

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

ADVANCE PROCESS CONTROL READINESS (BASE LAYER CONTROLLER ASSESSMENT)

PTS 20.00.20.45

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This new PTS 20.00.20.45 – **Advance Process Control Readiness (Base Layer Controller Assessment)** has been developed to provide standards, guidelines and methodology to carry out Base Layer Controller Assessment as a preparation for APC implementation. This document also includes the requirement and the deliverables for an effective Base Layer Controller Assessment as part of APC readiness.

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APPENDICES

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1 INTRODUCTION

The main purpose of this document is to provide standards, guidelines and methodology for Base Layer Controller Assessment (BLCA) as part of APC readiness assessment. The work flow of APC implementation can be summarised as follows:

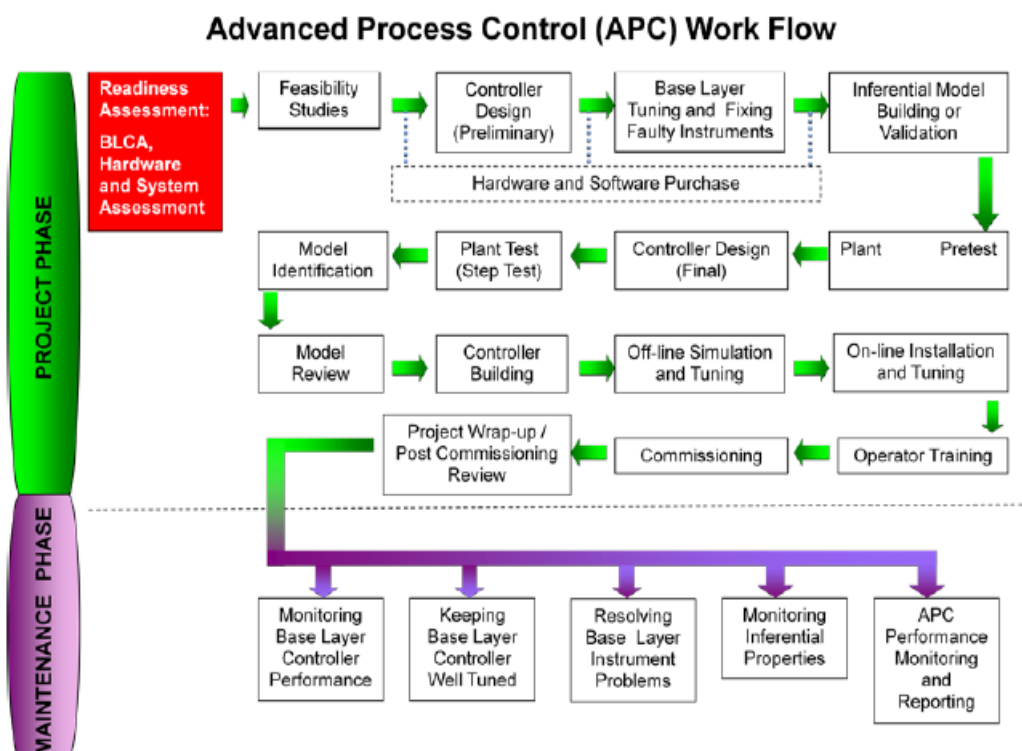


Figure 1

The performance of base layer controller need to achieve a certain standard before it is considered ready for APC implementation. It is intended for use by PETRONAS Engineers before embarking on APC applications or any other optimisation initiatives.

The methodology proposed in this document can be used to assess the performance of the base layer controllers in preparation for optimisation initiatives and ensure benefits sustenance. This assessment is to ensure quality delivery of a successful APC application.

This document provides a systematic approach in identifying potential problematic control loops using process engineering experience and base layer controller assessment evaluation tools.

Base Layer Controller Assessment can be carried out for plantwide or per unit operation basis depending on the scope of application. Base Layer Controller Assessment is a systematic method of checking the status & evaluates the performance of controllers to determine the overall health of the control system, enabling the search for non-compliance resulting from improper operation of controllers, faulty instrumentation, incorrect control strategies, limitations on unit operation and tuning settings.

This document does not cover comprehensive instrumentation performance evaluation and assessment. It focuses on the controller performance with respect to process requirement.

1.1 OBJECTIVE

The objective of this document is to provide standards, guidelines and methodology for Base Layer Controller Assessment (BLCA) via:

1. Rating, measuring and evaluating the performance of compliance controllers.(Refer to Section 2.2, Figure 2)
2. Consolidate reasons for non-compliance controllers and poor performing controllers. (Refer to Section 2.2, Figure 2)
3. Identifying the gap for improvement and prioritisation for rectification to meet standard requirements.

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1.3 DEFINITIONS

1.3.1 General Definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier/Vendor** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word “**shall**” indicates a requirement.

The word “**should**” indicates a recommendation.

1.3.2 Specific Definitions

Advanced Process Control (APC)

An APC manipulates several set points and/or valve positions simultaneously to achieve its control objectives. It employs a model predictor containing dynamic models of the process and predicts the process behaviour and responds accordingly.

Controller Mode

Controller mode refers to the mode of controller's operation on DCS, i.e. Manual Mode, Automatic Mode, Cascade Mode.

Automatic Mode

In automatic mode, the controller set point is entered by the operator. All control function & PID algorithm will determine the output of the controller.

Manual Mode

In manual mode, PID algorithm is suspended and operator is allowed to adjust the output of the controller.

Cascade Mode

In cascade mode, master controller sends a remote set point to slave controller. The remote set point is essentially the output of the master controller.

Controller Status

Controller status referring to whether controller is operating in compliance mode or in non-compliance mode.

Compliance

Controller is operating in the correct mode as per design intent. This includes:

- Controllers operating in automatic as per design intent (intermediate and advance regulatory control i.e. cascade, split range)
- Controllers operating in manual with valid operational reasons, i.e. standby controllers, on/off controllers (in automatic when in service), sequence controllers.

Non-Compliance

Controller is operating in the **incorrect** mode and not as per design intent. This includes:

- Master and slave controllers when a cascade is broken
- Split range controller operating in automatic with one or two of its handle (MV) is detached or not used
- Controllers operating in manual due to
 - incorrect control strategy
 - incorrect tuning settings (erratic control)
 - instrumentation and DCS system related issues
 - operator preference (norms)
 - process unit capacity and design limitation (e.g. undersized pump or control valve, heat exchanger)

Plantwide Base Layer In-Control Index

A measurement of plantwide base layer controller uptime. This index excludes manual controllers in compliance mode. Also known as plant controller service factor, plant controller uptime or plant controllability factor.

1.3.3 Abbreviations

APC	Advanced Process Control
ARC	Advanced Regulatory Control
BLCA	Base Layer Controller Assessment
DCS	Distributed Control System
HSE	Health Safety & Environment
MV	Manipulated Variable (Controller Output)
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
PIMS	Plant Information Management System
PV	Process Value
SP	Set Point

1.4 SOFTWARE & TECHNOLOGY UTILISATION IN PETRONAS

There are many software available in the market which can be used to perform time consuming data processing and computation for analysis. The analysis is meant for use as part of the assessment only. Good engineering experience and knowledge are still required for the analysis.

Example of software available are as follows:

<u>Vendor</u>	<u>Software</u>
i. Matrikon	CPM
ii. Yokogawa	Shell MDPro
iii. Honeywell	Loop Scout
iv. Control Station	Loop Pro
v. Aspen	Aspen Watch
vi. OSI PI	PI Control Monitor

Analysis can also be performed using spreadsheet if software is not available. Software used in PETRONAS is listed in Appendix C.

1.5 PERSONNEL INVOLVEMENT

BLCA should involve, but not limited to, process control engineer, Instrumentation & DCS engineer, technologist and operators.

Example of the role and function of each personnel is tabulated in the table below:

No	Personnel	Roles and Function
1	Process Control Engineer	- Lead and conduct BLCA - Assist process technologist to gather data - Perform data analysis - Review Control Strategy - Ask questions and draw information from all parties. Note: In some plants, process control engineer assume the role of process technologist during BLCA. (See role of process technologist)
2	Process Technologist	- Compile and provide documentation for reference, i.e. PFD, P&ID. - Provide information and troubleshoot problems from process perspectives. - Advise on the best time to collect data and provide data from PIMS. - Participate in base layer controller prioritisation since process technologist is well-versed with the plant economics.
3	Instrument /DCS Engineer	- Instrument engineer with in-depth process knowledge can lead and conduct BLCA with the support of process technologist or process control engineer. - Provide information and troubleshoot problems related to instrumentation and DCS. - Perform instrumentation health check and fixing instrumentation problems after BLCA. - Provide information related to DCS & PIMS.
4	Operators / Panel Man	- Provide information and explanation on the operability of controllers. - Provide information on the limitation faced while operating the unit operation or controller. - Advise on the best time to collect data. - Determine the requirements for a control scheme. - Participate in base layer controller prioritisation.

2 REQUIREMENTS AND DELIVERABLES

2.1 REQUIREMENTS

The following shall be the requirements for BLCA:

1. A comprehensive BLCA shall be carried out at least once in the plant's life time and monitored continuously.

Note: The duration of the first BLCA is expected to take between 1 to 2 months from the point that good data is made available for approximately 100 to 300 controllers.

2. The following documents shall be made available:

- Process Description
- Process Flow Diagrams (PFD)
- Process & Instrument Diagram (P&ID)
- DCS Graphic
- List of Intermediate and ARC controllers *with their design mode*
- Process Control Narratives / Process Control Functional Logic Diagram
- List of PID Tuning Parameters (Optional)

3. The following process data format shall be made available:

A minimum of 1 to 2 weeks uncompressed data at maximum of 1 minute interval at all normal plant operating condition. A minimum of 3 to 4 days of uncompressed data is still acceptable depending on plant operating condition.

