SCADA
Operator Interface
interface homme machine
Mensch-Maschine Kommunikation
Prof. Dr. H. Kirrmann
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Control room

Two human interfaces: old style mimic board (behind) and screens (front)
SCADA functionality

Data acquisition and display
store binary & analog data into process data base

Alarm & Events
record important changes and operator actions

History data base
keep a record of the process values

Measurand processing
calculate derived values (limit supervision, trending)

Logging & reporting

Human Machine Interface (HMI):
graphical object state presentation, lists, reports

Operator Command handling
binary commands, set points
recipes, batches, scripts (command procedures)

Interfacing to planning & analysis functions: CMMS, …
Operator workplace: three main functions

- Current state
- Alarms and events
- Trends and history
Human-Machine Interface to Plant (HMI-P)

Representation of process state
- Lamps, instruments, mimic boards
- Screen, zoom, pan, standard presentation
- Actualization of values in the windows
- Display trends and alarms
- Display maintenance messages

Protocol of the plant state
Recording process variables and events with time-stamp

Dialog with the operator
Text entry, Confirmation and Acknowledgments

Forwarding commands
Push-buttons, touch-screen or keyboard

Record all manipulations
Record all commands and especially critical operation (closing switches)

Mark objects
Lock objects and commands

Administration
Access rights, security levels

On-line help
Expert system, display of maintenance data and construction drawings, internet access
Human-Machine Interface to Engineering (HMI-E)

| Configuration of the plant | • Bind new devices  
|                           | • Assign names and addresses to devices  
|                           | • Program, download and debug devices |
| Screen and Keyboard layout | Picture elements, Picture variables, assignment of Variables to Functions |
| Defining command sequences | Command language |
| Protocol definition        | What is an event and how should it be registered? |
| Parameterize front-end devices | Set points, limits, coefficients |
| Diagnostic help            | Recording of faulty situations, fault location, redundancy handling |

Mainly used during engineering and commissioning phase, afterwards only for maintenance and modifications of the plant. Used more often in flexible manufacturing and factory automation.
Local Operator Console (printing)
Example: Siemens
Functions of the operator interface

- Process Graphics
- Event/Alarm Manager
- Trends
- Historian
- Controller Integration
- Recipes
Trends:
disappearance of custom HMI, increasing access over Windows (Internet Explorer), data entry by keyboard, touch screen, trackball (seldom mouse), buttons (hard-feel).
Example of Screen (EPFL air condition)
Each screen object can represent several process variables....
Alarm and Event Management

time stamps exact time of arrival (or occurrence)
categorize by priorities
log for further use
acknowledge alarms
prevent multiple, same alarms
sound alarm (different levels)
remove alarms from screen once reason disappeared (but keeps them in the log)
suppress alarms that are not meaningful (false alarms, section in maintenance)
link to clear text explanation
What is an alarm, an event?

A&E consider changes occurring in the plant (process) or in the control system (operator actions, configuration changes,…) that merit to be recorded.

Recorded changes can be of three kinds:
- informative: no action required
  (e.g. "production terminated at 11:09")
- warning: plant could stop or be damaged if no corrective action is taken "soon"
  (e.g. "toner low")
- blocking: the controller took action to protect the plant and further operation is prevented until the reason is cleared (e.g. "paper jam")

In general, warnings and blocking alarms should be acknowledged by the operator ("quittancer", "quittieren").

An alarm is not necessarily urgent, several levels of severity may be defined.

An event is a change related to:
  operator actions ("grid synchronisation performed at 14:35"),
  configuration changes ("new software loaded in controller 21"), and
  system errors ("no life sign from controller B3")
What triggers an alarm?

- binary changes of process variables (individual bits),
  some variables being dedicated to alarms

- reception of an analog variable that exceeds some threshold (upper limit, lower limit), the limits being defined in the operator workstation

- reception of an alarm message (from a PLC that can generate such messages)

- computations in the operator workstation
  (e.g. possible quality losses if current trend continues)

- calendar actions
  (e.g. unit 233 did not get preventive maintenance for the last three months)
Implementing alarms by variables

An alarm is often encoded as a simple 16-bit word sent by an object (thru PLC) in the plant. Each bit has a different meaning, the error condition is reset when the word is 0.

