WELCOME

EDF Energy Nuclear Generation Checking out Engineering Designs / Plant Modifications on Simulators

kashmir.singh@edf-energy.com
Nuclear Generation, EDF Energy, Barnett Way, Barnwood, Gloucester GL4 3RS, UK
+44-1452-652131

World wide experience

- What happens in the real world?
- Experiences of other nuclear utilities?
- Experiences of simulator vendors?
- Experiences from other major industries?

Nuclear Industry Survey

- The following survey questions were sent out to Utility Simulator Users Group (USUG) members on 10 July 2012:-

  What is your experience on using the simulator for the following:

  1. Checking out plant modifications first on the MCR training simulator before implementation on the plant, e.g. checking that the plant modification works as intended, that there are no interface problems with other plant systems, that the planned modification will work properly at various power levels, and under various plant evolutions, etc. Examples of problems found, optimisation of plant performance, how much time and money it potentially saved if the problems had been found on implementing the mod for the first time on the plant, etc. would be appreciated.
  2. Use of the MCR simulator to optimise plant performance.
  3. Use of Engineering Simulators experience for existing nuclear power stations or for New Nuclear Build. Please provide examples of benefits over MCR training simulators, and typical problems

4

Simulator vendors

- L3 MAPPS
- GSE
- Corys
- Tecnatom
- WSC

Experience from Nuclear Power Plant Simulation Conferences

- USA
- L3 MAPPS Owners Conferences
- Corys Owners Conferences
- European Nuclear Power Plant Simulation Conferences

USUG Survey - Nuclear Industry Utilities

- EDF Group
- Powergen
- Florida Power & Light (FPL)
- Energy Northwest – Columbia Generating Station
- Palo Verde
- Duke Energy – Oconee

USUG Survey - Nuclear Industry Utilities

- Southern Nuclear Operating Company
- Ontario Power Group (OPG)
- Exeloncorp
- Wolf Creek
- TVA – Sequoyah
- PGE