- Data compression in PIMS shall be removed. (There is a need to verify whether there are limitations on the capacity and loading of PIMS server and DCS network.)
- Tags required for the assessment shall be configured, historised and retrievable from PIMS.
 - FOXBORO : MEAS, SPT, OUT, MODE
 - YOKOGAWA : PV, SV, MV, MODE
 - HONEYWELL: PV, SP, OP, MODE
- Data shall be taken at the same time span for each tag.

- Data shall be taken at normal plant operating load as determined by the plant operators.
 - Data format shall be made consistent with the requirement of tool /software utilised for the assessment.
4. A suitable tool to perform assessment analysis. Refer to Section 1.4.
 5. Support and assistance from process technologist, operators, panel operators, and DCS & instrument engineers to provide inputs on process information such as process upsets, process behaviour, abnormal incidences, maintenance activities, etc for a specified assessment period.
 6. The assessor should have good process & operation understanding, statistical and process trends interpretation skills. The assessor should consult relevant personnel to verify the interpretation if he or she is not familiar with the process.

2.2 DELIVERABLES

At the end of the assessment, there shall be:

- Presentation
- Report
- Monitoring spreadsheet or database

containing the following information to verify the overall health of the controllers:

1. **Current mode of the controllers (i.e Auto/Manual/Cascade) versus design operating mode.**

The actual number of controllers operating in automatic & manual shall be quantified as follows:

Controller Mode:

- Total number of controllers
- % of Manual Controllers
- % of Automatic Controllers (Including Cascade Controllers)

Note: Please refer to Section 1.3.2 for the definition on mode. Please refer to Section 3.4.1 for method of computation.

2. **Current status of the controllers (Compliance/Non-compliance) against the standard requirements.**

The actual number of controllers in compliance and non-compliance mode shall be quantified as follows:

Controller Status:

- Total number of controllers
- % Compliance controllers
- % of Non compliance controllers

Note: Please refer to Section 1.3.2 for the definition on status. Please refer to Section 3.4.1 for method of computation.

3. Controller ratings for compliance automatic controllers.

Controllers shall be rated to Good and Poor performing controller based on engineering experience and controller performance assessment criteria. Please refer to Section 3.5 for the criteria of assessment. Please refer to Figure 2 for reference.

4. Reasons for non-compliance controllers & poor performing controllers.

Information on reasons for controller operating in non compliance mode (including manual mode) and poor performing automatic controllers shall be consolidated for further action. Please refer to Figure 2 for reference.

5. Controller's Prioritisation.

All controllers shall be prioritised according to its criticality and importance for systematic improvement implementation.

6. Recommendations for improvement for the following items:

- Controllers which may require tuning
- Controllers with instrumentation and system related issues
- Controllers which require review in process design
- Controllers with incorrect control strategy
- Controllers not operating in the correct mode due to operator preference.

The recommendations should also include readiness for implementation APC. This is to cater for specific requirements.

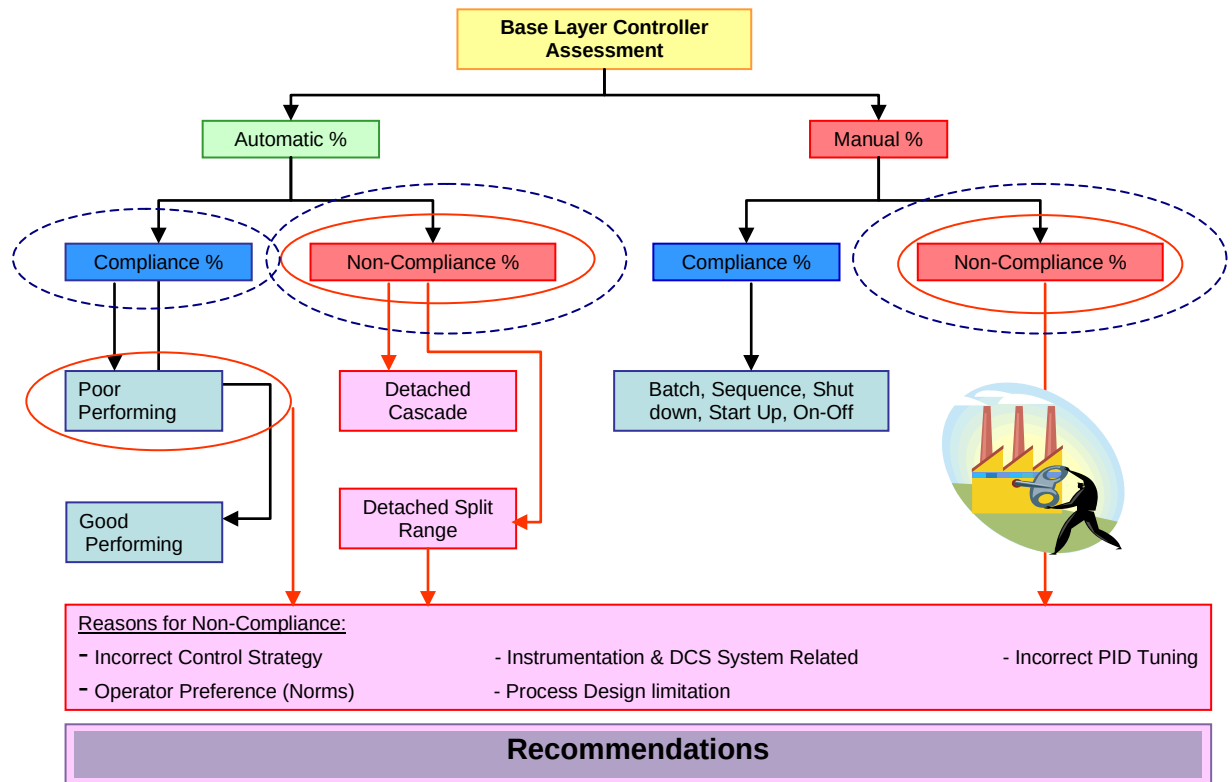
7. Plantwide Base Layer In-control Index.

At the end of BLCA, Plantwide Base Layer In-control Index to monitor the uptime of controller in compliance/design mode shall be established for continuous monitoring.

Please refer to the table below for classification of the index. Please refer to Section 3.4.2 for method of computation.

Index/uptime	Rating	Description
< 70%	Poor	Requires rectification on base layer controls
70% - 80%	Moderate	Requires rectification on base layer controls prior to APC implementation
80% - 95%	Good	Ready for APC Implementation with minor rectification on base layer controls
> 95%	Excellent	World class standard, ready for APC implementation immediately

Typical findings from BLCA shall be summarized as follows:



Legend:

○ Requires Improvement

○ Monitoring Controller Uptime (Plantwide Base Layer In-control Index)

Figure 2

3 ASSESSMENT METHODOLOGY

The methodology of BLCA is simplified to 4 phases in the following diagram.

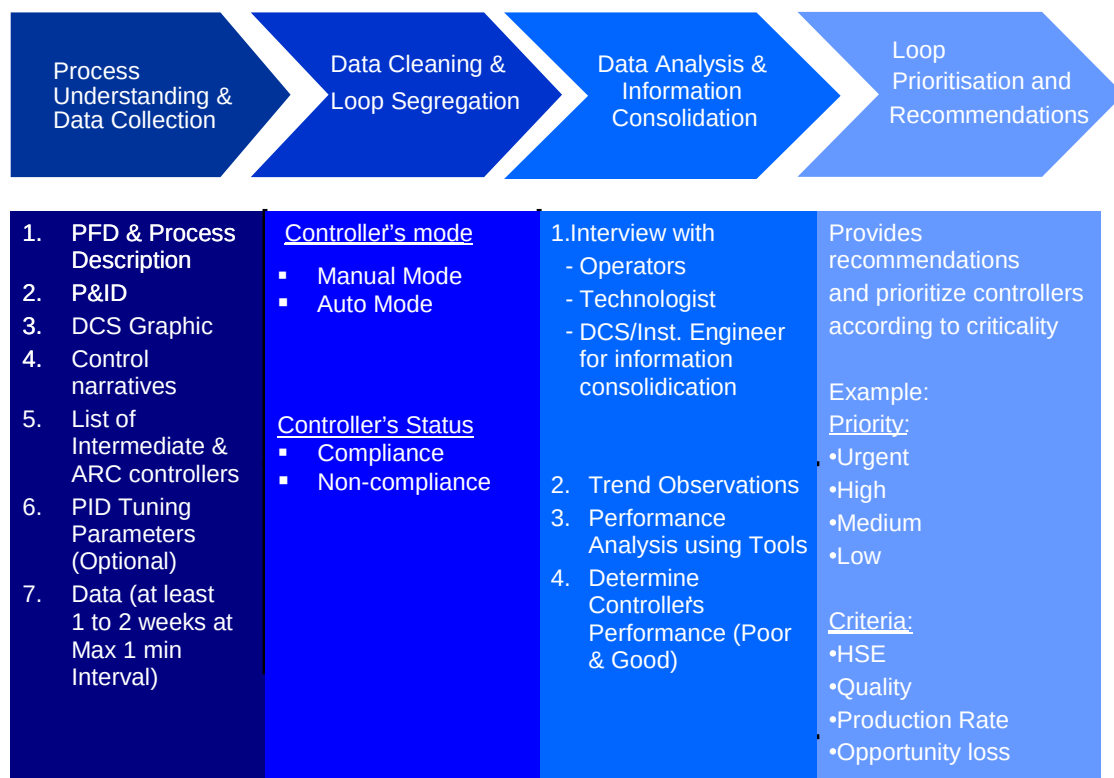


Figure 3

BLCA detail methodology comprises of the following steps:

Phases	Steps	Methodology
Phase 1	Step 1	Process Understanding
	Step 2	Data Collection
Phase 2	Step 3	Data Cleaning & Reconciliation
	Step 4	Loop Segregation & Computation of Percentage for Controller Mode, Controller Status and Plantwide Base Layer In-control Index.
Phase 3	Step 5	Data Analysis and Controllers Performance Ratings
	Step 6	Identify and Consolidate Reasons for Non-compliance Controllers and Poor Performing Controllers
	Step 7	Control Strategy Review
Phase 4	Step 8	Controllers Prioritisation According to Criticality and Value Creation
	Step 9	Reporting and Recommendations

3.1 STEP 1: PROCESS UNDERSTANDING

The engineer should be equipped with the skills to understand and interpret the technical language commonly used by process technologist, operators, and system & instrument engineers in order to effectively gather information.

