The Clear Path to Operational Excellence

2005 Yokogawa Conference & Exhibition

THE FUTURE OF PROCESS CONTROL

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OVERVIEW

- **Today we will discuss where we have been in Advanced Control, where we are today, and where we are going in future.**
- **During the last 25 years we have moved Advanced Control from the predominate use of PID controllers with lead lag blocks and decouplers to model based control.**
- **With the advent of model based control, the size of the controllers has gone from 3 manipulated variables and 3 controlled variables to 50 manipulated variables and 100 controlled variable.**
- **Today model based controllers include economic optimizers or they are integrated with a real time optimization system.**

PREDICTIVE CONTROLLERS TODAY

- **The maximum size of a predictive multivariable controller 20 years ago was limited to 10 manipulated variables and 20 controlled variables due to the constraint of computer speed.**

- **The value of building a large controller is the economics of the process can be defined and used to drive the controller to the right set of constraints.**

- **The early predictive controllers had embedded linear programs that specified the steady state for a controller based on the predicted steady state from disturbances and previous changes in the independent variables.**

- **The constraint on the size of a controller has moved from a computer speed limitation to problems with model identification.**

MODEL IDENTIFICATION TODAY

- **The model identification problems are unmeasured disturbances, process noise, and non-linearity's.**
- **To find a good model requires that the signal to noise ratio be greater than five, which means large moves must be made in the manipulated variables to prevent the signal from being attenuate in the backend of the process.**
- **A significant part of the noise is created by the PID controllers responding to unmeasured disturbances such as a two phase flow regime changing states.**
- **Step Response Curves in a controller model are in the context of the configuration and tuning of the PID control system when the dynamic test of the plant was done.**