USUG Survey - Nuclear Industry Utilities

- Xcel Energy – Prairie Island
- NPPD – Cooper
- Nucleoelectrica Argentina

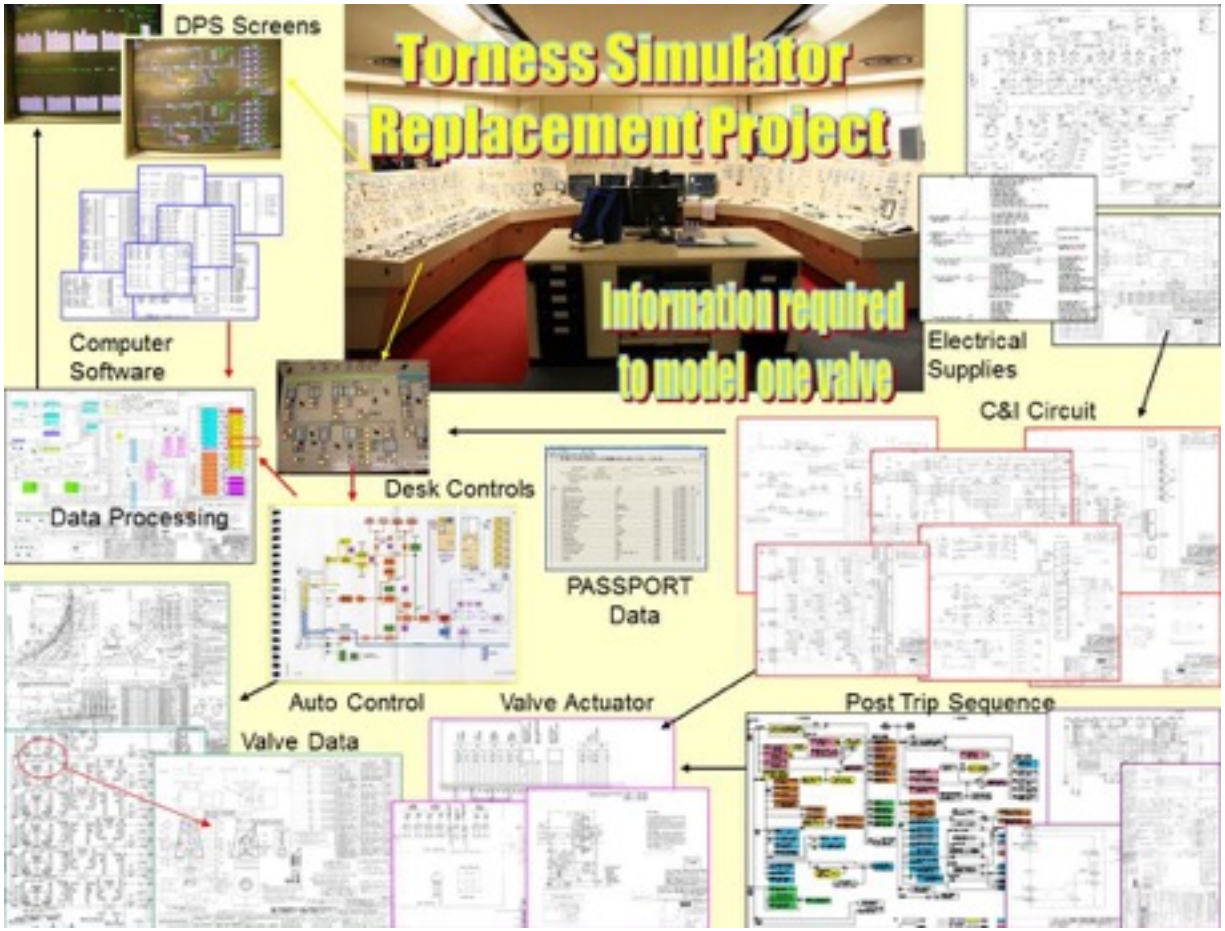
Corys Magazine July 2015

- Issues are now far too complex to be worked out on paper. Simulation is required to bring together diverse engineering tools, broaden the scope of test coverage, demonstrate an absence of risk

- Opex shows that paper based V&V activities do not pick up all issues, with problems coming to light after installation, during site testing and commissioning

- Simulation is becoming a productivity tool in its own right. The Corys simulator for the Taishan EPR absorbs engineering data at a phenomenal rate, delivering a major step forward every 3 months, an update every month, and improvements every week.

Complexity of Engineering designs



Corys Magazine July 2015

- Michel Esbrat, EDF, France: Use simulator for engineering for Flamanville EPR, and move from analogue to digital main control rooms for existing nuclear power stations.

- Thomas Jouanny & Pierre Laprand, EDF CNEN, France: EPR Project in UK has decided to combine both the design and validation of C&I within simulation. This approach will shorten lead times, make elementary systems design more reliable, and avoid late and costly corrections. With design and validation progressing in parallel, pruning can be done at source and the code delivered is verified. That will make for far fewer problems when reaching the full-scale testing phase.

EDF ENERGY

Corys Magazine July 2015

- Jeremy Carrion & Benjamin Henssien, EDF SEPTEN, France: The new SIRENE project will help with changes on existing stations. With Simulation it will be possible to predict and detail the impact of changes on the plant itself and on peripheral systems.

- Thierry Germier, Areva TA, France: Areva TA has been using design simulation for over 20 years, from design through to commissioning tests. During the design phases, the simulator helps with the definition and optimisation of systems and control mechanisms. During construction Areva compare actual C&I to the original design. To do this, the actual C&I and supervision software is emulated or stimulated, and then swapped with the simulated C&I used during design. In the light of the increasing complexity of digital C&I and supervision, this has now become indispensable.

Corys Magazine July 2015

- Romain Balp, Areva NP, France: Prior to the functional system tests that are due to commence at Taishan in 2015, a 3 month test campaign was conducted on the simulator. This involved standard operations, testing of elementary systems, unit regulation and the loss of electrical subdivisions or C&I subdivisions. This has delivered valuable information that would be difficult to identify and prioritise without a simulator.

