Upgrading the Reactor Power Control Concept with a Modern Digital Control System

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Overview

- Plant History
- Reasons for Retrofitting
- Structure of the Reactor Power I&C System
- Phase Plan for Project Execution
- System Engineering
- Quality-assurance Measures
- Preparatory Infrastructural Measures
- Commissioning of the Digital Control System
- Conclusion

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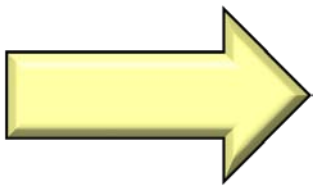
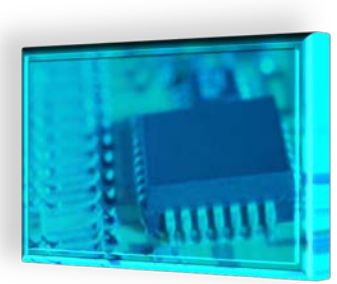
Plant History

- Pressurized-water reactor of the 2nd generation
- Pre-convoy series
- Erection starts in July 1977
- Commercial operation since April 1985
- Electrical nominal gross output approx.1450 MW

- Retrofitting the Reactor Power I&C System as well as the In-Core Neutron Flux Measuring System

Analog Technology





Modern Digital Control System

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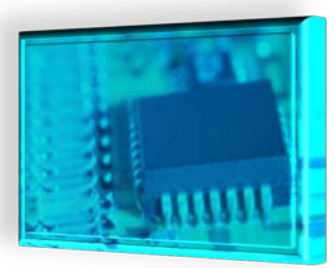
Reasons for Retrofitting

- Optimization of the plant's operational performance
- Improving the procedures in the event of disturbances or failures
- Better identification of abnormal operating states
- Optimization of the reactor power I&C messages and displays

  ➢ Increasing the plant's reliability, safety and availability

- Facilitation in future repair procedures / spare parts deliveries
- Upgrade the plant to the latest state of the art

  ➢ Modern and type-tested digital control system for safety I&C applications



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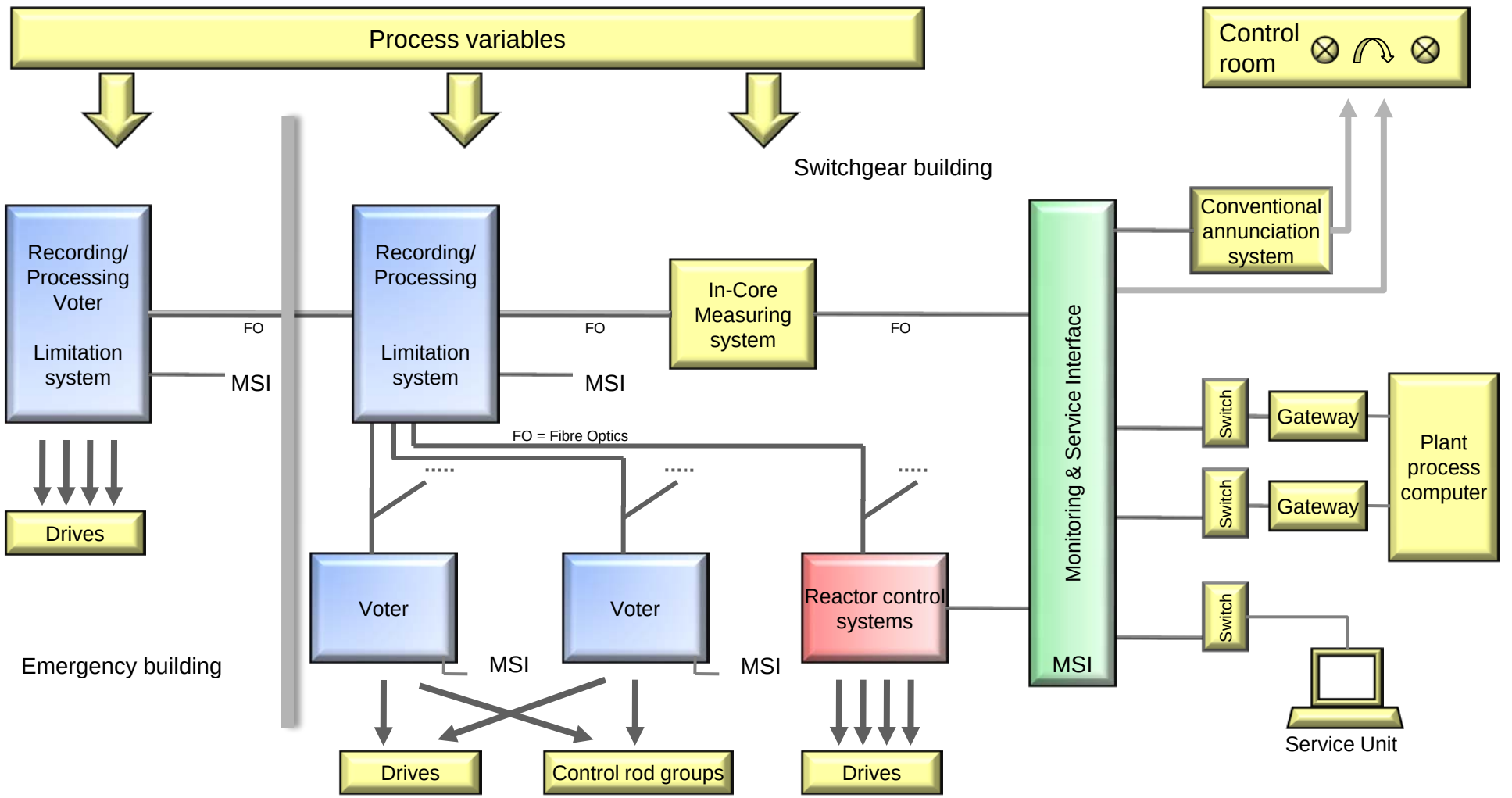
Structure of the Reactor Power I&C System (single redundancy)



