International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., Issue.3., 2016 (May-June)

RESEARCH ARTICLE

ISSN: 2321-7758

DYNAMIC PERFORMANCE ANALYSIS OF PFBR OPERATOR TRAINING SIMULATOR

T. JAYANTHI[1], Dr.K.VELUSAMY[2], H.SEETHA[3], N.JASMINE[4]

[1,2,3,4]Indira Gandhi Centre for Atomic Research, Department of Atomic Energy, Kalpakkam, Tamilnadu, India

T. JAYANTHI

Dr.K.VELUSAMY

H.SEETHA

N.JASMINE

ABSTRACT

The plant dynamic simulation and analysis is one of the important steps towards building a robust training simulator that represents the actual system / plant. The plant dynamics depend upon the originating event, the primary system from where the event is originating and the connectivity of the concerned system with the other associated systems that are subjected to disturbance. The ultimate aim of the performance analysis is to qualify the simulator for the intended purpose i.e. comprehensive training for the plant operators. The dynamic performance analysis is performed as per ANSI 3.5 standard to analyse the dynamic behaviour of the simulated process models user various simulated plant conditions. The degree of accuracy of the models is checked before the deployment of the simulator. This paper deals with plant dynamic analysis under Reactor Power Set Back state as a result of abnormal condition that occur due to malfunction or failure of system components in Steam Water System (SWS) of KALBR-SIM (i.e. KALpakkam Breeder Reactor SIMulator) Training Simulator meant for PFBR Prototype Fast Breeder Reactor. It discusses about the methodologies adopted to capture the simulated parameters, comparison of test results and the associated system dynamics with respect to each affected sub system, verification & validation process adopted for evaluating the performance etc. It also covers the system related alarms, log messages that are generated, indications and controls, validation process, checking of model credibility and implementation of simulator for the training purpose.

Key words: Full scope operator training Simulator, KALBR-SIM (KALpakkam Breeder Reactor SIMulator), Nuclear Power Plant, Prototype Fast Breeder Reactor, Human Error, Plant Dynamics, Performance Analysis and Safety Control Rod Accelerated Movement.

I INTRODUCTION

The Full Scope Operator Training Simulator has become an integral part of the operator training programme for imparting comprehensive training to the plant operators. The Operator Training Simulator provides a platform for the operators to perform, realize and understand the plant dynamics and enhance the skill sets to handle the abnormal and emergency conditions more confidently. The training imparted on plant dynamics acts as a means of minimizing risk while improving the performance of the operators. As per the plant statistics, Human Error is the main cause of concern for most of the accidents that take place in the nuclear power plant.

The main intension of introducing Operator Training Simulator in the training programme is to reduce the human error and increase the plant safety. Essentially, the Full Scope Training Simulators are used to provide a comprehensive training and retraining on full spectrum of the plant including normal operation, reactor startup operation, abnormal and emergency conditions of the plant. The ability to train the operator on events that are critical to the plant safety using training simulator is gaining more importance in the present scenario. It is necessary that the Simulators are built with process models with high accuracy to replicate the real plant and match the performance under normal and abnormal conditions.

Efforts are on continuously to reduce the human error through various means namely, improved plant monitoring & control system, deployment of Intelligent Human Machine Interface (HMI) system, well documented plant procedures and efficient information management system. The Full Scope Training Simulators play significant role in providing opportunity for the plant operators to attempt, operate and experience various plant conditions and empower them with necessary skill sets required for the real plant operation.

II BRIEF DESCRIPTION ON KALBR-SIM

KALBR-SIM is a Full Scope Replica Operator Training Simulator, built to replicate Prototype Fast Breeder Reactor (PFBR) in order to train the operators. (Refer Fig.1 for details). It is an engineering product designed and developed by synergizing the effort of all the system experts available in the related areas at Indira Gandhi Centre for Atomic Research (IGCAR).

Fig.1. KALBR – Training Simulator

The main objective is to provide a Virtual Control Room environment to operate, practice and train the operators on all possible reactor states and apply normal & emergency operating procedures wherever required. It also facilitates conducting transient/scenario based training to study and understand the plant dynamics [5].

III BRIEF DESCRIPTION OF PROTOTYPE FAST BREEDER REACTOR (PFBR)

Prototype Fast Breeder Reactor (PFBR) is a 500 MWe capacity, pool type reactor, utilizing sodium as the main heat transport medium.

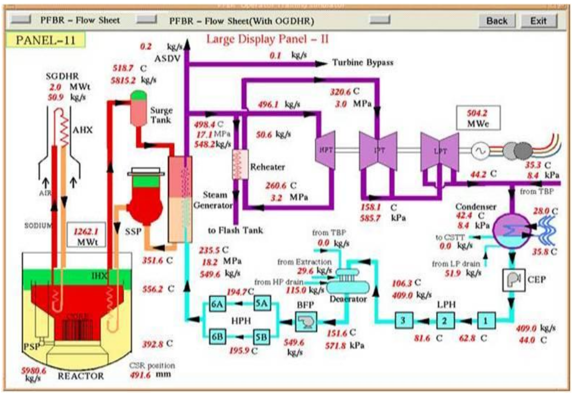

Fig.2. PFBR Flow Sheet

The reactor core consists of fuel sub-assemblies made up of (Uranium, Plutonium) mixed oxide fuel. The heat transport system consists of primary sodium circuit, secondary sodium circuit and steam water system. Steam and water system employs once through type steam generators producing superheated steam at very high temperature & pressure and adopts a reheat and regenerative cycle using live steam for reheating [8]. Fig.2 shows PFBR flow sheet. Energy conversion and transfer is done through Electrical System using 500 MWe capacity Turbo Alternator set with a plant efficiency of 40%.

