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SRESA Newsletter

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New

21st International Conference on Structural Mechanics in Reactor Technology - SMiRT 21

From the President's Desk

This is the fourth quarterly newsletter from SRESA: the earlier three issues were well received by the community in the field of reliability and safety. It is heartening to note that the membership of society has increased significantly in the last quarter.

The first article presents a review of various human reliability analysis methods employed for Probabilistic Safety Assessment. The second article presents the PSA activities in the area of fast breeder reactor technology at IGCAR and SRI, Kalpakkam. There is one feature article providing details about 21st International Conference on Structural Mechanics in Reactor Technology being held during November 2011 at New Delhi. An article on book review is also included in this issue which provides an overview of books titled 'Reliability Engineering and Life Testing' & 'Dependability of Networked Computer-based Systems'. The last section comprises of introduction of new members of SRESA and list of upcoming conferences.

Dr. S. K. Gupta

Inside this issue:

Human Reliability Analysis for Probabilistic Safety Assessments - Review of Methods

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Abstract - It is well known that the two major events in World Nuclear Power Plant Operating history, namely the Three Mile Island and Chernobyl, were Human failure events. Subsequent to these two events, several significant changes have been incorporated in Plant Design, Control Room Design and Operator Training to reduce the possibility of Human errors during plant transients. Still, human error contribution to Risk in Nuclear Power Plant operations has been a topic of continued attention for research, development and analysis.

Probabilistic Safety Assessment attempts to capture all potential human errors with a scientifically computed failure probability, through Human Reliability Analysis. Several methods are followed by different countries to quantify the Human error probability. This paper reviews the various popular methods being followed, critically examines them with reference to their criticisms and brings out issues for future research.

Keywords -Probabilistic Safety Assessment, Human Reliability Analysis, Human Error Probability

I. INTRODUCTION

Probabilistic Safety Assessment of a Nuclear Power Plant was ushered into realm of safety studies through the pioneering Reactor Safety Study or popularly called the WASH-1400[1] . This study was also the first to address the issue of Human Reliability contribution to System unavailability. Since then the field of Human Reliability Assessment has gone through several stages of development and detailing. The authors of the Human Reliability chapter of WASH-1400, were also the one's who contributed to the release of the first ever "Handbook of Human Reliability Analysis with emphasis on Nuclear Power Plant Applications"- NUREG/CR-1278[2]. This brought to light the implicit assumptions, considerations and calculations behind the quantification of Human Reliability embedded in the WASH-1400 study. One of the reviewers of the NUREG/CR-1478 commented, "The Handbook is like an instrument, a 'violin'. It looks simple, but it requires skills and arts to use it. He also called out for the need for training and exercises in the use of the Handbook".

This puts into perspective the fact that Human Reliability Analysis still flourishes as state of the art, because human performance and behavior continues to be an enigma. This is probably why, most HRA analyst's and HRA reviewers agree to disagree and yet there is a lot of development and effective research in this field.

II. HISTORICAL PERSPECTIVE

The chronology of development in the field of Human Reliability Analysis in Nuclear Power Plants provides some insights with reference to scope, coverage and details of the studies on Human Performance and behavior with reference to plant operations and maintenance. Table-1 presents the various significant developments in this field in chronological order, based on their date of publication.

One of the first extensive reviews of various developments in Human Reliability Assessments methods was made by D. Meister (1973) [19]. D. Meister is one of pioneers in the Human Reliability Research to have brought together the

developments in psychology which provides information on sensory/perceptual, cognitive and physiological responses to engineering situations associated with Human-Machine interface. Twenty two methods were critically reviewed and reported. At that time the techniques developed either used an analysis of historical data or the computer simulation of behavioral processes to quantify the human error probability. Of the methods reviewed only THERP has been listed in Table-I. This only indicates that almost four to five decades of research has tried to keep pace with the developments in the Human-Machine interactions and is yet seeking elusive standardized solution. Fig I shows the classification of the methods listed in the table into three categories. The first two categories (Task Related and Time Related) constitute the first generation methods while the Context related category constitutes the second generation methods.

An extensive list of references has been given for interested persons to obtain the details of each of the methods.