The engineers shall walk through the plant processes with the technologist and operator. A plant visit should also be carried out for process familiarization. Please refer to Appendix A for the list of potential questionnaires for process understanding.

Process information can be obtained from documentation such as process description, P&ID, PFD, DCS graphics and controller narratives.

Please refer to Appendix A for list of sample questionnaires for process understanding.

3.2 STEP 2: DATA COLLECTION

The following tags are required from PIMS for BLCA:

FOXBORO : MEAS, SPT, OUT, MODE

YOKOGAWA : PV, SV, MV, MODE

HONEYWELL: PV, SP, OP, MODE

The engineer should check and ensure that the above parameters are historised and can be retrieved from the Plant Information Management System (PIMS). If additional historisation is required, the capacity and loading of PIMS server and DCS network should be checked since configuration of additional tags and uncompressed data will occupy additional server space.

The data collected shall be:

1. Uncompressed data
2. Minimum of 1 to 2 weeks data. This is to ensure sufficient data points after data cleaning. In some instances, data of at least 3 to 4 days are acceptable if the response of the controller is consistent and the process is stable.
3. Maximum 1 minute interval. Data of less than 1 minute is preferable for analysis for fast loop such as flow controller.
4. Retrieved at all normal plant operating load as determined by plant operators.

3.3 STEP 3: DATA CLEANING AND RECONCILIATION

Data cleaning and reconciliation is carried out after data collection. Data cleaning and reconciliation can be carried out automatically in some software. If data cleaning feature is not available in the software used, it can be carried out manually via spreadsheet. After data reconciliation, the data can be loaded into the software directly.

In general, the following steps are performed during data cleaning and reconciliation:

1. Removal of tags with blank value or with bad inputs.
2. Ensure that all tags are within the same time span. If one tag is removed, the remainder tags with the same time span should also be removed.
3. Ensure that there is no blank space or truncated data in the data spreadsheets.
4. Arrange the data according to the format as specified by the software utilised.
5. Data reconciliation in the following conditions are carried out to ensure that OP and PV is within the correct scale for statistical analysis:

- For OP:
Typically controller OP is configured between 0% to 100% of range. However in some sites, OP of -5% to 105% of range is configured for safety reason. Under such circumstances, OP with less than 0% shall be treated as 0% and OP with more than 100% shall be treated as 100%. This is carried out to normalise the scale to 100% of range.
- For PV:
At normal operating condition, the transmitter should reads between 20% to 80% of transmitter span. PV data shall be normalised according to transmitter span for statistical analysis. For example, flow with less than zero value shall be treated as zero value; flow with value exceeding its transmitter span shall be treated as equal to the maximum transmitter span. Do not convert data with genuine negative value such as negative temperature.

Malfunction transmitters can be detected through data analysis using the following standards in PTS 32.31.00.32, Section 2.11.1

- Transmitter reading should not be more than 2.5% $[0.4\text{mA} / (20\text{ mA} - 4\text{ mA}) * 100\%]$ off scale on the lower scale.
- Transmitter reading should not be more than 6.25% $[1\text{ mA} / (20\text{ mA} - 4\text{ mA}) * 100\%]$ off scale on the higher scale.

3.4 STEP 4: LOOP SEGREGATION AND PERCENTAGE COMPUTATION OF CONTROLLER MODE, CONTROLLER STATUS AND PLANTWIDE BASE LAYER IN-CONTROL INDEX

From the software, the operating mode of the controllers can be distinguished since the mode tag of the loop is downloaded into the software together with the process value, set point value and controller output tag.

Segregation of control loops according to its mode and status is done manually on a spreadsheet or via software. The mode of the controller is determined by the mode tag collected from PIMS. As a first pass for the purpose of controller segregation, controller with uptime of 30% during the period of assessment is categorised to be in manual mode, while controller with uptime of 70% during the period of assessment is categorised to be in automatic mode. The actual status of the controller shall be determined in the next stage and is assigned based on standard engineering requirement as per design intent. Please refer to Section 1.3.2 for the definition of compliance and non-compliance controllers.

The controllers can be segregated into the following categories:

1. Controllers in manual mode.
2. Controllers in automatic mode.
3. Controller in compliance mode.
4. Controller in non-compliance mode.
5. Intermediate and ARC controllers. i.e. cascade, split range and override controllers
6. Controllers with fixed output. i.e. on/off controller, saturated controllers

Loop segregation is done to determine the number and the percentage of controller mode and status. This percentage indicates the overall health of the controllers. Items 5 & 6 are listed for reference and trouble shooting.

Plantwide Base Layer In-control Index should be computed for continuous performance tracking after BLCA. Plantwide Base Layer In-control Index indicates the uptime of the controllers operating in automatic as per design intent or in compliance mode. The index shall exclude manual controller in compliance mode.

3.4.1 Computation for controller mode and status

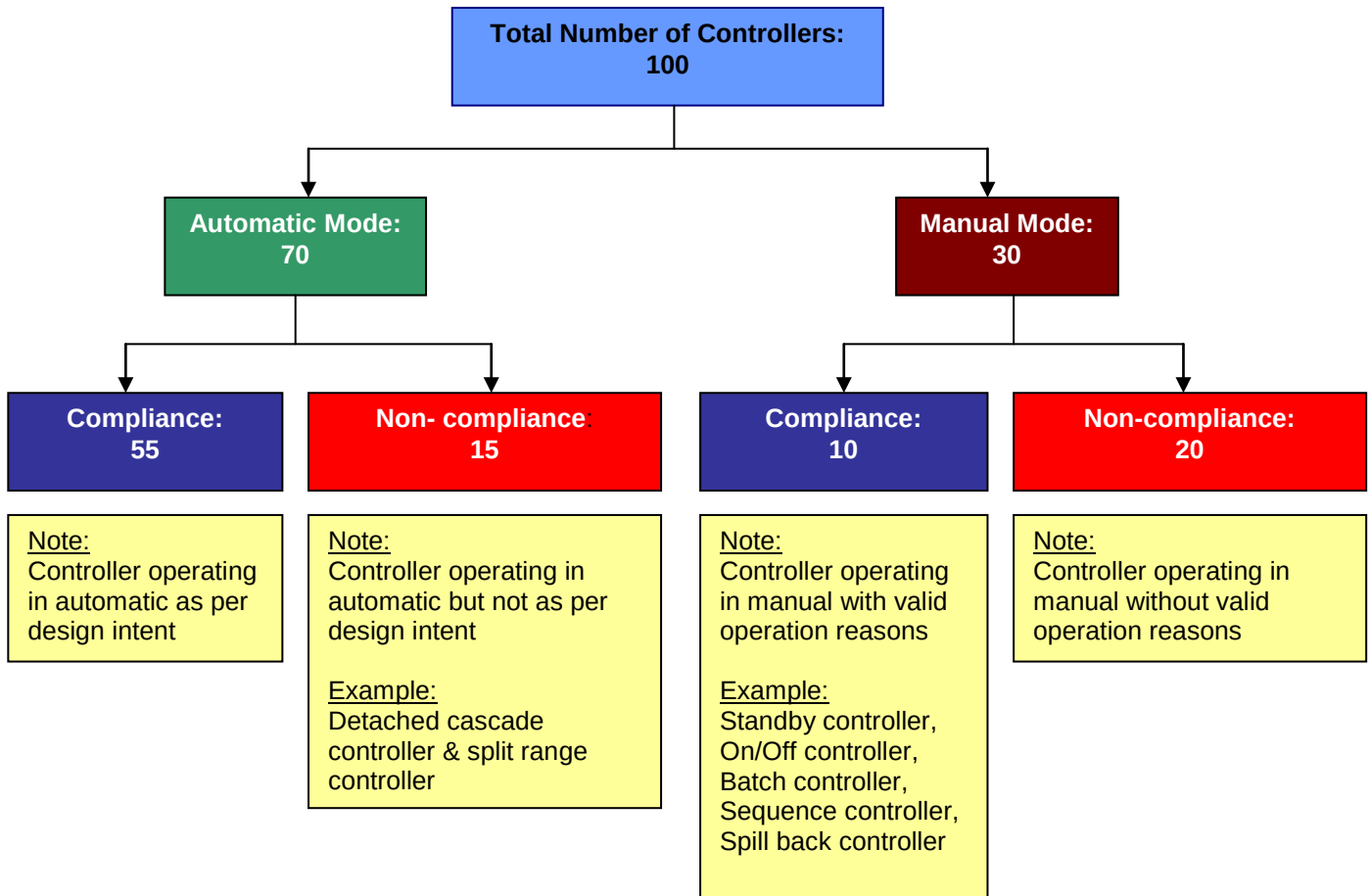


Figure 4

Example:

Computation of controller mode in %:

Total Number of Controller	= 100
# of Automatic Controller	= 70
# of Manual Controller	= 30
% of Automatic Controller	= $70/100 \times 100\% = 70\%$
% of Manual Controller	= $30/100 \times 100\% = 30\%$

Computation of controller status in %:

Total Number of Controller	= 100
# of Compliance Controller	= 55 + 10
# of Non-Compliance Controller	= 15 + 20
% of Compliance Controller	= $(55 + 10)/100 \times 100\% = 65\%$
% of Non-Compliance Controller	= $(15 + 20)/100 \times 100\% = 35\%$

3.4.2 Computation of Plantwide Base Layer In-control Index

Plantwide Base Layer In-control Index refers to the uptime of base layer controllers in design/compliance mode, in the plant within a specified time span (e.g. 1 month). Computation of Plantwide Base Layer In-control Index shall exclude manual controller in compliance mode. Please refer to Figure 2 for the breakdown of manual controller in compliance mode. Manual controller in compliance mode does not operate in automatic continuously within the same time span hence it is not a good representative to be included in the computation. The uptime and performance of manual controller in compliance mode such as batch controller and sequence controller shall be monitored separately when the controller is in service.

