives.

What are the advantages of using an APC besides simply driving multiple variables to a set target? What is the monetary attraction to implementing APC?

2.2 Benefits of Implementing APC

Each type of controller realises benefits for the user. As we move into realms of greater sophistication, the benefits are more.

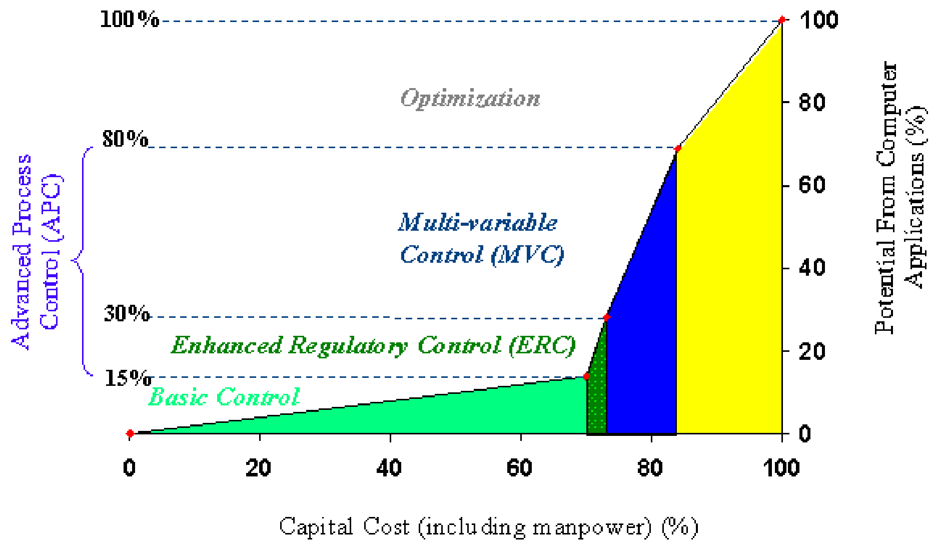


Fig 2-2 Expected costs v/s Benefits for different levels of controls

The immediate effect of making a move while keeping in view the amplitude of move and its consequence, is, a smoother operation. APC takes advantage of this. It pushes its controlled variables towards their constraints.

The real benefit from APC is obtained not just by reducing variations but by operating closer to constraints, as illustrated in Fig 2-3 below.

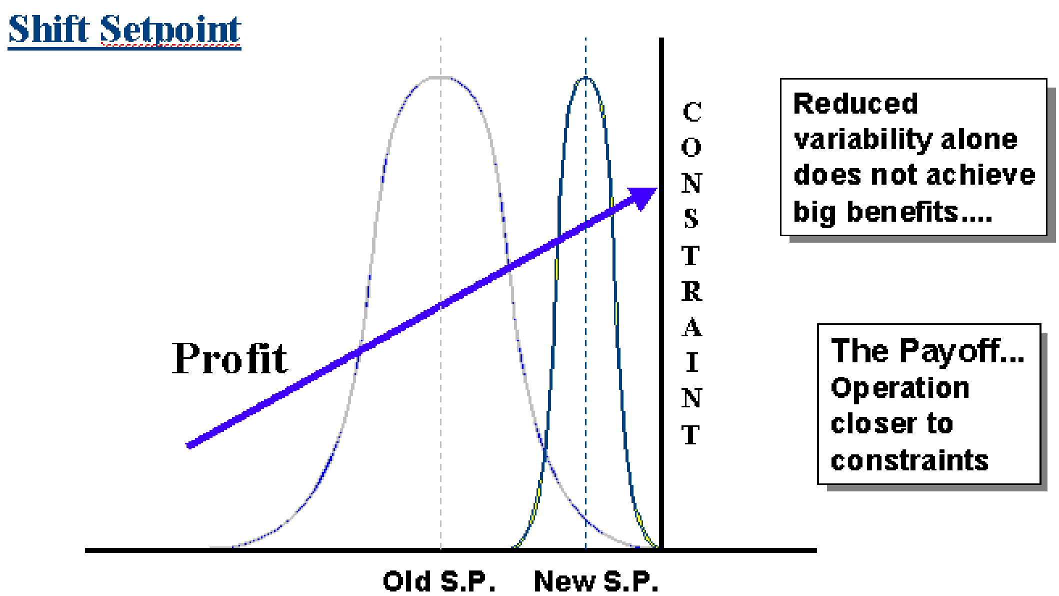


Fig 2-3 Reduced variability allows operation closer to constraints

The purpose of APC and an Optimization Feasibility Study is to determine the envelope of plant operability and control strategies that will drive the plant to run at the optimum, maximum yield or conversion and/or maximum throughput, while simultaneously honoring process, equipment and operating constraints.

In a crude unit, for example, large feed rates are commonly encountered.
An incremental change in the yield of profitable streams often generate very large annual benefits. However, the benefits achieved on a particular unit depend upon that unit's operating objectives and the plant environment.

The major benefits will come from some or all of the following general areas:

Increased throughput, to be achieved by better control of process parameters and the predictive controller's ability to exploit the hydraulic constraints wherever made available.

Managing Constraints like Furnace Capacity, Overhead Condensation, Heat Duties, Hydraulic limits, Column Flooding and Flaring.

Enhancing the unit performance by

Reduced Quality Give away against specification. When quality is a critical parameter, it is the general tendency to operate the plant at a condition where the average quality is better than necessary. It is cost to pay for being safe. With APC in place, the swings are reduced. This automatically translates into money due to reduced give aways.

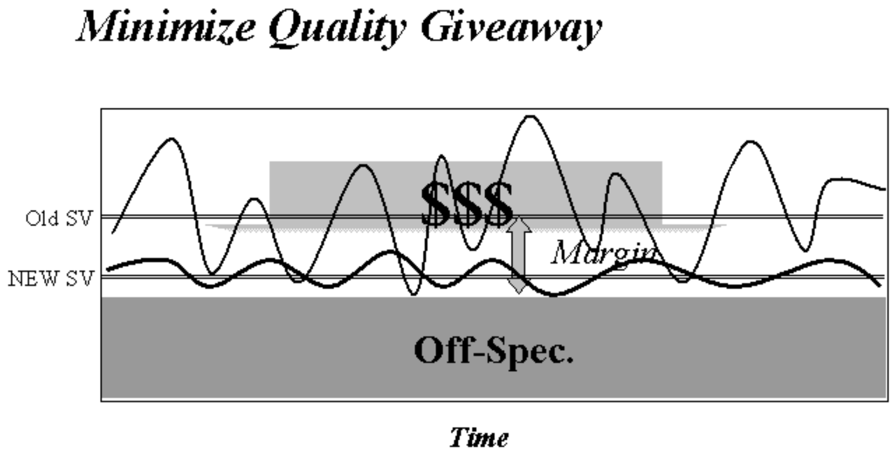


Fig 2-4 Reduced Quality Give Aways due to reduced variations

Increased production of more valuable products. In refineries where high value product is occasionally blended with low value products, it is imperative that only the requisite quantity of high value product be used. Any excess use is loss. APC with its smoothening effect minimises these losses while maintaining quality target.

Lower Pressure Operation. Generally, a distillation column operated at lower pressure means better separation and lower energy costs. Column operating pressure is dictated by cooling water temperature available to cool light components coming from top. APC can be configured to keep a constant watch on column top pressure or reflux temperature allowing the column to be operated at minimum possible pressure.

Less Flue Gas Oxygen. A typical case of multi variable controller. Target heater outlet temperature is maintained by simultaneously adjusting fuel rate and air flow rate (or excess oxygen). More oxygen or air implies lower hearth temperatures or higher fuel consumption for same heater outlet temperatures. Very low excess oxygen implies inefficient combustion or fuel loss.

Reduced Slop Make. APC not only minimise producing better quality product but also avoids making off-spec. product. Hereby it reduces slop make.

More Stable product quality for Blending or Downstream Unit

Reduced energy costs - lower fuel, steam and electricity usage and improved unit efficiencies.

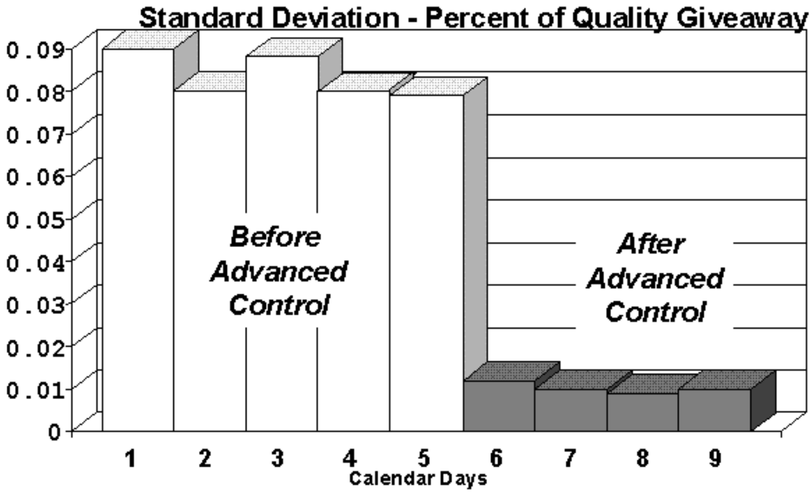


Fig 2-5 Reduction in Quality deviation after APC

Easier and smoother operation - less operator intervention. This will reduce their stress while more rapidly returning the process to normal operations and provides a smoother, faster, and better transition between different feed rates.

Reduction of reformer processing severity due to the reduced requirement for octane achieved by better Blend Property Controls.

Increased blender throughput as the need for reblends is reduced or eliminated. Potentially huge savings may be realized through reduction in operating incidents with the use of Blending APC solutions.

Reduced utility consumption (stripping steam, driving steam, air blower, etc.). When a column operates at lower pressures, reboil requirement is reduced.

Increased operating safety. This is in direct relation to uptime of APC. Higher uptimes signify less operator intervention in process. This reduces chances of error making process inherently safer.

Typical benefits obtained from a Reforming Unit are of the order of US¢ 10/bbl and the benefit range is US¢ 5-25/bbl of Unit feed. The figure when translated to Crude feed basis works out to US¢ 2/bbl. The major portion of this benefit comes from stabilizing the temperature profile, more stable stream qualities and improved control performance.

Implementation of APC/MVC in terms of Blend Property Control and Blend Ratio Control in the Blending area usually results in

Reduced quality giveaway

Optimum use of the more valuable components and additives

Reduced reblending requirements

Better usage of the available tankage.

Typical benefits range from US¢ 10-20/bbl of product.

With so many benefits, APC becomes an attractive proposition. Where are the pit falls?

2.3 Points to consider while selecting an APC

If one is earnest about deriving full benefits from APC, one should pay adequate attention to aspects of an APC package that provide for high uptime and easy maintainability. In the industry today, APC's are often silent spectators. The reason can generally be pinned down to lack of personnel with adequate knowledge of control theories, unwieldy models, lack of clarity and transparency in model and controller design and so on. One aspect of APC that is repeatedly ignored is the requirement to maintain it. It should be borne in mind that advanced controllers once they are designed and implemented also need to be maintained, just like any other piece of equipment such as a pump or compressor. How easy a controller is to handle, maintain or alter is determined by important factors such as

- Robustness
- How easily a controller adapts itself to changing process conditions. This directly influences extent of intervention required
- How easily it can be maintained, model updated or returned.
- How easily it can be remodelled, if necessary, for gross excursions in process conditions from what it is designed for.
- How one validates a model developed
- The peripherals that are required
- How easily it can be integrated with existing

2.4 Exasmoc's Answers

On all these counts, Exasmoc wins easily.

Exasmoc has been built with the end user in mind. In fact, it is designed by an end user. It is designed for use with minimal knowledge of control engineering. Knowledge of process and determination of control strategies are given greater importance. Because of this approach, controller design becomes "naturally" user-friendly. The over 400 applications bear ample testimony to the strength and flexibility inherent in Exasmoc. Description of their features such as "Grey box", "observer model", "intermediate variable", here below substantiate this.

The controller is "robust". Instead, of a simple bias updation that forces a controller to swing wildly with changes, Kalman filter is incorporated as error update mechanism. With this, the controller is able to handle changes easily. Controller action is smooth.

Easy model building and controller design tools are available. In a marked deviation from the customary controllers available in the market, the controller is viewed as a "Grey box" instead of as a "Black box". With the help of easy-to-use model building tools, the designer can build his process block by block. This approach makes it simple for the builder and for anyone else who may use it subsequently. The process can be built the way it is understood.

Possible to set economic targets for Exasmoc to optimize.

Excellent graphical features have been provided for model building. This assists one in understanding and appreciating the model he has developed. An added feature is statistical tools like F-statistics and confidence intervals that infuse a sense of self-assurance in the model developed.

PCTP operates in the familiar Windows 95/98/NT/2000 while Exasmoc operates in a Windows 2000 environment. Both these can be integrated into any existing environment with no difficulty.

3. Product Overview

AIDA, SMOC-PC and Exasmoc, provide the tools necessary to design, implement and maintain multivariable Advanced Control Strategies to effectively improve plant stability and maximise plant profitability in hydrocarbon processing and chemical industries.

Together, they can be said to belong to the general class of Multi Variable Model Predictive Optimising Controllers that can be used to identify a process and designed to drive process from one constrained steady state to another.