TABLE-I HUMAN RELIABILITY TECHNIQUES-CHRONOLOGY OF DEVELOPMENTS

S No	Techinque	Type	Used By The Following Agencies/Countries	Authors	Source	Year
1.	Technique for Human Error Rate Prediction (THERP)	Task Related (discrete nodal)	WASH-1400	L.W.Rook	Reduction of Human Error in Industrial Production, SCRM-93-62(14), Sandia, Laboratories, Alburquerque, New Mexico. [3]	1962
				A.D.Swain	A Method for Performing a Human Factors Reliability Analysis, Monograph SCR-685, Sandia, Laboratories, Alburquerque, New Mexico.[4]	1963
2.	THERP and Expert Judgement	Task Related (discrete nodal)	WASH-1400	Norman Rasmussen	WASH-1400 Reactor Safety Study- Appendix III Failure Data- Section 6 [1]	1975
3.	Time Reliability Curves (TRC)	Time Related	WASH-1400	Swain and Guttman	"Handbook of Human Reliability Analysis with emphasis on Nuclear Power Plant Applications"- NUREG/CR-1478 [2]	1983
4.	Success Likelihood Index Method (SLIM)- Multi Attribute Utility Decomposition (MAUD)	Context Related (2nd Generation)	US consultanting organizations- Pickard, Lowe, and Garrick (PLG) and Science Applications, Inc. (SAI). SAI is now called SAIC (Science Applications International, Co.).	D.E. Embrey et al	"SLIM-MAUD, An Approach to Assessing Human Error Probabilities Using Structured Expert Judgment," NUREG/CR-3518 [5]	1984
5.	Human Cognitive Reliability (HCR)	Time Related	India (NPCIL), Spain	G.W.Hannaman, A.J. Spurgin, Y.D.Lukic	Human Cognitive Reliability Model for PRA Analysis, Electric Power and Research Institute, Palo Alto, CA, draft report NUS-4531, EPRI Project RP2170-3. [6]	1984
6.	Systematic Human Action Reliability Procedure	Task Related (nodal)	EPRI	G.W.Hannaman, A.J. Spurgin	"Systematic Human Action Reliability Procedure (SHARP), EPRI NP-3583, Electric Power Research Institute, Palo Alto, CA. [7]	1984
7.	Human Error Assessment and Reduction Technique (HEART)	Task Related (grouped action)	UK Nuclear Power Utilities	Williams J.C	"HEART-A proposed method for assessing and reducing human error," Ninth Advances in Reliability Technology Symposium, Birmingham, IMICHE, London, UK. [8]	1986
8.	Accident Sequence Evaluation Program (ASEP)	Task Related (Nodal)	India (BARC), US utilities	Alan D Swain	Accident Sequence Evaluation Program – Human Reliability Analysis Procedure. NUREG/CR-4772. U.S. Nuclear Regulatory Commission, Washington, DC [9]	1987
9.	Cause Based Decision Tree (CBDT)	Task Related (discrete nodal) (2nd Generation)	US Utilities (this is one of the methods available in HRA calculator)	Beare et al	"An Approach to Estimating the Probability of Failures in Detection, Diagnosis, and Decision Making Phase of Procedure-Guided Human Interactions," Draft report for EPRI RP-2847_1, Electric Power Research Institute, Palo Alto, CA [10]	1990
10.	Operator Reliability Experiments (ORE)/HCR	Time Related	US Utilities	Spurgin et al	"Operator Reliability Experiments Using Power Plant Simulators," NP-6937, Volumes 1, 2, and 3, Electric Power Research Institute, Palo Alto, CA. [11]	1990
11.	ATHEANA	Context Related (2nd Generation)	USNRC	Cooper S.E et al	A Technique for Human Error Analysis (ATHEANA), NUREG/CR-6350 [12]	1996
12.	Cognitive Reliability Error Analysis Method (CREAM)	Context Related (2nd Generation)	European Human Reliability Consultants	Hollnagel E.	"Cognitive Reliability and Error Analysis Method: CREAM," Elsevier Science, Amsterdam. [13]	1998