- Vasily Palamarchuk, GET, Russia: Russian markets will benefit from using simulators to include engineering and the design of C&I.

In Practice?

- Some practical examples will now follow

Nuclear Industry Utilities

- Barcelona Conference, Oct 2012– EDF reported that many engineering design and operations errors had been picked up on Flamanville simulator

- HY1 Procedures and Processes checked out for 3 quadrant operation; simulator tripped on IGV position resulting in SOI changes

- Tested and proved plant controls logic for turbine governor controls and turbine protection for Oskarshamn 3 and Forsmark 3, which identified design problems up-front. Client had insisted on simulator first, then plant.

Nuclear Industry Utilities

- Seabrook made several changes to the simulator panels first, to try them out and train up operators, before implementing them on the station

- Note: All US Military Aircrew Flight System designs, builds, and revisions are engineered first on the simulator, and then second on the aircraft.

- Colombia – integrated a new digital control system for main turbine, and also reactor pressure control system for a Boiling Water Reactor

EDF ENERGY

Nuclear Industry Utilities

- INPO SER 5-9: “modifications must be tested thoroughly. The failure modes of the DEH modification had not sufficiently considered the effect of the modification to the turbine throttle pressure instrument range and associated instrument failure thresholds. Further, the plant simulator did not model the instrument failure thresholds”. A side effect of the turbine DEH modification, following the turbine trip and opening of bypass valves led to a rapid reactor depressurisation. The design review had not ensured that the change was acceptable for all plant conditions, including transients.

EDF ENERGY

Nuclear Industry Utilities

- Palo Verde – Digital Feedwater Control

- Duke Energy – Checked out Integrated Control System and Operator Aid Computer replacement; Triconex EHC upgrade (turbine control system); Unit Reactor Protection System (RPS) Engineering Safeguards (ES) replacement; Protected Water System implementation.

- Southernco: Recirc Pump motor Variable Frequency Drives upgrade

EDF ENERGY

Nuclear Industry Utilities

- Exeloncorp – Adjusting controller setpoints to control post-scram level response from feed water pumps; used to install orifice in feed water heater vents resulting in 8 MW improvement.
- Exeloncorp – Digital flow control computer upgrade, and using the simulator as part of SAT. Any delay in start-up because of this mod will be $0.5m per day as a minimum. Also allows operators to use it in training, before it goes live in the MCR

Nuclear Industry Utilities

- Wolf Creek – Integration of new plant computer revealed multitude of issues, which would not have been discovered until integration with the plant. Saved 1-2 weeks of work during tight Outage. Also finding lots of issues on new DCS control for turbine.

- Wolf Creek – Recent uprate of turbine rotors revealed that the extra MWs gained would not be as much as originally promised; several mods to plant computer system found problems that were able to be modified before installation on plant.

- Wolf Creek – comparison with plant events revealed component failures in the plant that were not realised by plant personnel, and were then able to be tracked down and fixed.

EDF ENERGY

Nuclear Industry Utilities

- Wolf Creek – surprised that other plants have not realized the great benefits the simulator gives beyond just training/testing operators

- Sequoyah – Digital control system installed on simulator to replace the feedwater control system. New procedures were refined, preliminary tuning of the control system gains was done on the simulator and resulted in much less tuning being required on the plant. Simulator also revealed a new source of reactor trip when one of the vital AC boards was lost; mod was done to the plant to prevent OPDT turbine runback on loss of the vital board.

EDF ENERGY

Nuclear Industry Utilities

- PGE – There was a problem with the MFW reg valves hunting. Plant hired a consultant to analyse the problem, who recommended some changes to the DFWCS programming. The hunting was duplicated on the simulator and the tuning factors were tried out; this showed that none of the changes would correct the problem. Saved plant resources and decided to work on the valve itself during the next Outage.

Nuclear Industry Utilities

- Prairie Island – Did it with control system replacements. Found it very beneficial.