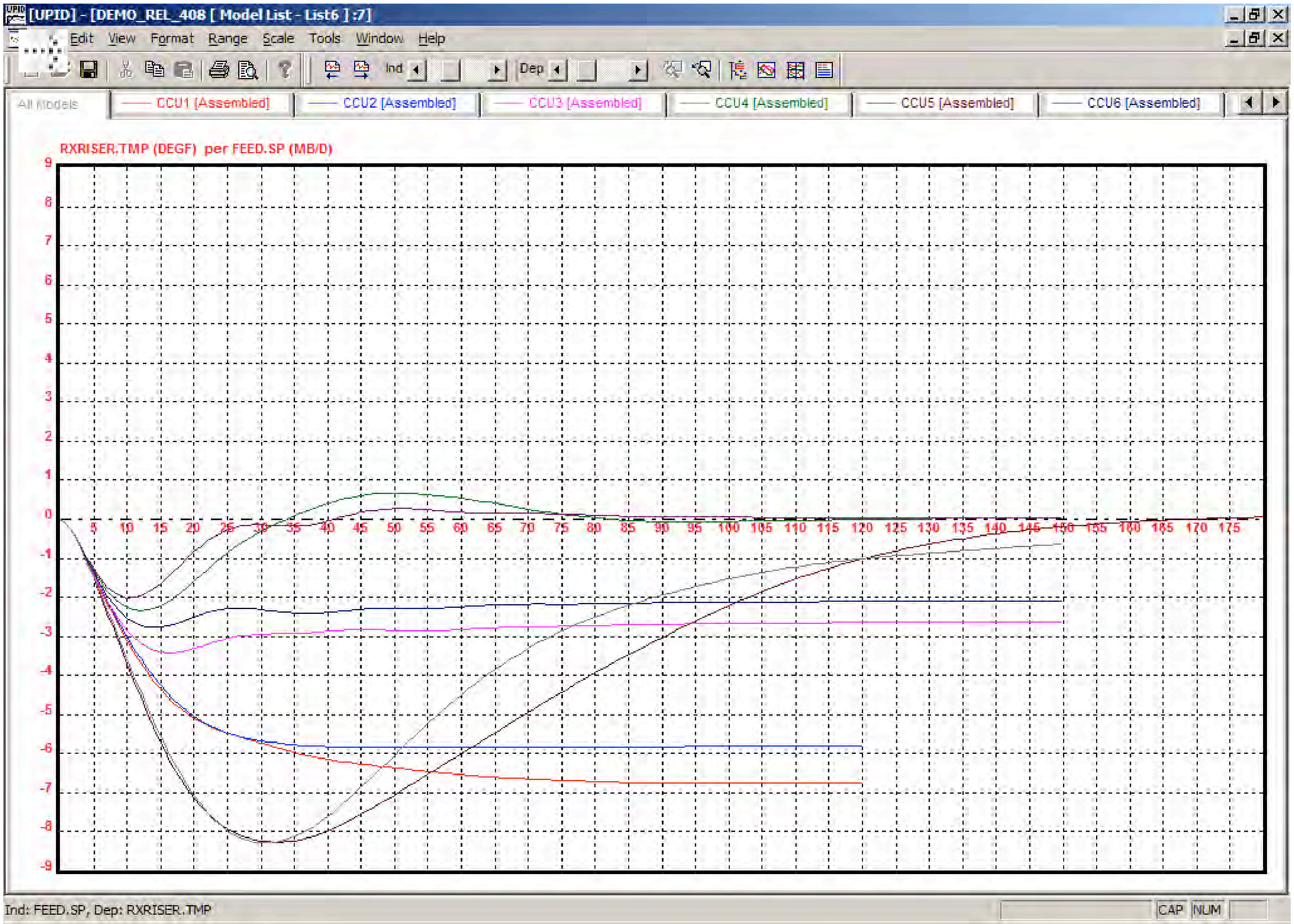
The Effect of PID Configuration Changes

- **Changing the PID configuration or making significant tuning changes results in the degradation of the model.**
- **The re-identification of the process model is avoided if at all possible due to the manpower cost and the disruption of normal operations**
- **Operators learn how a process will respond when the PID control system is in its normal configuration.**
- **It is important from a training point of view that operators understand the process will behave differently when the PID configuration is changed.**
- **If an Operator has not trained on a simulator or if he has not observed a particular system response when the PID configuration was in a different state, it can result in serious misunderstanding of the process.**

PERMUTATIONS FOR THREE CONTROLLERS

	Riser Temp Suction Press	Regen Temp	WGC
1	manual	auto	auto
2	manual	manual	auto
3	manual	manual	manual
4	auto	manual	manual
5	auto	auto	manual
6	auto	auto	auto
7	auto	manual	auto
8	manual	auto	manual

