School on TANGO Control System

Introduction (2)

Marco Lonza
FERMI

<table>
<thead>
<tr>
<th>Device</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet Power Supplies</td>
<td>~ 400</td>
</tr>
<tr>
<td>Vacuum Valves</td>
<td>109</td>
</tr>
<tr>
<td>Vacuum Pumps</td>
<td>230</td>
</tr>
<tr>
<td>RF Plants</td>
<td>16</td>
</tr>
<tr>
<td>Screens/CCDs</td>
<td>112</td>
</tr>
<tr>
<td>Beam Position Monitors</td>
<td>79</td>
</tr>
<tr>
<td>Charge Monitors</td>
<td>13</td>
</tr>
<tr>
<td>Beam Loss Monitors</td>
<td>201</td>
</tr>
<tr>
<td>Undulators</td>
<td>19</td>
</tr>
<tr>
<td>Stepper Motors</td>
<td>494</td>
</tr>
<tr>
<td><strong>Total number of CS variables</strong></td>
<td><strong>&gt; 60000</strong></td>
</tr>
</tbody>
</table>
The Analog Age

Analog Signals
The Control Room: '70-'80
The Digital Age

Analog Signals

A/D - D/A Conversion

Analog Signals
The Control Room: '80-'90
The Internet Age

A/D - D/A Conversion

Analog Signals

Digital Signals

A/D - D/A Conversion

Analog Signals

Analog Signals
The Control Room: '90-'00
Control System Concept

Signals
(Analog, Digital, Serial Lines, GPIB, Ethernet, ...)

School on TANGO Control System - Trieste 4-8th July 2016

Introduction - Marco Lonza
Control System Functions and Services

- Monitoring
- Control
- Alarms
- Logging
- Archiving
- Automation
- Feedbacks
- Data acquisition and management
- Equipment Protection
- Safety
Control Room: the future

Human-Machine interaction
Automation
Artificial Intelligence
Structured Control System

A/D - D/A Conversion

Analog Signals

Digital Signals

A/D - D/A Conversion

Analog Signals

Analog Signals
Distributed Architecture

- Distributed system
- LAN
- Levels or Tiers
- Field-bus
- Local/Field/Low-Level Computers
- Consoles/Workstations
- Hosts/Servers
Technologies: selection guidelines

✔ Performance
✔ Reliability & availability
✔ Modularity & flexibility
✔ Standardization
✔ Off-the-Shelf components (COTS)
✔ Comsumer/commodity
✔ Stability and long lifetime
✔ Free and Open Source software (and hardware)
✔ Cost
Digital Technologies

- Analog electronics
- ASIC
- FPGA
- PLC
- DSP/Microcontrollers
- Real-time Operating system
- Operating System

Deterministic behavior
Flexibility
Reliability
Programmability
Robustness
Field Computers

- CAMAC
- VME
- C-PCI
- AdvancedTCA/MicroTCA
- PXI
- Industrial PC (x86)

Industrial Computers based on Standard Backplanes
Servers

Used to provide the control system with common services: software execution, distributed file system, database, external access, data storage, network services, ...

- 19" rack-mount computers: multi-core multi-processor XEON based systems
- Blade Servers
- High speed redundant network connection
- Virtualized environments
- High Availability (HA) configuration
Consoles - Workstations

Used by operators and physicists as human interface to the control system

✓ Desktop high-end PCs
✓ Dedicated graphic cards with up to six screens
Data Network (LAN)

- Ethernet technology
- Switched distributed network
- Pervasive inside the plant
- Fibre optic uplinks and copper endpoints
- Speed of 100 Mbit/s to 40 Gbit/s

Control System Network

Router Switch

Peripheral Switch

F.O.

Copper

Firewall

Corporate Network

Internet
Protection and Safety Systems

Protection Systems: protect systems and devices from damage
Safety Systems: protect people from risks related with radiations, lasers, ...

- Usually this systems are based on Programmable Logic Controllers (PLC): computers used for automation in industrial plants
- No operating system, reliable and deterministic
- Fieldbus: industrial computer network used for real-time distributed control: Profibus, CANbus, Profinet, Powerlink, Ethercat, AS-I, LonWorks, BITBUS, ...

![Diagram showing Fieldbus, PLC CPU, PLC Peripherals, Ethernet, and Control System Network]
Embedded Controllers

**Smart Devices or NAT** (Network Attached Devices)
Instrumentation or devices with their own internal controller (DSP, Microcontroller, FPGA, ...) and a digital interface (Ethernet)

Courtesy of Tom Shea
Low Cost Embedded Platforms

- Arduino
- BeagleBone
- RASPBERRY PI
Embedded Controller
Example: Piezo Controller
Real-time system: a system which can guarantee a response within specified time constraints, i.e. can meet a deadline deterministically.

- Non real-time Operating Systems (running on field computers, servers and consoles):
  - Linux, Windows, Unix, VAX/VMS, OS X, ...