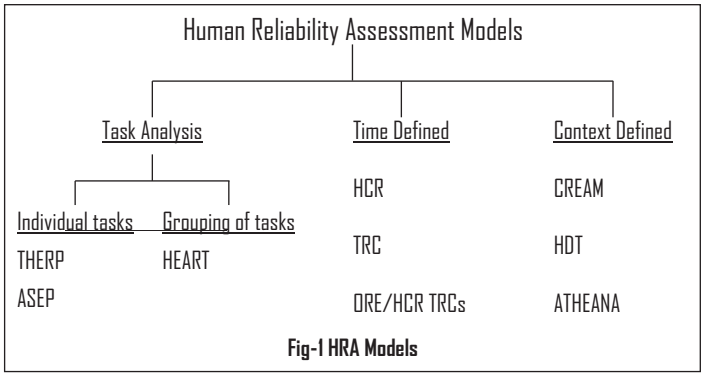

Fig-1 HRA Models

III CONCLUSIONS

Most commercial NPP's use the first generations methods based on task analysis and TRC's. Some utilities in US have adopted a hybrid method of task analysis and time related HEP, incorporated in the HRA calculator [18]. Canadian utilities use ASEP/THERP. The HCR method has been adopted by the Spain and India. British utilities use the HEART and NARA methodologies. Amongst the second generation methods, the HDT method has been used in Hungary and some plants in Russia. The French utility EDF currently uses MERMOS for all the dynamic human failure events.

Given this background it can be concluded the based on the simplicity and robustness, the first generation methods would still continue to be in use, while the second generation methods would be increasingly used to derive the benefits of building insights into the error forcing contexts.

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G. Srinivas is a Mechanical Engineer from IIT Roorkee(1987). He completed his M.Tech in Energy Systems Engieering from IIT Bombay (1990). He is now pursuing a PhD in Reliability Engineering at IIT Bombay as an external student. He has been with NPCIL since 1990. He is currently working as Additional Chief Engineer and has 13 years experience in the field of Probabilistic Safety Assessments of Nuclear Power Plants. Earlier, he had about 8 years experience in the field of Seismic qualification of Equipment by Analysis.

PSA Activities in IGCAR and SRI

A. John Arul, Indira Gandhi Centre for Atomic Research, Kalpakkam &
C. Senthil Kumar, Safety Research Institute -Atomic Energy Regulatory Board, Kalpakkam

The PSA activities in IGCAR were initiated in the later part of 1980s at the reactor physics division as safety system reliability studies for Fast Breeder Test Reactor (FBTR) and the Prototype Fast Breeder Reactor (PFBR). The main focus was on the PSA of fast reactors in addition to the development of related methodology and tools. The system reliability tool used initially was IAEA's PSAPACK and in-house developed Fault Tree analysis program. A working group was setup at IGCAR comprising of members with expertise in design, operation and safety analysis to carry out Level-1 PSA study for PFBR. The working group has recently completed the task of Level-1 PSA for internal events and report submitted to AERB for review. The probabilistic analysis was carried out using industry standard tools such as RISKSPECTRUM and ISOGRAPH.

Activities for FBTR: Estimation of decay heat removal system reliability was one of the earliest studies carried out. Subsequently, Loss of Off-Site Power (LOSP) frequency and duration correlation was estimated using site specific data available over 15 year time period. Using LOSP data as input and combining with DG system reliability Station Black-out (SBO) frequency and duration correlations were obtained. Since the SBO frequency as a function of duration is desired, two different methods viz., time dependent cut set evaluation and Markov Models were employed to compare and validate the analysis. This study was useful to make for the plant management and regulatory body to decide on the Allowable Outage Time for (AOT) for FBTR feeders.

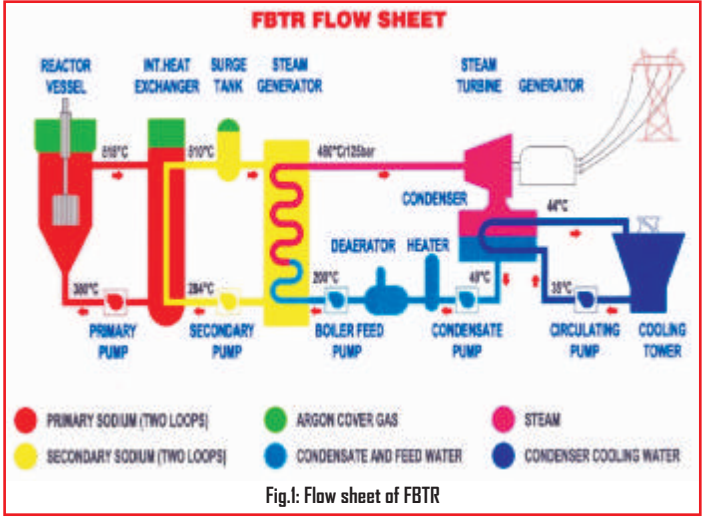


Fig.1: Flow sheet of FBTR

Seismic Re-evaluation of FBTR: Seismic re-evaluation of FBTR is a research project undertaken jointly by IGCAR and AERB/SRI, with a primary objective to review the extent of seismic excitation that the reactor and associated systems can withstand without compromising the desired level of safety and identify the seismic weak links. The re-evaluation was done by assessing seismic margin in deterministic format and seismic core damage frequency by means of seismic probabilistic safety analysis in probabilistic format.

