Published in the Journal titled "Productivity" published by National Productivity Council in April-June 2007 issue, Vol.48, No.1

Relevance of Knowledge Management at Power System Operation Control Centres in India

Vivek Pandey[1] and K. Momaya[2]

Abstract

Socio-technical systems are complex systems. They comprise of several sub-systems with interrelationships that mutually influence each other's performance. Indian Power System is one such system. The paper dwells on the issues related to knowledge management and its relevance to the performance of system operators at Power System Control Centres.

Keywords: Power System operation, System States, Situational awareness, Knowledge Management, Productivity, Performance

Introduction

A system is defined as an integrated set of components with an identifiable boundary working together for some purpose. Every system has a boundary, inputs, outputs, sub-systems and interfaces. The functional characteristics of a 'system' is determined by the 'intent of the design', the 'characteristics of its components', the 'interrelationships existing between them', the 'environment' in which it is operating and the 'constraints'. The behaviour of the various sub-systems is inevitably influenced by the behaviour of the other sub-systems. A system can be decomposed into its sub-systems or component parts for the purpose of design, implementation, analysis, and maintenance. But during the functional stage each of the system performs as an integrated whole. Therefore any new element that has to be installed has to be compatible and aligned with the rest of the system to be worthwhile.

System states

In the course of operation a system may dynamically pass through different states- '*normal*', '*alert*', '*emergency*', '*in-extremis*' and '*restorative*'. [Fink & Carlsen, 1978, 'State Transition Diagram', (IEEE Spectrum 1978].

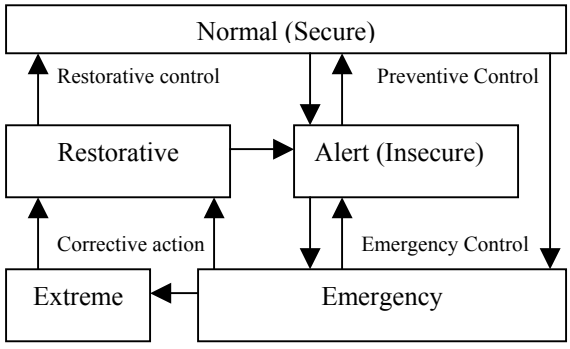

Figure- 1: State transition diagram

All these states except the 'normal' state are 'abnormal' and are undesirable. Therefore the system should be kept within the normal band for the maximum duration. A 'perfect', 'well-designed'

[1] Mr. Vivek Pandey is Deputy Manager in Power Grid Corporation of India. Limited. Views expressed are personal and may or may not represent the views of the organization.

[2] Dr. K. Momaya is an Associate Professor in the Strategic Management Group at the Department of Management Studies, Indian Institute of Technology, Delhi.

and 'well-maintained' system has inbuilt automatic control systems, feedback loops, and security mechanism that are capable of realising that objective. However the creating such utopian systems with reliability of 100 % would neither be technically feasible nor economically viable for the society. In a realistic scenario, the stakeholders relax their specifications and bargain for a system that has 'less than perfect' reliability and performance. We might term these systems as realistic system for the purpose our discussion. In a realistic system the efforts are directed to achieve acceptable reliability, efficiency and performance under the supervision of a system operator. The system operator is usually provided with the data of regarding the performance of the system at any given time to help him diagnose the system state. At times he might be provided with intelligent decision support systems to assist him in performing his designated role.

Role of a system operator

The realistic system may migrate from 'normal' to 'abnormal' state on account of perturbations internal to the system or external to the system. Usually the inbuilt control system is capable of automatically maintaining system stability during normal as well as abnormal states. However at times the control system may fail or malfunction, causing the system to migrate into an unsafe zone rather quickly. At this stage the system operator who is closely supervising the system must quickly sense the change in system behaviour (what is happening?), identify the underlying causes (why it is happening?), anticipate the future state (what might happen?) and make necessary interventions to prevent degeneration. This is generally termed as '*situational awareness*' and is defined as a mental model of our operating environment and our place in it. It often consists of four processes including perception, comprehension, projection, and prediction [*Loughgran and Stahl, November 2000, 'Gaming and Shared Situation Awareness'*].

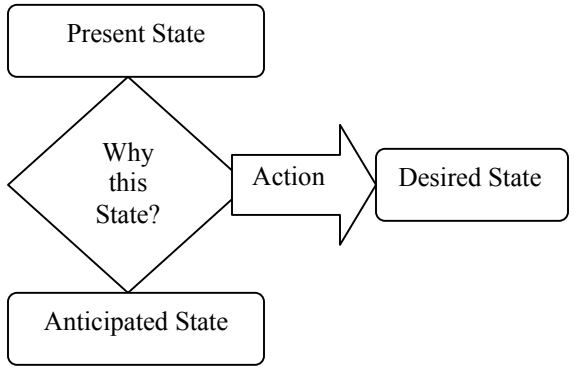

Figure-2: System Operator intervention

Needless to mention, the system operator has a huge responsibility in a system, as he becomes an inseparable part of the system itself. System operator is expected to analyse ambiguous situations with no pre-programmed instructions or rules. His performance becomes a vital variable in the performance of the system especially in online systems. His '*action scripts*' (interventions) in the system would be based on the '*mental simulations*' and '*mental models*' [Gary Klein 2003, '*Recognition-Primed Decision Model*'].