AIDA, **A**dvanced **I**dentification and **D**ata **A**nalysis package, this package is used to develop empirical process model between various interacting parameters

SMOC-PC, Off-line optimising controller used to design, simulate and tune the controller before the model and tuning parameters are downloaded to an on-line controller and

Exasmoc, On-line optimising controller that uses the downloaded parameters from SMOC-PC, communicates with DCS to drive the process to a constrained optimal steady state.

3.1 System Description

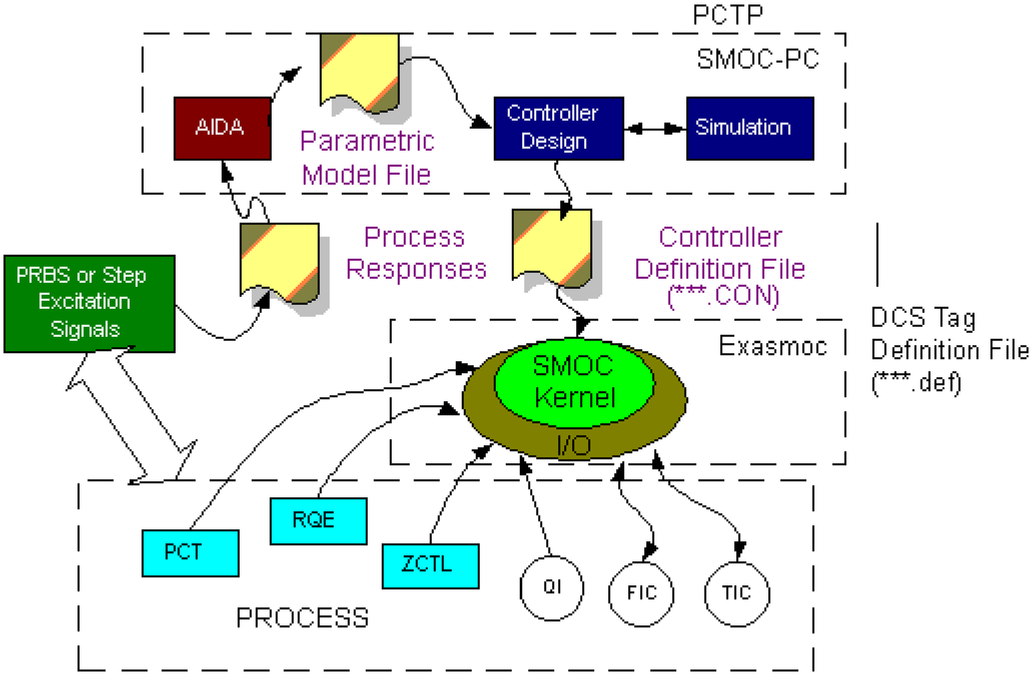


Fig 3-1 Information Flow between Plant, SMOC-PC and Exasmoc

Figure 3-1 above gives an idea of the level and extent of interactions that can be expected while operating an APC. Information has to be traded to and fro plant, will be analysed and used to develop controllers in an off-line environment and downloaded to an on-line controller. As a result, how this information flow is facilitated is decided and dependent largely on system employed at client's premises. This in turn influences system configuration.

4. System Configuration and Integration

We have a number of options available to suit any of client's configurations. The different possibilities are

- Integration with CENTUM CS 3000/CS 1000
- Integration with CENTUM CS/XL
- Integration with older versions of Yokogawa's systems
- Integration with other vendor system.

In each of the above possible configuration, it is possible either to provide two stations separately for Exaopc and Exasmoc or provide a single station wherein both Exaopc and Exasmoc will reside.

The principal components of an overall integrated system will be

- One PC running on Windows 95/98/NT/2000 for model building.
- One PC running on Windows 2000 that will act as Exasmoc station.

The difference in system configuration will be due to operating system of existing DCS, the communication network that is used by DCS and the corresponding communication protocol that needs to be established between DCS and Exasmoc station. To solve this problem, the Exaopc package provides an interface that is compliant with an OPC (OLE for Process Control Systems) standard interface developed by the OPC foundation. Exaopc is an OPC server running on Windows 2000, which can be connected to a variety of Process Control Systems and provides an OPC client with process data via OPC interface. With the package, the OPC client can acquire and define process data to and from Process Control and Exasmoc stations. While the Exasmoc station is connected to Ethernet bus, Exaopc is connected to both Ethernet via ethernet card and to the control bus.

4.1 System Integration

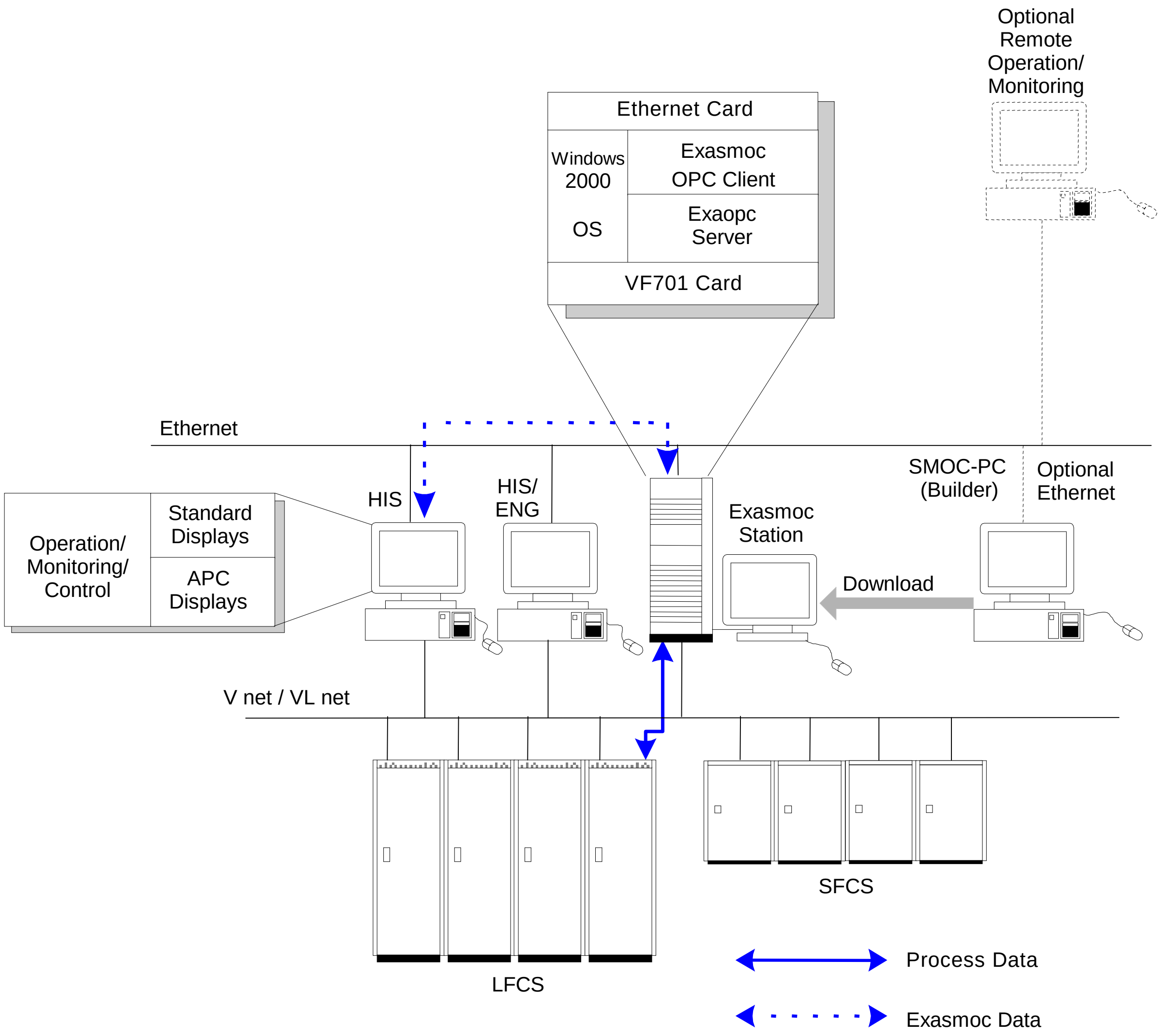


Fig 4-1 System Configuration when Integrating Exasmoc with CS 3000/CS 1000

Exasmoc Data	Data such as controller tuning parameters, weights, priorities, penalties for various controlled variables and economic variables, tags of different variables used in developing Exasmoc etc.
Process Data	Actual values of variables (manipulated, controlled, disturbance, etc.) that Exasmoc uses, constraints etc.