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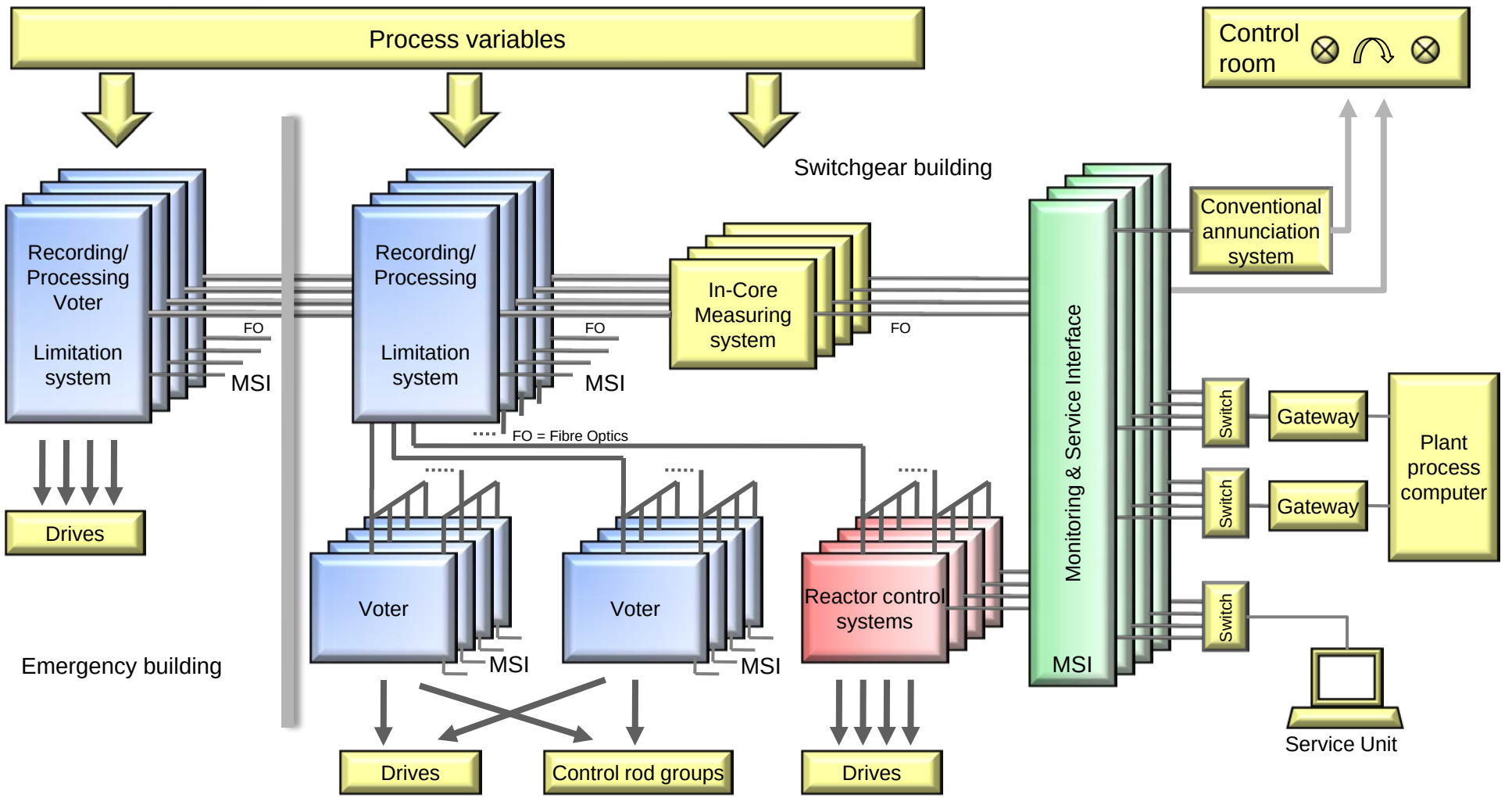
Structure of the Reactor Power I&C System (all redundancy levels)



