Optimization vs. Performance in the modern process control systems

Massimiliano Veronesi
Sales Support and Marketing
Process Control & Safety Systems
Vigilant Plant Services & Solutions
Yokogawa Italy

OMC 2015
Ravenna
Contents

• Control Hardware Optimization by Universal I/O
  – Shortening the delivery through loop-check anticipation
• HMI Hardware optimization through Virtualization
• Others ways to optimization
Why we are here: the Industry Challenge

- Strong competition
- Increasing Regulations
- Supply/Demand Fluctuation
- Consumer power

- Aging Operators
- Environment
- Aging assets
- Safe & Secure Operation
- Streamlined Production
- Maximum Asset utilisation
- Quality Assurance

YOKOGAWA
100th ANNIVERSARY 1915-2015
vigilantplant®

Copyright © Yokogawa Electric Corporation
March 24, 2015
Focus on the system design and project development

Project Execution
Managing uncertainty, project complexity, late changes, cost overruns, and deplies. The challenges gets even greater when the lack of manpower and technical resources are factored in.
Versatile Hardware and Flexible Project Execution
Automation Design Suite goes beyond traditional DCS engineering functionality. An integrated platform that facilitates project execution, systems integration, and site execution, delivers certainty and confidence throughout all project phases.
Software debugging: Virtual Test Function

- Simulate complete DCS on computers
  - Full-scale system can be tested without target hardware
- Wireless debug (wireless Factory Acceptance Test)
- Snap shots for evaluations
- Seamless integration with training simulation models
Avoiding Project Delays

Reduce delays and be assured of starting production on schedule

Application validation during FAT

Designed & constructed on site

Virtual I/O wiring

Last minute software marshaling

Smart Configurable IO

<OMC2015_Yokogawa>
Copyright © Yokogawa Electric Corporation
March 24, 2015
Hardware: Universal I/O reduces the footprint.

Traditional I/O

Controller → IOM → Marshalling board → Junction box

Universal I/O

Controller → IOM → Marshalling board → Junction Box

I/O design and relative works are eliminated.

Work
* I/O list & Controller sizing
* Power, grounding & fusing design
* I/O design
* Spares sizing
* Cabinet design
* Conduit & cable layout
* P&IDs
* Process narratives
* Installation package

Work
* Cabinet design
* Jumpers & terminations
* Wiring diagrams
* Cable layout

Work
* JB design
* Jumpers & terminations
* Wiring diagrams
* Cable layout
Smart Configurable I/O

“Best of both World”
Universal I/O + Signal Conditioner
Next Generation Smart I/O: N-IO (Network I/O)

- N-IO is designed with fewer components. A single module can be configured to support AI/AO/DI/DO.
- An optional signal conditioner can be plugged in to support a wide range of I/O signal types.
- The backplane allows I/O redundancy by design, resulting in a smaller footprint.
IO network Configuration

Node Interface Unit

Up to 100m by copper

System Network Vnet/IP

- Lower performance
  - Heavy load in the system network might affect real-time computations
- Less secure
  - System network is connected to OWS
- Less robust
  - Field environment might be hard for std. switches, hubs

\[ \text{Performance first!} \]

N-ESB bus

- Up to 50 Km by optical fiber, 100 Mbps
- Cat5e cable
- No hub or switch is required

N-ESB bus
IO network Configuration

Node Interface Unit

- Up to 100m by copper

N-ESB bus
- Up to 50 Km by optical fiber, 100 Mbps
- Cat5e cable
- No hub or switch is required

System Network Vnet/IP

- Next step under development: I/O bus shared among (limited amount of) different controllers
Termination

Field Signal Cables

Analog Signal

Digital Signal

Mix Signal

Plant Area

<OMC2015_Yokogawa>
Copyright © Yokogawa Electric Corporation
March 24, 2015
Marshalling Comparison of FIO and N-IO

Marshalling – Traditional (cross-wiring)

Marshalling – N-IO
Footprint: N-IO vs. Conventional IO

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>N-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-IO:</td>
<td>2,000</td>
<td>X 1</td>
</tr>
<tr>
<td>D-IO:</td>
<td>3,000</td>
<td>X 9</td>
</tr>
<tr>
<td>Total:</td>
<td>5,000</td>
<td>X 10</td>
</tr>
</tbody>
</table>

Cabinets: 17 vs. 10
# N-IO for Hazardous Applications

<table>
<thead>
<tr>
<th>Non-IS</th>
<th>Intrinsic safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-IO</td>
<td>IS base plate</td>
</tr>
<tr>
<td></td>
<td>IS base plate</td>
</tr>
</tbody>
</table>

- **Yokogawa**
- **P+F**
- **MTL**
Field Loop-Check without the controller

Local Cabinet can ship to site w/o FCS.