Plantwide Base Layer In-control Index (uptime) =

$$\frac{\text{Controller's uptime in hours in design/compliance mode}}{\text{Plant availability in hours}} \times 100\%$$

Plant availability in hours can be specified within an assessed period depending on the requirement of reporting. Normally, plant would report this index monthly. The index can also be calculated per unit basis (e.g process unit, utilities and offsite).

The control index shall take into account the mode of individual PID loops when APC is switched ON. PID controller override by APC shall be considered as in compliance.

Note:

- PID controller mode is changed to manual mode when APC is switched ON whereby APC is controlling the output of the controller.
- PID controller mode is changed to automatic mode from cascade mode when APC is ON whereby APC writes set point to the slave controller while the master controller is on set point tracking mode.

Example:

Total number of controller	= 100
Total day in a month	= 30 days
Total hours in a month	= 24 hrs x 30 days = 720 hrs
Plant/process unit availability	= 95%

Total hours of plant availability for 100 controllers = 720 hrs x 100 x 95% = 68400 hrs

Total controller uptime in compliance/design mode for 100 controller = 59870 hrs

$$\begin{aligned} \text{Plantwide Base Layer Control Index} &= \frac{59870 \text{ hrs}}{68400 \text{ hrs}} \times 100\% \\ &= 87.5\% \end{aligned}$$

3.5 STEP 5: DATA ANALYSIS AND CONTROLLER PERFORMANCE RATINGS

Only controllers with active PID actions can be analyzed for controller performance. Data analysis shall be carried out based on statistical controller performance assessment criterion and engineering judgement.

3.5.1 Controllers that cannot be assessed for performance

Performance of controller with its output fixed at a certain position cannot be analyzed using the performance assessment criterion since the PID action of controller ceases to response. Such behaviour can be observed in the following conditions:

No	Condition	Controller classification
1	Controller in manual mode would have output fixed at a certain position. PID algorithm is not executed when controller in manual. The output of the controller is changed by the operator and the set point tracks the process value if set point tracking is configured.	Controller in manual mode and are not in compliance
2	Controller in automatic mode with output at 0% or 100%.	CASE 2a: If controller is designed for ON/OFF operation during normal operation then it is considered as compliance (e.g. blow down controller) CASE 2b: If controller's output is normally required at 0% or 100% intermittently due to actual process condition, then it is considered as compliance. (e.g. spill-back flow controller, override controller) CASE 2c: If controller's final element is oversized or undersized during normal operation, then it is considered as not compliance due to physical limitation of the unit operation. CASE 2d: If controller's final element is found damaged on sites which result in saturation, then it is considered as not compliance.
3	Controller in automatic, but output is clamped on DCS (soft clamp) or in the field (hard clamp) to a certain position due to operational reasons.	Controller in automatic mode and are in compliance, however if the final element is clamped due incorrect sizing than it is considered as not compliance.

The reasons for non assessable controller as stated in the table above shall be recorded and rectified if required.

3.5.2 Controllers that can be assessed for performance

The output of controller varies when operator changed the set point of controller in automatic. PID algorithm of the controller will calculate the corresponding controller output based on the error measured (process value minus set point).

Data analysis using performance assessment criterion shall be performed on automatic controller with varying process value, set point and controller output. Automatic controller with fix set point and varying output is still acceptable for analysis of error only. However, set point changes should be introduced to analyse PID tuning performance.

The performance of controller can be analyzed using two approaches:

- a) Quantitative performance assessment using statistical controller performance assessment criterion.
- b) Qualitative performance assessment using engineering judgement and experience.

The result generated by statistical method may not represent the overall performance of the controller. Engineering judgement and experience is still required to verify and interpret the results. Please refer to Section 3.5.3 and 3.5.4 for further details.

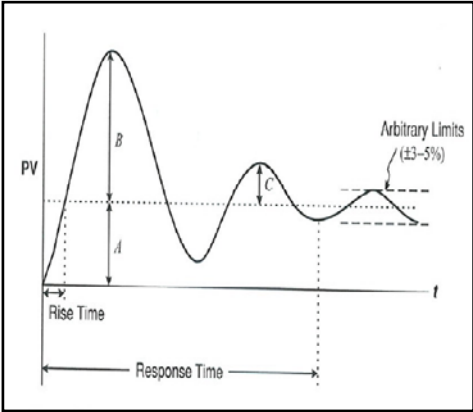
a) Quantitative Method: Controller Performance Assessment Criterion

The engineer should have good understanding of different controller performance assessment criterion as follows:

No	Controller Performance Assessment Criteria	Standard	Remarks
1	Controller Uptime	Above 70%	Applicable during the period of assessment only. Controller with less than 70% uptime requires immediate attention.
2	PV Noise Strength $X\% = \frac{\text{Standard deviation on PV}}{ \text{Average PV} }$ Or $X\% = \frac{\text{Standard deviation on PV}}{ \text{PV Transmitter span} }$ $X\% > 5\%$ High Noise Note: Measuring noise using PV transmitter span is more accurate. However, measuring noise using PV average is acceptable if PV	Less than 5% is acceptable.	There may be a requirement to install signal filter to reduce the noise depending on process requirement. High PV noise cause excessive wear and tear of final control element.

	span is unavailable. - The inverse of PV noise strength is equivalent to signal to noise ratio. - Measuring the noise with controller in automatic can be used as a pre-assessment to detect generic noise. Generic noise includes noise from the process, PID action and instrumentation physical noise. - To identify the actual source of the noise, the noise of the controller can then be measured by putting the controller in manual. This is done to rule out noise generated by PID action.		
3	Final control element operating range, MV	In general, a good final control element should operate within 20% to 80% of the design range. Equal percentage valve: 25% to 90% Linear valve: 10% to 80%	Otherwise final element is considered oversized or undersized due to lack of controllability.
		Guidelines	Remarks
4	Measure of stability	Higher stability indicates better performance. Depends on the definitions of stability in specific tools used for the analysis.	Each software has their specific indices, i.e. controller performance index (CPI), relative performance index (RPI), stability factor. This serve as a reference to determine the overall performance of the loop. Please refer to the software references for its specific definition.

5	Final control element travel index Example: MV travels %/hr Standard deviation on MV	Smaller index indicates better performance. Highly dependent on the design of final element. e.g. control valve, pump, fin fan.	Large % or standard deviation indicates that final element is working hard to stabilize the process. This may lead to faster wear and tear on the final element. Normally this is a concern to instrument or mechanical engineer.
6	Stiction and Oscillation Indices	Smaller stiction and oscillation indicates better performance.	Computed in some software using mathematical method, i.e. Fast Fourier Transform Stiction may result in oscillation. However, oscillation does not necessary caused by stiction alone. Oscillation can also be caused by process. Stiction and oscillation can also be identified visually through trend observation.
7	Deviation (error) caused by set point changes - Sum of Square of Error (SSE) - Integrated Square of Error (ISE) - Integrated Absolute of Error (IAE) - Integrated Time Square of Error (ITSE) - Integrated Time Absolute Error (ITAE) $SSE = \sum_i (e)^2 \quad IAE = \int_0^\infty e d$ $ISE = \int_0^\infty (e)^2 d \quad ITAE = \int_0^\infty t e d$	Smaller number indicates better performance. Off-line error analysis can be performed using this analysis technique.	This technique is used to analyze and compare controller response for PID tuning in response to set point changes. Of the five techniques, ITAE provides the most conservative settings while SSE & ISE provides the least conservative settings.

	$ITSE = \int_0^{\infty} t(e)^2 dt$		ITAE and ITSE are penalized by slow response since it is affected by time factor. This method is not suitable to be used for on-line monitoring since it is not able to differentiate and reject disturbance.
8	Variance and standard deviation on error	Smaller number indicates better performance. This technique can be used for both on-line and off-line error analysis.	Variance and standard deviation on error is more suitable for on-line performance monitoring and also for judging disturbance handling. Some software is able to calculate the minimum standard deviation for reference.
9	Decay Ratio Peak 2/ Peak 1 = C/B  Source: A Real Time Approach to Process Control By William Y Svrcek, Donald P Mahoney, Brent R Young	Optimum decay ratio depends on process characteristic. The result is for reference and comparison with re-assessment after improvement work.	In 1953, Cohen and Coon reported that this method provides the most optimum controller performance and responses at $\frac{1}{4}$ decay ratio. However, this is often judged to be too oscillatory by plant operating personnel and the criterion (decay ratio) only consider two points of the closed loop response, namely the first two peaks.