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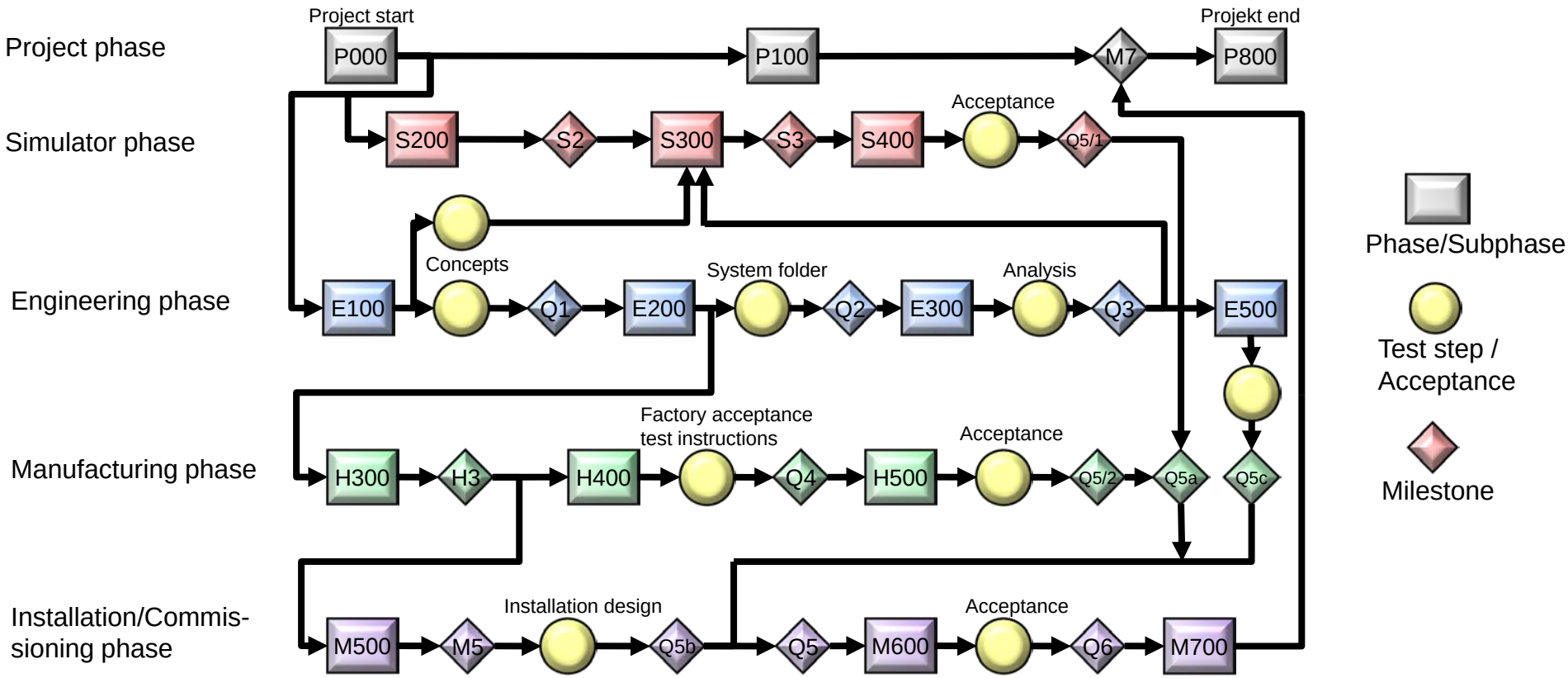
Phase Plan for Project Execution



- Phase plan structures the project activities
- Phase plan provides for a transparent and quality-assured implementation of the entire project