The process simulation details are derived from the Prototype Fast Breeder Reactor systems. The scope of simulation for operator training purpose has been drawn based on the past operational experience and general training requirements by referring to already operating plants in India.

IV BASIC REQUIREMENTS FOR A TRAINING SIMULATOR

Building a training simulator needs certain fundamental requirements to be fulfilled with respect to system requirements and resources (Refer Fig.3). 1. The very purpose for which the Training Simulator is to be developed i.e. Training Requirements. 2. The availability of human resource i.e. the domain experts based on system design & analysis and operational experience and modeling experts with adequate knowledge to build the models. 3. Providing the supporting systems in terms of Hardware and Software platforms using which the process models can be developed i.e. Computer based Development Platform. 4. The Training platform on which the developed models can be ported installed and commissioned. It includes providing an environment exactly matching the plant Main Control Room to impart training to the operators on various events with respect to the plant states. It is called replicated control room. 5. The final one is a strong Verification and Validation team of experts to qualify the models for the intended purpose. The experts are required to guide and evaluate the models with respect to the reference plant which is mandatory to meet the training requirements. Here the Fig.4 refers to Training Platform on which the operators can be trained.

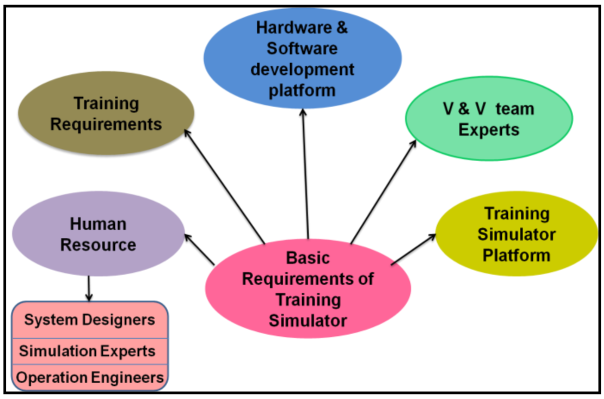

Fig.3. Basic Requirements of a Training Simulator

V HARDWARE AND SOFTWARE ARCHITECTURE

The physical components of Hardware Architecture comprises of Control Panels, Operator Information Consoles, Input/ Output systems, Instructor station, Simulation Computers, Simulation Network and Power Supply & Distribution system. The Simulation Computer executes various mathematical models of reactor sub-systems in real time [4]. It takes the input from Control Panel and Operator Console through I/O Systems, processes them and responds by giving the information to I/O system for display on indicator/meters, recorders and raise alarms in real time. The training simulator Control Panels are replica of the Plant Control Room Panels made up of mosaic tiles with grid structure. (Refer Fig.4).

The Operator Console caters to overall monitoring of the plant using the most important and frequently used signals and controls. The software architecture is depicted in Fig.5. The software architecture of simulator consists of four major components namely, process modeler, logic modeler, virtual panel modeler and instructor Module. The Process Modeler is used for developing process models, Logic modeler is for developing system logic circuits, Virtual Panel (VP) Modeler is for developing Virtual Control Room Panels for monitoring the simulated process parameters and the Instructor Module is for creating plant related scenarios and run the simulator to train the operators [5].

All other modules are supporting modules like MDSM (Messaging and Data Sharing Mechanism) for establishing communication between Process, Logic, VP, DB etc, IC Logger to save and restore information about the state of the simulator, Executive to control and synchronize the operation of various simulator components, and DB server to store and retrieve all the data pertaining to simulated models.

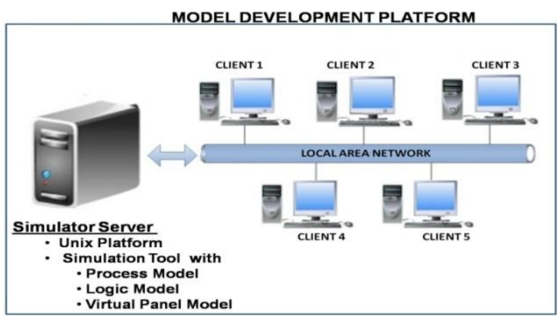

Fig.4. Hardware Architecture

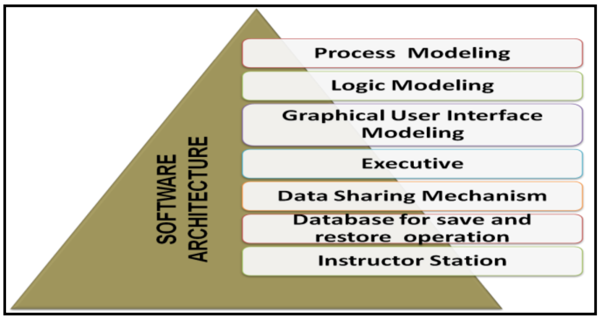

Fig.5. Software architecture of simulator

VI DESIGN AND DEVELOPMENT OF A TRAINING SIMULATOR

The design and development of a Training Simulator involves three basic functional models to be built namely, the Process Model, the Logic and the Virtual Panel Model. Essentially, the above three modules are developed based on the inputs collected through technical discussions, design and operation documents, system drawings, isometric drawings and P&ID diagrams. Refer Fig.6&7 for details.

