5th HOLMUG Technical Working Group Meeting,
Ringhals nuclear power plant site
October 16th - 17th.

on *"Nuclear Power Plant Control & Instrumentation"*

Super-Safety Concept

in Nuclear Integrated Safety Management

An example of on-line monitoring application to CRDM for operational safety

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Introduction

Italian situation

- Stop to nuclear energy IS OVER in Italy AFTER 20 years from referedum in Nov. 1987
- New national policy on Nuclear Energy
- New regulatory body (Agenzia Sicurezza Nucleare)
- New nuclear agency (ENES replacing ENEA)
- New nuclear industry group (Ansaldo + Sogin..)

ENEA/S Responses

Advanced research responses relate to the integrated life cycle of nuclear plant systems:

- **New rules for COLs – Production Technologies –**
- **Safety and Economy of exploitation-**

Super-Safety concept

Super-Safety (SS) –What is it?

SS is the unified and complete supervision of critical systems,

its dynamic functions and consequences involved in the operators and managers decisions.

SS is a total protection extendend in time and space, as well as related to the cause-consequences propagation managed together in technological, cognitive and socio-organizational layers

SS has to satisfy current society requirements related to its self and the environment safety (on sustaiability level)

New tasks
New technologies
+ New social constrains

➔ New RTD approach is necessary

→ SS Strategy (SSS)

SAFETY: Four layers of safety building

The systemic socio-cognitive (top -down object-based goal-oriented approach) is applied to the modelling of the problem.

4 layers of safety building from the operator goal-oriented points of view:

- (1) natural safety, it employs only the safety properties of physical processes engaged in the system external functions.
- (2) critical safety; it is realized by the shut-down of the system functions under critical conditions. An automatic switch-off equipment is installed.
- (3) controlled safety; a supervision of safety-indicating variables and the model-based regulation of their control variables (in open and close loops) are realized.
- (4) super-safety; an integrated supervision of the controlled safety is performed, the models employed in the controlled safety layer can be modified according to the managerial preferences of the object/process owner or some external normative requirements.

An intrinsically safe nuclear technology is included in the safety analysis in the above defined layers.

Allocation of nuclear On-Line Monitoring Strategy (OLMS) in frame of SSS

Top-down Approach

Technological Safety

Operational Safety

Policy-Making Safety

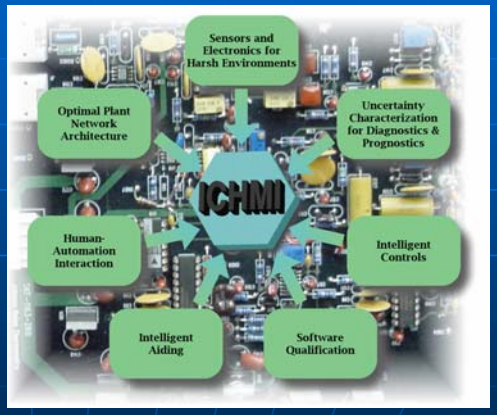
Human-technology & Organizational Safety

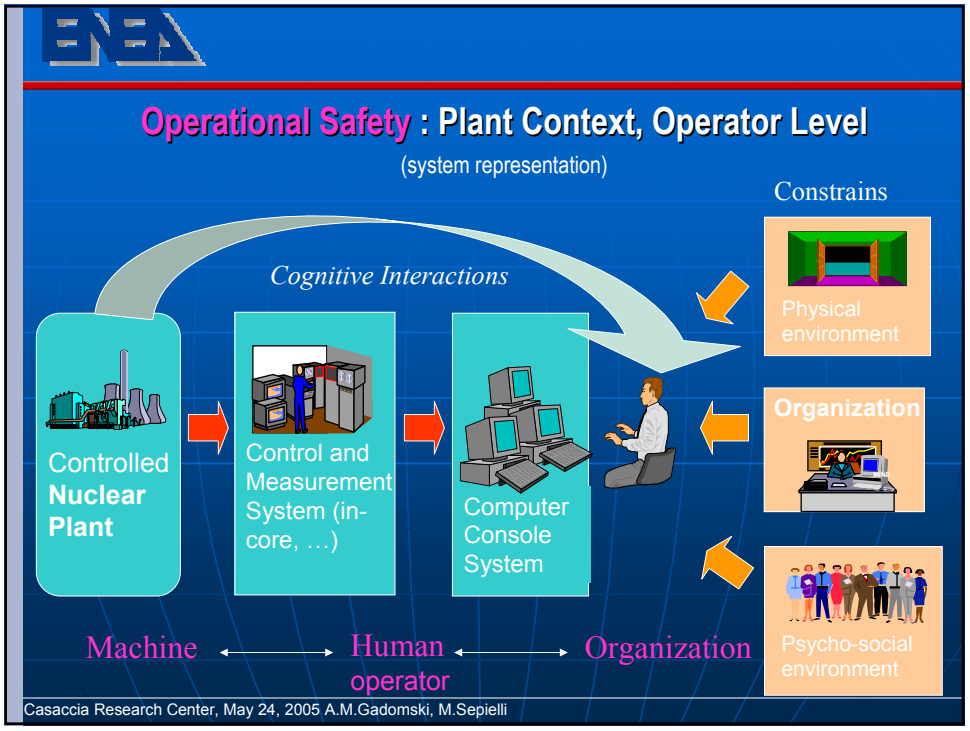
… On-Line Monitoring Strategy ?