- Real-time Operating Systems - RTOS (running on field computers):
  - OS-9, VxWorks, LynxOS, QNX, WindowsCE, RTEMS, ...
  - Linux RT extensions (RT-Linux, RTAI, XENOMAI), Linux + Preemptive Scheduling (Kernel >2.6)
Languages and Protocols

Programming Languages
- Assembly
- C
- C++
- Java
- Python

Communication Protocols
- TCP/IP
- UDP
- Modbus
- SNMP

Middlewares
- CORBA
- OPC
- DDS
- ZeroMQ
Programming languages and protocols are not sufficient to develop the software for a distributed control system: a software framework is needed to help the development of client/server control applications.

- TANGO
- EPICS
- ACS
- TINE
- DOOCS
- Karabo
- !CHAOS
- CODAC
- UNICOS
- MADOCA
- LabVIEW
- SCADAs
- ...
Architecture and Technologies: the FERMI control system

Controls Network: Gigabit Ethernet, HA configuration, 5500 End Points, Wi-Fi

Control system consoles: low consumption PCs with 4 monitors

Control system servers: hot-backup configuration, XEN virtual machines

VME crates with Emerson 7100 PowerPC CPU boards

Intel-based rack-mount acquisition servers

Siemens S7 PLCs

Field computers

Equipment and machine protection systems, PSS, undulator controls

Direct I/O

Network switch

Field Ethernet network

Serial device servers

RS-232/485

Profibus peripherals

Operator Panels
Digital Feedback Systems

- need to keep constant a process variable: ex. electron beam trajectory
- read sensors and set actuators continuously at a given repetition rate
- processing of the sensor signals made by digital controllers
- dynamic system control theory and digital signal processing techniques
- repetition rates up to 500 MHz
- feedback systems essential to allow operability of the accelerators and assure the quality of the photon beams
Elettra: Orbit Feedback System

- 96 Beam Position Monitors (BPM) and 82 corrector magnets
- 10 kHz repetition rate
- 12 processing units acquiring beam position data from the BPM detectors
- Data shared in real-time through Reflective Memory fiber optics
- 10 kHz D/A converters generate the analog correction signals sent to the corrector power supplies
Control Algorithms:
- PID dedicated to low frequency noise components
- Harmonic Suppressors dedicated to periodic noise components at 50, 100, 150, 200, 250 and 300 Hz

Results:
- attenuation bandwidth of 150 Hz (random noise)
- almost complete suppressions of the main 50 Hz harmonics
Scientific Data Management

- Experimental stations generate huge amount of data to be stored and processed
- Detectors producing more than 500 MB/s (1.8 TB/h) of images, will be x10 in the next few years with the new generation of detectors
- Big challenges for data transfer, storage and processing
- Big data, data deluge
Graphical User Interfaces

✓ Physicists and Operators interact with the machine through software applications and Graphical User Interfaces (GUI) running on the control room consoles

✓ Many languages and open source widget libraries available

✓ GUIs must be:
  • comprehensive
  • easy to learn
  • useable
  • clear

✓ Technology, psychology and art!

combine all of them could be an issue
TANGO is a toolkit for building distributed control systems

- Open source and free of charge
- Object oriented, topology independent, highly scalable
- Multi-platform (Linux, Windows)
- Multi language: C++, Java, Python
- Configuration tools, Administration tools
- Archiving service
- Access control service
- Logging service
- Alarm service
- GUI Toolkit for Java, C/C++, Python
- Web interface
TANGO as a software bus

LabVIEW binding

Tango binding

TANGO JAVA/C++/Python clients

Industrial SCADA binding

TANGO Software Bus

Device Server

Device Server

Device Server

Device Server

Device Server

Device Server

EPICS server

OPC server

Hardware electronics

Modbus server

Data socket server

PLC network

Acquisition system

PLC or embedded system
TANGO Collaboration

- TANGO has been adopted by many European institutes: ESRF, SOLEIL, Elettra, Alba, ANKA, MAX-lab, DESY, Solaris, FRM-II, ELI-ALPS, ELI-Beamlines, ELI-NP, Univ. of Szeged, INAF, ONERA

- TANGO collaboration ruled by a contract presently signed by eight institutes, which defines the governance and the organization

- In March 2015 the Square Kilometer Array (SKA) decided to adopt TANGO
Other TANGO users

Logos of various companies and institutions.
The MARS CITY Project

✓ MARS CITY is a program spearheaded by the Italian Mars Society (IMS) which main goal is to provide an effective test bed for field operation studies in preparation of manned missions to Mars

✓ The command, control and communication system of the MARS simulation station is developed in TANGO
The Extreme Light Infrastructure (ELI) is a new research infrastructure project and part of the European ESFRI Roadmap, with an investment volume exceeding 850 million€.

ELI is the latest laser equipment in the world. Research projects studying the interaction of light with matter at intensity 10 times higher than currently achievable values. Ultra-short laser pulses of a few femtoseconds (10-100 fs) duration and power up to 10 PW.

The facility will be based on four sites. three of them are presently being implemented in Czech Republic, Hungary and Romania.
Dzięki!

Thank you!

Gracias!

Grazie!

Mulţumesc!

تشكر