Activities for PFBR: Initially system reliability studies were performed for Shut Down System (SDS) and Safety Grade Decay Heat Removal System (SGDHRS). The focus of these studies was on getting safety clearance for various safety systems of the reactor. The studies were then extended to Operation Grade Decay Heat Removal System (OGDHRS), Class III power supply system and other safety related systems. The analysis of each of these systems involves the modeling of human error, common cause failure and support systems modeling. The human error modeling was carried out using THERP (Technique for Human Error Rate Prediction) and ASEP (Accident Sequence Evaluation Program) models. Optimization studies were also performed during the conception stages of SDS with respect to the number and distribution of absorber rods and signals.

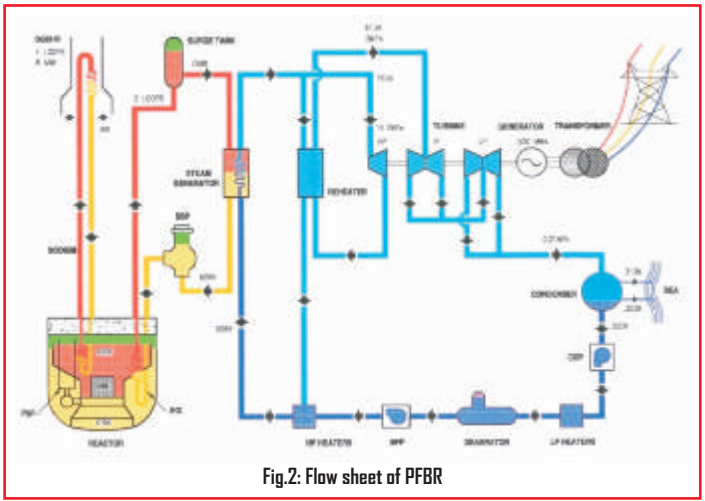


Fig.2: Flow sheet of PFBR

Level-1 PSA of PFBR: The level-1 PSA of PFBR was completed and the report was submitted for review. The salient feature of this study is the integration functional failure probability in the accident sequence models namely event trees. Large fault tree small event tree approach was followed. Three core damage states were identified. Analysis indicates that the Core Damage Frequency (CDF) of PFBR is well within the internationally accepted limits and analysis methods and subsystem contributions are in conformity with results from other fast reactors.

The other highlights of the PSA activities are:

a) Development of a fast reactor reliability Database: Since, appropriate use of good quality data is essential for any meaningful quantitative analysis effort was made to develop a system for reliability data base (called Fast Reactor Reliability Database at IGCAR-FREDI) using SQL server and has a compilation of data from different data sources like on-site data collection, NUREG reports, IAEA documents etc. A front end and analysis module (named Reliability Information System for Safety Analysis - RISSA) was also developed with a wide range of capabilities for data search and analysis and reporting, including Bayesian updates.

b) Functional Reliability Analysis of Safety Grade Decay heat Removal System (SGDHRS). The SGDHRS in PFBR is a natural circulation based system whose operation is initiated by opening of mechanical air dampers, and is considered to be a passive system as per IAEA classification. Since there are no pumps in this system, the reliability of functionality becomes important and reliability analysis of this system was carried out as per REPAS/RMPS methodology with advanced importance sampling procedures. A method was also developed for integrating functional failure probability with hardware failure probability.

c) Human reliability analysis: A program has been developed for the pre-incident and post incident human interaction events as per ASEP models. The validated program is useful for consistent analysis. Collaborative project works were undertaken with Anna University, Chennai on Human Reliability Analysis expert system development.

d) Seismic PSA for PFBR: The seismic PSA of PFBR is currently in progress. The site specific hazard curve is to be developed and response of various systems to seismic activities are to be analyzed. The fire PSA and flood PSA will be taken up subsequently.

e) PSA of fuel cycle facility: An integrated fuel cycle facility for PFBR named as Fast Reactor Fuel Cycle Facility (FRFCF) is being planned at Kalpakkam. PSA of one of its plant viz., Reprocessed Uranium Oxide Plant is in progress.