- Southern – Implemented VFDs to drive plant recirc pumps. Found problems with the designed plant logic. The basic start-up logic was fundamentally flawed. The system would never have started up as designed. Additional main control panel changes were required to make it work. The simulator saved the plant a number of days of Outage time and thousands of dollars.

EDF ENERGY

Nuclear Industry Utilities

- Cooper – Been very successful with implementing significant mods (DCS) on the simulator before the physical plant. In both cases (Reactor Vessel Level Control System / Reactor Feed Pump Turbine Speed Control System, and the Digital Electro Hydraulic Control System) we were able to debug the plant system. Also, operations staff were able to train on the new systems before they were installed on the plant.

- Cooper is currently on the second “breaker to breaker” run, which is mostly attributable to equipment upgrades, especially the RVLCS/ RFPT Control Systems upgrades

EDF ENERGY

Nuclear Industry Utilities

- Nucleaoelectrica Argentina – L3 MAPPS Sim News magazine, June 2014

> "We are hopeful that this will be a great tool for plant software modifications, engineering changes, etc that can be fully tested on the simulator prior to introducing them on the plant."

> "We will use the simulator for engineering testing of design changes for new equipment to be installed on the plant."

EDF ENERGY

INPO

- Event Report 12-69, 30 Aug 2012 – 40 trips out of 62 were due to equipment, 8 due to Human Performance, 14 due to external events, e.g. national grid, severe weather, clogged screens, etc

- Equip trips – 33% due to design vulnerabilities (original and recent mods); 33% -work management and maintenance; 14% - preventative maintenance programme

- Trip reduction practices - … engineering functions/ operations validated at vendor sites, in the simulator, and on site prior to installation.

INPO Nuclear Power Plant Software Quality Assurance

- Good Practice, INPO 12-014, Dec 2012 – recommends that testing of station digital computing systems typically includes simulator testing and the creation of a mock-up identical to target implementation, where feasible, to ensure the intended safety function is accomplished