N-IO Validation Tool

Scope of New Validation Tool (VT)
Comparing With Current work and Flexible Binding Workflow

- Reduce the time span.
- Deadline of IO freezing is shifted by flexible binding

Current Workflow

YOKOGAWA Flexible Binding

End of Wiring Check
Virtualization
Why virtualization in industrial plants now?

To reduce the number of PC boxes in plants

- It tends to increase the number of ?? server, ?? historian, etc.
- There is increasing of concern of both CAPEX and OPEX
  - e.g. Foot-print, OS maintenance, power consumption
- The number of server PC is a serious issue for the control systems with server-client architecture

To segregate the maintenance of hardware and software

- Windows OS is migrating every a few years and the previous OS becomes obsolete soon
- The latest PC hardware and previous OS may not be compatible
- Many of software applications in the control systems highly depend on OS and are less compatible with newer OS
  - Maintenance concern at the failure of the existing PC hardware
CAPEX Reduction - General Evaluation -

- Adopting VMware for virtualization
- 1:10 server consolidation ratio (10 virtualized machines can run in a server)*
- Lower electric power consumption and cooling cost
- Reduction of maintenance cost
- Reduction of footprint
- Smoother component migration
- Easy backup and restore

* This is an assumption, it will depend on the application for the real project

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not virtualized</td>
<td>Virtualized</td>
<td>Not virtualized</td>
</tr>
<tr>
<td>No. server</td>
<td>20</td>
<td>2</td>
<td>50</td>
</tr>
</tbody>
</table>

KUSD

<OMC2015_Yokogawa>
Copyright © Yokogawa Electric Corporation
March 24, 2015>
Space, weight, and number of boxes/cabinets

- Assumed that server height is 2U, and 7 servers can be installed in a cabinet

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not virtualized</td>
<td>Virtualized</td>
<td>Not virtualized</td>
</tr>
<tr>
<td>No. server</td>
<td>20</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>No. cabinet</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Power consumption assumption

- No matter the size of the project, virtualization can reduce 84% of the power consumption than non-virtualized system

<table>
<thead>
<tr>
<th></th>
<th>Not virtualized</th>
<th>Virtualized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small/medium/large</td>
<td>100%</td>
<td>16%</td>
</tr>
</tbody>
</table>
The virtualization works as an application on the host OS such as Windows, Linux

VMware Workstation, VirtualBox, etc

Works as the host OS

PC resource can be consumed as much as possible for virtual PCs

- VMware ESXi, Microsoft Hyper-V, RedHat KVM, etc.
For server virtualization in working environment, hypervisor tends to be adopted

- Official support of Yokogawa systems are also in hypervisor type
- However using Hyper-V is not recommended for workstation with Yokogawa components inside

<table>
<thead>
<tr>
<th></th>
<th>Host type</th>
<th>Hypervisor type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptability</td>
<td>Easy to use</td>
<td>Some level of knowledge is required</td>
</tr>
<tr>
<td>Resource usage</td>
<td>Larger overhead (Lower performance)</td>
<td>Smaller overhead (Higher performance)</td>
</tr>
<tr>
<td>Security</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Scale</td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td>Performance</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
The performance issue

- Virtual network is working in the virtualization software
- Virtual NICs and virtual switches are working (emulating)
- Only Physical NIC are suitable for real-time deterministic applications \(\Rightarrow\) Performance first!

![Diagram showing virtualization and actual network connections](image_url)
The performance issue

If the PC is a quad core machine then 3 virtual machines may be the maximum to be deployed (1 core for the main application and 1 core for each of the 3 virtual PCs). If Hyper-threading is enabled, then double the number of cores are required.

- (Number of requested cores) = (CPU reservation frequency) ÷ (Frequency of CPU of physical server) x 2 ← if HT is enabled
- (CPU reservation frequency) = (CPU req. frequency) x (Number of cores) ÷ 2
- Es.: Required CPU resources are 3.00 GHz and 4 cores, with 2.8GHz physical Server:
  - (CPU reservation frequency) = 3.00 GHz x 4 cores ÷ 2 = 6 GHz
  - (Number of req. cores) = (6/2.8) x 2 = 2.14 x 2 = 4.28 → 5 (rounded up)

**Condition:**

\[ \sum [\text{CPU reservation frequency of Yokogawa Products}] \times 1.25 < [\text{CPU resource}] \]

Where [CPU resource] = [CPU frequency - in GHz] x [No. of cores] x [No. of CPUs]

- Es. Sum of CPU reservation frequency = 6.00 + 6.00 = 12.00 GHz
- the CPU resource for one server machine with frequency 2.60 GHz and 8 cores is 2.6 GHz x 8 cores = 20.8 GHz
- 12.0 x 1.25 (VMSphere Overhead) < 20.8
The performance issue

- Using SAS3 or RAID4 configuration to secure the performance is needed. Using SSD5 is not recommended because of lower endurance.
  - VMware allows three types of formatting for virtual storages. It is strongly recommended to adopt “Thick provisioning (Eager Zeroed)” with securing area in advance and with executing zero formatting. Using “Thin provisioning” causes lower performance, and Lazy Zeroed causes disk access error.