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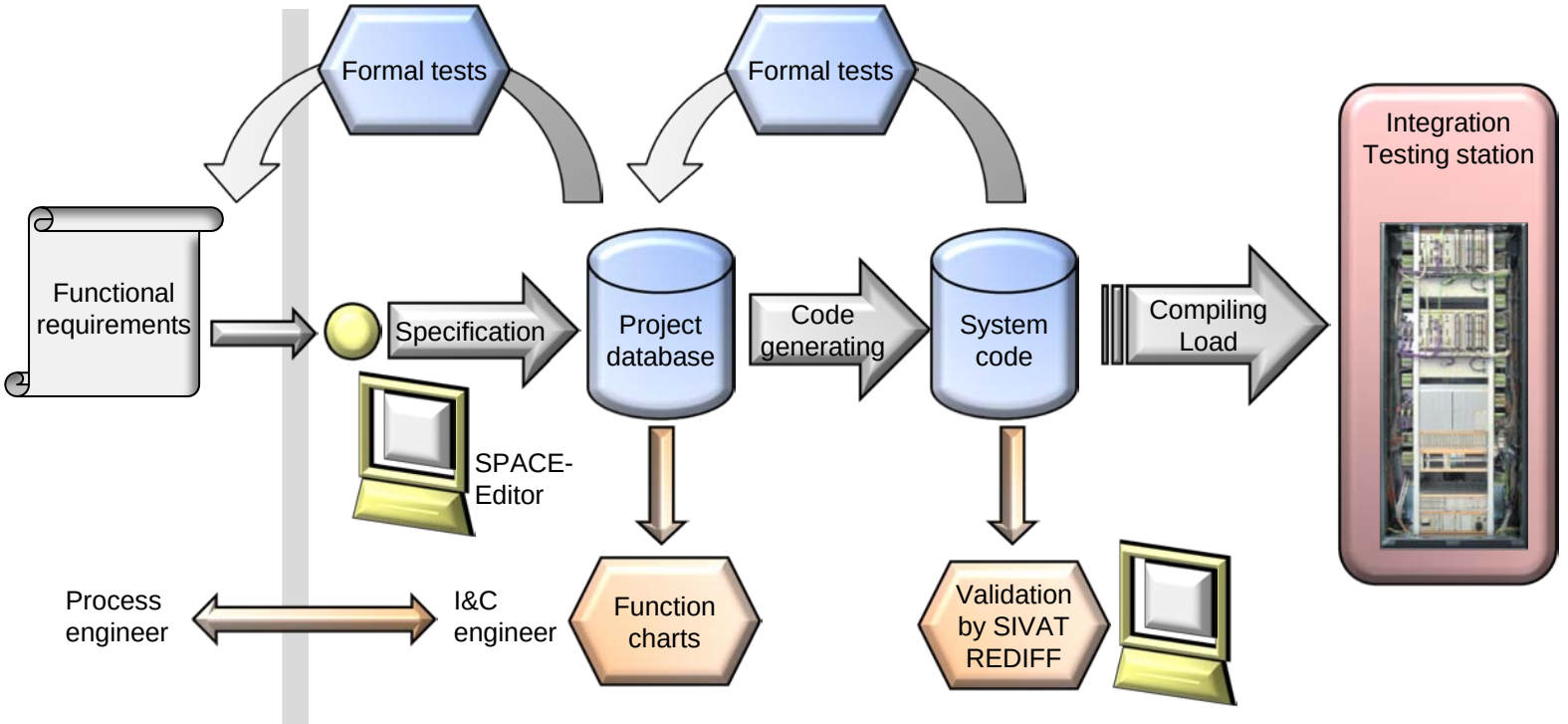
System Engineering



- System engineering by using tool system SPACE
  - SPecification And Coding Environment
- Provides graphic editor, code generators and testing tools
- Generates a consistent specification
- Generates executable programmes automatically

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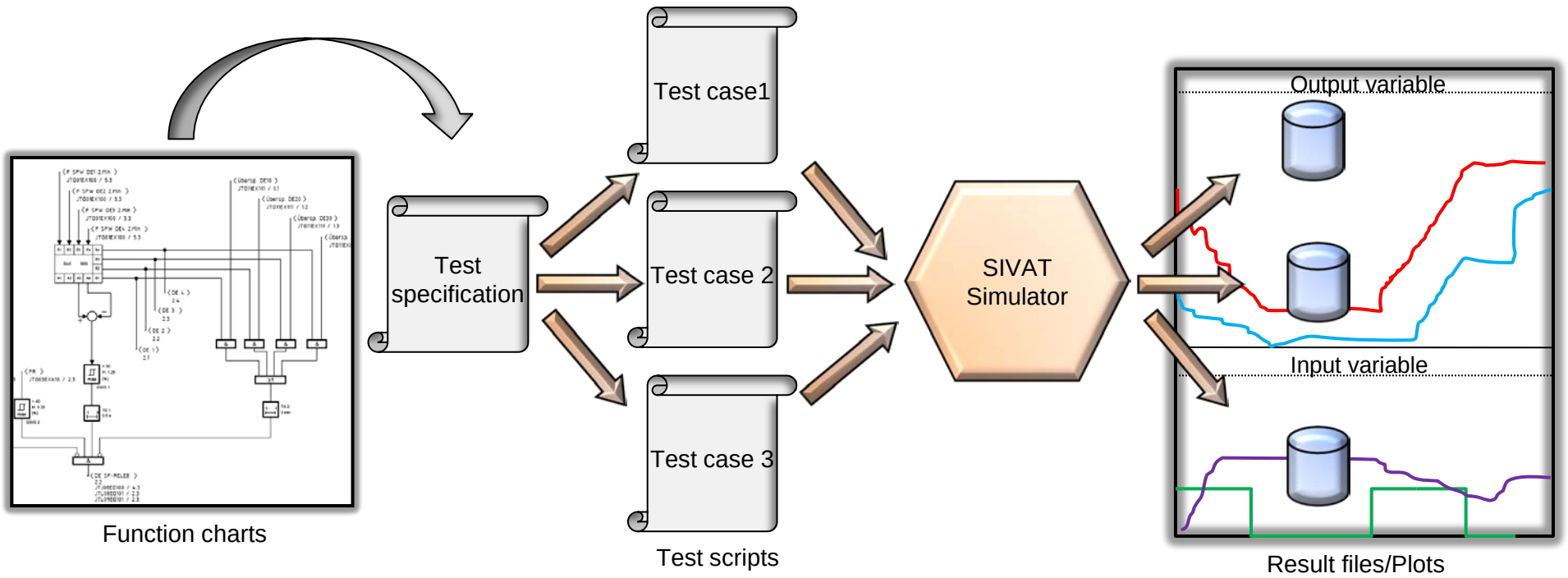
SIVAT (Simulation & Validation Tool)



