Evolution of the Building Management System in the INFN CNAF Tier-1 datacenter facility

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Summary

- The INFN CNAF Tier-1 resources: Infrastructure and IT
- Development of a new Building Management System (BMS): requirements and primary objectives
- The StruxureWare™ Building Operation software (SBO) architecture
- The Power Usage Effectiveness (PUE) and other relevant metrics
- Integration with Open Standard (Web Services) and the Tier-1 Monitoring tool
- Future development and conclusion
INFN CNAF Tier-1 resources

- 6 EMERSON Chiller
  - 300 KW each of cooling capacity
  - Periodic auto-rotation of active vs standby (N+2 redundancy)
  - Integrated freecooling

- 1 Dedicated electrical line from energy distribution network
  - 15,000 V Voltage
  - Up to 4.0 MW Power

- 2 EuroDiesel Rotary diesel UPS
  - 1700 KVA each
    (1340 KW Real Power with a ~0.8 cosφ)
  - 3-5 days autonomy
    +
  - 1 Standard diesel generator (no UPS)
    - 1250 KVA
    - can be used for emergency power or not-IT equipment (e.g. chillers)

- 3 Transformers
  (2 in production, 1 reserve)
  - 2.5 MVA each
  - 15,000 V => 400 V
  - 2 separated 4000 A electrical distribution lines (RED & GREEN)
The INFN CNAF Tier1 is hosted in a complex university building 😊

Installation used all available space in 2009

A total of 1950 m² is used for:

- 2 IT Resources Rooms (250 m² + 350 m²)
- 4 Additional locations:
  - Transformers Room
  - UPS Room
  - Chiller Room
  - Power Room

-1 FLOOR AREA: 6 Chillers, water pumps & pipes Room

-2 FLOOR AREA: 2 IT Rooms and 1 Power Distribution Room

Complex distribution of technical plants...

=> DETAILED BMS!
INFN CNAF Tier-1 IT rooms

- **44 APC InRow RP (IRP)** Precision Cooling with 2-ways valves, 3 Fans and humidity control. (Cold water provided by chillers)

- 50 KW of cooling capacity each IRP => **1600 KW** with N+2 redundancy in 6 "Aisle" over 2 different rooms

- **48 Racks** for IT equipment with a 10KW cooling capacity (Room 1=> 2-Aisle)
  - **76 Racks** for IT equipment with a 20KW cooling capacity (Room 2=> 4-Aisle)

- Hot Aisle containment (without floating floor) with environmental sensors (T&H) in HOT and COLD corridor

- **Water Setpoint:**
  
  - (chillers): 15°C /20°C
  
- **Air T & Humidity Setpoint:** (IRP group control): 24°C & 45%/60%

- Cold/Hot detected
  
  - **Air T:** 24°C/31°C
INFN CNAF Tier-1 IT resources

Tier-1 for all LHC experiments (Alice, Atlas, CMS, LHCb) and ~20 others non-LHC (including Astroparticle Physics)

- Tier-1 cluster computing power:
  205,000 HEP-SPEC06
  provided by 22,000 CPU cores

- Tier-1 disk space capacity:
  ~20 PByte net used space
  80 disk servers (8 GPFS clusters)

- Tier-1 tape space capacity:
  1 Tape library with 10,000 slot capacity (Oracle SL8500)
  ~ 34 PByte tape used space (8.5 TByte cartridge)

- Tier-1 network facility:
  4 Core Switches
  350 x 10Gb/s Ports
  468x 1Gb/s Ports
  6+2 (general purpose) x 10Gb/s WAN Connections
A new BMS => Objectives:

- The old BMS system was the TAC VISTA software:
  - currently phasing out... 😊
  - Many "cons" (difficult to edit, no compatibility with open protocols, GUI based on Java etc...)

- We need a more flexible system that could re-use the "sensors" and "collectors" hardware (to limit the hardware cost of the migration) and improve user-friendly management

- The "natural" choice is the Schneider StruxureWare™ Building Operation software (SBO) architecture:
  - Full compatible with Modbus protocol (TCP/IP and serial)
  - Full compatible with the TAC VISTA Lonworks network (re-use cabling&HW)
  - The webstation GUI user interface just need a standard browser (no Java or other plugin needed); works directly on mobile devices! 😊
  - Open to standard protocols (e.g. webservice serve&consume)
  - Migration from TAC VISTA was easily split into 3 phases over 8 weeks period:
    1) TCP Modbus "aisles" & "PLCs" => can run both on VISTA and SBO (6 weeks test phase)
    2) Serial Modbus => OUT on VISTA & IN only on SBO (2 weeks "critical")
    3) Lonworks Network & ALL alarms/trends => ONLY SBO ACTIVE! (2 weeks for finalize)
The Schneider SBO architecture

- The core of the software management, web user interface and archiving is based on 2 servers:
  - **Enterprise software server**: runs the core software for management & backup of the configuration.
  - **Report Server**: used for archiving the long-term trends (Microsoft SQL Server) and adds advanced reporting options.
The Schneider SBO architecture

- **3 Automation Servers** provide the "engines" for the BMS system, in 3 "strategic" physical locations (-1 Floor Area, Power Distribution Room & Transformer Room):
  - Runs stands-alone
  - Collect data directly from the Lonwork Network, Modbus Serial and Modbus TCP (PLCs) and provides control logic