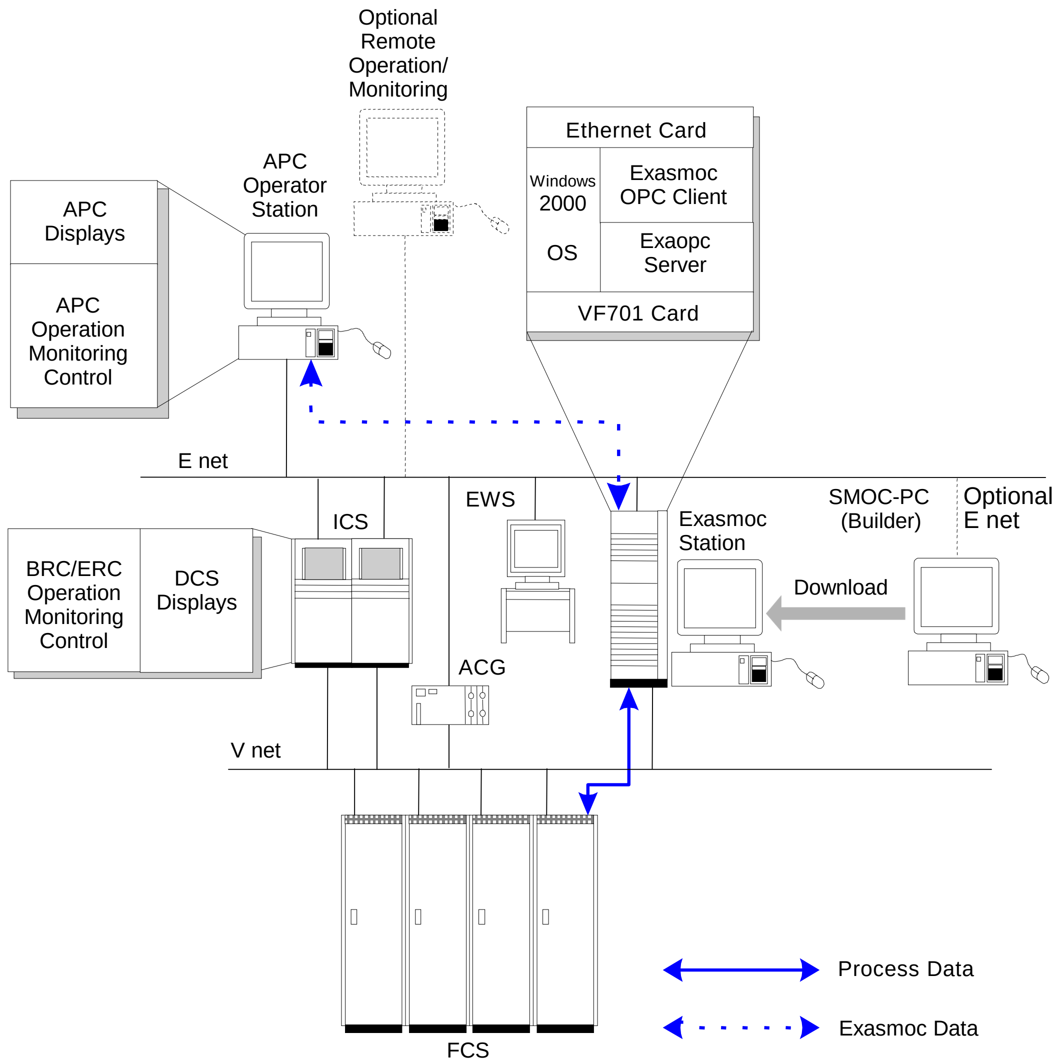


Fig 4-2 Configuration when Integrating Exasmoc with CENTUM CS

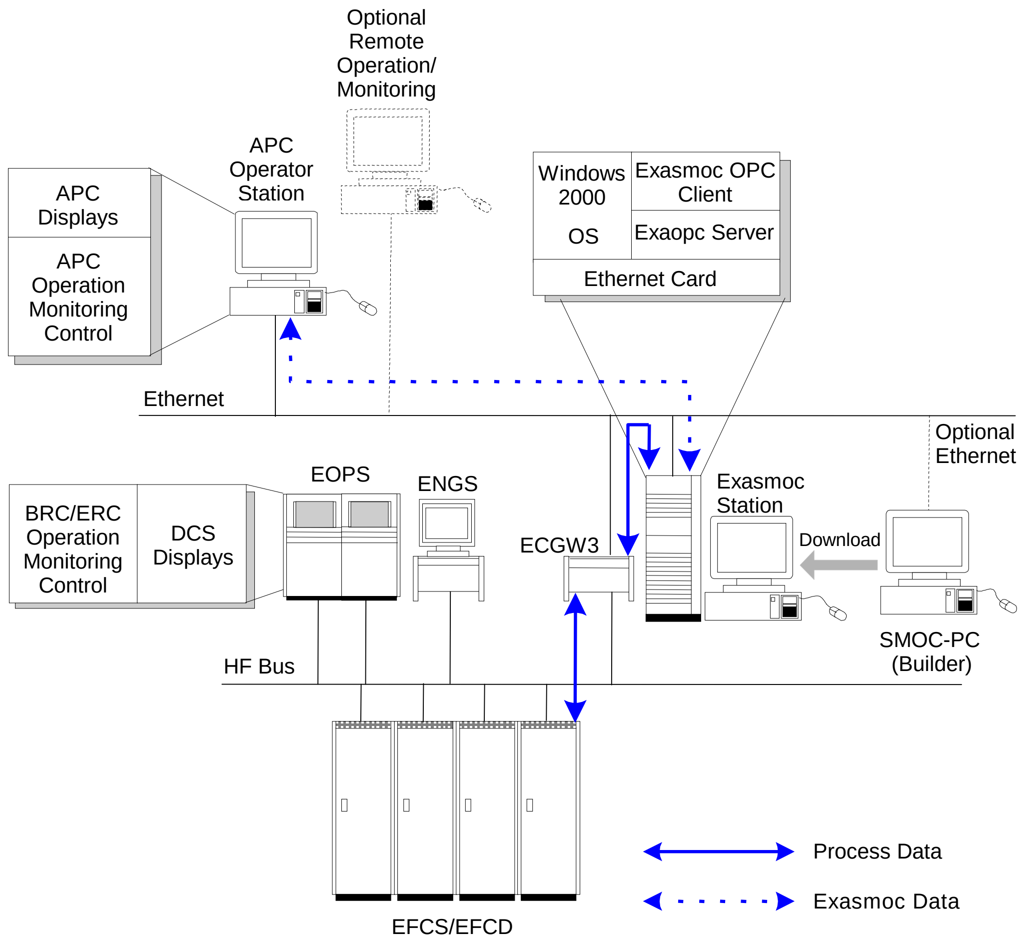


Fig 4-3 System configuration with CENTUM XL

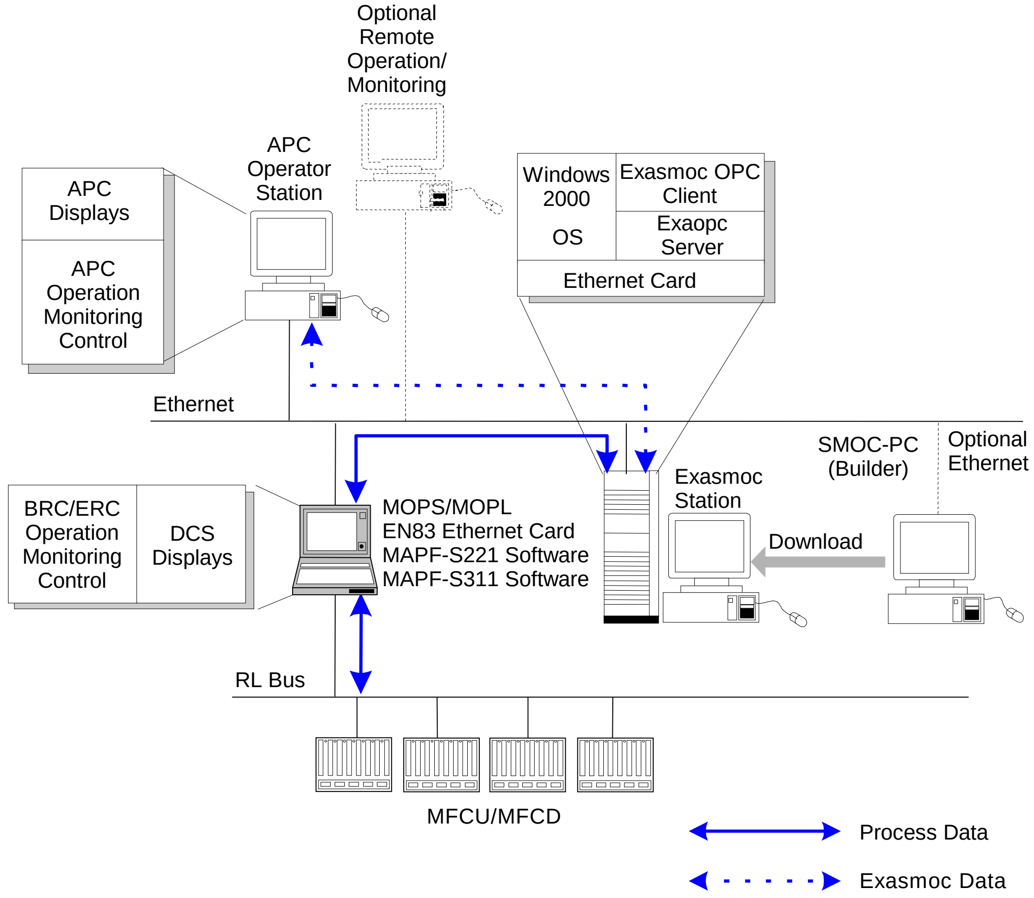


Fig 4-4 System configuration with µXL

4.2 System Integration with other DCS

In case there are other vendor DCS operating at client's premises, Exasmoc can still be easily integrated with the system by simply providing compatible OPC client software.

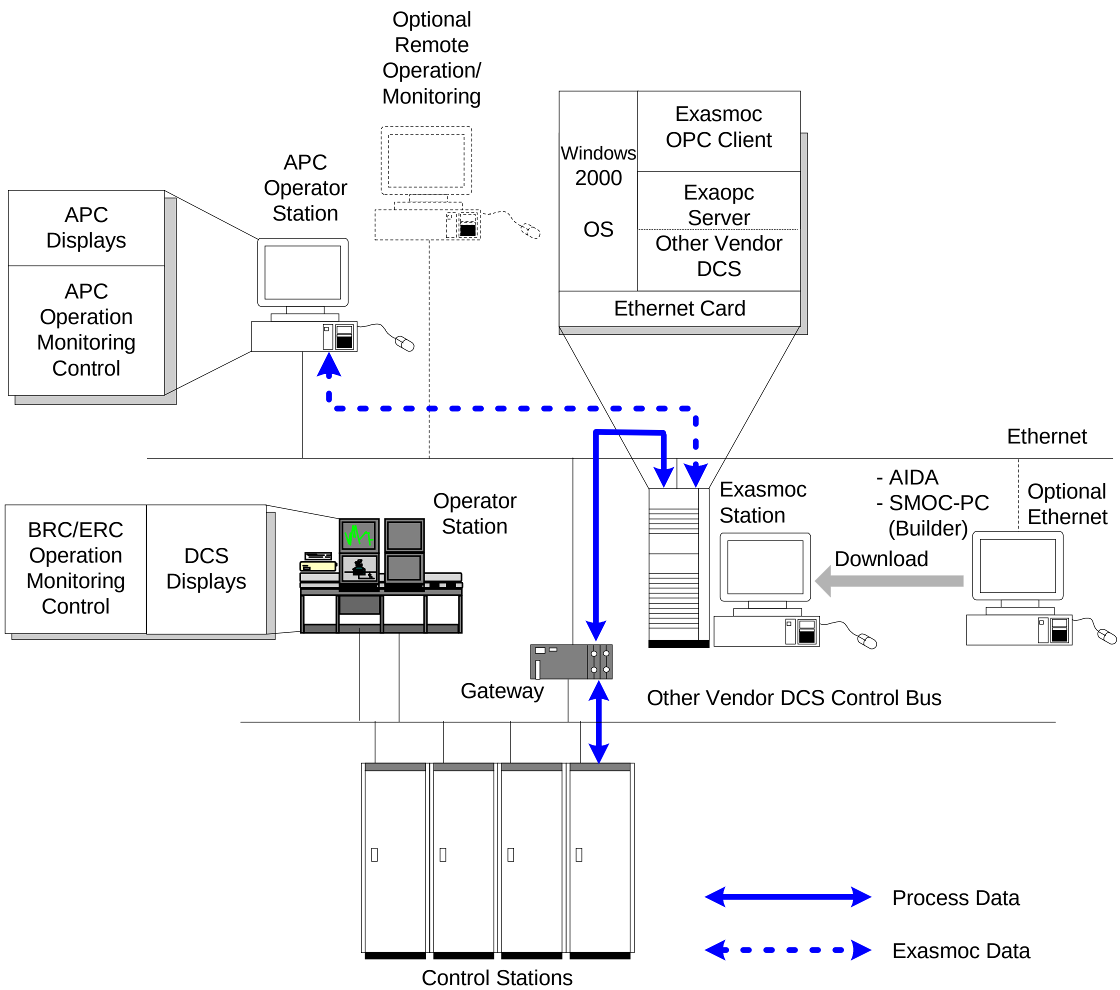


Fig 4-5 System configuration with other vendor DCS

Other vendor DCS — Each vendor of DCS uses a customised database management system. Since Exasmoc has to access and utilise this database, it has to be made available by the particular DCS vendor. Exaopc will be tailored based on information made available by vendor.

5. Features of AIDA

5.1 Advanced Identification and Analysis (AIDA)

The first and foremost task in designing a controller is to develop a model.
An "AIDA MODEL" is the behavioural representation of a process. It represents process behaviour to specific process inputs. AIDA establishes, mathematically, the relationship between input (manipulated) and output (controlled) variables. This is crucial in defining the scope of control algorithm. It should represent adequately aspects of system behaviour. And more. It should also be robust so that it invests the controller with sufficient flexibility to face uncertainties in the process.

5.1.1 General Technical Description

AIDA is a software package used to estimate a linear dynamic model for a process unit. AIDA is one component of Shell's Off-line Advanced Control general package PCTP (Process Control Technology Package). A linear dynamic model of a process unit is for instance required to implement a Model Predictive Control application such as Exasmoc.

Deriving a dynamic model for a plant on the basis of plant data is called "**Identification**". A plant test is performed on the unit of interest while process data is collected at a given sampling period, typically one minute. Collected data include the set-point of the plant operating handles (the process inputs, or manipulated variables), the plant operating variables that are affected by changes in the process inputs and for which there are regulation or optimisation objectives in the future advanced control scheme (the process outputs, or dependent variables), and a number of associated variables that provide information on the current plant conditions and help obtain a more accurate model (the measured disturbance variables).

AIDA generates a linear, dynamic, parametric model that could be a first order, second order or ramp. That is, plant data is used to establish the relationship between various interacting variables. It fits a discrete-time transfer function model and then converts it into a continuous (Laplace) transfer function. It then uses "white" noise to reflect unmeasured disturbances. This is a significant departure from what is normally used in the industry. All other models are developed using either step or impulse response. These models by nature, are sensitive to disturbances or can have excessive noise in them.

5.1.2 Features of AIDA Modelling Package

The essential features of **AIDA** modeling technique are:

- Laplace transfer function model (first order, second order or ramp)
- **Unmeasured disturbance and noise model**
- Automatic time delay estimation
- Option to set constraints on model parameters
- **Includes stochastic component**
- **Graphical model builder**
- **Good statistical tools to validate models**

5.1.3 Advantages of using AIDA Modeling Package

- Model accepts both step test and PRBS (Pseudo Random Binary Sequence).
- Advantage of using PRBS is
  - amplitude of test signal can be reduced by 20% to 50% of step response test.
  - Process disturbances do not affect experiment
  - Operator can move other inputs to control process while testing is underway
  - Time required for plant test is reduced.
- Generates a transfer function model and a noise model using Box and Jenkins method. This ensures that the transfer function model is free from effects of unmeasured disturbance and noise.
- Statistical tools available to validate model
- Accepts multiple data sets. This helps eliminate outliners from being used for modeling.

5.1.3.1 Model Structure

A plant model is developed by observing plant's response and behaviour to a step or impulse change made to input. The response and mathematical equation representing this response become the process model. Data collected from plant to indicate response is never free from noise. Therefore, a mathematical equation striving to represent this response inadvertently incorporates noise in its equation as if it were a response. Source of this noise could be any of process noise or measurement noise.

Secondly, in a multi-variable interacting environment, it is practically impossible to model the effect of all influencing input components.

Therefore, we need a model that is able to adequately represent process response while simultaneously rejecting uncertain components from data collected.

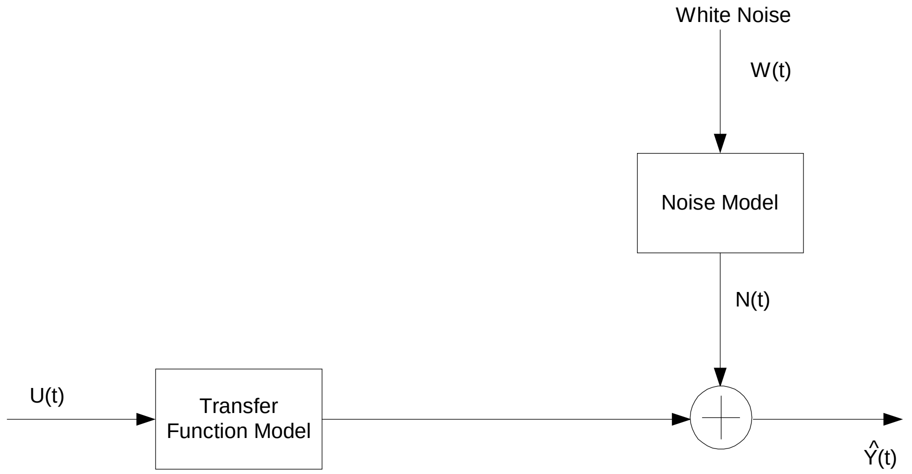


Fig 5-1 Block Diagram of AIDA Model Generation

5.1.4 Demonstration of power and flexibility of AIDA

By showing a series of examples, we will demonstrate the power and flexibility of AIDA package. Figure 5-2 below gives the system response to step changes made to a manipulated variable, the plot of values of a controlled variable to step changes in a manipulated variable.