- SIVAT provides a simulation environment for the control system
- Discrete tests on the engineered control functions after the code generation
- Generating the test specifications on basis of the function charts
- Simulation run based on test scripts
  - ➢ Identifying and elimination of project engineering errors at an early phase

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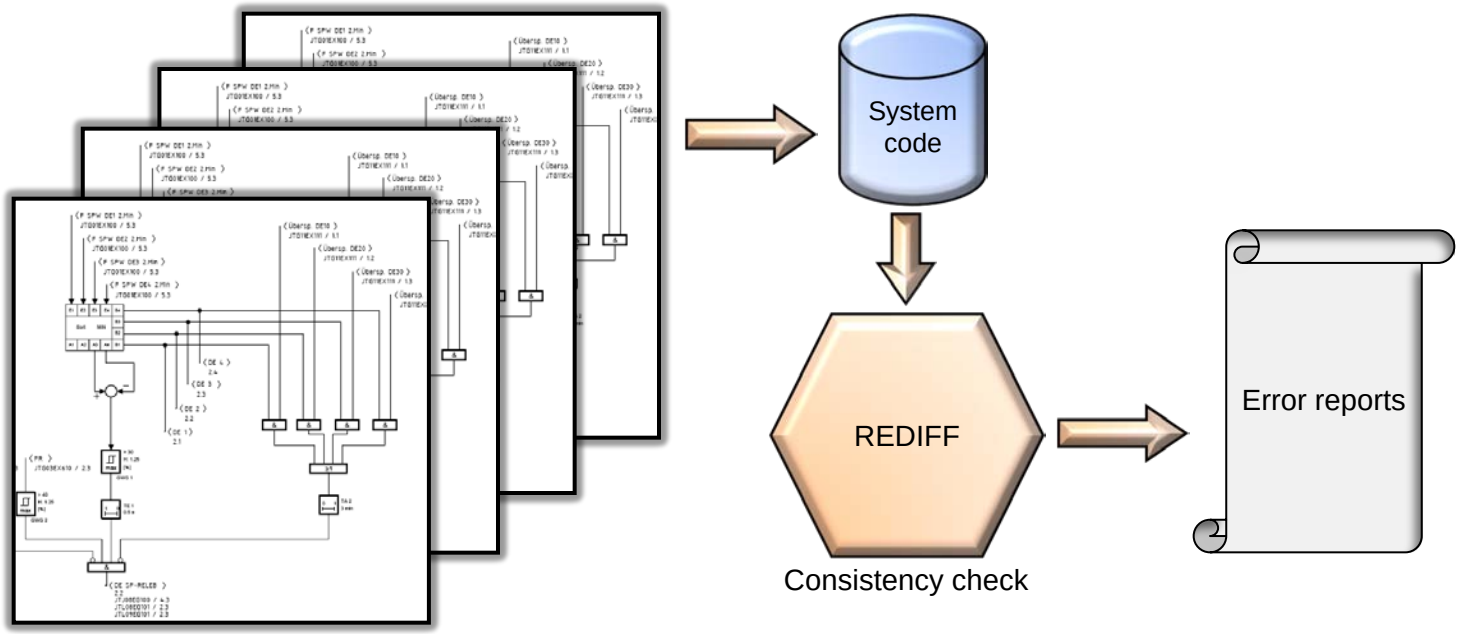
REDIFF (Redundancy-Comparison-Tool)



- REDIFF provides a redundancy comparison tool
- Checking the redundant function charts for consistency
- Shows the discrepancies between redundant function charts
  - ➢ Identifying and elimination of project engineering errors at an early phase