Once the models are built and tested for satisfactory operation, all the modules are integrated and tested. Invariably, some of the modules have been developed using indigenous/conventional tools and many are developed in-house based on the uniqueness of the system (Internal and External models).

Essentially, all the models are brought into the same environment for ease of handling. The integrated testing is carried out to check the integrated performance under steady state first and the gross errors if any are brought to the notice of the developer. A systematically developed model will pass through this test more easily.

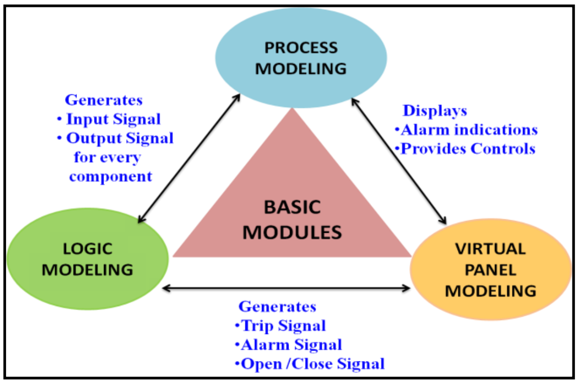

Fig.6. Basic Functional Models

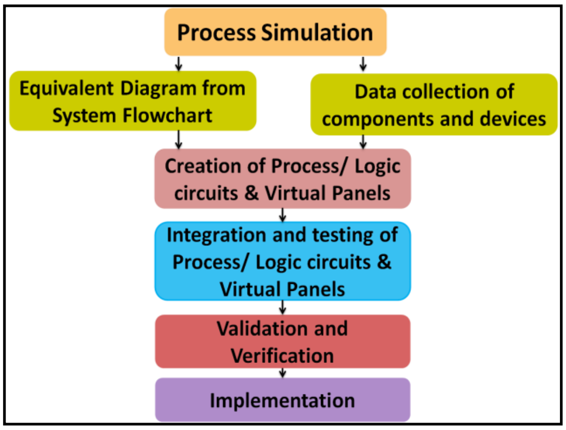

Fig.7. Steps involved in building the simulator

VII DEVELOPMENT OF PROCESS MODELS AND ASSOCIATED PLANT DYNAMICS

The design and development of KALBR-SIM includes modeling of various reactor subsystems (Refer Fig.8) like Neutronics, Primary & Secondary Sodium, Decay Heat Removal, Steam & Water, Electrical, Fuel Handling and PFBR Instrumentation & Control systems. The development work is carried out in collaboration with various systems. All the plant conditions that are mandatory for training the operators are included in the simulator development.

The important plant operating conditions that are taken into account for modeling of PFBR Operator Training Simulator include, Reactor Start up Operation, Power Rise Operation, Full / Partial Power Operation, Reactor Criticality (Hot, Cold and First Criticality), Fuel Handling Operation, Reactor Trip under various conditions, Shut down of Reactor, Reactor Power Setback etc [5]. Refer Fig.9 for details.

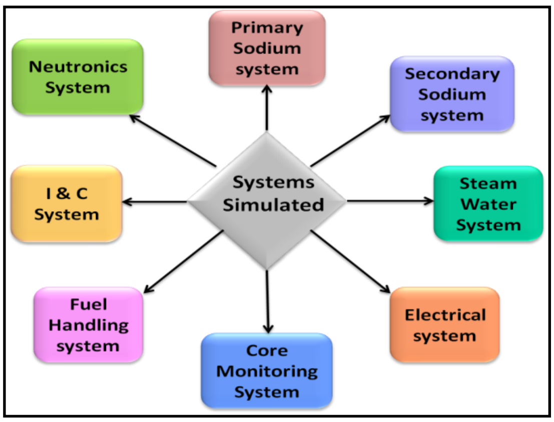

Fig.8.Simulated Reactor Sub Systems

Simulation of transient conditions and related incidents and malfunctions such as failure/ tripping of pumps, heat exchangers, malfunction of valves, control systems etc affecting the system performance by altering the normal operation have also been modeled in KALBR-SIM.

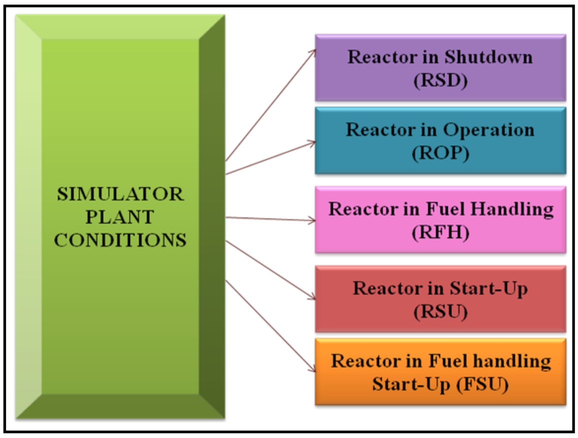

Fig.9. Simulated Reactor States

VIII INTEGRATION OF VARIOUS PROCESS MODELS

The Process models can be broadly classified into two categories, Internal models which are developed using the inbuilt components and devices in a tool and the External models which are developed in-house using system transfer functions considering various transient conditions [6]. The Internal models include simulation of Steam Water System and Electrical System where as the external models include simulation of Neutronics System, Primary & Secondary Heat Transport System, Fuel Handling System, Core Temperature Monitoring System etc. All the process models are interfaced and brought into simulator environment for final integration and testing, leading to development of Full Scope Operator Training Simulator. (Refer Fig.10 for details).