10	% Overshoot $\text{Peak 1/ set point change} \times 100\% = B/A \times 100\%$ Please refer to figure in item 9	Smaller number indicates better performance. The result is for reference and comparison with re-assessment after improvement work.	High overshoot is frequently a concern to panel man. Note that some process is intentionally overshoot to obtain faster response.
11	Rise Time Please refer to figure in item 9	The rise time is highly depended on the process characteristic. The result is for reference and comparison with re-assessment after improvement work.	
12	Response Settling time Time required for the PV to reach and remain inside a band whose width is equal to plus minus 5% of the total change in step change (95% of response time). Please refer to figure in item 9	For flow & pressure (liquid) controller usually settles within less than 1 minute of valve movement. For others, highly depended on process characteristic.	

b) Qualitative Method: Controller Performance Assessment Criterion

Quantitative method should be used to measure the performance of the controller. However, qualitative method based on engineering judgment shall be used to verify the result generated by software.

Qualitative method depends on the engineer's process data/trend interpretation skills and process understanding to search for abnormalities. Among the performance characteristic which should be observed are as follows:

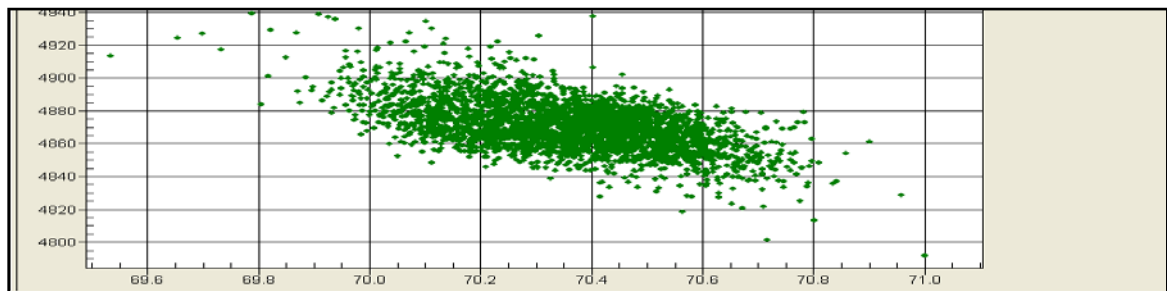
1. Magnitude and frequency of PV & MV oscillation:
To determine whether the oscillation is acceptable, i.e. some oscillation is acceptable in less critical equipment (level surge drum) to reduce disturbance down stream.
2. PV & MV settling time:
Fast or slow response depends on process characteristic, e.g. flow control should settle fast, temperature control may be slower. Fast response may not always be the best, solely depend on process requirements.
3. PV & MV limiting (Saturation):
This normally indicates that there are problems with the loop. i.e. final element undersized, oversized or clamped. The MV may be clamped due to operational reasons.

4. Mode of operation (Auto/Manual/Cascade):
To indicate whether operator operates the controller as per design intent and there are no operational issues, e.g. intermittent manual mode instead of auto mode for some reasons.
5. Unusual disturbance from the process:
To locate the source and cause of disturbance based on process understanding and experience. Disturbance may be caused by interaction between control loops.
6. Control valve characteristic:
Plotting process values (PV) versus controller output (MV) scatter plot in excel to observe the characteristic of the control valve, i.e. hysteresis, stiction, and oscillation.

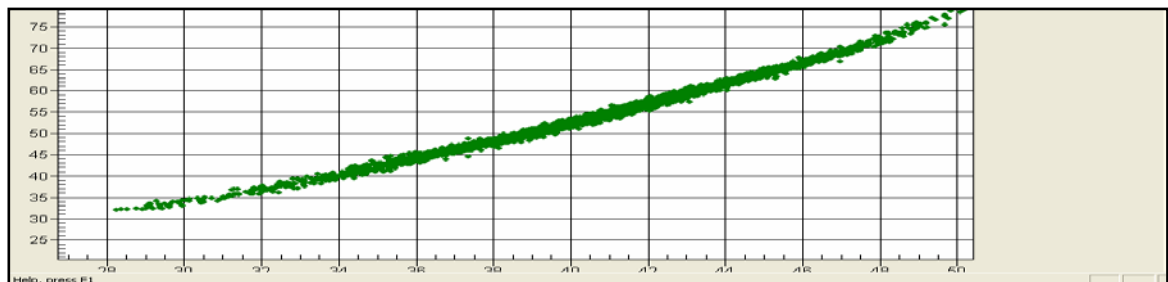
Examples of Process Value (PV) versus controller output (MV) scatter plot in excel spreadsheet:

Example 1: Normal Control Valve Characteristic (Flow Controller)

Controller 1 Description: Reverse action with narrow MV operating range

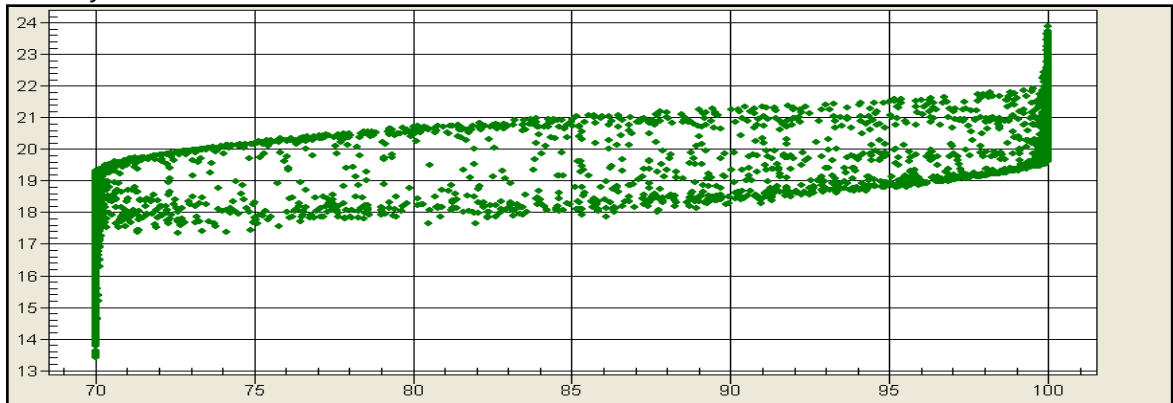


Controller 2 Description: Direct action with wide MV operating range



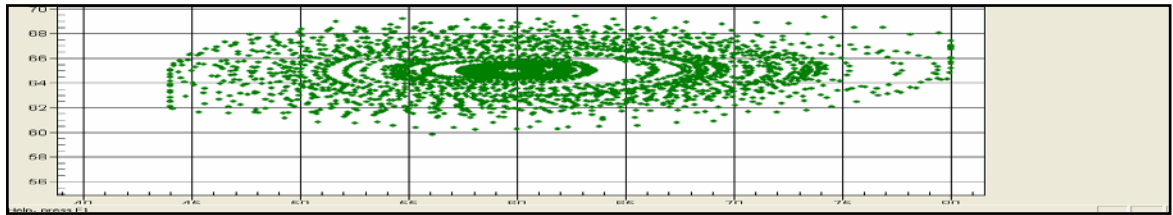
Example 2: Control Valve Hysteresis (Pressure Controller)

Description: Split range with MV operating between 70% to 100%. This is a typical pattern of valve hysteresis.

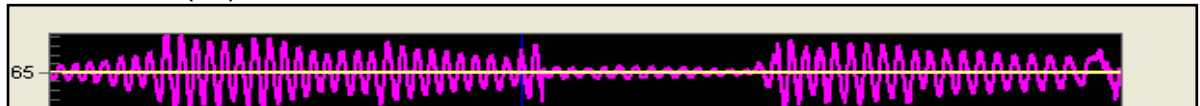


Example 3: Oscillation (Level Controller)

Description: This is a typical oscillatory response where MV and PV have similar patterns.



Process Value (PV)

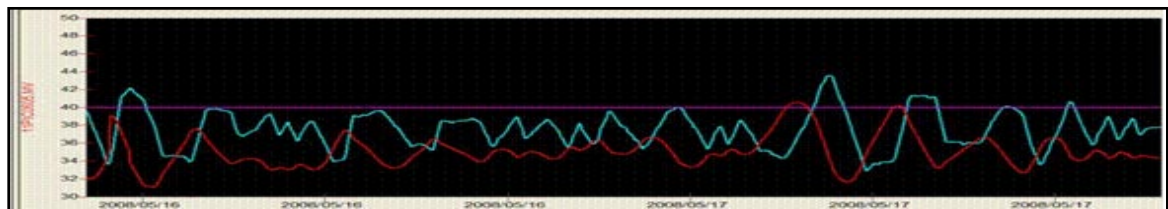
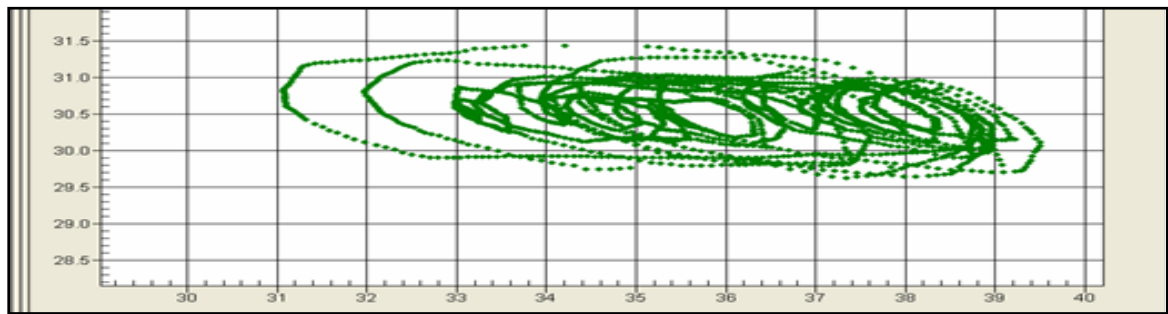