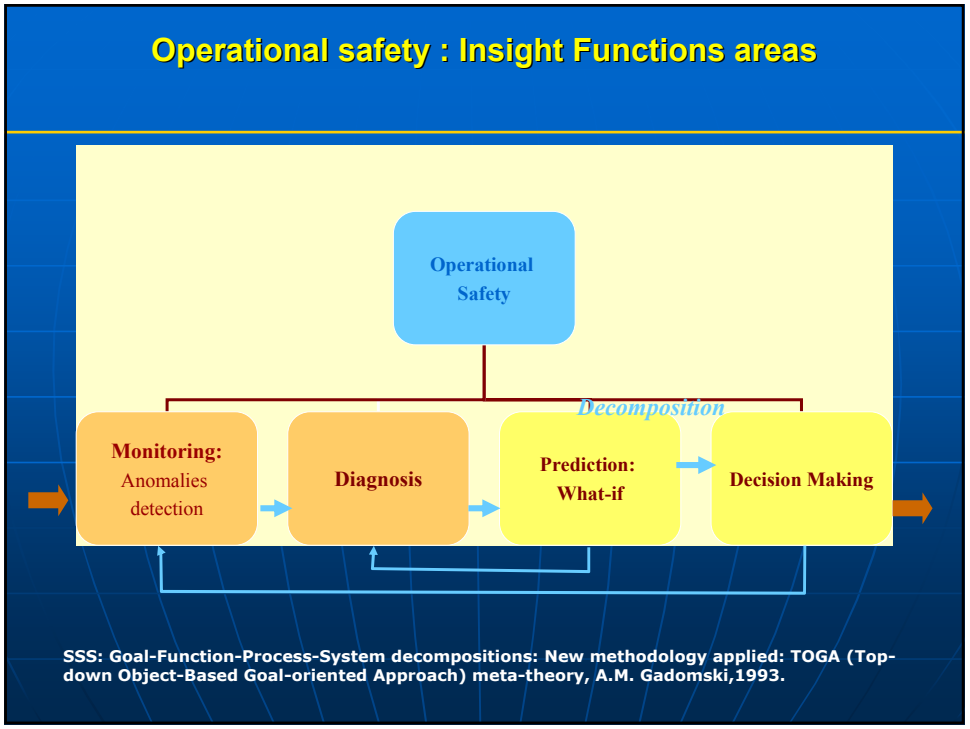
On-Line Monitoring Strategy: Instrumentation, Controls, and Human-Machine-Interface