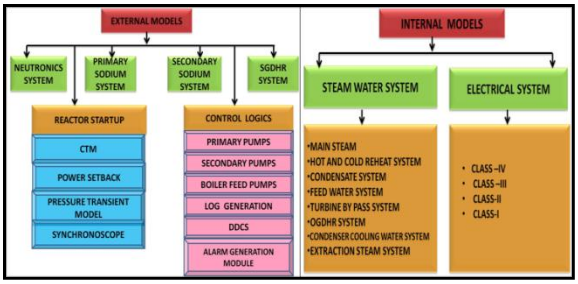

Fig. 10. Classification of Models

IX NEED FOR TRANSIENT SIMULATION AND ANALYSIS

The transient simulation helps in understanding the dynamic behaviour of the plant in a time frame extending from few seconds to tens of seconds. Fundamentally the plant design safety limits are fixed by the design experts, based on the transient analysis study conducted extensively, taking into consideration the various interconnected system behaviour. The ultimate goal is to safeguard the plant and the personnel under all normal and abnormal conditions of the plant.

The dynamic simulation study using training simulator can provide the operators, an opportunity to understand the system dynamics, the equipment performance and changes that would occur in the system with indicative parameters like pressure, level, temperature, flow etc. with respect to time. The operator can understand the system behaviour and subsequent level of stabilization after being subjected to a disturbance like pump trip or pump seizure etc. and visualize and gain more insight about the plant dynamics. This will help the operator to make quick and accurate decisions towards improving the performance and safety of the plant.

X PERFORMANCE TESTING

As the main purpose of the simulator is for training the operator, the developed models are subjected to performance testing. It includes testing under steady state and transient/disturbed condition of the plant. The performance accuracy has to be maintained within the stipulated limits, in order to qualify the simulator for training purpose. The following paragraphs describe the various categories of transients and analysis carried out on the KALBR simulator (Refer Fig.11).

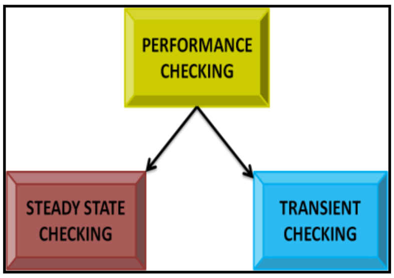

Fig.11. Performance Testing

XI IDENTIFICATION OF BENCHMARK TRANSIENTS

The Bench Mark Transients represent a list of important transients identified for simulation, based on the Final Safety Analysis Report. They are used for evaluating the process models and further qualification of the simulator for the purpose for which it has been built. As per the Final Safety Analysis Report, the Design Basis Events are grouped into four categories viz. Cat-1, Cat-2, Cat -3 and Cat-4 starting from more frequently occurring incidents to less frequently occurring incidents [3]. Category-1 events indicate the normal operations that would take place in any plant like Reactor Start up, Shut Down, Full Power Steady State Operation and Part Load Operation etc. Category-2 events indicate a situation, arising due to failure of coolant pumps, causing main core cooling affected, like - Primary Sodium Pump Trip, Secondary Sodium Pump Trip, Boiler Feed Pump Trip, and Condensate Extraction Pump Trip due to pump fault or motor fault. Category-3 events indicate severe situation which can impair the core cooling at a faster rate like - Primary Sodium Pump Seizure, Secondary Sodium Pump Seizure etc. Category-4 events indicate the rare events that would occur due to material defect like Primary Pipe Rupture, causing heavy reduction in the coolant flow through the core (Refer Fig.12 for details). Exposure to such occurrences and events will essentially improve the understanding of the plant personnel about the system dynamics and actions to be taken. (Refer TABLE I for details).

Here the Incidents / Events and Malfunctions are chosen from the above referred document i.e. Final Safety Analysis Report for inclusion in the training simulator.

A systematic training on the events causing transient situation in the plant will prove its worth once the trained operators are deployed in the actual plant. The list of Bench Mark Transients that are considered for qualifying the simulator for training purpose include continuous withdrawal of one CSR, One primary sodium pump trip, One primary sodium pump seizure, Primary pipe rupture, One secondary sodium pump trip, One boiler feed pump trip, One condensate extraction pump trip, Turbine trip etc.[2].

The Instructor Station facilitates, loading of plant scenarios for performance study and system analysis. It also provides a platform for conducting training sessions for the operators and monitoring of simulator operations and operator actions / response [1].