As a result of sustained encouragement from Shri. S.C. Chetal, Director, IGCAR and Dr. Baldev Raj, Former Director, IGCAR, the reliability activity has grown over the years, through collaborative work and training programmes and IGCAR now has reliability expertise available in each of the design groups including FBTR and SRI. IGCAR is also embarking on a program on structures and component reliability in collaboration with premier academic institutes of the country.

Mr. A. John Arul has been working in risk and reliability analysis of fast reactor safety systems for the past fifteen years at IGCAR. He is an MSc in physics and is from the 32nd batch of BARC training school. Current research and project activities are passive system reliability, software systems reliability and external events PSA.

Dr. C. Senthil Kumar is involved in reliability and probabilistic safety assessment (PSA) of nuclear power plants. Some of the areas of his interest include seismic safety assessment, passive system reliability, software reliability, real time systems and software development.

21st International Conference on Structural Mechanics in Reactor Technology - SMiRT 21

Indian nuclear science and technology community is excited to witness a mega international event called 'SMiRT21'. This conference is being organized by Homi Bhabha National Institute along with other supporters during 06 to 11 November, 2011 at India Habitat Centre, New Delhi.

H.E. Dr. A. P. J. Abdul Kalam, Chief Guest for SMiRT-21

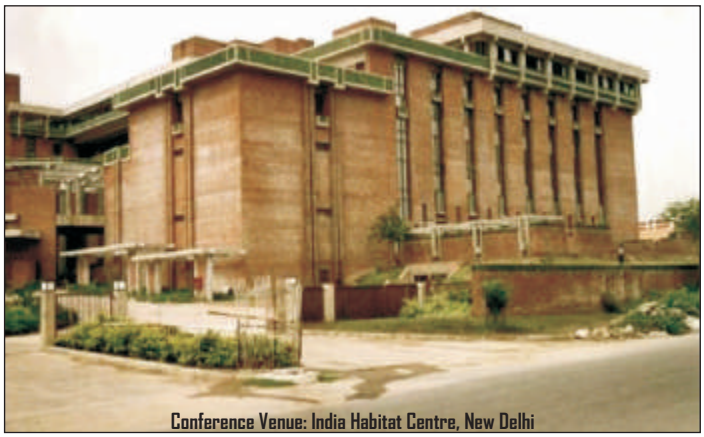
The conference will be inaugurated by H.E. Dr. A.P.J. Abdul Kalam, Former President of India at Hotel Ashoka, New Delhi. Prof. B. K. Dutta, Dean, Engineering Sciences, HBNI, is the Chairman of the conference. The conference covers a wide range of topics in the area of nuclear technology like design, operation, maintenance, regulation, safety, waste management, etc. It is for the first time that such a conference - SMiRT is being organized in India.

Sustained nuclear power generation faces new challenges today. The world has more than 450 operating plants that must continue to produce electricity at a competitive cost for extended period. While only one-third of the world's nuclear power units (137 out of 439) are under operation in Asia today, the picture will be distinctively different in future. Asian region is poised to become a world leader in nuclear power development. Of the 56 units currently under construction in the world, about three-fourths (42 units) are in Asia. Similarly, of the 94 units planned world over, 73 will be set up in Asia. This reaffirms that the Asia is leading the world in the growth of nuclear power generation. A developing Asia is expected to see the greatest increase in regional nuclear power generating capacity, accounting for 96% of the total projected growth. The conference will be co-sponsored by a number of Indian institutions from all facets of its enterprise: regulatory bodies, research centers, academic institutions, reactor component manufacturers, national laboratories, engineering and construction firms, nuclear utilities and national professional societies.

Closed fuel cycle enables realization of full energy potential of uranium, reduces amount of high level waste generation per unit of electricity generated and makes way for tapping vast global thorium reserves for energy generation. Development of safe structures for nuclear reactors and associated fuel cycle facilities through research and development is an ongoing activity and need to be pursued with vigour to make commercial global deployment of closed fuel cycle a reality.