Permutations $= 2^{\text{number of controllers}}$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RXRISER.TMP (DEGF) per FEED.SP (MB/D)
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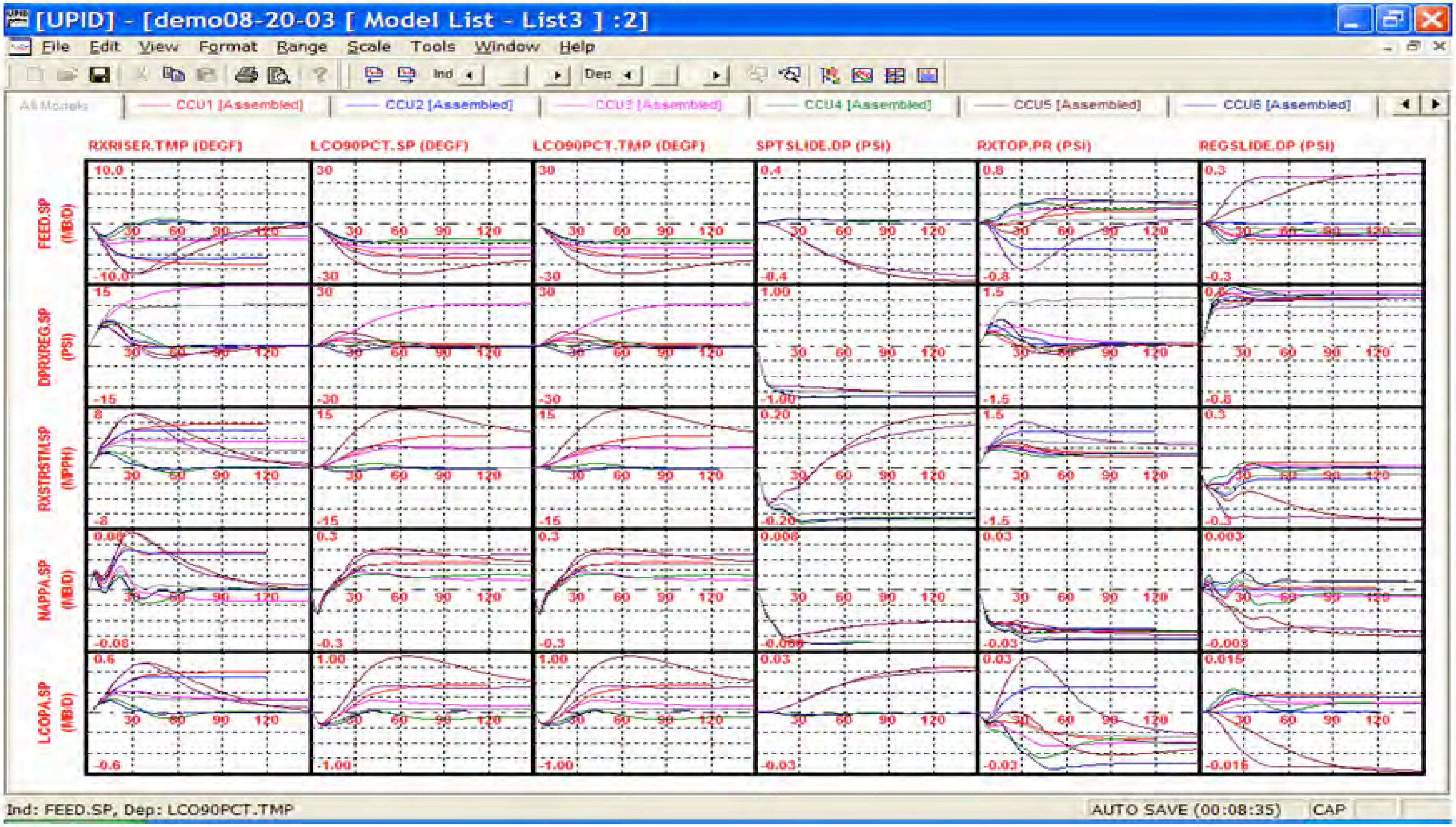
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LCO90PCT.SP (DEGF)
LCO90PCT.TMP (DEGF)
SPTSLIDE.DP (PSI)
RXTOP.PR (PSI)
REGSLIDE.DP (PSI)
FEED.SP (MB/D)
DPRXREG.SP (PSI)
RXSTRSTM.SP (MPPH)
NAPPA.SP (MB/D)
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THE FUTURE OF PROCESS CONTROL

- **The newest variant to traditional process control is the ability to solve a process simulation in real time and provide advice to the operator.**

- **The Advisor takes advantage of current computing power and the use of Finite Impulse Response (FIR) models to run a simulation of the process 100 to 150 times real time.**

- **The simulation is based on where the process is and where it going as a function of where it has been.**

- **A “What If” feature permits an operator to ask the Advisor what the consequences are of making set point, PID configuration, or tuning changes and know the answer in a matter of minutes rather than hours.**

THE FUTURE OF PROCESS CONTROL

- **Also on the near term horizon are large multivariable controllers that can execute in a few seconds**
- **They will have adaptive features which permit the process model to be modified in real time.**
- **The increasing power of computers and the development of the Adaptive Multivariable Controller (AMC) will permit the eventual replacement of the PID controller with predictive controllers.**
- **Alarm management will be based not only on the current state of the process but where it is going in the future.**

A New Paradigm for Advising and Training Operators

- **New technology has been developed that will change the way operators are trained and how they interact with the process.**
- **The new paradigm has a number of features that have not been possible in the past.**
- **On-line real time mode or " What If " mode which permits prediction of future responses based upon proposed operator changes (Operator Advisor).**
- **On-line training background permits use of real time system as if it was an off-line training simulator with scenario capabilities.**
- **Off-line standalone training simulator where the FIR model is used with tradition training methods.**