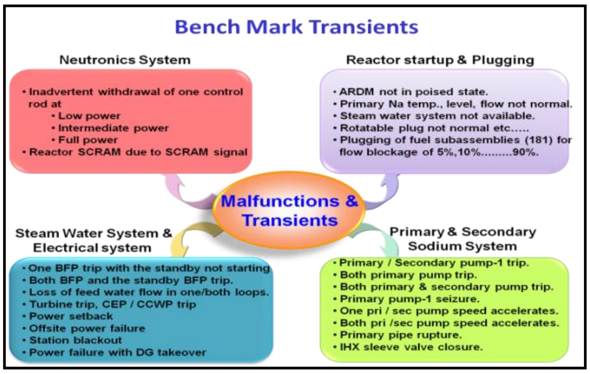

Fig.12. Benchmark Transients

XII REACTOR POWER SET BACK AND ANALYSIS OF BENCHMARK TRANSIENTS

Reactor Power Set Back (RPSB) is a phenomenon which is initiated by the events, originating from the balance of plant. Essentially, the RPSB operation brings the power to safe lower level (which is normally 60% of nominal power) by lowering the Control Safety Rod (CSR). This control action provides sufficient time to rectify the fault and allows the reactor to resume back to the full power state. The Reactor Power Set Back event is generally preferred over Reactor SCRAM in Prototype Fast Breeder Reactor in order to reduce the thermal shocks experienced by the reactor components over the life time of the plant. At the same time the event does not affect the operation of boiler feed pumps that supply coolant to the steam generators. A procedure has been established, based on the transient analysis and several parametric iterations for attaining the RPSB state in case of certain critical conditions observed in the balance of plant. The critical conditions as per the Plant Safety Analysis Report include the actuation of Emergency Relief Valve on the Steam Header, Turbine-Generator Trip, reduction in Deaerator Feed Water Level and the collapse of vacuum in the Main Condenser.

TABLE- I: DESIGN BASIS EVENTS

Category	Occurrence	Examples
Cat - 1	> 1	**Normal operation, planned startup and shutdown**
Cat - 2	$10^{-2}<f<1$	**Off-site power failure, pump trip**
Cat - 3	$10^{-4}<f<10^{-2}$	**Station black out, Pump seizure**
Cat -4	$10^{-6}<f<10^{-4}$	**Primary Pipe Rupture, SSE (safe shutdown earthquake).**

As per the procedure, when Reactor Power Set Back is initiated, the Control Safety Rods are driven down simultaneously (in bulk) to reach a power level slightly lower than the required level for the first time and then allowing it to stabilize, based on the triggering events stipulated by Plant Safety Analysis Report. The extent of insertion of control safety rod to bring the power down to RPSB state is a function of initial position of Control Safety Rods. The power initially reduces below the required level and recovers back to reach 60% power level. While recovering back, the RPSB command (by the triggering signal) is set off so that, it reaches the stipulated power level and stabilizes.

XIII REACTOR POWER SET BACK DUE TO TURBINE- GENERATOR TRIP

The Turbine-Generator (TG) is the main component in the balance of plant which plays a crucial role in energy conversion i.e. the heat energy in the form of steam is converted into electrical energy. The PFBR TG set is designed for 500 MWe electrical power while the turbine is fed by super heated steam at 497 deg C with 172 bars pressure. The safe Turbine-Generator operation is ensured by the critical parameters like turbine speed, lube oil pressure/temperature and steam inlet temperature/ pressure / flow etc. In case of crossing of threshold by any of the above parameters, a safe state trip is initiated by the Turbo-Supervisory system to safeguard the TG set. This is followed by a sudden closure of Governor Valves and the CIES valves which in turn raise the header pressure above the normal limit as the normal steam path is arrested. On sensing the pressure raise, the Steam generator (SG) safety logic system initiates sudden opening of turbine bypass valve at 17.5 MPa and dumps the steam in the main condenser which has a dump capacity of 60%. The difference of flow between SG inlet and outlet raises the SG pressure further, to actuate the Emergency Relief Valves (ERVs). There are three sets of such Emergency Relief Valves, mounted on the Steam Header that gets actuated to release the steam pressure to safeguard the steam system components. Simultaneously, the actuation of ERV passes the required trigger signal to the reactor safety logic system to initiate Reactor Power Set Back in order to bring the reactor to a new equilibrium state.

Preparations are made in advance, to capture the simulated process parameters. It includes, Reactor inlet/ outlet temperature, coolant flow through the core, Hot/Cold pool sodium temperature, secondary sodium inlet/outlet temperature of Steam Generator, Feed water inlet and steam outlet temperature, flow/ pressure of Steam Generator, steam main header pressure / temperature, HP bypass inlet pressure / flow / temperature, HP / LP spray flow, Cold reheat pressure / flow / temperature etc. Simulated test screens and main flow sheet mimic diagrams are used for checking the dynamic changes in the systems parameters on the occurrence of the incident. (Refer fig 13, 14, 15, 16).