The 21st Structural Mechanics in Reactor Technology will be dedicated to the Art, Science and Practice of the Structural Mechanics. The conference will aim to cover all the technical and professional practice issues. It will focus on the need of and the contemporary issues affecting the Structural Mechanics profession worldwide and highlight the profession's interface with the impact on society by improvement of the public image, standing & credibility of nuclear technology in general and structural mechanics in particular. All efforts will be made to bring together the best and the brightest in the world of structural mechanics to meet and discuss the momentous issues in the profession. Around 600 delegates around the world are expected to attend the conference.

TECHNICAL TOPICS covered include a) Mechanics of Materials, b) Fracture Mechanics and Structural Integrity, c) Applied Computations, Simulation and Animation, d) Characterization of Loads, Modelling, e) Testing and Response Analysis of Structures, Systems and Components, f) Design and Construction Issues, g) Safety, Reliability, Risk and Margins, h) Issues Related to Operations, Inspection and Maintenance, i) Fuel Cycle Facilities, j) Waste Management, and Decommissioning, k) Challenges of New Reactors



Conference Venue: India Habitat Centre, New Delhi

Dr. Anil Kakodkar

There are many star speakers in the conference. The high point of the conference is Thomas Jaeger Lecture by Dr. Anil Kakodkar, Former Chairman, Atomic Energy Commission and Homi Bhabha Professor, India.

Other prominent speakers of the conference are as follows:

Key note speakers:

- Mr. Louis Echavari, Director General of OECD/NEA on 'Nuclear Power in the Aftermath of The Fukushima Dai-ichi Accident'.
- Prof Heki Shibata and Hiroshi Abe, Ex-President and the Member of IASMiRT on 'What I referred the Seismic Safety Code and Guide before the Fukushima event, and How shall we revise it'?
- Mr. Gerry Frappier, Director General of Directorate of Assessment and Analysis Canadian Nuclear Safety Commission on 'Status of nuclear reactors in Canada and plans for the future'.
- Mr. Osamu Motojima, Director-General, ITER on 'Status of ITER Project and Fusion research'.
- Mr. Jean-Marc Miraucourt, Director of Nuclear Engineering for In-operation Fleet and Decommissioning, EDF on 'EDF policy for long term operation of French NPPs'.

Some of the plenary lectures include:

- Dr. Ratan Kumar Sinha, Director, Bhabha Atomic Research Centre, India on 'Structural Mechanics for High temperature Reactors and ADS'.
- Dr. Baldev Raj, Former Director, Indira Gandhi Centre for Atomic Research, India on 'Structural Mechanics for Fast Breeder Reactors'.
- Dr. A. K. Suri, Director, Materials Group, Bhabha Atomic Research Centre, India on 'Advanced Materials & Fabrication Challenges of Fusion Reactors'.
- Mr. S.A. Bharadwaj, Director, Technical, Nuclear Power Corporation of India Limited, India on 'Structural Mechanics for Heavy & Light Water Reactors'.
- Mr. S. Yoshimura, University of Tokyo, on 'High Performance Computation and walkthrough visualization for seismic safety of nuclear power plants'.

There are several workshops planned during the conference. For further details visit the conference website https://smirt21.hbni.ac.in.

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Book Reviews

Title of the book: Reliability Engineering and Life Testing

Author: VNA Naikan

The advances in technology and increasing automation necessitate more focus on ensuring dependability of systems used in critical applications. This is important in view of the consequences to human life and environment during system failures. This book titled "Reliability Engineering and Life Testing" addresses an important aspect of dependability viz., Reliabilityand its related topic viz., Life Testing. The concepts of reliability and various models used for different types of engineering systems are discussed, in detail, with appropriate real time examples. A wide coverage of all relevant areas of reliability such as statistical methods for reliability, life testing, accelerated life testing, data analysis for reliability estimation, etc. are discussed.

Thebookisausefulresourceandreferencematerialforreliabilityanalystsandresearchers. It provides the basic concepts in all areas relevant to reliability and describes various methodsandtoolstoperformanindependentreliabilitystudyinanyindustry.

Title of the book: Dependability of Networked Computer-based Systems

Authors: Ajit Kumar Verma, Srividya Ajit and Manoj Kumar

It is a challenging task to measure dependability attributes on real-time systems. This book explores the analysis, simulation and limitations in the implementation of complex systems, addressing a variety of issues and challenges in the application of computer based systems in dependability and safety critical applications. It covers a variety of dependability modeling methods: stochastic process, Markov and semi-Markov models, stochastic Petri-net based modeling formalisms, Monte Carlo simulation, etc.