EDF ENERGY

UK Health and Safety Executive

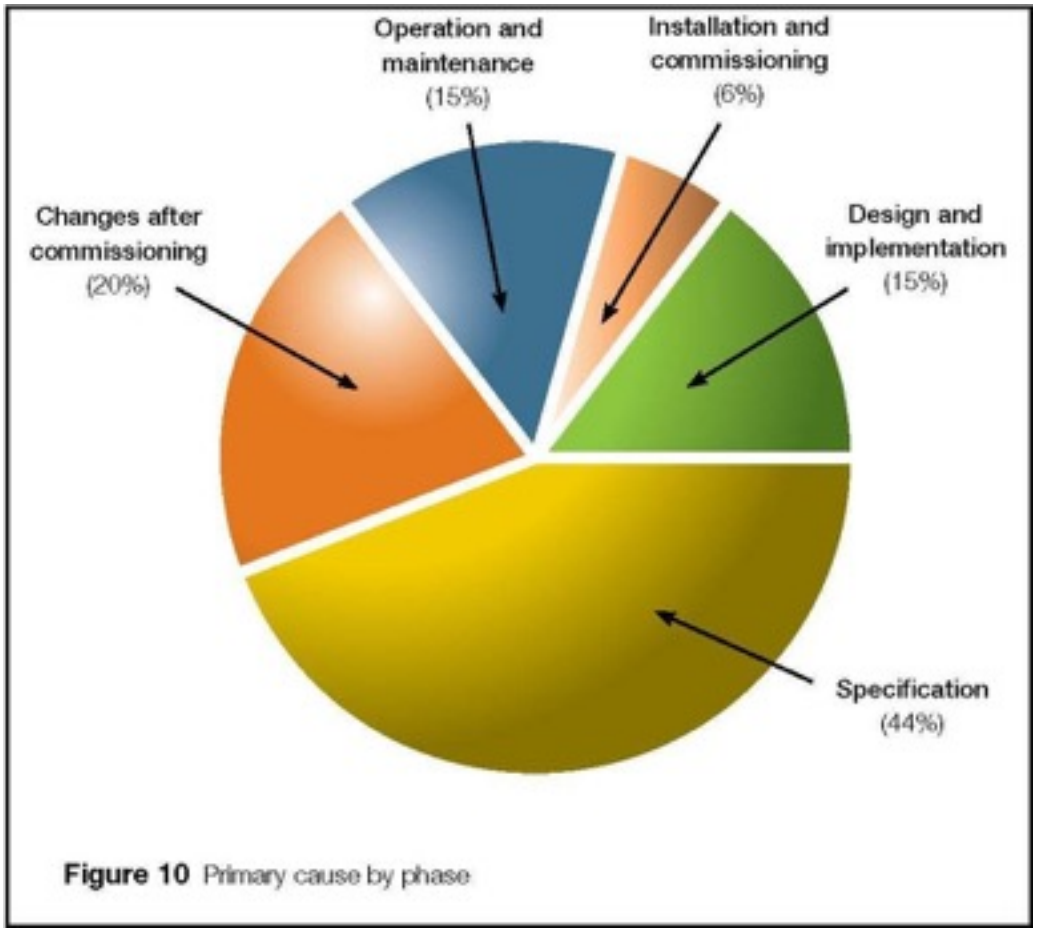


Figure 10 Primary cause by phase

Simulator Vendors – Experiences - GSE

- GSE
  - Law in Sweden requires that a mod must be available for training on the simulator 12 months prior to implementation on the plant to ensure that this benefit is realized. Some systems have been sent back for a complete rework as a result of their failing to work correctly in the plant simulator, and there was one case where the project was cancelled. These examples saved the plant tens of millions of US Dollars.

  - Upgrades to digital control systems. On average there are 100 errors in the control logic, of which approx 10 would take between 1 to 5 days to resolve by the control experts. Assuming that each day the plant is down costs the plant 1 million dollars; this equates to a saving of 10 million Dollars. Also, customers have been able to reduce scheduled outage costs for such upgrades by as much as 2 weeks.

EDF ENERGY

No need for hard desks

Simulator Vendors – Experiences - Corys

- Developed since 2007 with EDF-SEPTEN engineering simulation platform, using it for basic engineering validation of plant mods (SULTANE project).
- In the USA some of our customers are thinking of using Soft/Glass Panels for checking out plant mods before actual implementation, without disturbing the Simulator MCR heavy training schedule
- Used Ling Ao II and Flamanville 3 EPR simulators for testing engineering design, I&C design, developing operating procedures, DPS MMI development, minimize risks of delay during plant design and construction, validation of accident strategies, safety probabilistic studies, validation of accident procedures, validation of Human Factor studies, validation of periodic test procedures, integration of data from various contractors for the EPR design, etc., before being completed and used for operator training.
- Bellefonte Nuclear Station is using a simulator delivered by Corys to develop the man-machine interface to the digital control system and for the design of the safe shutdown panels.
- Fuel Route Simulator – this has enabled testing of the whole process before implementing mods at site, thereby reducing on-site testing time. Fuel Route PLC software release issues have been detected and new loading/unloading procedures have been tested on the simulator.

EDF ENERGY

Simulator Vendors – Experiences – L3 MAPPS

- Simulators at Idaho National Laboratory (INL) will help utilities convert old nuclear power plant control rooms running on analogue systems to digital
- Dept of Energy's Human Systems Simulation Laboratory will test the safety and reliability of proposed technology replacements before they are implemented. Improvements can be made by studying human interactions with instruments and responses to alarms.

- Large number of engineering design problems found on the Engineering and MCR training simulators at OL3 in Finland and FM3 in France.

- Candu Energy will use engineering simulator to develop and validate the MCR and to design and test programmable electronic systems and human-system interfaces

- Navy Integrated Platform Management Systems use simulators for V&V work, with problems being picked-up and resolved, e.g. undersized hydraulic power plant, SSS clutch could not be unlocked, incorrect starting procedures for prime mover.

Simulator Vendors – Experiences – L3 MAPPS

- One of the important project goals was achieved in 2000 with the Krško full scope simulator by being able to perform the training of operators and testing of operating procedures using the simulator configuration with the new steam generators and associated modifications modeled prior to the actual plant startup after the modernization outage. In one instance, a procedural deficiency was identified that would have caused a reactor trip and initiation of safety injection.