A New Paradigm for Advising and Training Operators

- **The real time mode advises the operator and the training background mode teaches the operator through the use of scenarios.**
- **In the real time mode the operator can answer "What If " questions based on where his process is and where it is going.**
- **The real time mode is initialized with the current state of the process, the configuration of the DCS control system, and the prediction of the future response.**
- **The prediction is made with an open loop model based on the changes in the valves for a time to steady state in the past.**

A New Paradigm for Advising and Training Operators

- **With the all valve prediction, the prediction is not influenced if the operator changes the mode of the PID configuration or changes the tuning.**
- **The FIR model runs 100 to 150 times faster than real time which makes it possible to use it for "what if" questions an operator may have for changes he is anticipating making.**
- **With these speeds an operator has time to test several potential sets of changes.**
- **The Operator Advisor (OA) runs on a PC attached to a DCS and will scan the process and DCS configuration at regular intervals.**

A New Paradigm for Advising and Training Operators

- **Operator Advisor uses an open loop model of the process and an emulation of the PID controllers.**

- **The OA maintains a prediction of the path the process will follow in reaching steady state.**

- **The measurements from the process will be used to update the prediction in the same manner as used by a predictive controller.**

- **The prediction is maintained at all times regardless of what is happening in the background.**

A New Paradigm for Advising and Training Operators

- **A dynamic model based on first principle engineering will not execute more than two to three times real time, even with multiple computers and parallel processing.**

- **FIR models created from the New Technology permits the model of a large process unit to run over 100 times faster than real time without compromising quality in the representation of the dynamics.**

- **The advantage of the increase in simulation speed is the efficiency in training gained by increasing the number of scenarios an operator can experience in a fixed time.**

- **Further, the speed of execution of a scenario and the scoring of performance can convert the training into a video game rather than a boring training exercise.**

A New Paradigm for Advising and Training Operators

- **Most first principle engineering training simulators have fallen into disuse due to the specialized skills required to maintain the system of differential equations used by the simulator.**
- **The same model used by the multivariable controller can be used by the training simulator and Operator Advisor.**
- **The controller model will be maintained, since it is apparent to management the multivariable controller makes money.**
- **The synergism with the controller significantly reduces the cost of the engineering manpower needed to create and maintain the simulator.**
- **The obvious payout for an Operator Advisor is the prevention of unscheduled shutdowns and safety of the unit.**

The Evolution of an Adaptive Multivariable Controller

- **Identify the process using traditional test methods and build an FIR model of the process.**
- **Convert the closed model to an open model.**
- **Use the open model in real time to predict where the process will go in the future.**
- **Build a predictive multivariable controller that uses the open model and the real time prediction.**
- **Controller will take advantage of multiple CPUs and parallel processing to solve the control problem every 1 to 2 seconds.**
- **The feedback correction to the prediction at each execution of the AMC will permit all the valves to be in manual.**

The Evolution of an Adaptive Multivariable Controller

- **A number of advantages for adaptive control emerge with the AMC using an all valve model.**
- **Eliminates the concern with a PID controller saturating a valve and thereby changing the PID configuration.**
- **When a valve is saturated, the PID controller is effectively in manual.**
- **Eliminates the interaction between PID controllers which reduces the noise level in the measurements.**
- **Knowing precisely where the valve is positioned permits a higher quality non-linear transform for the valve to be found and adapted.**