Controller Output (MV)



Example 4: Oscillation & Stiction (Flow Controller)

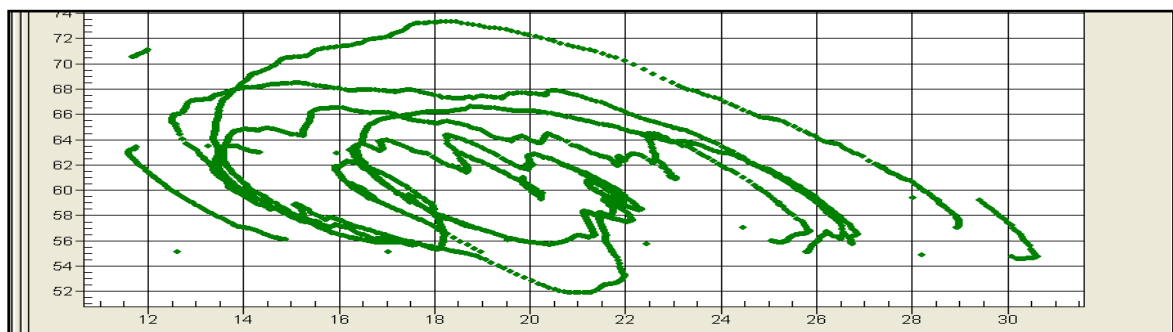
Description: Obvious lag time for PV response against MV.



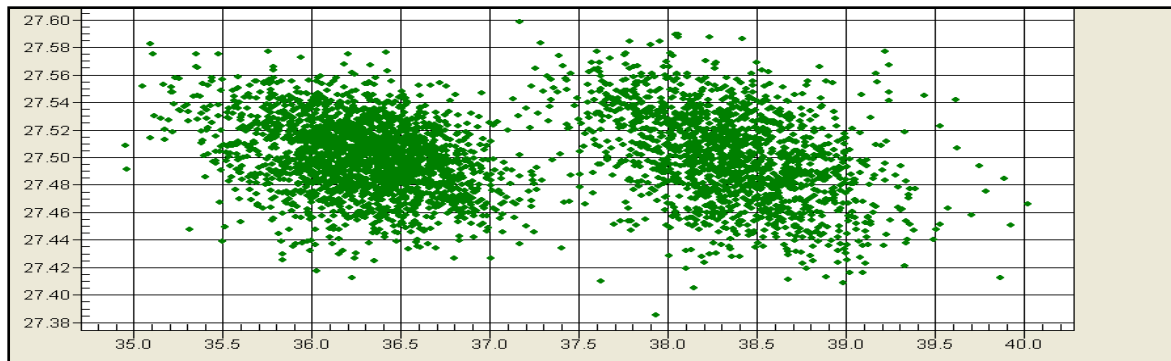
Legend:

MV
PV
SP

Example 5: Non-linear or Abnormal Process Behaviour (Level controller for an evaporator)



Example 6: Normal process behaviour, Control valve operating at two different operating points (Pressure Controller)



3.5.3 Controller performance ratings

The main purpose of performance ratings is to rate the controller performance, namely:

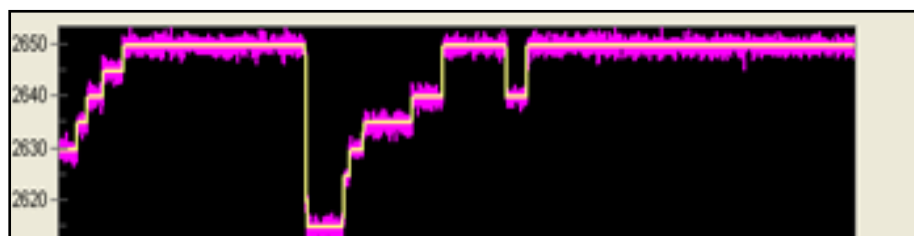
1. Poor Performing Controllers
2. Good Performing Controllers

Controller ratings are rated based on the performance assessment criterion in Section 3.5.3 and 3.5.4. A general guideline for controller performance classification is attached in Appendix E.

Improvement programs shall focus on poor performing controllers. However, further improvement can also be carried out on good performing controllers when requirement arises. It should be stressed that the performance of good performing controller may deteriorate over time due to wear and tear of equipment and process changes. Therefore it is very important to monitor the performance of base layer controllers continuously.

Example of Good Performing Controllers:

Description: Process value follows set point closely at every set point change with acceptable MV movement and reasonably fast settling time.

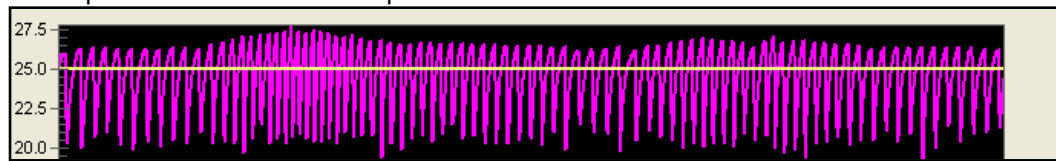


Legend:

— SP
— PV

Example of poor performing controllers:

Description: PV oscillation for a pressure controller.



Legend:

— SP
— PV

3.6 STEP 6: IDENTIFY AND CONSOLIDATE REASONS FOR NON-COMPLIANCE CONTROLLERS AND POOR PERFORMING CONTROLLERS

Panel operators, technologist and instrumentation engineers shall be interviewed to consolidate and troubleshoot the potential reasons for non-compliance and poor performing controllers.

All findings, observation, potential problems and explanation of non-compliance and poor performance shall be recorded and consolidated for further investigation. Please refer to Appendix B for the list of sample questions asked during the interview session.

Interview sessions of panel operators from different shifts are highly recommended. This is to ensure consistent findings. Technologist & Instrument Engineers should also verify the explanation from the panel operators to ensure that the explanation make sense and logical.

Other than problems related to the process and instrumentation, engineers should also highlight problems related to DCS configuration. Problems related to DCS configuration which can be observed from the data are:

1. Set Point tracking function is not activated when controller is in manual. (SP does not track PV when controller is in manual)
2. Master controller is not in initialization mode when slave controller is detached. (SP does not track PV of master controller and OP of master controller does not track SP or PV of slave controller)
3. OP of non-selected controller (not in-control) does not track the OP of selected controller (in-control). This is not applicable to override controller.
4. PV freeze at last good value, bad input or no value.
5. Incorrect DCS graphic, e.g. Incorrect process flow, Incorrect colour indication.

3.6.1 Generic reasons for non-compliance and poor performing controllers

Generic reasons for non-compliance and poor performing controllers can be divided into 5 categories:

1. Incorrect control strategy
2. Instrumentation and system related issues
3. Limitation in process unit and process design
4. Incorrect PID tuning
5. Operator preference (Norms)

BLCA shall be followed up with thorough checking of the health and physical condition of the instrumentations by instrument engineers and technicians before implementing any improvement initiatives.

3.7 STEP 7: CONTROL STRATEGY REVIEW

If controllers are operating against original design intent, process control engineers shall further investigate and evaluate the effectiveness of the existing control strategy. Instrument engineer shall also check the current health of the instrumentation and verify that the instrumentation is healthy. Any control strategy changes shall be agreed by all relevant parties.

The new control strategy shall meet the following criteria:

1. Meeting safety, control objective and process requirements
2. Easy to operate and not too complicated
3. Able to function with available instrumentation
4. Meeting most effective response time

All control strategy changes shall be fully documented in controller narrative for reference.

3.8 STEP 8: CONTROLLER PRIORITISATION ACCORDING TO CRITICALITY AND VALUE CREATION

Prioritisation of controllers allows systematic corrective actions to be taken during improvement initiatives, in which attention shall be given to controllers in descending priority, i.e. Urgent, High, Medium and Low

Prioritisation shall be carried out by process control engineers, process technologist and operators. The Prioritisation shall focus on the importance of controllers based on process requirements and shall not be dictated by the reliability of the unit operation and instrumentation.

The following method is recommended for Prioritisation to determine which problematic controller to be tackled first among hundreds of problematic controllers plantwide:

Stage 1:

In stage 1, controllers are prioritised into 3 categories namely High, Medium and Low according to its impact in reference to 4 criteria namely HSE, Quality, Production Rate, and Opportunity Loss.

Weightage of between 1 to 3 is assigned to each criterion below:

- | | |
|---------------------|--------------|
| 1. Quality | Weightage: 3 |
| 2. Production Rate | Weightage: 2 |
| 3. Opportunity loss | Weightage: 1 |

The impact of each controller towards the criteria above is assigned as follows:

- | | |
|-------------------|-----------|
| 1. Very Important | Impact: 3 |
| 2. Important | Impact: 2 |
| 3. Less Important | Impact: 1 |
| 4. Not Important | Impact: 0 |

A score is assigned to each priority below: (Score = Impact x weightage)

- | | |
|-----------|----------------|
| 1. Urgent | HSE loop |
| 2. High | Score: 14 - 18 |
| 3. Medium | Score: 6 - 13 |
| 4. Low | Score: 0 – 5 |

Please note that the score, impact and weightage assigned above is just an example only, it can be changed according to user preference.

HSE loop shall be given first priority and it will be automatically classified as URGENT. APC loop should be given higher impact for its respective criteria (i.e. production rate, quality, opportunity loss) which will ultimately result in a higher score cum higher value creation.