- The Krsko simulator was very well accepted by the plant personnel. In addition to playing its irreplaceable role in training, it supports other functions such as accurate procedure testing and upfront testing of plant modifications. As an example, in cooperation with L-3 MAPPS, the turbine control system was replaced before actual replacement at the plant. Again, during testing on the simulator it was possible to identify deficiencies that would, if not uncovered, have caused an unnecessary plant trip.

EDF ENERGY

Simulator Vendors – Experiences – Tecnatom

- Almaraz plant uprate to 108% - errors detected in SCD algorithms and alarm setpoints, control loops stability improved, set-points in steady state and transients were verified, unexpected behaviours were predicted (oscillations at 50%)

- Angra 1 – Ovation control loops re-designed - 12 errors found with set-up, integration, tuning and logic.

- Asco – Pressuriser control level optimisation, turbine runbacks efficiency analysis, low power problems analysis with FW fail to one SG

- Spanish Regulator – requires training for major plant mods on simulator prior to implementation in plant, operator shifts demand this training, and engineering depts take advantage of the simulator in order to improve the design and in order to complement the validation process

EDF ENERGY

Simulator Vendors – Experiences – WSC

- John Stevens, President – Barcelona ENPPS Forum, Oct 2012: everyone else uses simulators to check out designs and plant changes, and that the nuclear industry was lagging behind.

Others?

- Airbus – fuel flow to 4 engines and 11 fuel tanks centre of gravity optimisation, controls for 21 pumps/43 valves/other mechanical components. Validation completed months earlier than previously, saved 8 months in integration of the fuel design system.
- UK – Smiths Aerospace – General Electric – Aircraft flight control systems, thrust reversers, high-lift systems, systems actuators for civil and military aircraft
- Italian – Alenia Aermacchi – Aircraft autopilot validation and optimisation; overall time cut by 20% from developing to installation

Others?

- Aircraft – much faster development process, designs tested and validated, test multiple control loops rather than test one loop at a time, complex scenarios can be considered
- Tesla
- Motor car industry
- Google
- Netflix
- Uber

They all use CAD and simulation to design and test new products (Institution of Engineering and Technology (IET) magazine, Aug 2014 & Nov 2016)

EDF ENERGY

Economic Benefits

- Efficient training
- Reduced instruction cost
- Reduced Safety risks – M&M Protection Consultants, process industries may incur loss to accidents in the range of $1-2 billion over 10 years
- Increased Unit uptime – increases work-force skills and knowledge of their assets; if reactor year income was $100m, then just 0.5% production increase is $500k

Economic & Nuclear Safety Benefits

- Nuclear Utilities – find & resolve problems up-front, optimise designs, save on installation/testing/commissioning. Better designs mean greater generation, reduce challenges to nuclear safety, improve nuclear safety with better designs, less intervention by MCR staff, increased profits.
- Simulator Vendors – help to make the nuclear industry safer, generate more power, produce and optimise better designs, open up a new product market, make better profits, produce some glossy leaflets, send them to company CEOs and ask to see Operations and Engineering Directors / Managers. Tell them what & how it has been done elsewhere (without giving names).

EDF ENERGY

Economic & Nuclear Safety Benefits

- A typical nuclear utility company with 16 reactors probably spends $600m/year on engineering works/plant modification and outages. Tremendous scope for improvements

Economic Benefits

- Improved Unit reliability

- Payback and Return-on-Investment – reduced start-up time, reduced downtime, increased operating efficiency can save millions each year

- Costs offset against Corporation Tax.


Engineering Simulators

SZB Simulator Official Opening – 7 March 2003

Hartlepool Simulator Official Opening- 28 Mar2007

Heysham 1 Simulator Official Opening- 14 Sep 2007

Hinkley Point B Simulator – Aug 2011

HY2 Simulator Official Opening – 24 Feb 2015

THANK YOU

EDF ENERGY