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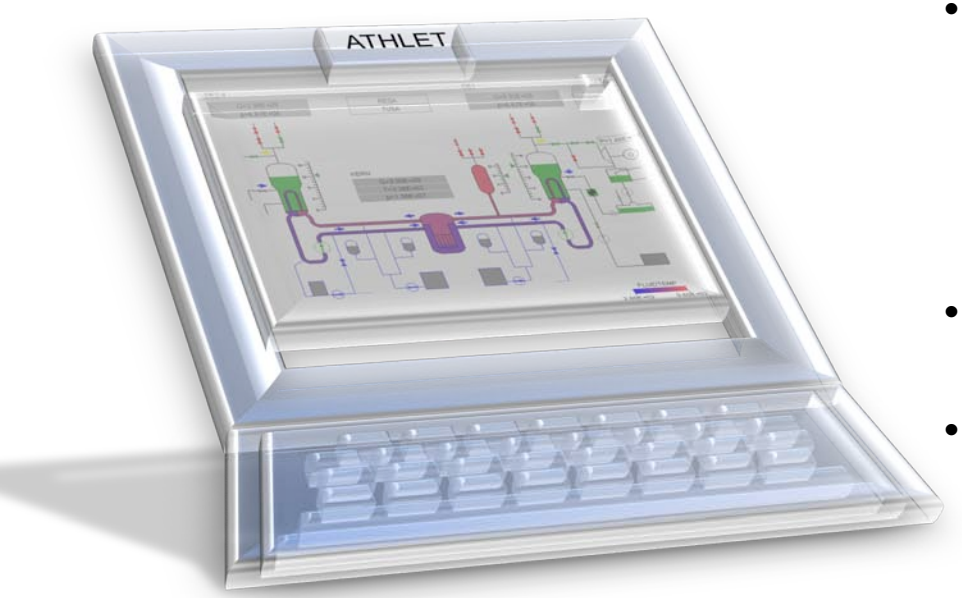
Quality-assurance Measures (ATHLET)



- Simulator program ATHLET enables computer-aided modeling of
  - reactor protection functions
  - limitation functions
  - major control functions
- Examination and recalculation of transient trends
- 35 Transient trends examined

- Result of the examination:
  - ➢ The changes in the reactor power I&C system functions fulfilled the criteria defined in the Reactor Safety Commission guidelines

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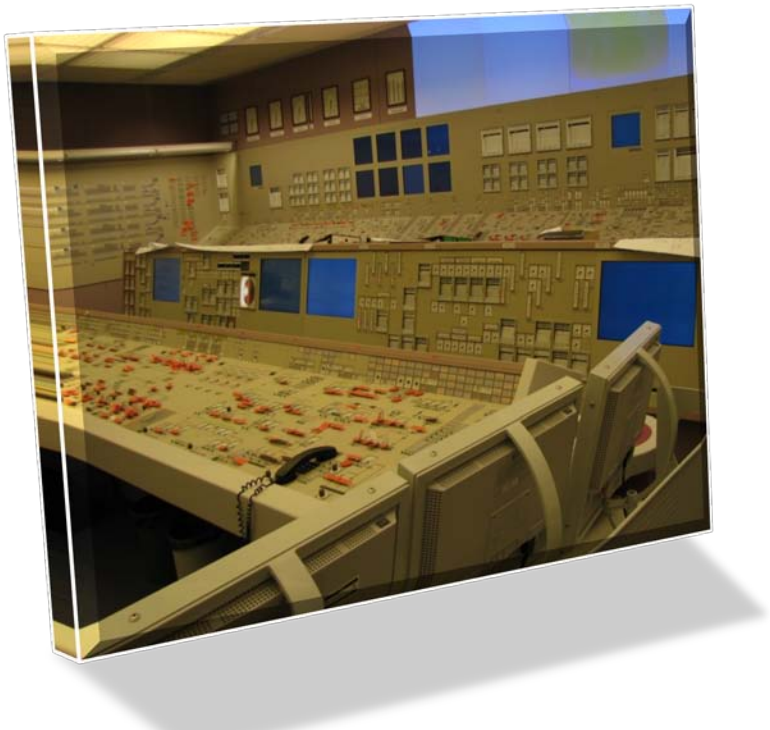
Quality-assurance Measures (Plant Simulator)



- Adaptations on the plant simulator in the test center in Essen
  - system and peripheral specific
- Integral test of the interactions between the control functions by simulating the process variables
- Simulations included the performance of plant transients

- Result of the Simulations :
  - ➢ Verifying of the specified functions and the improvements made for an operational plant optimization
  - ➢ Transferring specific know-how to the on-plant personnel