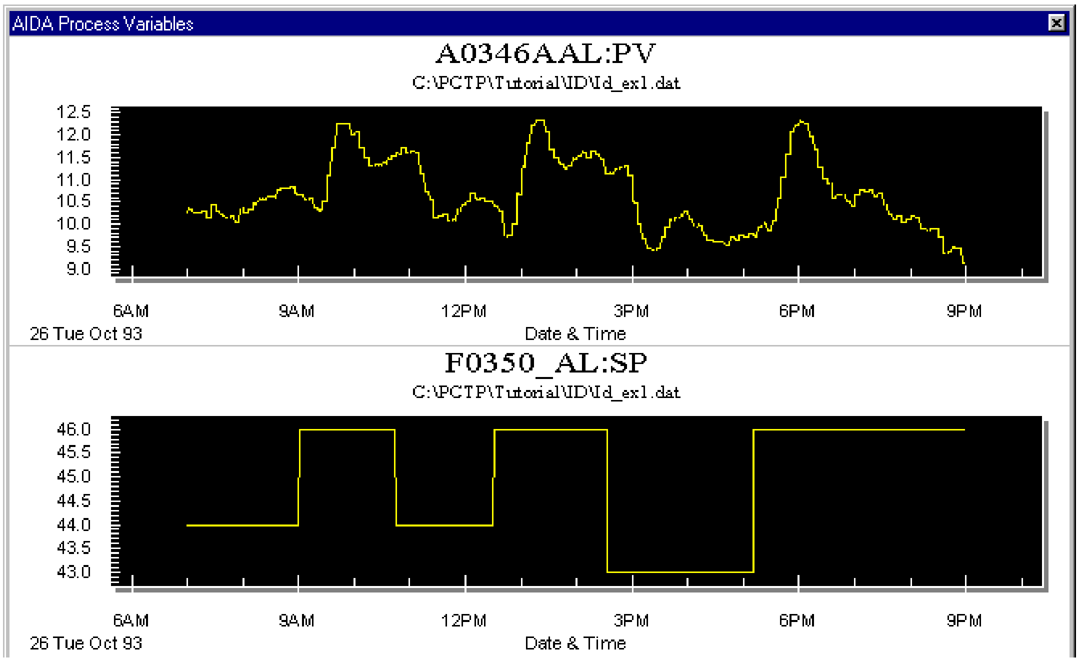


Fig 5-2 Plant step response model

Error Model

For this input, AIDA predicts model in two parts, one the deterministic part and the other is stochastic, or the undetermined parts, caused by say measurement inaccuracies or even process noise. The deterministic part is input to Exasmoc controller.

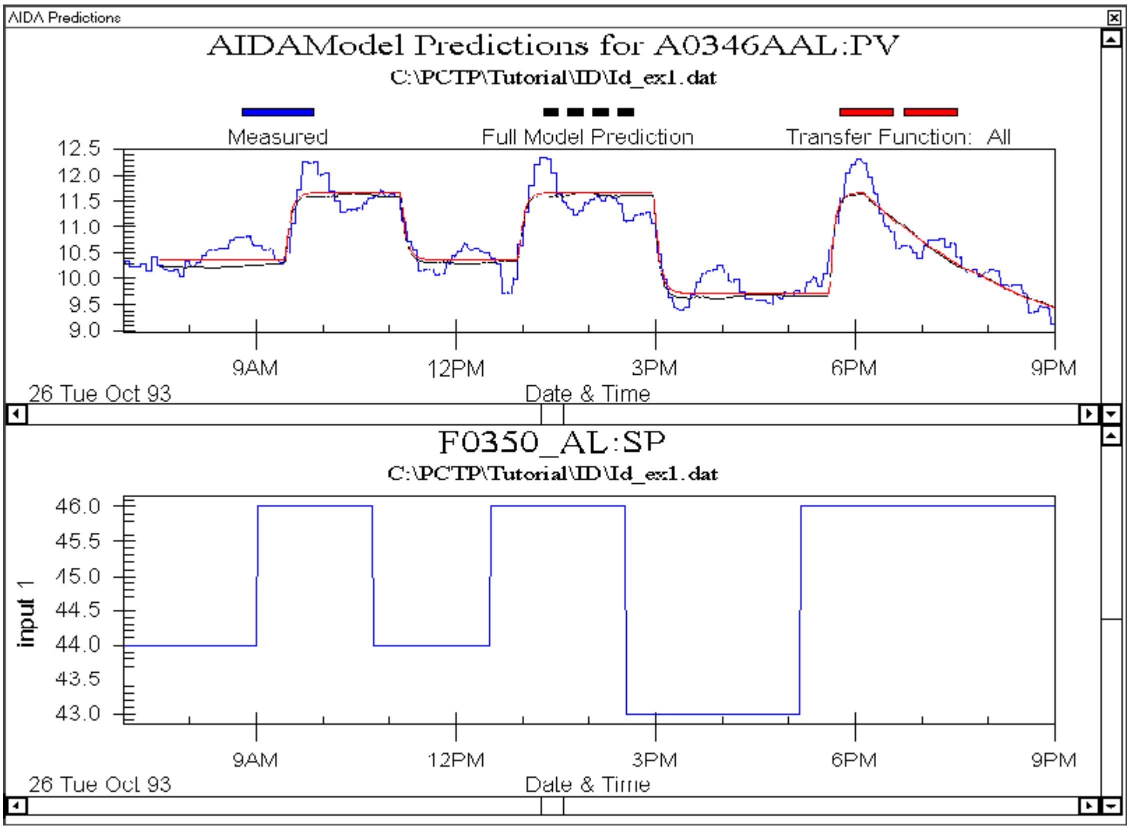


Fig 5-3 AIDA Model Prediction display

The noise model in the figure 5-3 is from unmeasured disturbance and noise in the data. This ensures that the transfer function model that will be used by Exasmoc is free from effects of noise and unmeasured disturbance.

Multiple Input Data

In AIDA it is possible to develop relationship between multiple inputs and output.

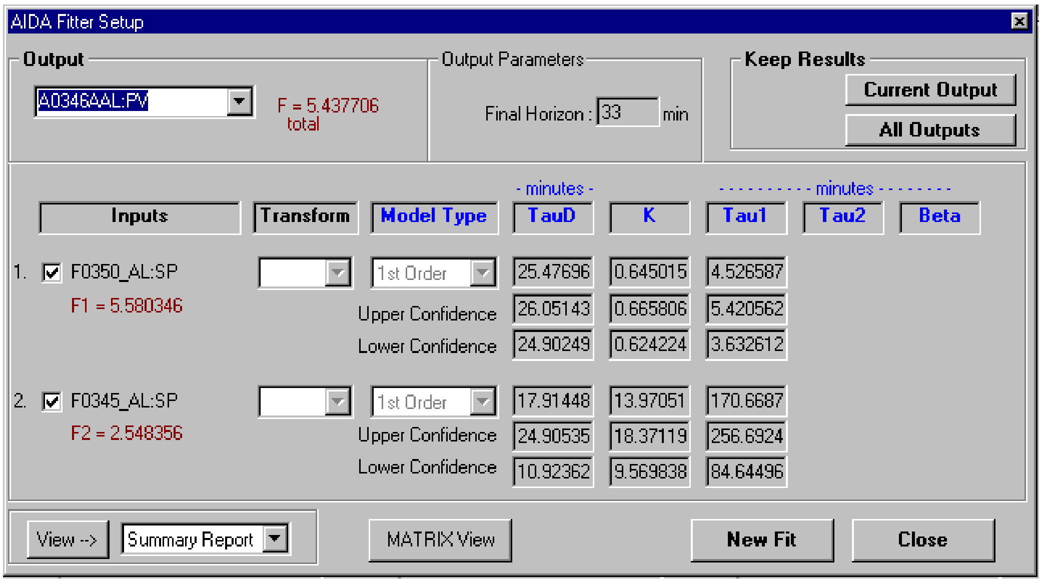


Fig 5-4 AIDA Fitter setup (Multiple Inputs)

Statistical Tool to validate model

From the figure above, one can get a feel of the "goodness" of model by using F-statistics. A value of over two indicates good model. It is also clear from inspecting F-statistics that extent of influence of one variable is much less in comparison to the other. By unchecking the relevant box and refitting the data, a new set of parameters can be obtained for one input variable.

Confidence Bands

AIDA calculates the 99 percent confidence bands for the model parameters. This allows one to judge the variability in the parameter estimates. Boosting the signal-to-noise ratio in the data set tightens the confidence bands in the parameters. The ratio may be boosted by increasing the magnitude of the input changes. Collecting more data which has the same level of excitation also tightens the confidence bands. One may choose either method to obtain better confidence bands. The choice is a tradeoff between higher perturbations of the outputs and inputs versus longer plant tests.

Confidence Bands on Coefficients

An Finite Impulse Response (FIR) algorithm generates the 95 percent confidence bands for the step response coefficients as well as estimates of these coefficients. The confidence bands are useful in judging the quality of the estimates. They are also useful in determining if the model has reached steady state, i.e. the last few step response coefficients are not changing. It is shown graphically in Fig 5-5.

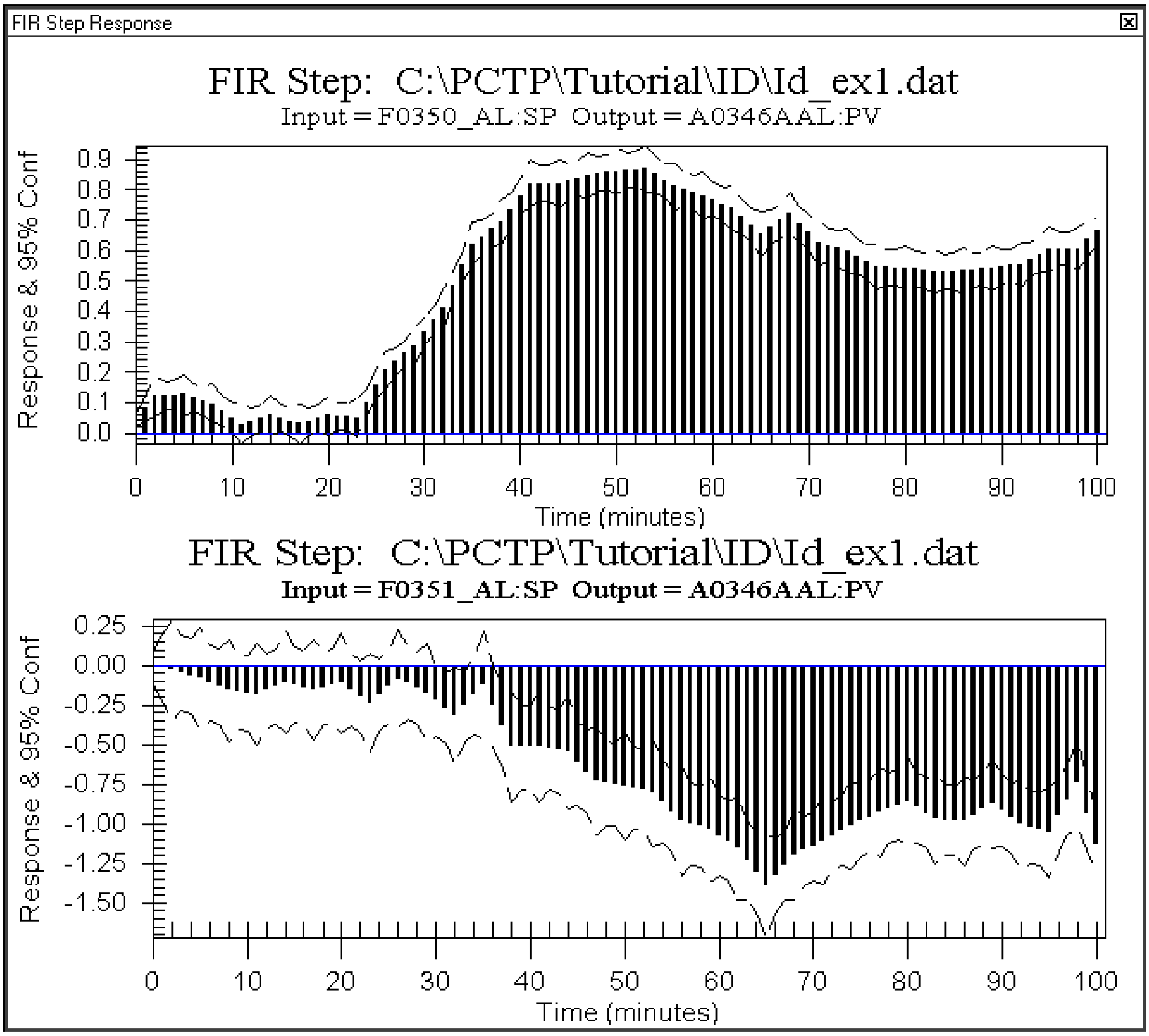


Fig 5-5 Confidence bands for step response.

Possible to freeze-unfreeze some or all parameters.

In AIDA it is possible to freeze some or all the parameters of a model. This tool can be used to validate parameters generated from one set of data by using it on another set of data.

Cross Correlation

This option allows one to plot the cross correlation function between the selected output and any inputs/general variables. This is a method for screening if the inputs/general variables have any effects on the output variable. Those that have more than two significant contiguous correlation coefficients are candidates for inclusion in the fit.