The Evolution of an Adaptive Multivariable Controller

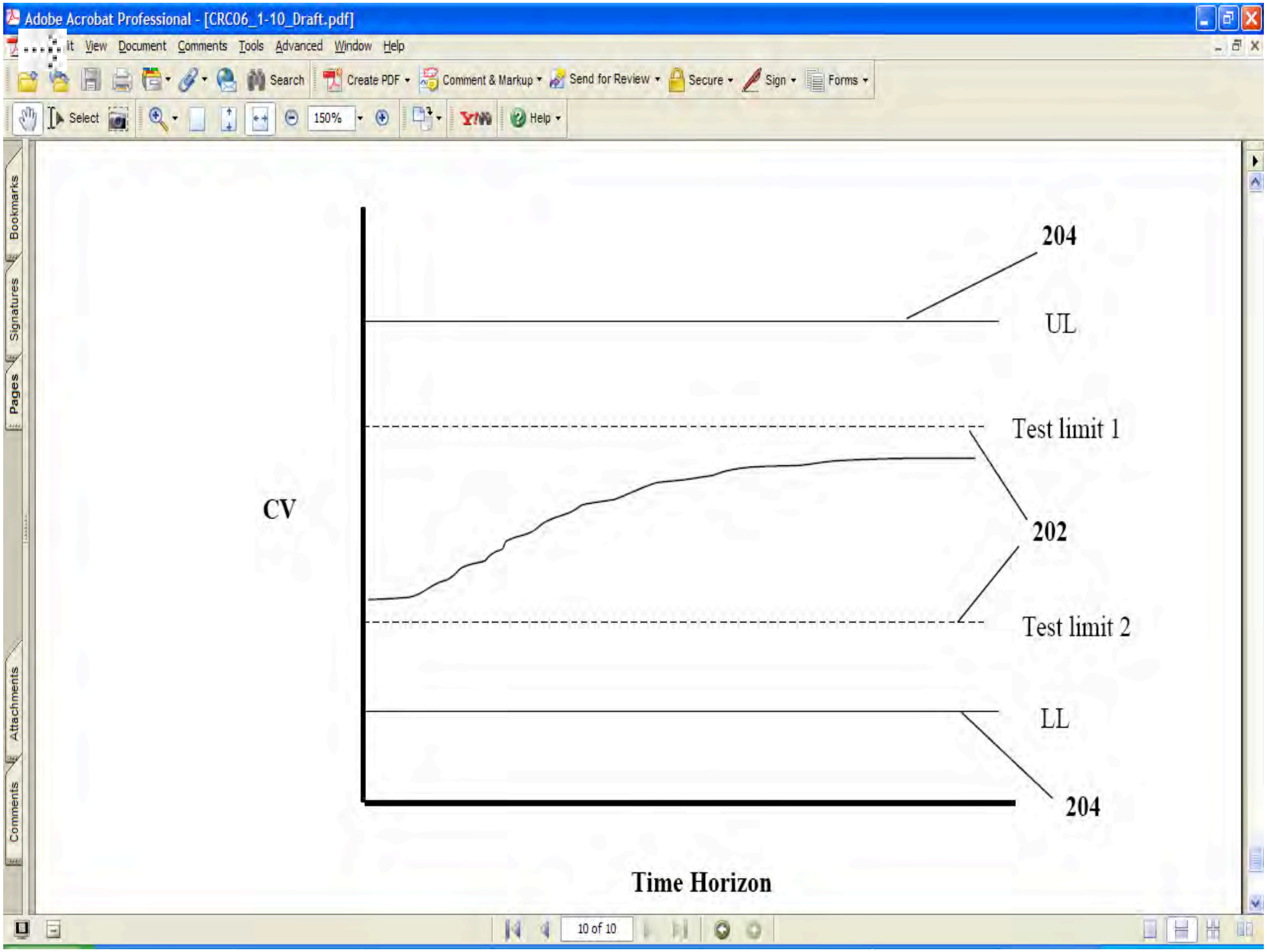
- **When the AMC is in the adaptive mode both the valve transforms and the model will be updated.**

- **The controller will have defined a set of test limits for the dependent variables when in the adaptation mode that are inside the normal operating limits.**

- **When the prediction is inside the test limits, the AMC will not calculate a corrective move.**

- **The response of the controller to random test perturbations is the primary cause of correlation in the identification mathematics.**

The Evolution of an Adaptive Multivariable Controller



Alarm Management with Future Predictions

- **The Operator Advisor will use the updated model from the AMC.**
- **The prediction from the Operator Advisor can be used to predict future alarm conditions when the AMC is not running the process.**
- **When the AMC is in control its prediction could be used to identify future alarm conditions.**
- **The integration of the OA or AMC into the alarm management system will permit potential problems to be addressed before they occur.**

In the More Distant Future

- **The Proportional Integral Derivative (PID) Controller will be replaced by an Adaptive Predictive Controller (APC).**
- **Simple single loop APC will be maintained for operators to use during abnormal conditions where manual intervention is required.**
- **The single loop APC will be much more effective in dealing with controlled variables that have a significant dead time or a slow initial response.**
- **The Operator Advisor of the future will use the single loop APC.**