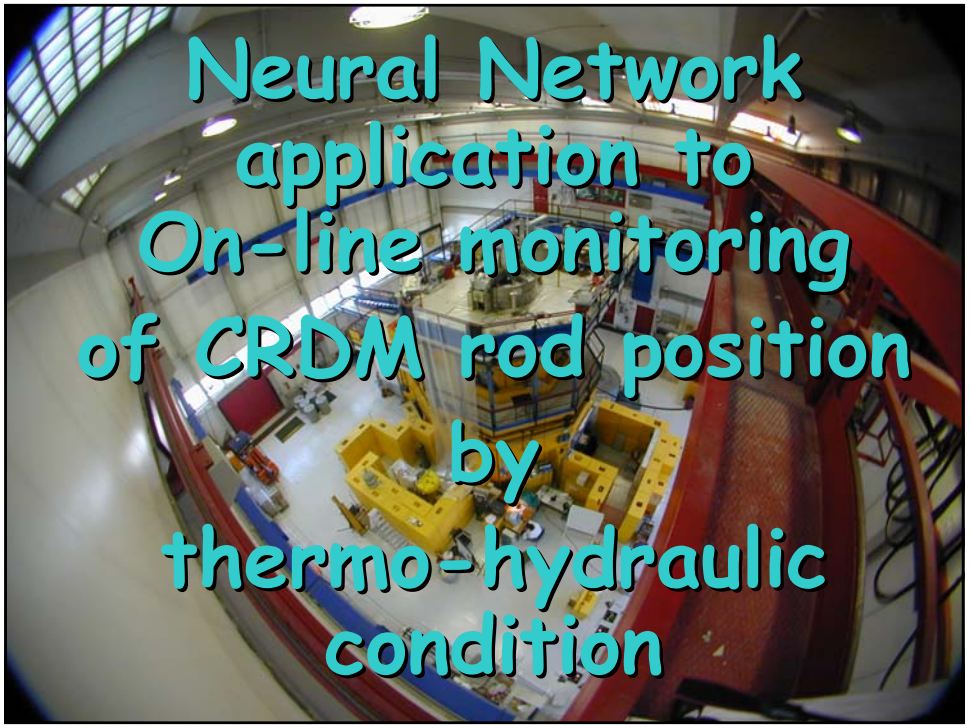
Introduction

- Instrumentation, Controls, and Human-Machine-Interface (ICHMI), are essential enabling technologies that strongly influence nuclear power plants performance.
- Plant sensor on-line monitoring, data validation through soft-computing process and plant condition monitoring techniques would help identify plant sensors drift or malfunction and operator actions in addressing nuclear reactor control. On-line recalibration can often avoid intervene with manual calibration or physical replacement of the drifting component.




Operational Safety : Plant Context, Operator Level
(system representation)
Constrains
Cognitive Interactions
Physical environment
Organization
Controlled Nuclear Plant
Control and Measurement System (in-core, …)
Computer Console System
Psycho-social environment
Machine
Human operator
Organization
Casaccia Research Center, May 24, 2005 A.M.Gadomski, M.Sepielli


Operational safety : Insight Functions areas
Operational Safety
Decomposition
Monitoring: Anomalies detection
Diagnosis
Prediction: What-if
Decision Making
SSS: Goal-Function-Process-System decompositions: New methodology applied: TOGA (Top-down Object-Based Goal-oriented Approach) meta-theory, A.M. Gadomski,1993.



Neural Network application to On-line monitoring of CRDM rod position by thermo-hydraulic condition

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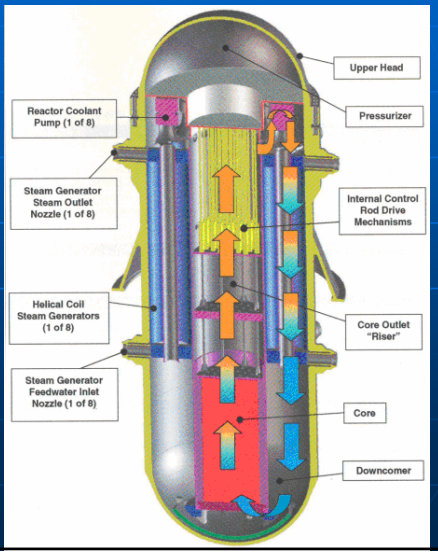
Neural Network application to on-line monitoring of CRDM and thermo-hydraulic condition

Activity

- The activity will concern the application of the method to validation and thermohydraulic prediction in a III+ generation light water nuclear power plant featured with an integral pressurised primary system, where access to CRDM (Control Rod Drive Mechanism) system is physically hampered and rod positioning can be accurately and safely controlled from exterior only.
- The activity described is aimed at validating data obtained by TRIGA reactor measurements through soft-computing models based on neural networks (NN).