Visually and mathematically, AIDA instills a sense of confidence in the user. He can be doubly sure of the model he is developing. **It is easy, not only for the person who develops the model, but, also for anyone who may subsequently use it or called upon to remodel.**

6. Features of Exasmoc

Exasmoc controller is requires SMOC-PC, which is the off-line design and simulation package. It is a computer-based package designed for synthesis and simulation of linear, multivariable, model predictive controller, Exasmoc. It allows Process Control engineer to design and test Exasmoc controller prior to their implementation on an on-line system. The other is Exasmoc, which is the on-line package.

The different steps of Exasmoc controller development are

- Configure process models
- Configure controller objectives
- Set tuning factors
- Generate .def (DCS Tag definition file) and .con file (Controller definition file)
- Test controller by simulating
- If performance is adequate, download to on-line Exasmoc.

6.1 Some common terminology

Some of the more commonly used terminology in Exasmoc application are

POV: process output variables
Any variable whose behaviour will be predicted by Exasmoc

CV: controlled variables
Those variables that will be directly controlled by Exasmoc.
A CV is defined as a linear equation of a POV or POVs.

Intermediate Variable
Those not directly controlled but included to improve control performance (i.e., POV's but not CV's)

MV: Manipulated Variables
Those variables for manipulation by Exasmoc

DV: Disturbance Variables
Those variables are not available for manipulation but whose effects will be taken into account in Exasmoc

Action Model:
The effect of manipulated variables on process output variables

Measured disturbance model:
The effect of those disturbances that can be measured on process output variables

Unmeasured disturbance model:
The effect of those disturbances that cannot be measured (i.e., the source of the disturbances is not measured). It includes - stochastic/noise model, intermediate variables, disturbance, model component for integrating process

6.2 Features of Exasmoc Optimising Controller

- **In Exasmoc, it is possible for the user to configure the controller by setting up the process model. As opposed to the usual "Black Box" representation of a process for other MPC's, Exasmoc visualises it as a "Grey Box". This concept allows the user to develop block by block, the process. The user has the option of allowing Exasmoc to pick the model from AIDA or develop it himself.**

- **It is possible to define, in addition to CV's, MV's, DV's, another variable called Intermediate variable. Intermediate variable is used when a measure of that variable is indicative of a change of controlled variable in advance (for eg. column top temperature against top quality).**

- **Controller objectives can be easily set as "maximise", or "minimise". The optimiser within Exasmoc will automatically drive the variables towards this target without violating any constraints. (*1) It is user friendly.**

- **On-line update of model using Kalman filter. This updates on-line the error model called "observer model" providing for and more robust control. Fig 6-1 is block diagram of Kalman filter incorporated into control scheme.**

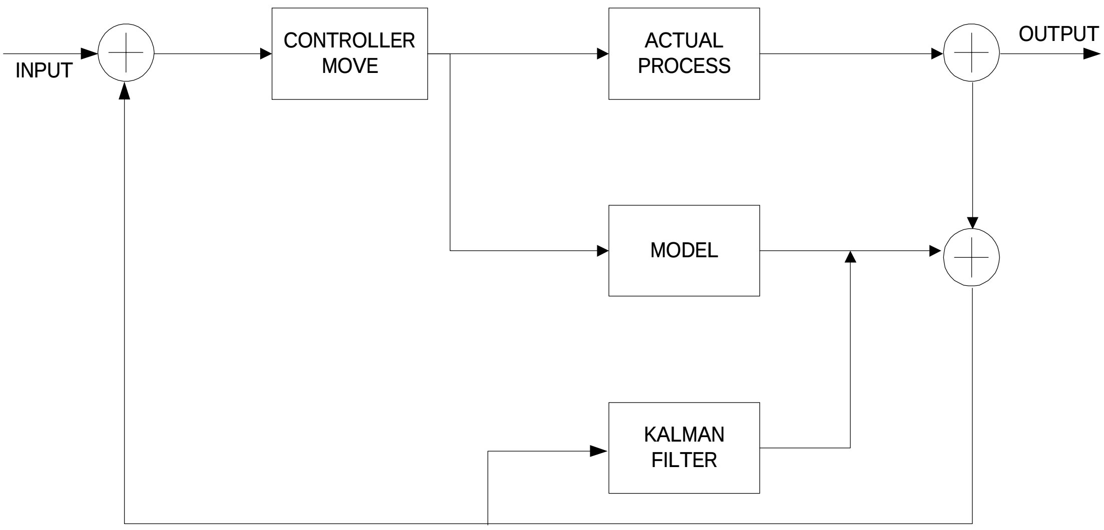


Fig 6-1 Block Diagram of Kalman Filter in Control scheme

*1: It allows for slogan and setvalue control and are online tunable.

6.3 Advantages of using Exasmoc

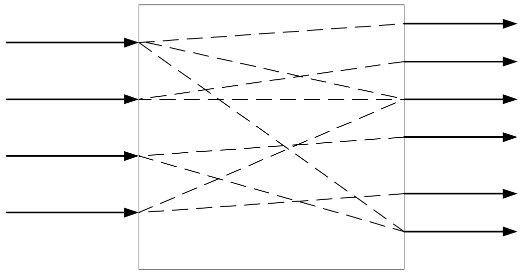


Fig 6-2a Traditional Black Box Model

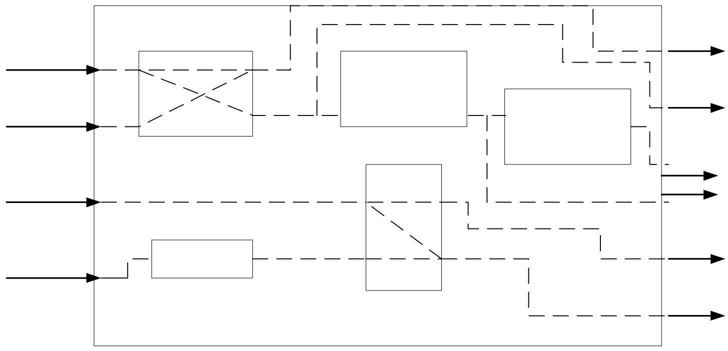


Fig 6-2b Gray Box Model

- The Grey Box model almost resembles a Process Flow Diagram. This model can be built by a Process Engineer, as he understands the process. It makes the process of developing the controller easier, simpler and faster. A very big advantage of "Grey Box" modeling is its transparency. It is easy to tune transfer function parameters by closely observing plant behaviour. Interactions among process variables is lucidly presented making model intelligible for all.
- A variable defined between a manipulated and controlled variable is an "intermediate variable". That is, this variable has a relationship with both the manipulated and controlled variable. Example of an intermediate variable is top temperature of a distillation column. This has relationship with reflux (a manipulate variable) and top quality (controlled variable). By defining an intermediate variable, Exasmoc is able to take action to maintain a controlled variable at its target when it notices a change in intermediate variable, before the controlled variable moves away from its target.
- When building Exasmoc models it is a standard function to include "intermediate variables".

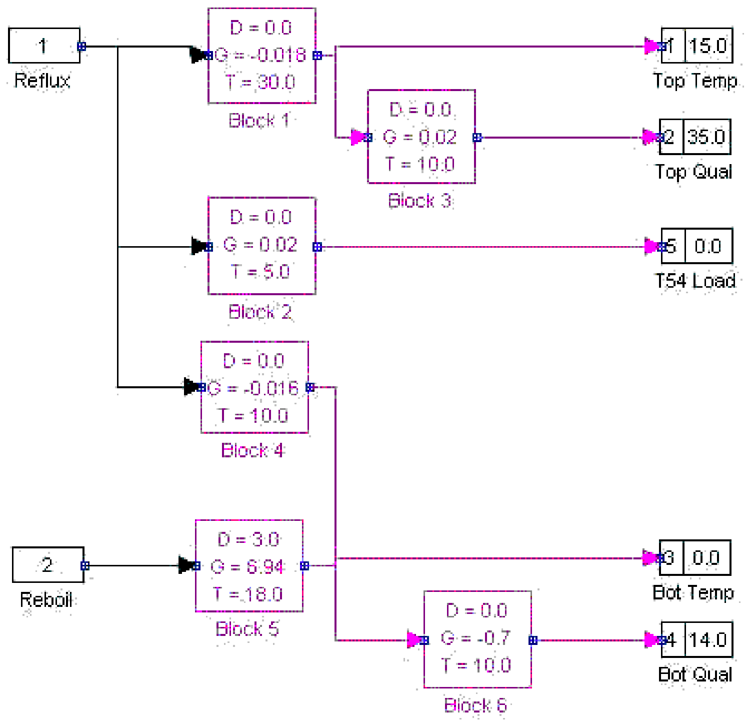


Fig 6-3 SMOC-PC's Graphical Builder

The figure 6-3 depicting SMOC-PC's graphical builder is a picture of clarity. The interactions that were considered at the time of modelling the controller are easily understood by any one. Any model parameter can be effortlessly changed.

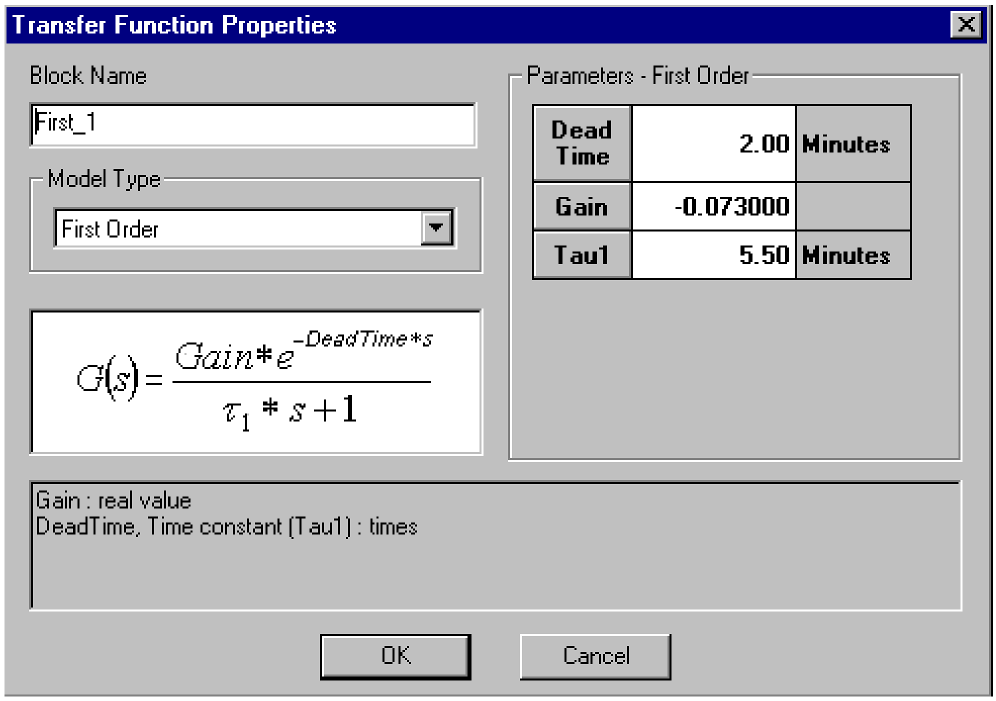


Fig 6-4 SMOC-PC's Graphical Builder

There are separate models for measured disturbance and unmeasured disturbance. A measured disturbance model is a kind of feed forward controller that takes into consideration influence of parameters not within the control purview of a defined controller. Controller acts to move all controlled and manipulated variables when it senses a movement of its disturbance variable. Unlike a disturbance variable, which though outside of controller's jurisdiction is still measurable and predictable, an unmeasured disturbance is unpredictable and random, with no clear-cut dynamics. These arise out of errors in model prediction, vagaries of measurement disturbance or even process noise. These are easily handled by unmeasured disturbance model based on Kalman filter mechanism.

The figures 6-5 and 6-6 below explain both of above significant features

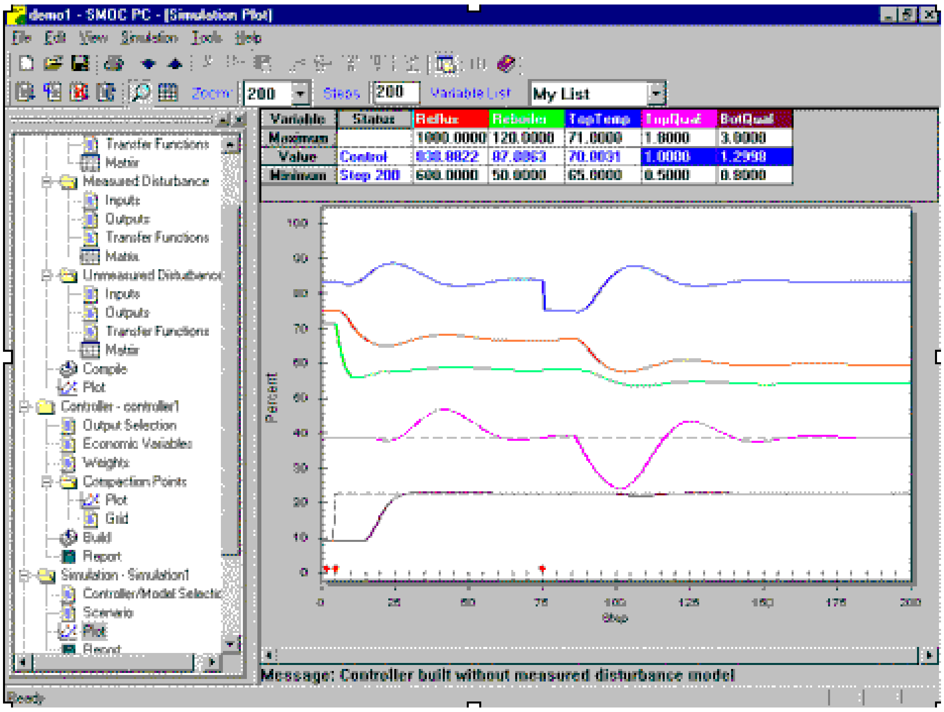


Fig 6-5 Control Action without Observer Model

The first curve in above figure represents a column's top temperature, the second curve is reflux flow to the column and the fourth curve is representative of top quality. Top quality is the variable of interest and hence is declared a controlled variable. Reflux is controlled based on quality measurement. Top temperature is a good indicator of quality. However, control action is initiated only after quality changes. There is a gap between the time temperature changes and when the quality changes. Since control action is initiated only after quality changes, the time taken to bring quality back to its desired value will be high and will necessarily introduce a swing in quality. The two peaks on quality curve before it settles down are indicative of controller's inability to bring quality back into stream.