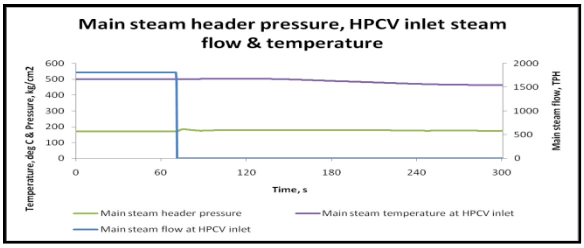

Fig.13. Turbine Trip - Pressure / Temperature/ Flow Graph

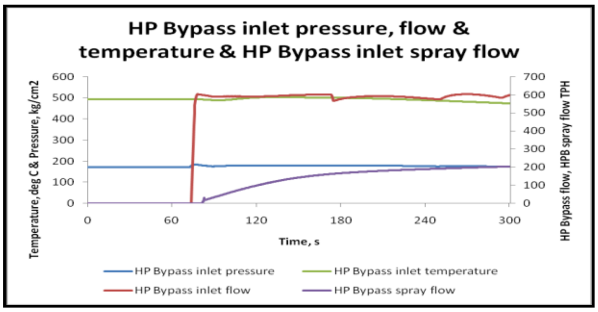

Fig.14: Turbine Trip - HP Bypass Pressure / Temperature/ Flow Graph

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in
Vol.4., Issue.3., 2016
(May-June)

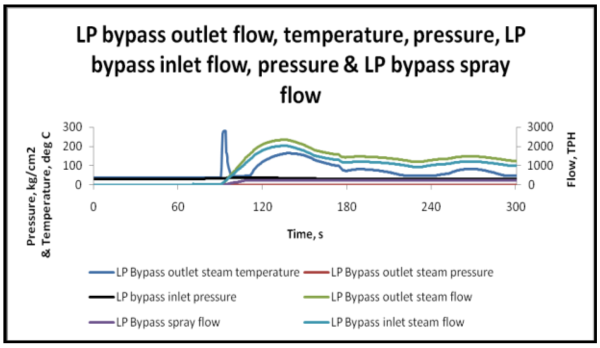

Fig.15: Turbine Trip - LP Bypass Pressure / Temperature/ Flow Graph

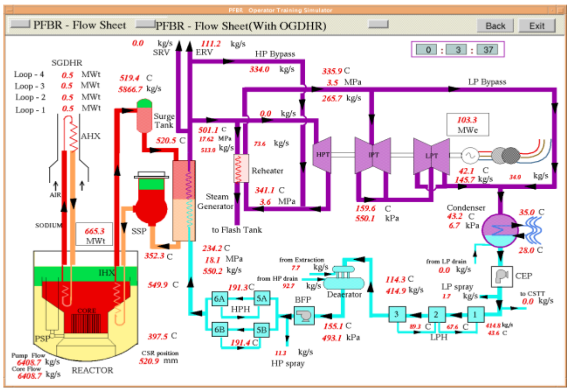

Fig.16: Turbine Trip - LP Bypass Pressure / Temperature/ Flow Graph

XIV REACTOR POWER SET BACK DUE TO DEAERATOR LEVEL LOW

Generally, in a Nuclear Power Plant, the water quality requirement is maintained by Condensate Extraction System and Feed Water System. The condensate extracted from the condenser hot well is passed through online condensate polishing unit, drain cooler, three sets of Low Pressure Heaters and finally to Deaerator. Thus the main cycle flow and the thermodynamic requirements are maintained. In the condensate system, the Condenser, Condensate Extraction Pumps (CEP), Condensate Polishing Unit, Drain Cooler, LP heaters and Deaerator are the main components.

In PFBR, three numbers of CEP of 50% capacity is deployed. Under normal condition of operation, two CEPs will be running taking suction from the condenser hotwell and the discharge will flow to deaerator through condensate polishing unit, drain cooler and 3nos of LPH connected in series for preheating the condensate. Normally, in case of tripping of any one of the running pump, the standby pump gets the start permission by the control logic. If the standby pump does not take over within the stipulated time then the scenario leads to one CEP trip with standby failed to take over. This incident reduces the condensate flow that reaches the deaerator while the Boiler Feed Pump continuous to deliver 100% feedwater flow to Steam generator. Ultimately, the deaerator water level reduces to a low level where the power set back is initiated. This can be observed from the simulated parameter profiles in Fig17, 18, 19 & 20.