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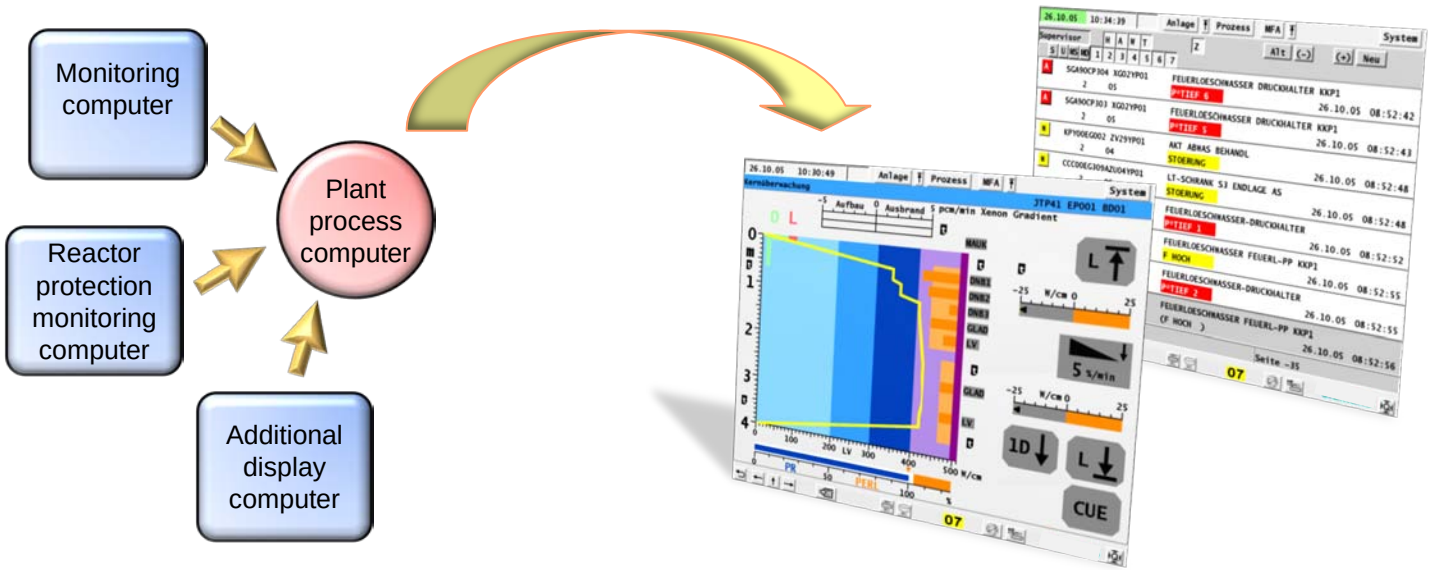
Preparatory Infrastructural Measures (Plant Process Computer)



- Preceding project to replace the plant process computer
  - Integration of the existing single-computer systems into a redundant high-performance and consistent plant process computer
  - Optimization of the human-machine-interface by modern on-screen-based operating and visualizing techniques as well as the control room design

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Preparatory Infrastructural Measures (Power Supply System)

- Preceding project for upgrading the power supply system
  - Identifying the power and space requirements of the new reactor power I&C system
  - Preparation of the battery rooms for an increase in capacity
  - Installation of switch bays with additional outgoing circuits and a discharge inverter for the batteries

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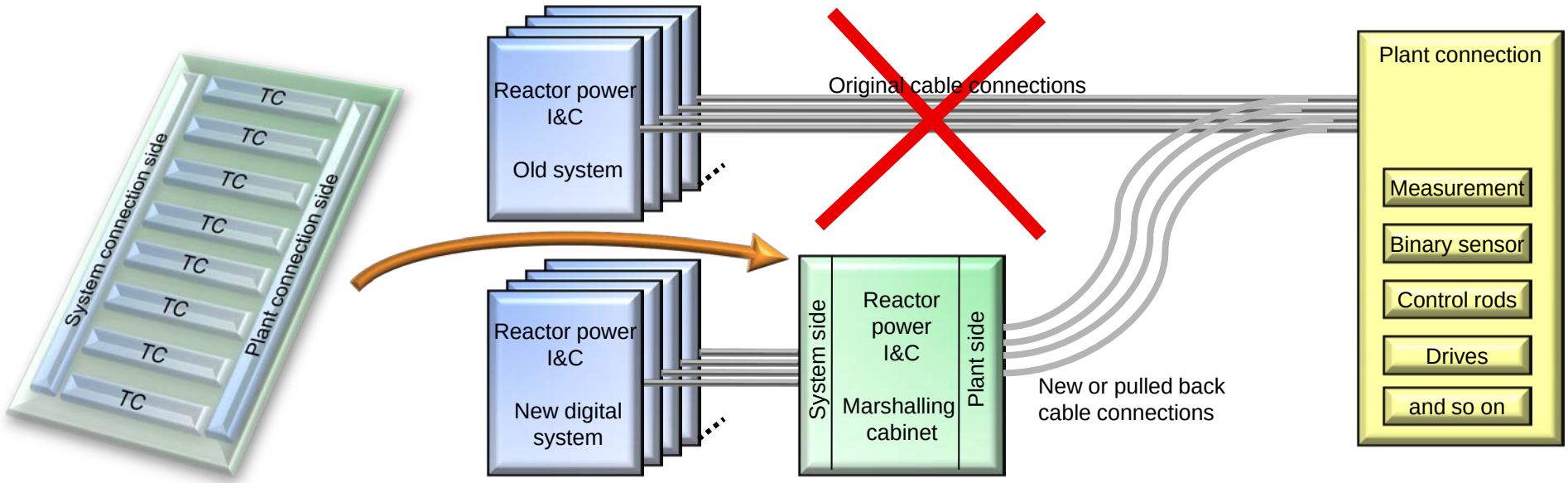
Preparatory Infrastructural Measures (Marshalling Cabinets)