This coding allows to display the error message in several national languages. A database contains the translations.

Problem: keep devices and alarm tables in the operator workstation synchronized
Example of a log: states, alarms,

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
<th>Value</th>
<th>Description</th>
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<td>50</td>
<td>Compteur pieces dans bac</td>
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<td>151</td>
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<tr>
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<td>2</td>
<td>GP : Mot R3 Temps de Cycle de Production</td>
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<tr>
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<tr>
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<tr>
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<td>Gpct2ofpbonne</td>
<td>4823</td>
<td>GP : Compteur 2 Ordre de Fabrication Piece bonne MD</td>
</tr>
</tbody>
</table>
Alarm messages

As bandwidth became available, devices can send alarm and event messages instead of alarm variables.

These messages include alarm details, and especially environment information
(under which circumstances did the alarm occur)

![Diagram of alarm message structure]

- **event type**
- **format**
- **plant state**
- **event number**
- **object**
  - environment 1
  - environment 2
  - environment z

Type: information, state report, disturbance
nr parameters, structure
operation, maintenance, stopped, emergency stop
return to normal. Value overrun, value underrun
plant object and sub-object

The variable values are included when parsing the multi-lingual human-readable messages

"robot 5 on cell 31, motor 3 overheat (96 °)." "robot 5 de cellule 31, moteur 3 surchauffe (96 °)."
Trends allow to follow the behaviour of the plant and to monitor possible excursions. Monitored process data (sampled or event-driven) are stored in the historical database. Problem: size of the database (GB / month)
Historian

The historian keeps process relevant data at a lower granularity than the trend recorder, but with a larger quantity.

Data from different sources is aggregated in one database, normally using data compression to keep storage costs low.

Data are analysed according to "calculation engines" to retrieve "metrics":
- performance indicators
- quality monitoring
- analysis of situations (why did batch A worked better than batch B)

Build the audit trail: "who did what, where and when"
especially in accordance with regulations (e.g. Food and Drugs Administration 's CFR 11)

Examples:
- ABB's Information Manager
- GE's iHistorian 2.0
- Siemens's WinCC-Historian
Additional functions

printing logs and alarms (hard-copy)

reporting

display documentation and on-line help

e-mail and SMS, voice, video (webcams)

access to databases (e.g. weather forecast)

optimisation functions

communication with other control centres

personal and production planning (can be on other workstations)
Special requirements for the food&drugs industry

The US Food&Drugs administration (FDA) requires a strict control of production for pharmaceuticals and food (FDA 21 CFR Part 11).

All process operations must be registered, the persons in charge known, the document signed (electronic signature), tamper-proof records kept.
Engineering tools

draw the objects

bind controllers to variables

define the reports and logs

define recipes (=macros)

distribute the SCADA application (on several computers,…)

support fault-tolerance and back-ups

define interfaces to external software (SQL, SAP, etc.)
Elements of the operator workstation

- Alarms processing
- Alarms logging
- Trend processing
- State logging
- Process data base
- Actualisation
- Simulation
- Instructor desk

Process data
Plant
Populating the Process Data Base

Process data represent the current state of the plant. Older values are irrelevant and are overwritten by new ones ("écrasées", überschrieben)

Process data are actualized either by
- polling (the screen fetches data regularly from the database (or from the devices)
- events (the devices send data that changed to the database, which triggers the screen)
Each station broadcasts cyclically all its variables: the control bus acts as an online database. Datasets are replicated by broadcast to any number of destinations.

Advantage: real-time response guaranteed

Drawback: bus bandwidth may become insufficient with large number of urgent data
Event-driven operation

Every PLC detects changes of state (events) and sends the new value over the bus. Each operator station receives and inserts data into its local database. Data are readily available for visualization. Multiple operator workstations could be addressed in multicast (acknowledged) or broadcast.

Drawback: consistency between databases, bus traffic peaks, delays.
To reduce bus traffic, the operator stations indicate to the controllers which data they need. The controllers only send the required data. The database is therefore moved to the controllers. The subscription can be replaced by a query (SQL) - this is ABB’s MasterNet solution.
Operator Workstation design

Graphical User Interface
- access by Keyboard, Mouse, Trackball, Touch screen, Light pen
- display of values, colours, shape depending on variable value
- operations on visual objects (scaling, combination, events) and on acting objects (page change, sequence of events,..)
- navigation from page to page (hierarchical, shortcuts, search,..)