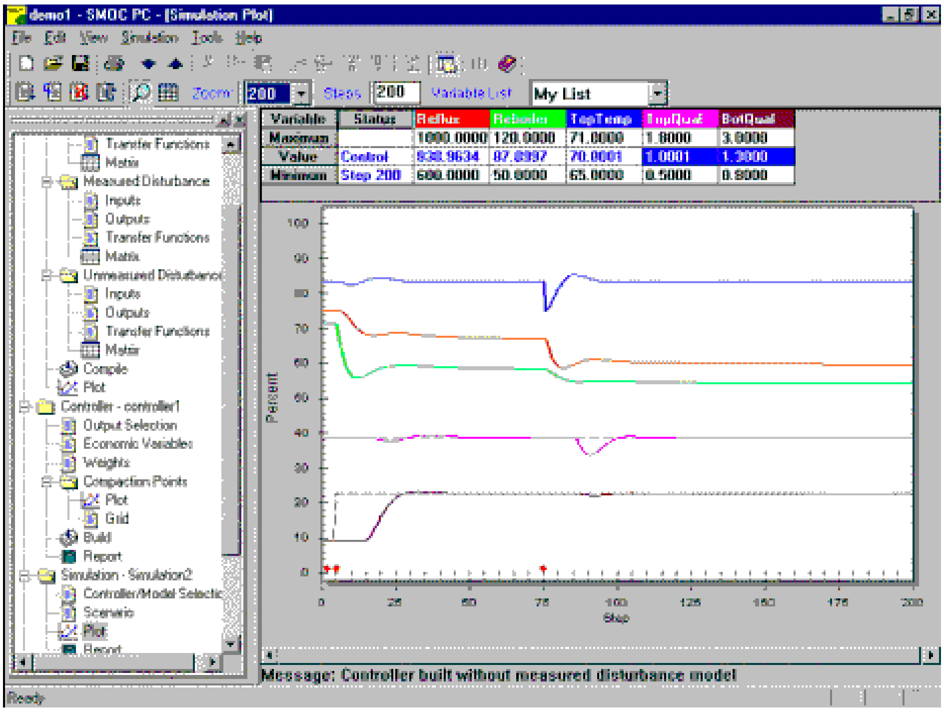


Fig 6-6 Control Action with Observer Model

In the same situation, if the top temperature is declared as an intermediate variable while designing the controller, the controller swings into action immediately when it senses a drift in top temperature from its desired value to alter reflux flow. The controlled variable in this case also is top quality. The result is, action to retain the top quality is taken even before quality has moved away from its point. In addition, it should be noted that controller does not act when the quality changes. It "remembers" it has taken the necessary action. This results in minimal excursion of top quality from its desired value. What are missing in the second curve, prominently, are the wild swings in quality curve. A good indication of smooth control action by SMOC-PC.

Another important feature offered is the robustness invested in control system, by including an error model. Robustness of a controller is its attribute that allows it to handle dynamically, unpredictable or unmeasured disturbances. The controller is able to learn by observing process behaviour and adjusts its control action to suit that.

Suppose, the controller acts without an "observer model". The resulting control action on the process based on an erroneous model will be as shown below. Note that what is seen, as process behaviour is the result of changes arising in process and noise.

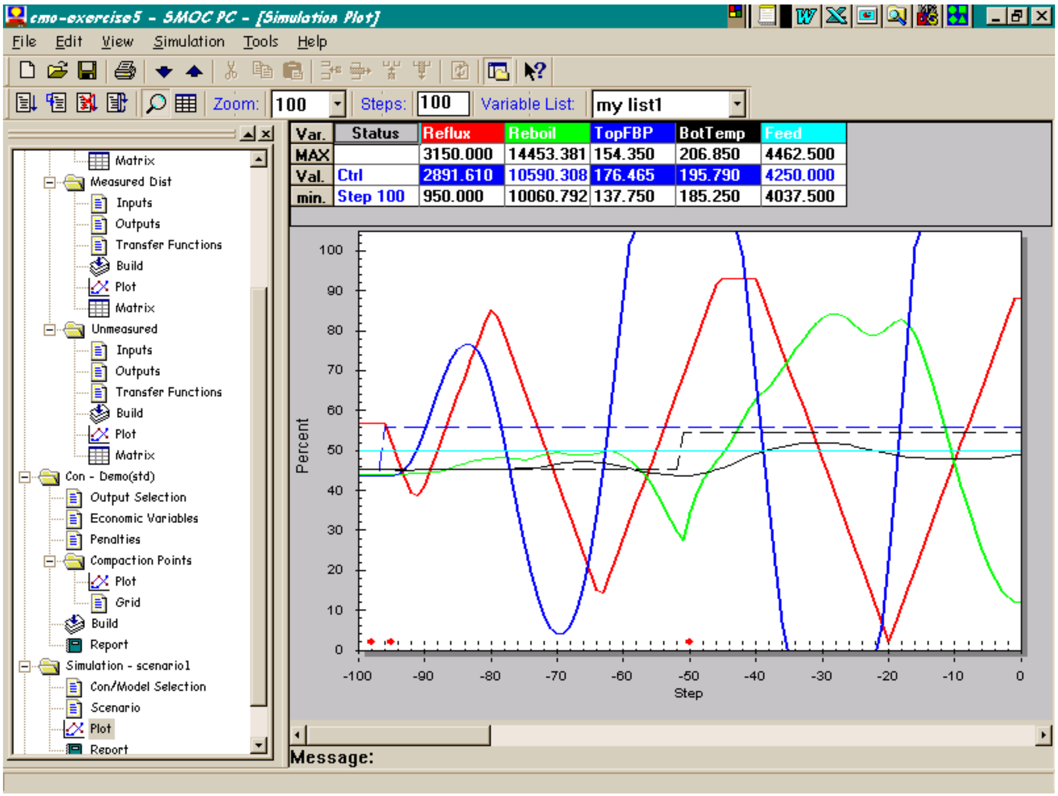


Fig 6-7 Control Action resulting from erroneous model

It is highly unstable. The wild control action is the result of using an erroneous model, measurement noise and process noise.

If an observer model were incorporated, the erroneous output from the controller because of poor model is smoothened out and a control action as shown below in figure 6-8 will result.

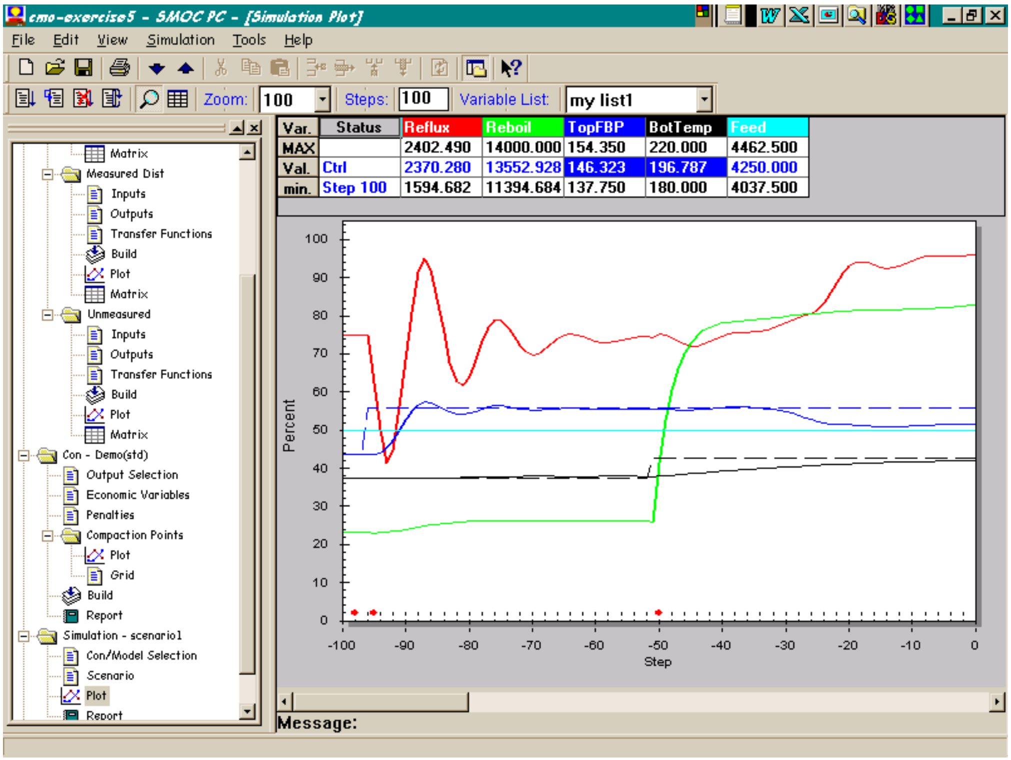


Fig 6-8 Control Action with "Observer Model"

The controller realises the difference in behaviour of actual process and what is predicted by the model input to it. Slowly it adjusts its control action and inspite of erroneous model, tunes itself to "real" conditions.

In addition to all the superior features that are offered, the package is user-friendly. AIDA/SMOC-PC are powerful design tools designed by an user for an user. The operator will find it very easy to navigate through the package. This is in addition to being reliable and proven in over 400 applications with on-line time exceeding 95 %.

6.4 Advanced Features of Exasmoc Controllers

One of the remarkable and distinguishing features of Exasmoc that sets it apart from its peer controllers is the Unmeasured Disturbance Model. This feature covers a wide range of situations encountered in a process plant and imparts the controller versatility and adaptability. The full potential of implementing APC is realised only when operator retains the controller on-line. This is possible only when controller is equipped with technology and features that cover a wide gamut of practical plant situations.

While designing a controller and simulating it off-line, the controller works in an ideal environment, free from disturbances, fluctuations, uncertainties and process eccentricities. These hit the controller on the face and cause it to run haywire once it is implemented. The best efforts of a control engineer to simulate these conditions and tune a controller, off-line, are not good enough to equip the controller to countenance real-life situations.

So, how does Exasmoc get over this?

The value of a Process Output Variable (POV) measured in the plant is used as feedback by the controller. This measurement is subject to variations or noise. These variations could be due to,

- simple instrument fluctuations
- those less pronounced and marginally influential input parameters whose effects have not been modelled
- mismatch between action model, used by the controller and actual process behaviour

These effects are incorporated as a simple ramp block between the disturbance and POV of interest. This is generated automatically for all POV's once an action model is developed for Exasmoc using the Graphical Model Builder.

There are cases where value or directional movement of one process parameter will be indicative of value or directional movement of another. For example, column top temperature to top quality. Generally, the parameter of interest in this case will be top quality and the parameter used to control this would be top reflux. So, logically an action model will be developed indicating relation between top reflux and top quality. We can in addition, develop a model between top temperature and top quality. This could be incorporated as an 'intermediate variable' (a variable declared between top reflux and top quality). The model between top temperature and top reflux will again be automatically, incorporated in the unmeasured disturbance model. The effect of this on control action is that, the controller will act to move reflux when it sees a movement in temperature not caused by reflux change. (A practical example of such a situation could be a rainstorm that will bring down column top temperature without the influence of reflux). Column top temperature is neither a controlled variable nor a manipulated variable. Yet, the controller uses it as a watchdog to keep quality on target.

There are numerous occasions in a plant when control action of low-level PID controller is not in sync with model predictive controllers (MPC) of APC. A good example would be a reactor bed temperature, which may be strongly influenced and hence controlled by a furnace outlet temperature. When an APC sends a signal to change furnace outlet temperature, it implicitly assumes that the temperature has changed. So, in its next cycle if APC realises that reactor bed temperature has not taken its predicted value, it again moves the set point of furnace outlet temperature. Actually, the PID controller of furnace outlet temperature is taking its time (because of process dynamics) to bring it up to the set point. Since the controller is unaware of PID's action, moves are made rapidly. This will very soon drive the process unstable. This situation is avoided by incorporating the PID action into the action model of Exasmoc. This effectively tells the controller to 'keep cool' until PID has acted to reach Exasmoc's set point.

Additionally, it is possible to incorporate into the action model, the destabilising effects of certain process parameters that are neither manipulated nor controlled variables and the effects of which cannot be easily modelled.

The output of an unmeasured disturbance model is an 'Observer Matrix'. When the observer matrix is put through a Kalman Filter, the controller is told to take action only for those fluctuations in the plant that need attention. Random fluctuations are rejected.

It is possible to use these tools to effectively model any plant in a wide range of circumstances.