The book will be useful for practicing engineers to ensure system dependability at the design, operation and maintenance stages.

Reviewer: Dr. C. Senthil Kumar (Safety Research Institute)

Upcoming Conferences

International Conference on Advances in Nuclear Science and Engineering (ICANSE)
Date: 14 to 17 November 2011
Venue: Denpasar, Bali, Indonesia
Website: http://portal.fi.itb.ac.id/icanse2011/
ICANSE-2011 aims at summarizing recent research activities relevant to the advanced development of application in the nuclear science and engineering and facilitate communication among relevant experts.
Organized by: InstitutTeknologi Bandung (ITB) Indonesia

44th Annual Convention of Operational Research Society of India &International Conference on Operations Research for Sustainable Development in Globalized Environment
Date: January 6-8, 2012
Venue: Calcutta Business School, Bishnupur, 24-Paraganas (South), West Bengal 743503
Website:http://www.orsi.in/pages/events/annual-convention.phpandhttp://www.orsical2011.org

Workshop on "Quantitative Tools and Techniques"
Jointly organized by Operational Research Society of India, Calcutta Chapter & Indian Institute of Management Calcutta
Date: January 4-5, 2012
Workshop Venue: Indian Institute of Management, Joka, D.H. Road, Kolkata 700104

The Annual Reliability & Maintainability Symposium (RAMS) 2012
Securing tomorrow's Future with Reliability and Maintainability
Date: January 23-26, 2012
Venue: John Ascuaga's Nugget Hotel, Reno, Nevada, USA
Website:http://rams.org/rams-2012-call-for-papers/

International Conference and Workshop on Computational Intelligence in Energy Security
Date: June 11-13, 2012
Venue: University of California, Berkeley
Website:http://ijsaem-sig.blogspot.com/p/sig.html

8th International Conference on Simulation in Risk Analysis and Hazard
Date: 19 to 21 September 2012
Brac, Croatia (Hrvatska)
Website: http://www.wessex.ac.uk/12-conferences/risk-analysis-2012.html
Covering a series of important topics of current research interest and with many practical applications, the conference is concerned with all aspects of risk analysis and hazard mitigation.
Organized by: Wessex Institute of Technology, UK

Eighth International Triennial Calcutta Symposium on Probability and Statistics
Date: 27 to 30 December 2012
Venue: Kolkata, West Bengal, India
Website: http://triennial.calcuttastatisticalassociation.org/sympBrochure.php
The Symposia bring together researchers in Statistics and Probability on a common platform to facilitate exchange of ideas. A number of eminent researchers will attend. Sessions on invited and contributory papers and posters will feature.
Organized by: Calcutta Statistical Association & Department of Statistics, University of Calcutta

27th Symposium on Applied Computing (SAC-2012)
March 25-29, 2012
Venue: Trento, Italy
Website: http://oldwww.acm.org/conferences/sac/sac2012/

New Members

The society approved the following scientists / engineers as life members of SRESA. SRESA welcomes the new members and looks forward to their valuable contribution and support.

Dr. N. K. Goyal received his PhD degree in Reliability Engineering from IIT Kharagpur in 2006. He is serving IIT Kharagpur as a faculty member since 2006 as Assistant Professor in Reliability Engineering Centre. He is a PhD guide and published more than 10 numbers of papers in international journals. His current academic interests are system reliability modeling, life testing, probabilistic risk assessment and software reliability.

Shri R. Bharathan, Outstanding Scientist, is working in Reactor Group, BARC for more than 30 years. He is looking after maintenance of process Instrumentation of all the research reactors in BARC.

Shri V. M. Shanware is working in BARC since 1991. His areas of expertise include design, detailing, procurement & commissioning of all types of control & process instrumentation; SCADA application program development using LabVIEW and implementation.

Shri M. K. Sharma is working in BARC since 1999. His areas of expertise include embedded systems, VLSI design, VHDL modellig & design and FPGA design.

Prof. Subrata Chakraborty is working as Professor at Department of Civil Engineering, Bengal Engineering & Science University, Shibpur (WB). His area of specialization is Civil Engineering (Structures).

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Society for Reliability & Safety (SRESA)

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