The definition of each of the criteria above is defined as follows:

No	Criteria	Definition
1	HSE	If fail to perform, this could trigger safety alarms such as fire or explosion or lead to environmental or health problems.
2	Product Quality	If fail to perform, quality of product may be effected.
3	Production Rate	If fail to perform, not able to ramp up or down the production rate.
4	Opportunity Loss	If fail, plant not at optimum mode, no optimisation.

Example 1:

Unit	Description	HSE Loop YES/NO?	Product Quality	Production	Opportunity Loss	SUM	LOW ; MEDIUM ; HIGH	Remarks
LICxxx	Ethylene feed	NO	3	2	3	13	HIGH	APC Loop

Score = Product Quality (3) x 3 + Production (2) x 2 + Opportunity Loss (1) x 3 = 16

Since score of 17 falls within the region of HIGH (14 to 18), hence priority assigned is HIGH. This is also an APC Loop.

Example 2:

Unit	Description	HSE Loop YES/NO?	Product Quality	Production	Opportunity Loss	SUM	LOW ; MEDIUM ; HIGH	Remarks
LICxxx	Ethylene feed	YES	1	1	0	5	URGENT	

Score = Product Quality (3) x 1 + Production (2) x 1 + Opportunity Loss (1) x 0 = 5

Score of 5 falls within the region of LOW (0 to 5), however it has impact on HSE, therefore it is automatically prioritised as URGENT.

Stage 2:

In stage 2, ranking is done to help the relevant engineer to systematically rectify problematic controllers according to level of difficulty. The ranking is done as follows:

1. Controller with HIGH priority is further ranked according to difficulty, i.e. Easy to Do, Difficult to Do. Similar ranking is done for controller with MEDIUM and LOW priority at later stage. Such ranking can be done after some investigating has been carried out on the control loop.
2. Controllers which can be rectified easily is placed in sections 1, 3, 5 and controller which is difficult to rectify is placed in sections 2, 4 and 6 according to its priority (score).
3. Controller with HIGH priority has high value creation with regards to production rate and product quality while controller with LOW priority does not contribute to significant value creation.
4. It is recommended to rectify controller in section 1, follow by sections 2 to 6. It should be noted, that in practice, working period on some sections may overlap. For example, some corrective action on controllers in section 2 may require turn around; therefore, engineers should proceed with controllers in section 3.

High Priority (High Value)	Medium Priority (Medium Value)	Low Priority (Low Value)	Example
Easy To Do 1	Easy To Do 3	Easy To Do 5	PID Tuning problem, Transmitter Range Changing, Adding PV Filter
Difficult To Do 2	Difficult To Do 4	Difficult To Do 6	Controller Strategy Modification/Review, Requires Plant Turn around to replace, repair or redesign instrumentation, requires process hard ware modification

Please refer to Appendix G for template/format for controller prioritisation spreadsheet.

3.9 STEP 9: REPORTING AND RECOMMENDATIONS

Finally the results, findings and recommendations shall be reported in the most comprehensive and systematic manner. It should illustrate the current status, the health and the gap for improvement. The assessment result should include the following information:

No	Items	Remarks
1	Total number of controllers assessed	Breakdown the number according to process unit i.e. process, utilities.
2	% and number of controller in manual mode	Not all manual controller are in the correct mode
3	% and number of controller in automatic mode	Not all automatic controller are in the correct mode
4	% and number of controller in compliance mode	Breakdown of manual and automatic controller in compliance mode. This includes manual batch controller, shut down controller or standby manual controller.
5	% and number of controller in non-compliance mode	Breakdown of manual and automatic controller in non-compliance mode. This include detach cascade and split range loop.
6	% and number of controller in non-compliance mode for optimisation loop only	e.g. Advance Process Control (APC)
7	% and number of non-compliance controller according to its reasons	Breakdown of non-compliance reasons according to the following categories: 1. Incorrect control strategy 2. Problems with Instrumentation 3. Limitation in process unit and process design 4. Problems with controller tuning 5. Operator preference (Norms)
8	% and number of poor performing controller	
9	% and number of good performing controller	
10	% and number of controller requires improvement	This included % of non-compliance controller and % of poor performing controller for controller loop with high priority i.e APC loops
11	% and number of controller decommissioned	Controller no longer in used
12	% and number of automatic controller which cannot be analysed due to saturated MV	This requires further investigation by engineer to determine whether controller is operating in compliance mode.
13	Recommendations & Conclusion	1.Way forward for improvement or rectification programs. 2.Readiness of implementation for optimisation programs.

At the end of the BLCA, the plant shall be equipped with a complete spreadsheet/database of the status, history and health of each controller being assessed

for monitoring purpose. The database/monitoring spreadsheet of the assessment should contain the following information: Please refer to Appendix F for the recommended format.

No.	Items	Description
1	Control loop tag number	Control Loop being assessed
2	Control loop description	Location of controller, e.g. deethaniser reflux flow
3	Control loop P&ID page number	Location of controller, i.e. 101-13-01
4	Process fluid	Record the process fluid and the state of the fluid
5	Controller uptime / mode	% of time in automatic
6	Controller status	Compliance or Non-Compliance
7	Quantitative result of controller performance assessment criteria: Example: 1. Standard deviation on error 2. Standard deviation on MV 3. Controller Performance Index/Stability factor/Real Performance index 4. Noise Strength	Record the statistical result of performance assessment.
8	Observation and remarks Example: 1. Process overshoot, 2. Process settling time 3. Process disturbance 4. Process limitation 5. Instrumentation limitation 6. Control Valve Oscillation and Stiction 7. Control Valve hysteresis 8. History of instrumentation problems 9. Controller MV and PV saturation	Record all observations and all potential problems and explanation provided by the operators, technologist and instrument /DCS engineer during the interviewing session
9	Performance ratings	Rate controller to Good and Poor Performance controller according to assessment standards and guidelines. Please refer to section 3.5.2 and Appendix E for controller performance classification.
10	Priority	i.e. High/Medium/Low/Easy to do/Difficult to do
11	Main reason for non-compliance	Summarised and categorised the main reason for non-compliance. 1. Incorrect control strategy 2. Problems with Instrumentation 3. Limitation in process unit and process design 4. Problems with controller tuning 5. Operator preference (Norms)
12	Recommendations	Provide recommendations

4 CONCLUSION

BLCA is a methodology to identify problematic loops along with its potential problem using in depth process knowledge and basic instrumentation knowledge.

BLCA provides an overall health check of the controller in the plant thereby saving a considerable amount of time for operators, technologist and instrument engineers. Relevant OPU engineers can work on the problematic loops immediately.

It is highly recommended to carry out the following after BLCA:

1. Immediately resolve the problems related to non-compliance or poor performance controller according to its priority. A comprehensive health check on the instrumentation of the problematic loops identified shall be carried out to identify whether the problems are instrumentation related. Not all problems are instrumentation related!
2. Tracking the uptime of controllers (Plantwide Base Layer In-control Index) and continuously monitoring the performance of controller. The performance of controller may deteriorate over time due to wear and tear or change in plant process behaviour.
3. Overall BLCA result and conclusion as tabulated below shall indicate the readiness for APC implementation.

% of compliance	Rating	Description
< 70%	Poor	Requires rectification on base layer controls
70% - 80%	Moderate	Requires rectification on base layer controls prior to APC implementation
80% - 95%	Good	Ready for APC implementation with minor rectification on base layer control
≥ 95%	Excellent	World class standard, ready for APC implementation immediately

Note: Refer to Section 2.2 and Section 3.4.1 for computation of % of compliance controllers. Computation of % of compliance in the table above takes per unit number of controller as basis. Plantwide Base Layer In-control Index from Section 2.2 and Section 3.4.2 can also be used to indicate readiness for APC implementation.

A sample of controller pre-commissioning check list is attached in Appendix D. The checklist is useful to verify the actual health of controller before attempting to revert to compliance mode. The sample checklist should be tailored to the OPU DCS type and version.

5 REFERENCES

- a. EWB – Base Layer Controller Assessment, February 2009, Level 1, Rev. 0 (PR-EWB-APC-008) by Poo Hwei Ching, GTS APC Senior Engineer
- b. EWB – Base Layer Controller Assessment – Project case Study, February 2009, Level 1, Rev 0 (PR-EWB-APC-011) by Poo Hwei Ching, GTS APC Senior Engineer
- c. EWB – Important PID references from Honeywell, Foxboro & Yokogawa DCS, Level 1, Rev 0 (PR-EWB-APC-017) by Poo Hwei Ching, GTS APC Senior Engineer
- d. A Real Time Approach to Process Control 2nd Edition, William Y. Svrcek, Donald P. Mahoney, Brent R. Young, John Wiley & Sons, Ltd
- e. Process Dynamic and Control, Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, John Wiley & Sons, Ltd
- f. Shell MD PRO User Manual
- g. Loop PRO User Manual
- h. PI Control Monitor User Manual

6 APPENDICES

APPENDIX A: SAMPLE QUESTIONS FOR PROCESS UNDERSTANDING

The intent of these questions is to enable the assessor to understand the overall process and the functionality of the controllers being assessed. In summary, to check the understanding, the following questions below can be answered:

- What is the purpose of the plant/unit?
- Where does the feed come from?
- Where does the product go?
- What are the 3 or 4 most important constraints that operators worry about?
- What are the product specifications?
- Does feed composition changes and if so how often and how fast are these changes?
- What is the current constraint on throughput? Are these equipment / safety limitations?
- Have there been historical incidences of higher than normal throughput and what conditions allow for these?
- What is the typical yield of the unit?
- What parameters impact yield of the unit? Are any of these constrained?
- How much flexibility is there in operating the unit?
- On a typical stable operation shift, which are the handles that are most frequently operated by the operator?
- Are there any known issues with measurements on the process?
- Are there APC controllers?
- What is the control objective of each controller?
- What type of DCS model, version?
- What type of Plant Information Management System/Historian (PIMS)?