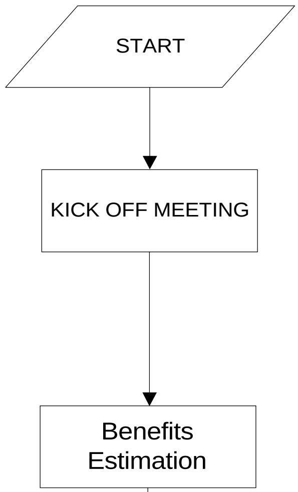
Exasmoc has capability of handling "crippled modes" when bad data are received or when MVs become unavailable: Exasmoc can cater for these situations as well as it is configurable to continue functioning even when some measurements or means of actions are not available. this is an essential part of the high uptimes achieved by Exasmoc and something which shows its adequacy in an industrial world where these kinds of things are the norm rather than the exception. Another feature participating to this robustness are the reference models (first order filters) that can be tuned on-line and are a very powerful way or handling in a separate way setpoint tracking and rejection of disturbances.

Optimisation: Not only you can define economic objectives but you can define multiple objectives at the same time and they can be on both MVs and CVs. this means that the scope of Exasmoc is much wider than the pure maximisation of a profit function. This is especially relevant when no on-line optimiser is present, Exasmoc can look after a number of economic objectives on its own. - mathematical representation of models and QP resolution:

Exasmoc uses state space models instead of FIR (Finite Impulse Response) which are more robust (FIR (Finite Impulse Response) model shapes can be rugged and lead to some "noisy" control moves, Exasmoc models are smooth by design).

- Delays handling is very efficient (via the common delays concept) meaning again more robustness in case of long deadtimes a known traditional problem with all controllers.
- control criterion is a rigorous one solved by an efficient relaxation algorithm. input constraints are taken into account right from design not a posteriori.
- economic optimisation uses a QP rather than an LP. It is less prone to switching from one corner of the vertex to another meaning again more stability against noise.

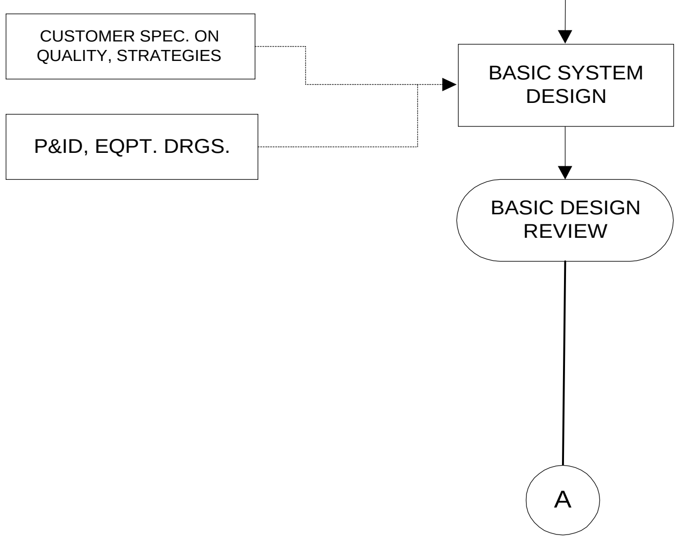
7. Project Execution Steps



Upon receipt of purchase order, Yokogawa will form a Project team by assigning a Project Manager and experienced APC engineers to the project. The team members will familiarise themselves with project background material in preparation for project kick off meeting.

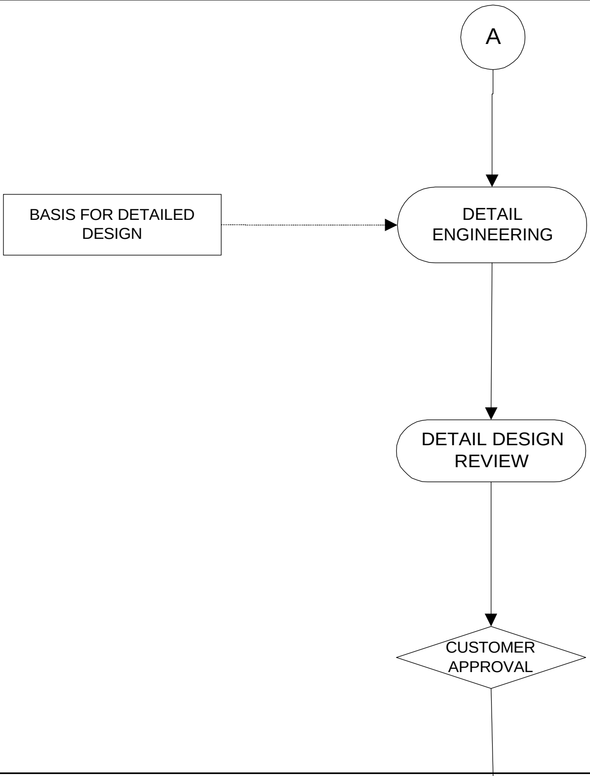
In the kick off meeting, the teams from Yokogawa and Client will decide upon Project organisation, communication channel and Project schedule.

In order to assess the potential benefits of the project, the economic drives of the units under study is established. With knowledge of product economics (including intemediate products), product scheduling, feed changes (if relevant), operational constraints and plant historic data (lab results, plant data) the potential benefits are calculated.



Based on information gathered during base level study, a basic system design using Advanced Regulatory Control and SMOC is made.

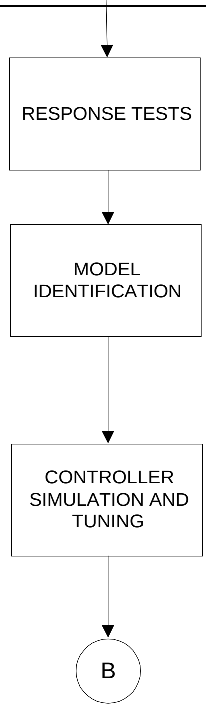
The Basic Design is reviewed by Client. This study will form the basis for detailed engineering which commences the next phase of Project.



During detailed design, activities like data confiuration, interface design, details of hardware integration, procedure for step response tests etc., are detailed and finalised. After the preliminary design review meeting, all comments on preliminary design will be incorporated to prepare detailed design of specification of SMOC. This document will be submitted to Client for approval. An approval of this document will constitute a design freeze of the project. The next step will be implementation.

Before going ahead with Plant test, two important steps will be completed.

1. procedure will be drawn out for the test.
2. ensure all instruments are in working order.

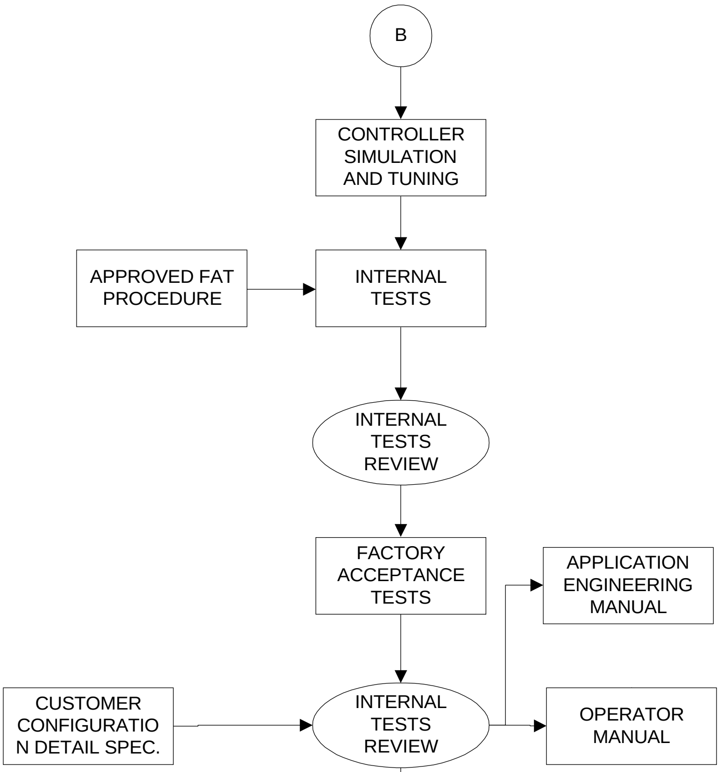


Once the detailed design is met with Client approval the next step is plant test. A plant test is conducted on a 24-hour basis. A high quality plant test will generate an accurate model. It will enable control engineers better understand process behaviour and its constraints.

The test response data is analysed using an model idenification software to generate a model to be used by SMOC-PC. The output at this stage is a dynamic relationship of manipulated variables with each controlled variable.

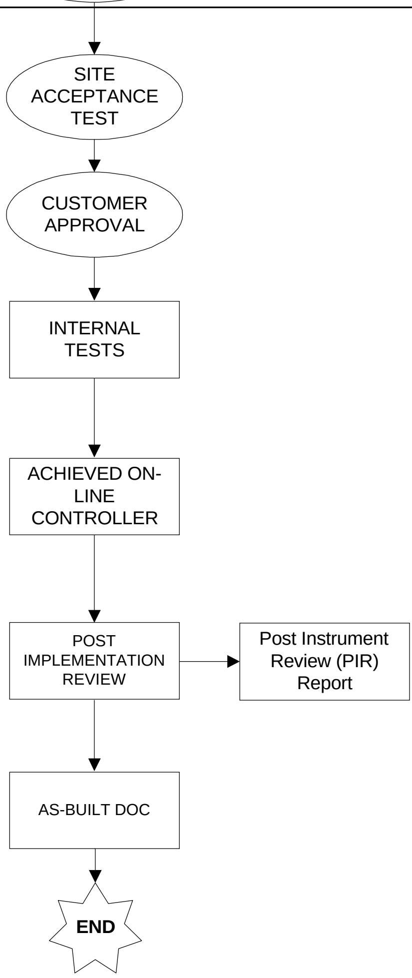
The model so developed is run through an off-line controller package. The controller behaviour will be studied for changes in set point, measured and unmeasured disturbances and will be suitably tuned.

The output is a tuned controller configuration file that can be read by Exasmoc.



The next stage is to build Exasmoc controller using models developed. Observing the performance of controller in an environment that simulates process response, the controller is fine tuned, relative priorities set for controlled and manipulated variables. The output is a tuned controller that can be read by Exasmoc on-line software.

The next phase is Factory Acceptance Tests to validate the system functionality. Prior to offering it to customer for tests the system is tested thoroughly by Yokogawa's engineers. This test also presents a good opportunity for customer engineers to acquaint and train on the system.



The performance of controller that has been developed will have to be tested at site. This is the principal aim of the next step called Site Acceptance Test. Parameters of off-line controllers are downloaded and Exasmoc is allowed to run on predicion mode. Prediction errors and calculated control moves are evaluated for accuracy. Once the dynamic model has been verified, controller is commissioned. On-line performance is evaluated and djustments made as necessary.

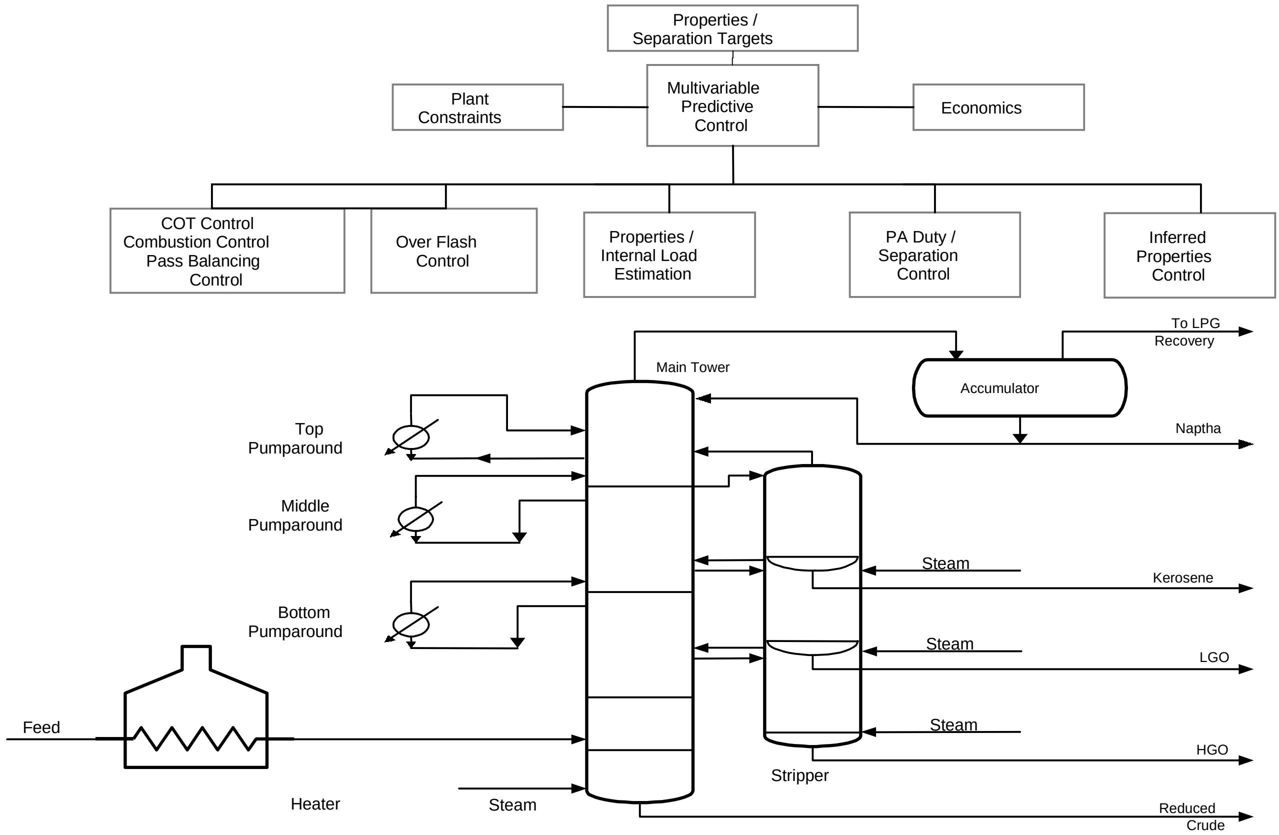
After successfully commissioning the controller, the next and crucial step is to evaluate benefits accrued out of implementing APC.