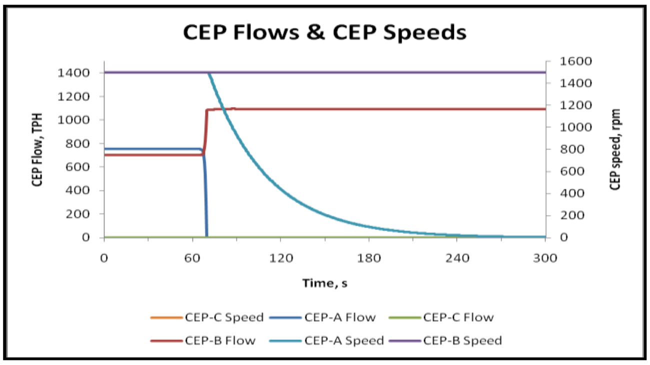

Fig.17. One CEP Trip - CEP flow and speed Graph

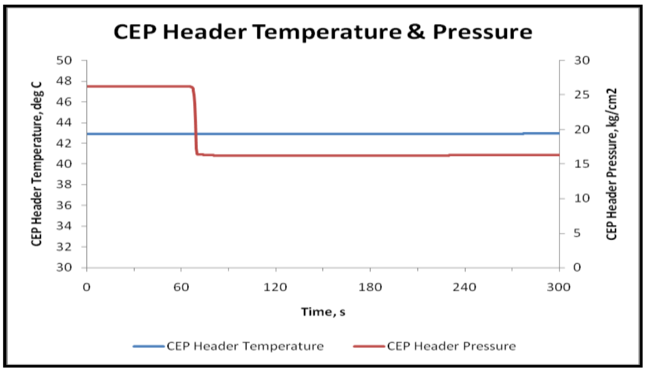

Fig.18.One CEP Trip - CEP temperature and pressure Graph

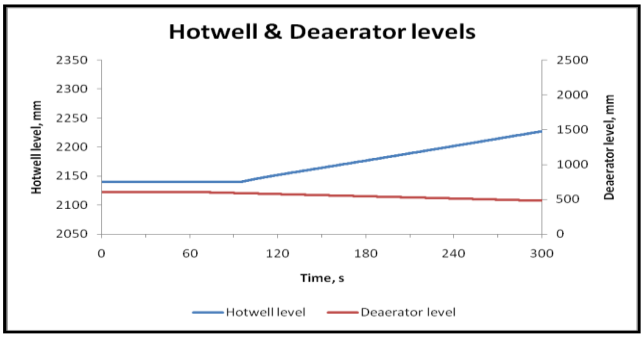

Fig.19. One CEP Trip - Hotwell and deaerator level Graph

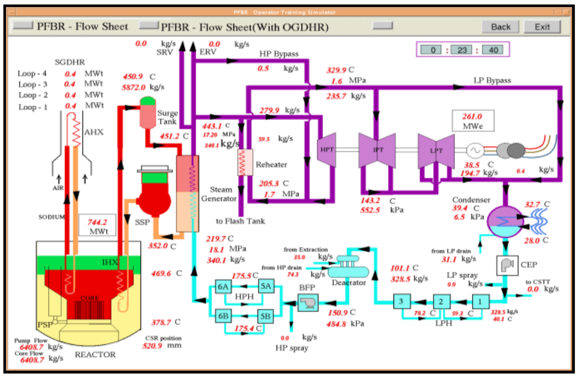

Fig.20. One CEP Trip - PFBR Flow Sheet with Reactor Power Set Back

XV VALIDATION OF PERFORMANCE OF PROCESS MODELS

The process models are subjected to Verification & Validation (V&V) process in order to ensure that the original design requirements are incorporated successfully and the user requirements are met. The evaluation of process model performance is yet another mile stone to be crossed in the development of training simulator. Essentially, it is a methodology adopted to qualify the Training Simulator for the intended purpose. (Refer fig.21).

In the present setup, the Training Simulator needs to pass through two V&V Committees i.e. Local Verification & Validation Committee (LVVC) and an External Verification & Validation Committee (EVVC). Basically the performance of process models under steady state condition and transient conditions are demonstrated to the Design Experts belonging to Local Verification & Validation Committee. Here, the mass balance, thermal balance and the plant dynamics are checked as a first level of approval. At this stage small modifications, tuning of components and controls are carried out to achieve the required performance. Once approved, the second level of approval is obtained from the External Verification & Validation Committee (constituted by the experts from various other units of Department of Atomic Energy) through a detailed demonstration of the process models. This includes various plant operating states like plant startup, power raise (part load and full power), steady state and emergency conditions. Normally technical minutes of meetings are prepared to record the comments offered by both the expert team for further incorporation and testing. In such cases approval is obtained after the implementation of the comments. The V&V documents are prepared and submitted for approval based on the demonstration and detailed presentation to the LVVC and EVVC.226-022602.

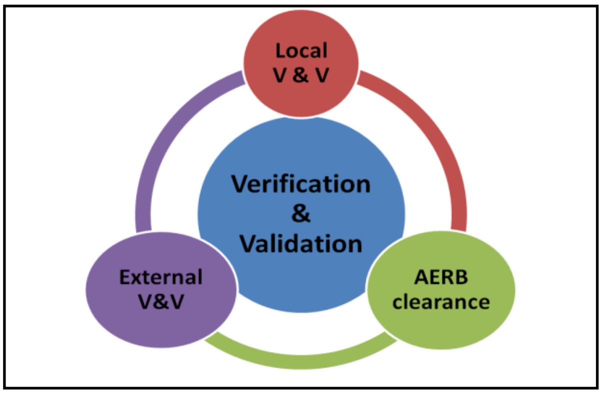

Fig.21: Verification and Validation

XVI STANDARDS FOLLOWED

The standards ANSI 3.5 – 1998 edition and IAEA – TECDOC – 995 / 1411 are referred for building and testing the operator training simulators. The standard provides general guidelines for conducting performance testing on the Training Simulator and a methodology for testing the suitability of a Full Scope Operator Training Simulator for the intended purpose. Essentially, the plant safety, equipment availability, and efficient operation are kept as common goals to be achieved. The error limits specified by the standard indicates an allowance of 1 – 2% for the steady state operation. Normally, the performance test results under steady state conditions are evaluated adhering to the reference standard. Large deviations are not observed as the Modeling and Simulation is subjected to rigorous V&V process. Slight deviations outside the stipulated boundaries are corrected by tuning the models. The error limits specified for transient condition is 10-15 %.