Neural Network application to on-line monitoring of CRDM and thermo-hydraulic condition

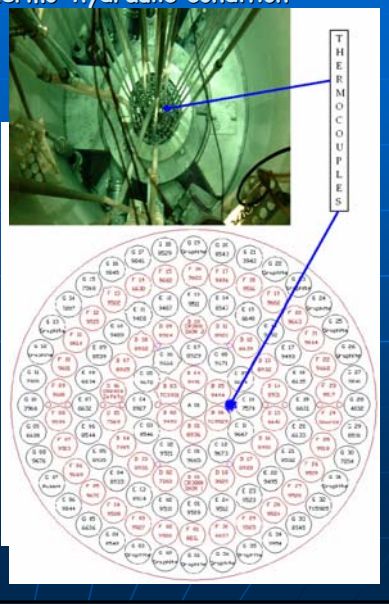
Description of the reactor

The reactor is a typical TRIGA light-water (research) reactor with an annular graphite reflector cooled by natural convection, with a power of 1MW.

The reactor core is placed at the bottom of the 6.25-m-high open tank with 2-m diameter. The core has a cylindrical configuration.

Inside the core there are 91 locations, which can be filled either by fuel elements or other components like control rods, a neutron source, irradiation channels, etc.

The core temperature is measured by 8 thermocouples situated above and under the core, while the fuel temperature is measured in two fuel elements instrumented with thermocouples



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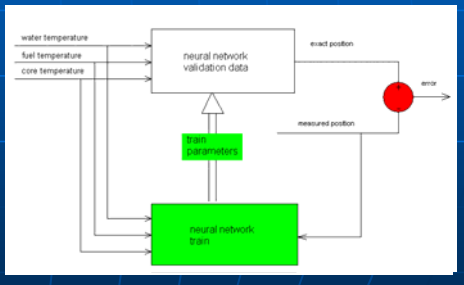
Neural Network application to on-line monitoring of CRDM and thermo-hydraulic condition

Neural Network Structure

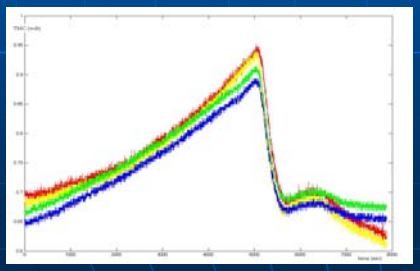
- **Validation Net**: used for data validation, initially trained through the use of reactor data
- **Train net**: : used for training and parameters updates every time an error, due to the difference between the value generated by the first net and the value measured from the instruments occurs.

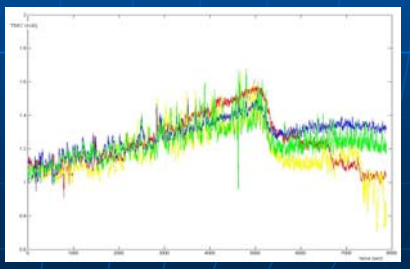


Neural Network application to on-line monitoring of CRDM and thermo-hydraulic condition

Reactor data:

- To train the net a campaign of data acquisition has been carried out.
- From this campaign emerged that some signals, as originated by the thermocouples, are very close when the control rods position is inverted





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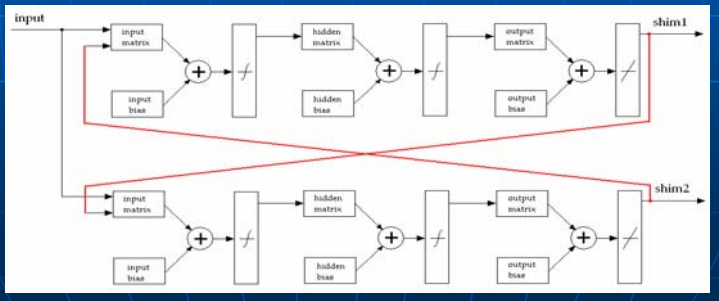
- This unexpected difficulty could cause a mistake in the training phase of the net.
- In order to remedy to this, since the rods can be moved one for time, and since the position of a control rod depends both on thermo-hydraulic conditions and the position of the other control rod, it is chosen to divide the net in two different nets



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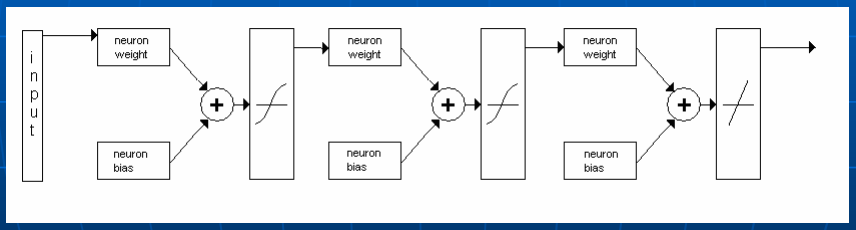

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Train data set

Data validation SHIM1 net

- Input data: core temperature (8 thermocouple); fuel temperature; SHIM2 rod position.
- Output data: SHIM1 rod position.