APPENDIX B: SAMPLE QUESTIONS FOR CONSOLIDATING REASONS FOR NON-COMPLIANCE AND POOR PERFORMING CONTROLLERS

- Why is the controller operating in non-compliance mode?
- Why operators detach the cascade loop or split range controller?
- Why is the controller fluctuating or oscillating?
- Why is the controller output saturated at one position, is there a clamp?
- How did operator operate a particular control scheme?
- What causes the sudden disturbance in the process value?
- Are there any problems on the instrumentation (control valve, measurement transmitter)?
- How often operator placed the controller in manual mode or non-compliance mode?
- Do you require this controller in the process?
- How often is this process unit shut down?
- Is the oscillation in process value acceptable to the process unit?
- Is the controller responding too slow or too fast?
- Is the control scheme efficient and easy to operate?
- Can the process unit handle the sudden spike or disturbance from upstream?
- What is the alarm or trip setting of this controller?
- Is this part of APC loops?
- What is the state and phase of process fluid control by the controller?
- Is the process unit in good condition?
- Is this controller still in service?
- Are there limitations on the operation unit or instrumentation?
- Is the performance of controller being monitor continuously?

Note: The interviewed personnel may not have all the answers to the above question. The assessor may need to do further investigation, consolidation, verification and judgement.

APPENDIX C: ADVANCE CONTROLLER PERFORMANCE SOFTWARE USED BY PETRONAS OPU GROUPWIDE

The following is the list of sites in PETRONAS that has controller performance software applications installed:

<u>Operating Unit</u>	<u>Controller Performance Software</u>
PETRONAS Penapisan Melaka Sdn. Bhd	Matrikon (APC & PID)
PETRONAS Penapisan Terengganu Sdn. Bhd	Matrikon (APC only)
Malaysia LNG Sdn. Bhd. (1, 2 and 3)	Shell MDPro, PI-Control Monitor
PETRONAS GAS Berhad	Shell MDPro
Group Technology Solution	Shell MDPro, Loop Pro, Matrikon

APPENDIX D: SAMPLE OF CONTROLLER PRE-COMMISSIONING CHECK LIST

Application Title Or DCS Tag				
Application No.				
	YES	NO	N/A	Resp.

6.1 FIELD INSTRUMENT VERIFICATION

Is there a known problem with the valve? e.g. passing, stiction				
Is valve operating with bypass partially open/fully open or passing?				
Measurement sensor has been calibrated, range tallies with DCS				
Control valve has been calibrated				
Loop checks completed (transmitter to DCS), (note : apply caution in case PV tied to ESD)				
Stroke check completed				
Installation check (actual vs drawing)				
PV check with controller on Manual				

General Application Structure

Do all inputs receive the correct parameter?				
Do all outputs go to the correct destination?				
Are tag frequencies (scan time) set correctly?				
Are tags scheduled (before/after) correctly?				
Are all tag ranges satisfactory?				
Are all control actions correct?				
Is coding correct?				
Have NMODE and MODEPERM been set appropriately for all tags?				
Is PVCLAMP set appropriately for each tag?				
Has any impact on other control schemes been fully considered?				
Does the initial tuning appear reasonable?				
Are the relevant Site standards followed for schematics, toolkit usage etc?				
Does the application make efficient use of resources?				
Have all affected schematics been modified to show changes?				
Has all documentation been completed/updated satisfactorily?				
Are all applicable tags historised				

6.2 SWITCHING ON/OFF

Will the application turn on/off safely?				
Can a process bump occur on turn on?				
Are SP tracking (PMX) and PV tracking done in the appropriate places?				
Are all relevant PV and control initialisations done?				
Are time-out intervals (TDC) appropriate?				
Has SHEDMODE (TDC) and SHEDTIME (HPM) been set appropriately?				

Signal Validation

Are the correct tags validated?
Do the validation parameters appear reasonable?
Does the application respond correctly to a failed signal validation?
Does the application respond correctly to a recovered signal validation?
For operator entered data in control, is there a reasonableness check on the number entered?
HPM - is logic function [CHECKBAD](#) required?

6.3 APPLICATION LIMITING

Does the application require [SP/OP clamps](#), OP ROC limits, in any tag?
Is the operator alerted satisfactorily to abnormal conditions?
Are [SP/OP tolerance](#) checks required?

Site reviewer agrees to commission application/put tag on Auto?

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Signed	Print	Date
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APPENDIX E: CONTROLLER PERFORMANCE CLASSIFICATION

Controller Performance Classification	Key In General Status (Y/N)
Controller in compliance mode or operating as per design. No operational Issues.	Y
Controller Uptime > 70%	Y
Controller output not saturated and operating within 20 - 80%	Y
Process value noise strength is < 5%	Y
Controller process value does not oscillate significantly	Y
Controller process value reach set point reasonable well	Y
Controller does not have apparent instrumentation issues (stiction & hysteresis, unreliable measurement)	Y
Satisfactory stability measurement (According to software)	Y
Controller Performance	GOOD

Note: Controller shall be rated as POOR if any of the criteria above is violated.

APPENDIX F: SAMPLE TEMPLATE/FORMAT FOR BLCA DATABASE/MONITORING SPREADSHEET

No	Name	Description	Pro. Fluid/ state	P&ID No.	Performance Assessment Statistical Result	Uptime (%)	Noise (H/L/N)	Performance	Status	Priority	Observation/Remarks	Recommendations	Main Reason for Non Compliance
1	LICxxx	C1201 level	HCL Liq	xxx	xxx	100%	N	Poor	Compliance	Urgent	MV is oscillating. Slight stiction detected.	1) Check Instrumentation 2) Possible tuning.	Instrumentation Problems
2	LICxxx	C1202 level	HCL Liq	xxx	xxx	80%	H	Good	Compliance	High	MV sometimes saturated at 100% when there is upstream disturbance, level increase from 50 to 52.5%. MV changes from 50% to 100%. Valve/Pump may be undersized and shows slight hysteresis characteristic. Disturbances happen during rainy day. More load during rainy day, more condensation. Need to check control valve, tuning setting and pump design.	1) Check Instrumentation 2) Check pump design. 3) Possible tuning.	Process design limitation
6	LICxxx	V1203 level	NaOH	xxx	xxx	100%	L	Poor	Compliance	Medium	MV sometimes saturated at zero. Direct acting controller. Valve close at zero while level accumulating. Valve may be oversized. Normal operating MV is <20%. Check control Valve, tuning setting and pump. Common to have problem with pump P1604 cavitations and strainer block.	1) Locate source of oscillation. 2) Check Instrumentation Reduce noise variation. 3) Possible tuning.	Instrumentation Problem
7	LICxxx	No.2 Decanter level	H2O	xxx	xxx	90%	N	Good	Compliance	LOW	PV & MV is oscillating. Need to investigate the cause of oscillation, suspect coming from V1204. There is a large buffer tank down stream to absorb the disturbance, therefore this may be acceptable.(T1201)	1) Check Instrumentation 2) Check pump design. 3) Possible tuning.	Tuning problems

No	Name	Description	Pro. Fluid/ state	P&ID No.	Performance Assessment Statistical Result	Uptime (%)	Noise (H/L/N)	Performance	Status	Priority	Observation/Remarks	Recommendations	Main Reason for Non Compliance
8	FICxxx	HCL flow	HCL	xxx	xxx	0%	N	NA	Non-Compliance	Urgent	Operator does not like the control strategy. Controller response to slow, operator prefer to look at another measure indicator to control flow.	1) Check instrumentation 2) Review control strategy	Control Strategy
9	PICxxx	T1201 press.	N2	xxx	xxx	100%	H	NA	Non-Compliance	Medium	This is a split range controller. Valve A is detached from the controller, always open at 100%. Limitation in Nitrogen capacity.	1) Review control valve size and process design	Process design limitation
10	TICxxx Master	F1301 Temp	H2O	xxx	xxx	0%	N	NA	Non-Compliance	Urgent	Master controller is normally detached from the slave controller. If connected will caused instability in temperature	1) Check Instrumentation 2) Review Control Strategy	Control strategy

APPENDIX G: SAMPLE TEMPLATE/FORMAT FOR CONTROLLER PRIORITISATION SPREADSHEET

No	Unit	Description	HSE Loop YES/NO?	A) Product Quality	B) Production	C) Opportunity Loss	SCORE	LOW; MEDIUM ;HIGH	Easy to Do (E) or Difficult to Do (D)	Remarks
1	12FIC1211	XXX feed	NO	3	3	3	18	HIGH	D	APC Loop
2	12FIC1212	XXX feed	NO	3	2	2	15	HIGH	E	APC Loop
3	12FIC1213	XXX feed	NO	3	2	3	16	HIGH	E	APC Loop
4	12FIC1214	XXX feed	YES	3	3	2	17	URGENT	D	APC Loop
5	12FIC1232	C1201 condensate top up	NO	2	2	2	12	MEDIUM	D	
6	12FIC1241	Caustic Injection to C1202	NO	2	2	1	11	MEDIUM	E	
7	12FIC1253 - Ratio	Conc.Caustic to steam condensate	NO	2	1	0	8	MEDIUM	E	
8	12PIC1290	K1201 purge gas	YES	2	1	1	9	URGENT	D	
9	12LIC1221	Condensate to V1208	NO	1	1	0	5	LOW	E	
10	12LIC1231A	C1201 (XX quencher) level controller	NO	1	0	0	3	LOW	D	
11	12FIC1111	V3101 feed	NO	0	1	0	2	LOW	E	

Weighage:

A	3
B	2
C	1

Score:

HIGH	14 - 18
MEDIUM	6 - 13
LOW	0 - 5