- It is mandatory to configure the Yokogawa product to use enough memory area exclusively to secure performance in both off and on-process.

- Generally the clock of guest OSs may be delayed when the load on Hypervisor becomes too high. If the demand of time synchronization is severe, the synchronization period should be set shorter.

- One physical server PC failure stops multiple server functions: highly available industrial server is recommended

- SAS (Serial Attached SCSI): The interface to connect up devices for hard disk drives to computers
- RAID : Redundant Array of Independent Disks
- SSD : solid-state drive using flash memory
Virtualization Benchmarking

Current Yokogawa System architecture

Virtualized Architecture

Benchmarking: Number of PC (Server/Workstation)

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Performance First: Excluding Servers with Vnet/IP modules
Example of on-process systems
Example of on-process systems
Example of off-process systems – Operator Training systems

Trainees’ clients

Instructor’s

VMWare

OTS on VM Server

OmegaLand
Win 2008

ExaPilot
Win 7

ExaOPC
Win 2008

FCS
FCS

SCS
SCS

HIS
Win 7

ENG/SENG/HIS
Win 7

SCS

Win 7

Win 7

Win 7
Other performance vs. optimization
Integration with subsystems: which way?

**Sub-system communications**
- Data for HMI: OPC/ModbusTCP
  - Client (redundant) workstation can manage up to 100,000 variables
- Data for control logics: put (redundant) communication module in one rack of the related CPU in charge

**Modbus / Profibus**
- Redundant Configuration is available.

<table>
<thead>
<tr>
<th><strong>OPC DA+HDA (or UA)</strong></th>
<th><strong>Modbus/TCP (or RTU)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits</strong></td>
<td><strong>Drawbacks</strong></td>
</tr>
<tr>
<td>- Lower Controller CPU load</td>
<td>- Affecting Controller CPU load (to be distributed among the DCS controllers)</td>
</tr>
<tr>
<td>- High throughput</td>
<td>- Not supporting A&amp;E with timestamps</td>
</tr>
<tr>
<td>- A&amp;E by OPC A&amp;E</td>
<td>- Unreliable IT technology</td>
</tr>
<tr>
<td></td>
<td>- Subsystem data NOT directly available in DCS controller for control/logic functions</td>
</tr>
</tbody>
</table>
Integrated Process Control & Safety System

→ Integrated Control+Safety system provides optimization + performance at the same time

Master station automatically assigned
Reference time broadcasted every 10 seconds
Time shifts are adjusted very smoothly 0.005 ms (0.05%) at 10 ms interval.
External clock synchronization available (via time server)
Multi-monitor vs. performance

- Multi-monitor/Graphic windows
  - Each mimic call data from the system bus while one single operator cannot pay attention to more than $\frac{5}{12}$ windows at the same time: prevent it by limiting the number of graphic windows which can be called by the operator by FIFO mechanism.
Others ways to optimization

- **Alarm optimization**
  - Complying to ISA18.2 and Eemua-191 Standard

- **Control Loop Performance Monitoring**
  - Evaluate improvements through simulations

- **Best Practices Employment**
  - Operator sequences executed by flow-charts

- **Plant performance quantitative measurements**
  - KPI, Downtime analysis, Data reconciliation
  - Sequence of events and Safety Functions monitoring

- **Energy management**
  - Monitoring or optimization

- **APC**
  - Multivariable Predictive Control
APC: Multivariable Predictive Control

Specification or limit

Operator target

Benefits

PERCENT OF LIMIT

Standard deviation of controlled variable

Base Case  Stabilise

BEFORE APC  APC ONLINE  SETPOINT MOVED CLOSER TO LIMIT

Operator target

PERCENT OF LIMIT

90  92  94  96  98  100  102  104

Benefits

APC ONLINE

100th ANNIVERSARY 1915-2015

The clear path to operational excellence

Copyright © Yokogawa Electric Corporation

<March 24, 2015>
Do not load the DCS with these tasks: do it at upper level!
Increased plant productivity and availability with ISA100 wireless for process control

The new CENTUM VP supports a new specialized PID function block that compensates for any packet loss. With this function block, the dynamic response after signal recovery is smooth and stable. As a result, wireless control is dependable.
Conclusions

- Different kind of Optimization or Functions are attractive and may lead to significant Capex/Opex reductions...
- ... but also to some performance issues.
- Clever engineering should carefully consider the right balance between optimization and performance with respect to the specific application.
Thank you for your attention!
Any question?