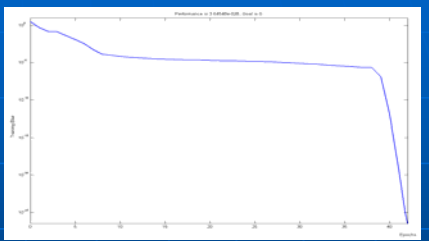
Data validation SHIM2 net

- Input data: core temperature (8 thermocouple); fuel temperature; SHIM1 rod position.
- Output data: SHIM2 rod position

Neural Network application to on-line monitoring of CRDM and thermo-hydraulic condition

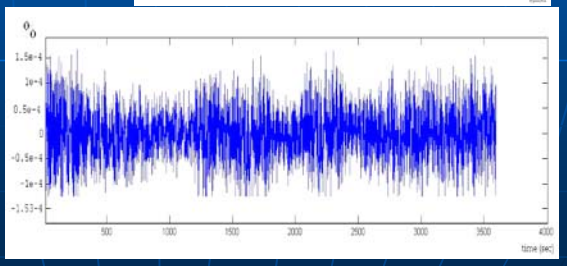
Training

- After the training process (42 epochs), the value of the achieved train performance has been 3.6e-28.



Training outcome

- experimental data match with training data
- rod position percentage error is 1.5e-4



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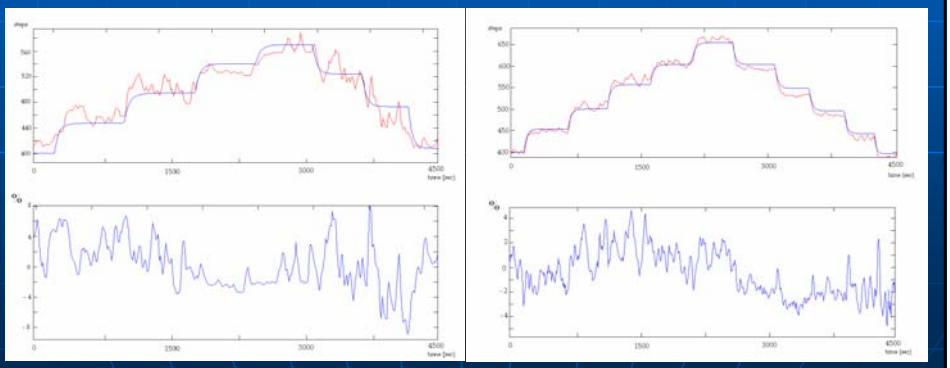
- In order to make the case study concrete several simulations, with different data, from those used for training, have been carried out.



TECHNICAL Conclusion (1)

Neural Network application to
on-line monitoring of CRDM and thermo-hydraulic condition

The outcome obtained in this applications have been satisfactory as the error in steady state resulted less than the expected one and the training method quite effective. Testing will continue with increasing of data scanning rate and signal filtering, to improve the answer during status transitions and investigate how to decrease oscillations during the steady-states.

ENEA/S' SPECIFIC INTERESTS (2)

1. **New Approach to Intelligent Console Network for Nuclear Supper Safety**

2. Suggested initiative: to propose for UE and IAEA the organization of:

European Network of the Research and Consulting Centers for the development of Super-Safety & High Intelligent Nuclear Operations Grid (SSHINO).

This new SS Strategy should:

- **include in the safety operation human management and organization responsibility**
- **extend the concept of safety on the emergency propagation in space and time**
- **adapt technology to humans by high-intelligent ICT support network.**

Operational Super-Safety mission . ENES intends to follow two main closely interdependent RTD directions:

- **1. Nuclear integrated super safety management**
- **2. High intelligence add network for design, planning and operations.**

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END