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**LON NETWORK**

- ~30 "Xenta Family" programmable modules (reused from TAC)
- ~300 "Points" (variables or states)
- 2 separated bus
- Implements control logic (e.g. chiller rotation)

**PRIVATE LAN**

**MODBUS NETWORK**

- Use both Serial (rs484/rs232) and TCP/IP
- ~4500 "Points" (variables or states)
- Connection to 6 redundant PLCs (PLCs are used for electrical switch logic & electric measuring instrument)
The Data Center Expert

- The Tier-1 BMS is integrated by another Schneider (formerly APC) software package: **The StruXureware Data Center Expert (DCE)**

- Fine monitoring, tuning and notification over the Datacenter "Aisles" components and Metered Power Distribution Units (PDUs)

- With the MODBUS TCP Output Module => **DIRECT INTEGRATION IN SBO**

[Diagram showing temperature readings for Room 2 Aisle 4]
The INFN CNAF Tier-1 BMS

- Power Switch state, Electrical values, Temperature & Humidity values, Fan states etc...
- Mail alarms notification fully customizable
- User-friendly Graphic Pages for HVAC (Heat, Ventilation and Air Conditioning), Electrical circuit diagrams, Mechanical Pages, Fire prevention system, Flooding & Water Leaking (-2 Floor) etc...

WATER PUMPS
The INFN CNAF Tier-1 BMS

- Information from the DCE software are integrated in SBO

**SBO** is the central "entry point" for the INFN CNAF Tier1 BMS!
**BMS METRICS (LOGS & TRENDS)**

- The **metrics** *(state and variable values)* are one of the **most important features** of an optimal **BMS**.

- **LOGS & TRENDS** represents the "history" of the physical quantities in the technical plants & datacenter rooms.

- **Essential for:**
  - Identification of periodic "hot spots" or critical area
  - Datacenter HVAC/Power optimization
  - Reverse engineering of specific conditions
  - Data center Power/HVAC outage or major failure (fire) analysis
The SBO architecture has increased the number of metrics we are collecting and the archiving duration (=> Report Server & database)

- Over 2500 LOGS & TRENDS collected! => HIGH DETAILS
- Intuitive system GUI => TREND
- 15 minutes granularity
- Optimized for variable state (e.g. a power switch condition is logged only when a change occurs)
- Over 10 years of history possible (but it is just started 😊!)
BMS METRICS (PUE and pPUE)

From Wikipedia => "Power usage effectiveness (PUE) is a measure of how efficiently a computer data center uses energy; specifically, how much energy is used by the computing equipment (in contrast to cooling and other overhead)."

- Increasing cost of Electrical Power => PUE reduction is fundamental!!!
  
  \[
  PUE = \frac{\text{Total Energy}}{\text{IT Energy}}
  \]

- We also introduce the partial PUE (pPUE) in order to monitor the power demands specific area of the infrastructure and optimize them.

  \[\text{e.g. POWER CONTINUITY pPUE} = \frac{\text{UPS Energy} + \text{IT Energy}}{\text{IT Energy}}\]

Indicator of the Rotary Diesel Power Continuity Energy Loss
Serve & Consume Web Services capability of the SBO software

- SOAP request using standard code
- NDA Agreement signed with Schneider for the Web Services Serve of "strategic" variables
- Access to the "current value" of BMS variables from the INFN CNAF Tier-1 Monitoring Infrastructure (see next slide)
- Future implementation for the Web Services SBO Consume e.g. connecting to external weather forecast => Automatic adjust of HVAC scheduling

SOAP REQUEST

```xml
<?xml version="1.0" encoding="UTF-8"?>
<soapenv:Envelope
    xmlns:soapenv="http://soap-envelope"
    xmlns:soapenv="http://soap-envelope">
    <soapenv:Header/>
    <soapenv:Body>
        <GetValuesRequest ......................
```

- WEBSERVICE CLIENT
  "Consume"

- WEBSERVICE "SERVE" = 26 °C

- SBO ENTERPRISE SERVER "Serve"
Tier-1 Monitoring Infrastructure

- Monitoring made with Opensource components:
  - **Backend**
  - Metrics: Sensu for standard metric measurements + custom python scripts (implementation of SOAP requests)
  - Data Storage: InfluxDB, Whisper

- **Frontend**
  - Uchiwa for notifications and status
  - Grafana for charting
Tier-1 Facility Dashboard

- PUE: 1.813
- Room 1 Temperature: 26 °C
- Room 2 Temperature: 25 °C
- Total Power Consumption: 1.116 MW
TCP MODBUS sensors expansions

- A study for using low-cost platforms (Arduino with specific modules) as Modbus compatible sensors collector is under way...
- Could be used for additional/redundant monitoring with a minimum economical effort.
- Could help providing very "custom" sensors (e.g. "home made" dust sensor)
Conclusion

- The BMS choice for the DCE/SBO software for migration was successful
  => Good reliability and Great compatibility!

- Our PUE and pPUE analysis show we need big improvement!
  - Increase chiller efficiency => project for a chiller tech refresh
  - Fine granularity of rack power consumption => increase the number of metered PDUs
  - Rotary UPS power loss => big issue 😞

- The SBO compatibility with open standard (WEB SERVICES) improve our BMS integration and "open-mindedness"

- Standardization of communication (MODBUS) => Possibility to integrate different platforms (e.g. the Arduino tests)

THANKS FOR YOUR ATTENTION!