- Marshalling cabinets with two terminal sides (system connection side, plant connection side) which are linked via planned transverse connections (TC)
- Connecting the system cables of the digital control system to the system connection side already after the installation of the control cabinets
  - Signal-specific preliminary tests (cold tests) independent of the overhaul activities
  - Detecting and elimination of wiring errors prior to the overhaul activities
  - More time for the remaining overhaul activities

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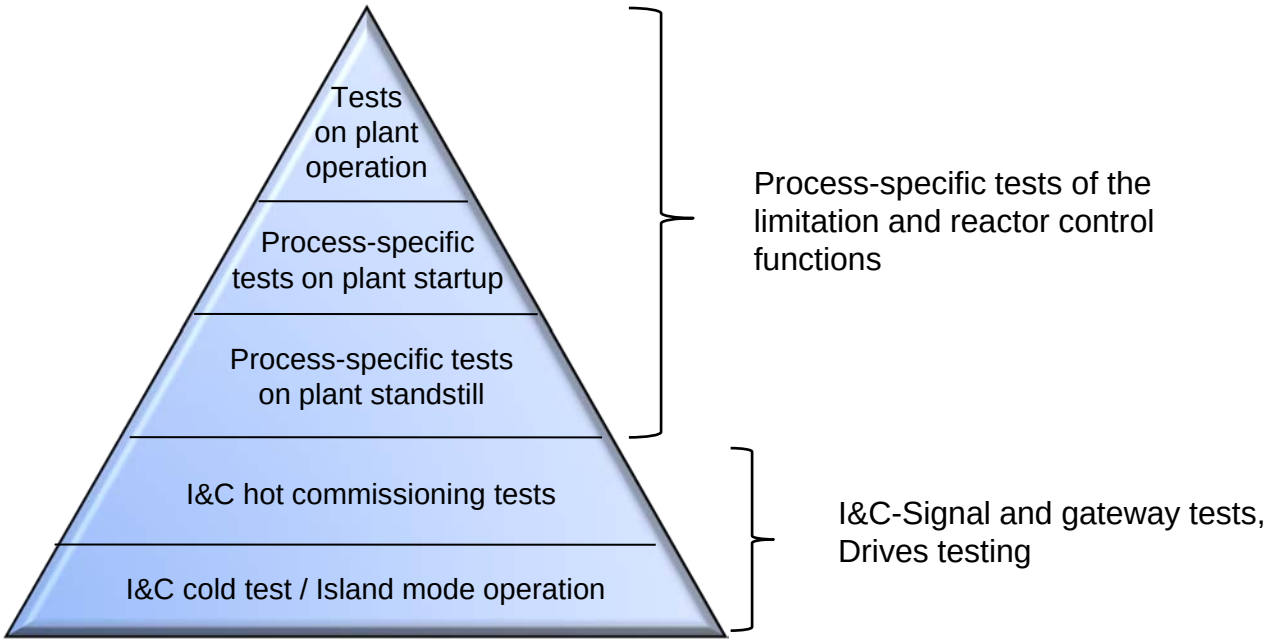
Commissioning of the Digital Control System



- Commissioning of the entire system in step by step
- I&C commissioning tests → process-specific commissioning tests
- Consistent documentation of the commissioning procedure
- Tests in the presence of the officially appointed inspector
  - ➢ Quality assured procedure to ensure the specified control and process-specific functionality

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Conclusion

- Project execution on basis of a phase plan
- Documentation along with the phase-specific tests
- Preparatory infrastructural measures
- Consistent using of quality assurance measures
- Participation of the officially appointed inspector „TÜV SÜD Energietechnik“

  - ➢ Performing a fluently commissioning procedure on the plant ✓
  - ➢ Despite the large volume of replacement work successfully retrofitting of the reactor power I&C system without causing a relevant extension of a periodic plant standstill ✓
  - ➢ Fulfillment of the stringent quality requirements applicable to such a complex system ✓

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Thank you for your attention!