XVII CONCLUSION

The role of training simulators has evolved significantly over the period and today it is one of the major components in the training programme. Experts in each field have expressed the necessity of implementing simulator supported training for the plant operators and improve their decision making capability. Hence, it is all the more important to have strict adherence to the standards and the Verification & Validation process in order to maintain the required degree of accuracy of the Operator Training Simulators. The transient simulation and performance analysis study ensures that the simulated process models represent the real systems under consideration with an acceptable degree of accuracy [7]. Training the operator on transients and related plant dynamics adds yet another dimension to the knowledge gained by the operator. The knowledge on system dynamics that are critical to plant safety and the plant response to disturbances that arise from the changes in the state of components and equipments are equally important for efficient monitoring and c7ntrol of the plant. It is highly essential to train the operators on various plant states and the associated plant dynamics. A Full scope Replica Operator Training Simulator caters to such requirements and provides a strong platform for imparting the plant knowledge to the operators. The Full Scope Replica Simulator is a major step towards enhancing the operator capability there by significantly improving the safety of the plant.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support and guidance provided by the colleagues from Reactor Design Group. The authors are greatly indebted to the constant guidance & motivation provided by Director, IGCAR.

REFERENCES

[1] Jayanthi T, Satyamurty SAV, Kuriakose K.K, Srinivasan S, Jayalal ML. Scope Document on PFBR Operator Training Simulator. PFBR/ 08610 / DN / 1000 /Rev C, 2013

[2] Jayanthi T, Rajeswari S. Training Requirements of PFBR Simulator. PFBR/08610/DN/1008/Rev,2008

[3] Final Safety Analysis Report, Chapter 14. PFBR Events Analysis Report. March 2010.

[4] Jehadeesan R, Jayalal ML, Satyamurty SAV. Hardware Architecture of PFBR Simulator. PFBR/08610/DN/1001/Rev A, (2005)

[5] Jayanthi T, Narayanan KRS, Natesan K, Satish Kumar L, Tanmay Vasal, Selvaraj P, Kuriakose K.K, Satya Murty S.A.V. Transient Simulation and Performance Analysis of KALBR Simulator for PFBR Operator Training. Proceedings of International Conference on Advances in Engineering and Technology. AETAEE, Elseveir-2013, 615-628.

[6] Jayanthi T, Seetha H, Narayanan KRS, Jasmine N, Rashmi Nawlakha, Bindu Sankar, Jaideep Chakraborty, SatyaMurty SAV, Swaminathan P. Simulation and Integrated Testing of Process Models of PFBR Operator Training Simulator. Asian Nuclear Prospects (ANUP-2010) and published in Energy Procedia (Elsevier Publication).

[7] Jayanthi T, Velusamy K, Seetha H, Satya Murty SAV. Verification and Validation of Simulated Process Models of KALBR-SIM Training Simulator .International Journal of Computer, Control, Quantum and Information Engineering Vol:9 No:2, 2015, Pages 367-377

[8] Jayanthi T, Velusamy K, Natesan K, Seetha H, Narayanan KRS, Jasmine N, Satya Murty SAV. Real Time Simulation and Performance Testing of Process Model of Nuclear Power Plant. IIJC, VOLUME 4, ISSUE 3, JULY, 2014 ISSN (Print):2231:2153, ISSN (Online):2230:9039, page(s) 719-724.

A BRIEF BIOGRAPHY OF AUTHORS

T.Jayanthi received her B.E (Hons) Degree Madras University, T.N in 1983. She joined in Indira Gandhi Centre for Atomic Research (IGCAR) in 1984, worked as a commissioning Engineer in FBTR and various other projects in IGCAR. Presently function as Head of Simulator Section and working on Development and implementation of PFBR full scope operator training simulator and related research and development activities. She has more than 45 Journal Publications / Conference Papers / proceedings.

Dr. K. Velusamy is currently the Head of the Thermal Hydraulics Section as well as Head of Mechanics and Hydraulics Division at Indira Gandhi Centre for Atomic Research. He is also a Professor in

Homi Bhabha National Institute-Mumbai, India. He has specialized in Computational Fluid Dynamics (CFD) and has solved many challenging multi-modal heat transfer problems. He has the distinct ability to develop simplified models for interconnected subsystems and integrate them with CFD codes for detailed analyses of critical components of Liquid Metal cooled Fast Breeder Reactors. He has participated in many IAEA-Coordinated Research Projects. He has played an important role in obtaining clearance for Prototype Fast Breeder Reactor project from various safety bodies appointed by Atomic Energy Regulatory Board. He is an elected Fellow of Indian National Academy of Engineering and was awarded the DAE Scientific and Technical Excellence Award for the year 2006 HBNI Distinguished Faculty Award in 2015 and DAE Group Achievement Awards 9 times. He is a member in Editorial Board of Annals of Nuclear Energy. He has guided 12 PhDs theses He has more than 225 publications including 92 in Journals. He has over 500 citations to his credit.

H.Seetha received her B.E Degree from Bharathidasan University, T.N in 1997. She joined in Indira Gandhi Centre for Atomic Research (IGCAR) in 2001. She is currently a Scientific Officer-E in Electronics, Instrumentation and Radiological Safety Group-IGCAR. She has 14 Journal Publications / Conference Papers.

N.Jasmine received her B.E Degree from Anna University, T.N in 2007. She joined in Indira Gandhi Centre for Atomic Research (IGCAR) in 2008. She is currently a Scientific Officer-D in Electronics, Instrumentation and Radiological Safety Group-IGCAR. She has 7 Journal Publications / Conference Papers.