Page layout

Page code

Page logic

On-line database

Historical database

DB optimised for fast access (in RAM)

OPC

I/O interface

Fieldbus

OPC

I/O interface

Ethernet

Oracle dBase
Access
MS SQL, ..
Example: Intellution's Fix32 internal structure

C/C++ tasks
VB tasks
OBDC interface
DDE interface

DB block
raw process data

DIT

SAC (Alarm & Change)

I/O driver

OPC

Draw
View

HTD History & Trends

DBB
HTC
PDB

Printer Alarm Queue
File Alarm Queue
Historian Alarm Queue
Scada SW architecture

- Command language & procedures
- Remote Device Configuration
- FDT / DTM / XML
  Communication stream

- HMI
  ActiveX

- Application functions

- ODBC/SQL
  History database

- OPC AE
  Alarm & Event handling

- Historian

- OPC DA
  Process database

- Measurand processing

- Data Acquisition

- Field protocols: 101, 61850, HTTP

- Reporting & Logging

- Standards
Model-Viewer-Controller: from E-commerce to Industry Operator Screen

The basic structure is the same....
...and why not simply Microsoft .NET?

The value of the visualization tools is not in the basic platform (which is often Microsoft, Java, .NET or similar) ...

... it is in the conglomerate of tools and interface to different control systems they offer.

Some (Iconics) offer a library of ActiveX - Controls representing automation objects.

Protocols to a number of commercial PLCs are needed (ABB, Siemens, GE,...)

There is a growing similarity between products for SCADA and for E-commerce, but each is optimised for another market.
Why not Enterprise platform?

Figure 2. Confirming, selecting, and applying component units (Class chart by UML description).
An example of SCADA requirements

Action is based on production batches, signing in a new batch, identifying the paper material, filling good and responsible machine driver.

Connection to Mitsubishi A series and Siemens S7 PLCs, with asynchronous or Ethernet cable.

Connection to asynchronous ASCII-protocol communication devices for example F&P Bailey FillMag.

Process diagrams 4-5 pcs. including dynamic displays for valves and cylinders 40-50 pcs.,
mo ters 20 pcs., heaters 20 pcs., thermocouple-inputs 30-40 pcs.,
additional analog inputs 10 pcs.

Real time and historical trends 40-50 pcs.

Sequence displays including step-displays and clocks.

Alarm displays with additional help displays including text and pictures.

Parameter set displays for PID-controls, filling automates and servo drives.

Storing logged data to a transferable database.

quite different from E-commerce, but the platform could be the same...
## Generic visualization packages

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB</td>
<td>Process Portal, OperatorIT interact</td>
</tr>
<tr>
<td>CTC Parker Automation</td>
<td>CitectSCADA (AUS, ex CI technologies, <a href="http://www.citect.com">www.citect.com</a>)</td>
</tr>
<tr>
<td>Intellution (GE Fanuc)</td>
<td>Intellution (iFix3.0) 65000 installs, M$38 turnover</td>
</tr>
<tr>
<td>Iconics</td>
<td>Genesis</td>
</tr>
<tr>
<td>National Instruments</td>
<td>LabView, Lookout</td>
</tr>
<tr>
<td>Rockwell Software</td>
<td>RSView</td>
</tr>
<tr>
<td>Siemens</td>
<td>WinCC, ProTool/Pro</td>
</tr>
<tr>
<td>Taylor</td>
<td>Process Windows</td>
</tr>
<tr>
<td>TCP</td>
<td>SmartScreen</td>
</tr>
<tr>
<td>USDATA</td>
<td>Factorylink, 25000 installs, M$28 turnover</td>
</tr>
<tr>
<td>Wonderware (Invensys)</td>
<td>InTouch, 48000 installs, M$55 turnover</td>
</tr>
</tbody>
</table>

...XYCOM, Nematron, Modicon PanelMate, OIL System PI Data Historian.
Ann Arbor Technology, Axeda, Eaton Cutler-Hammer, ei3, InduSoft, Opto22, ....