This will mark the end of project.

8. Examples of APC Implementation

There are over 400 applications of Exasmoc in various refineries and petrochemical plants operating in different environments to meet differing objectives across the globe. They have recorded an impressive 95 % or more uptimes. The highest in the industry for such products.

8.1 Benefits of APC in a Crude Unit



Application:

A Crude distillation column is a very complicated separation unit. Within a column, crude oil is separated into several fractions and each fraction has several properties that need to be controlled. It is difficult to control product properties because

a) they must be controlled simultaneously and

b) their measurements are usually available once several hours from the laboratory or from on-line analyzers (after long time delays).

However, product properties can be inferred from other measurements. By applying inferred property calculations with Multivariable Predictive Control (MPC), the performance of a crude unit can be significantly improved.

Strategy:

- Improve control by implementing MPC on inferred properties. This reduces the effects of disturbances such as changes in charge flow, charge temperature, ambient temperature, tower pressure, and crude composition.
- Take advantage of "range of acceptable specifications" for each product. Control each product at or near the high or low limit of its specification range. MPC controller has the ability to increase yield of certain desirable products without compromising the specification of the other products.

Result - This upgrades product from a less valuable streams while maintaining each product within their quality limits.

- Control external circulating reflux to achieve better and close separation between adjacent products. MPC can additionally take consideration of tray flooding etc.

By improving the unit stability, maximizing feed pre-heat, and improving furnace operation, etc. The overall unit through-put can be increased.

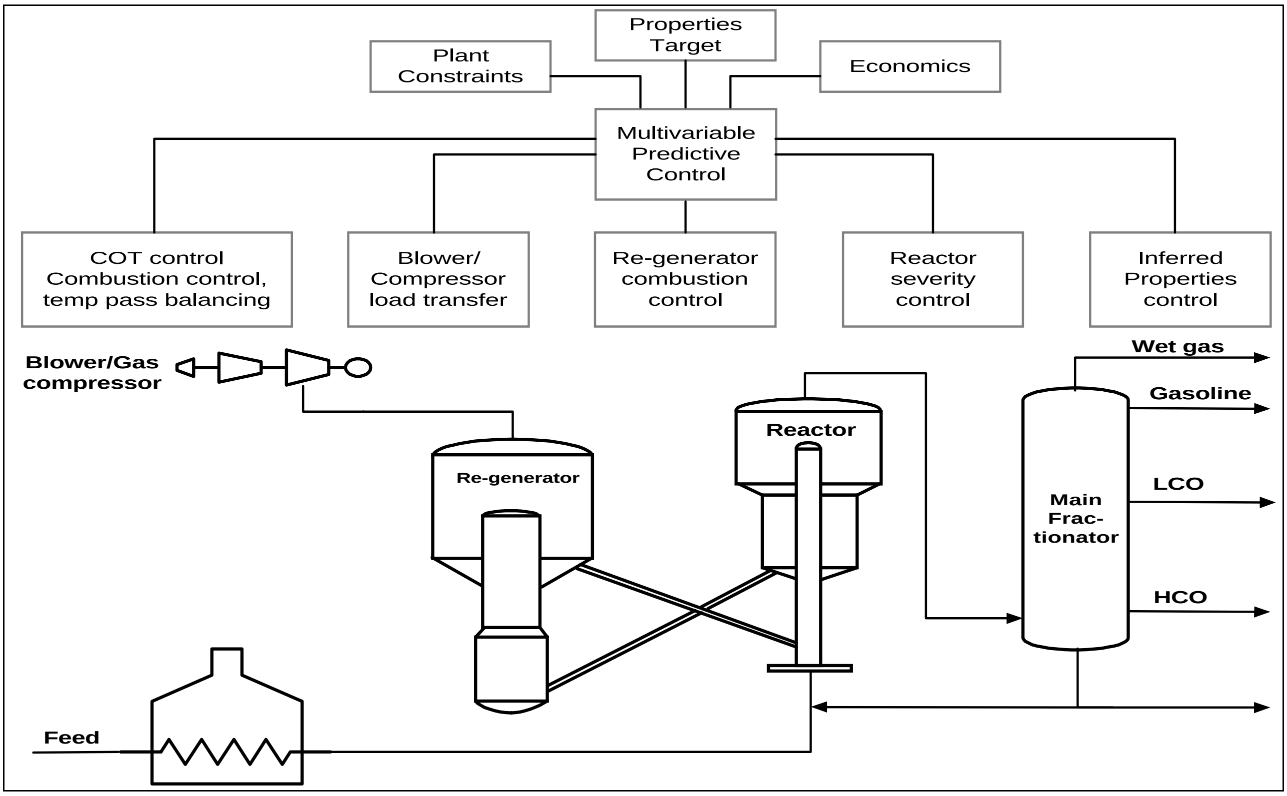
- Result - Increased energy savings due to closer control of crude overflash, optimum heat recovery from pump-arounds, reduced rework on rundowns to produce on-spec. product.

An MPC controller does its work through lower level PID controllers. To maximize the effectiveness of an MPC controller, these lower level controllers must be integrated into larger Enhanced Regulatory Control (ERC) groupings like furnace combustion controls, pass balancing controls, preheat exchanger train controls, etc..

Economics:

Many successful installations of this crude unit control technology have proven benefits from maximum yield of most valuable products, reduced variability in product quality, reduced energy consumption, increased throughput, and more stable unit operation.

8.2 Benefits of APC in Fluidized Catalytic Cracking Unit



Application

FCCU presents unique control problem because of its characteristic and typical design and operational requirements. A combined knowledge of Advanced Process Control and the intricacies of process result in stable and profitable control of Unit.

Yokogawa's extensive first-hand experience with FCCU control enables us to recognize these requirements and to develop an FCCU advanced control technology which overcomes these difficulties.

1. FCCU feed is a mixture of heavy oils, and on-line analysis or characterization (other than API gravity) is not practical. Water slugs in feed and frequent recycle of heavy aromatic make matters worse.
2. The pyrolysis is catalytic and involves complex, competing side-reactions of high molecular weight, long-chain and aromatic hydrocarbons, further defying the selection of proper operating conditions for a desired product yield.
3. Though catalyst activity is an important parameter it is not easily measurable.
4. Coke production rate cannot be predicted. An unmeasured variable, this has a major impact on reactor yields.
5. Pressure is an important and critical parameter with wide ranging influence on reactor yields, stripper efficiency, coke combustion, energy consumption of wet gas compressor, catalyst back flow etc.

6. Peculiarities and uncertainties are further compounded by
   - Presence of heavy rotating equipment.
   - Reactor exit gas flow is a mixture of hydrocarbons and not easily analyzable.
   - Feed to main column is in superheated state and its flow or composition cannot be measured easily.
   - Presence of catalyst as solid, liquid or gas leading to problems of plugging in heat exchangers etc. Control scheme has to provide for purging, back flushing etc.
   - Vagaries of weather.
   - Metallurgical temperature limitations.
   - The process is a mix of endothermic and exothermic reactions. Therefore, control systems has to deal with heat, mass and pressure balance simultaneously.

Control Scheme Objectives

Yokogawa's fluid catalytic cracking control technology is designed to overcome the difficulties described in the previous section and to increase the feasible operating range of the FCC Unit. This increase in operating range may be used to realize the following types of benefits:

1. Process additional FCCU feed,
2. Increase reactor severity (conversion)
3. Decrease utility costs
4. Increase recovery of more valuable products.

Reactor/Regenerator Controls

Riser Temperature Control:
This strategy controls riser temperature (conversion) at the setpoint provided by the operator or the optimizer

Feed Rate Control:
Reactor fresh feed is manipulated to maintain the unit against one or more constraints. These constraints include feed setpoint, compressor suction pressure, air blower constraint, fractionator limits, etc.

Regenerator Combustion Control:
This strategy maintains control of the combustion of coke and provides maximum regenerated catalyst activity and temperature without violating regenerator physical constraints.

Wet Gas Compressor Loading Control:
This strategy operates the gas compressor at maximum capacity to lower FCCU reactor and main fractionator pressure. This allows the reactor/regenerator differential pressure controller to transfer load to the air blower.

Air Blower Load Transfer Control:
This strategy minimizes regenerator pressure, allowing the air blower to work against a lowered pressure head to move more combustion air. This increases unit capacity for more feed throughput or higher conversion.

Main Fractionator Controls

The control objective of the main fractionator to insure that gasoline and LCO produced in the reactor is indeed separated properly and not lost into less valuable products by poor fractionation. The general concepts of heavy oil fractionation and of Yokogawa's boiling point calculation technology are described below.

General FCCU Main Fractionator Control Theory

The main fractionator is an important part of the fluid catalytic cracking unit. The function of the main fractionator is to separate the reaction products produced in the FCCU reactor into intermediate streams which can be further processed into final products. Since its feed is a superheated vapor stream, the main fractionator is also a major source of refinery energy, particularly from the bottoms slurry-pump-around exchangers.

The basic engineering principles involved in main fractionator distillation are similar to those used in other distillation towers. However, there are significant differences.

1. The feed and the products are a mixture of many molecular types, and therefore, the separation between adjacent products streams is not as sharp as you would expect in a light products fractionator.
2. A number of intermediate products are produced in addition to the bottoms and overhead products in the distillation tower.
3. The feed entry point is near the bottom of the tower and there is no reboiler. Instead, heat is supplied by the incoming feed stream, which is a vapor from the FCCU reactor overhead. Unlike most distillation columns except the crude unit, the FCCU main fractionator has no reboiler or other external source of heat input.
4. The internal vapor and liquid rates will vary up and down the tower due to the withdrawal of products and the removal of heat in side reflux exchangers. Extensive heat exchange is provided between fresh feed, product streams and refluxes.
5. The tower internals are unconventional, particularly in the bottom section of the tower where catalyst is present.

Expected Benefits

Due to the large feed rates commonly encountered on FCC Units, small percentage changes in unit profitability often generate very large annual benefits. The benefits achieved on a particular unit depend upon that unit's operating objectives and the plant environment. However, the major benefits will come from some or all of the following general areas:

- Increased fresh feed capacity or throughput
- Closer control of desired cracking severity or operation closer to optimum severity
- Smoother, faster, and better transition between different feed rates
- Reduced utilities consumption (stripping steam, driving steam, air blower, etc.)
- Longer run time due to less wear-and-tear by reduction in constraint violations such as regenerator temperature limits, compressor rpm, etc.
- Increased operating safety
- Increased production of more valuable products
- Improved operating stability and fewer upsets

These benefits are obviously very dependent on the feed, product, coke, and utilities prices assigned by the customer.

ADVANCED PROCESS CONTROL SOLUTIONS
Exasmoc

TI 36J06D10-01E

INDEX

A

Advanced Features of Exasmoc Controllers 6-9
Advanced Identification and Analysis (AIDA)........5-1
Advantages of using AIDA Modeling Package......5-2
Advantages of using Exasmoc 6-3
Application 8-2, 8-4

B

Benefits of APC in a Crude Unit..........................8-2
Benefits of APC in Fluidized Catalytic Cracking Unit 8-4
Benefits of Implementing APC 2-2
Brief Introduction to Model Predictive Control Techniques 1-5

C

Confidence Bands 5-5
Control Scheme Objectives 8-5
Cross Correlation...5-6

D

Demonstration of power and flexibility of AIDA.....5-3

E

Economics 8-3
Error Model 5-4
Examples of APC Implementation 8-1
Exasmoc's Answers...2-6
Expected Benefits..8-7

F

Features of AIDA 5-1
Features of AIDA Modelling Package 5-1
Features of Exasmoc...6-1
Features of Exasmoc Optimising Controller 6-2

G

General FCCU Main Fractionator Control Theory 8-6
General Introduction to MVC and MPC 1-1
General Technical Description.............................5-1
Glossary...1

M

Main Fractionator Controls 8-6
Model Structure 5-2
Multiple Input Data..5-5

O

Objectives of Multi Variable Controllers 1-4

P

Points to consider while selecting an APC............2-5
Possible to freeze-unfreeze some or all parameters...5-6
Product Concept..2-1
Product Overview 3-1
Project Execution Steps 7-1

R

Reactor/Regenerator Controls.............................8-5

S

Some common terminology.................................6-1
Statistical Tool to validate model..........................5-5
Strategy 8-3
System Configuration and Integration 4-1
System Description...3-2
System Integration..4-2
System Integration with other DCS......................4-6

W

What does an APC do? 2-1
What is a Multi Variable Controller (MVC)?..........1-1
Why is a Multi Variable Model Predictive Optimising Controller necessary? 1-2

Revision Information

Title : ADVANCED PROCESS CONTROL SOLUTIONS Exasmoc
Manual No. : TI 36J06D10-01E

Oct. 2001/1st Edition/R2.20
Newly published

Written by Process Information System Dept.
Systems Business Div.
Yokogawa Electric Corporation
Published by Yokogawa Electric Corporation
2-9-32 Nakacho, Musashino-shi, Tokyo 180-8750, Japan
Printed by Yokogawa Graphic Arts Co., Ltd.