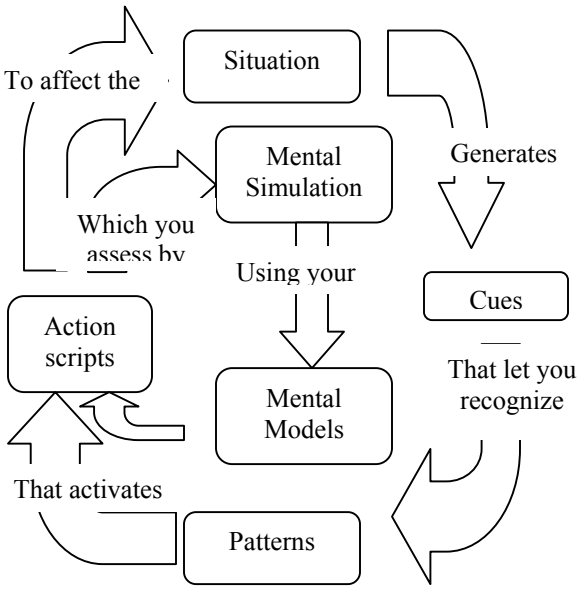

Figure-3: Recognition-primed Decision Model
[Adapted from Recognition-Primed Decision Model in Gary Klein's, Intuition At Work, Currency Books, 2003]

System operator's job is thus in the domain of knowledge work

Productivity of System Operators

One basic way of defining productivity is "output divided by input" (O/I). If Company X uses 100 units of input to produce 100 units of output, their productivity ratio is 1. However the problems in applying productivity measures to system operation results from the intrinsic complexity of the work and the general disagreements about what to evaluate. The complexity of system operation arises from several factors. It is not routine, involves much independent judgment, and requires several people to work together. Furthermore, a considerable amount of knowledge is required to do the work.

The tasks performed by a system operator inter alia involve collecting information (supervising the system), executing control actions, contingency analysis (what if scenarios), problem solving and decision- making. The impact of their actions is reflected in operating variables of the system, which are intangible in nature. The non-routine nature of the job means that it is very difficult to measure a norm. There is no obvious average to observe and record, so any measure will be somewhat inaccurate.

Further the degree of independent judgment involved system operation means that the "norm" may vary from individual to individual. Each person can accomplish the work in his or her own way, further complicating measurement of a norm. The dependency of one worker on another can mean that, although one worker is performing very well, the problems of another worker determine the overall performance.

It emerges from the above discussion that more research is required in developing suitable indices of measuring productivity of system operators. Therefore the usage of the term 'productivity' in the rest of the article should be understood as referring to the system operator's performance in general.

Indian Power System Operation (PSO)

The frameworks discussed in the preceding paragraphs are applicable to the Indian power system as well. Indian power system comprises of hundreds generating stations based on different technologies, which are coupled together with the help of a vast transmission system. Each of these components is owned by different utility. The consumers whether they are industrial, commercial, agricultural, domestic or government establishment are hooked to this network at different nodes for consuming this product which is delivered to them within milliseconds of being generated. For the stability and reliability of the integrated system, supply must continually match the demand, even though they are temporal and stochastically varying. Various components of this system interact with each other in a dynamic fashion. Ensuring reliable, efficient and economic operation of this machine involves extensive off-line as well as real-time coordination between thousands of personnel affiliated to different utilities involved in the chain. Even a seemingly innocuous human error or a technical snag has a potential to pull down the entire power system within seconds resulting into a blackout that has huge social, economic and political implications. This vulnerability makes power system operation a '*mission critical*' activity and the system operator as an indispensable entity

Power System Operation (PSO) in India is being coordinated through five regional and more than thirty state control centres. These control centres are owned by different utilities and they collaborate with each other for executing their statutory responsibility of ensuring a secure, reliable, efficient and economic power system operation.

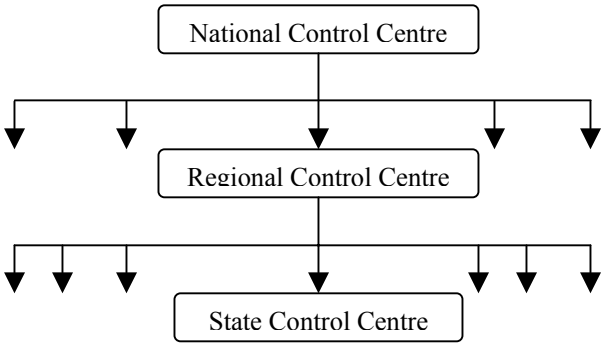

Figure-4: PSO control centres in India

Relevance of KM in PSO

Power system is a socio-technical system. Its success depends on success of its design, performance of its subsystems, their inter-relationships and the performance of the system operator. The coordination services offered by the power system operators are unique and mission critical. While the performance of the subsystems could be improved by requisite investments in technology and other infrastructure, the performance of the power system operators would be a function of their domain knowledge, problem solving skills and motivation to deliver. Unlike the commercial organizations competition in power system operation is not against any other organization but against the randomly occurring combination of expected and unexpected events

trying to destabilize the power delivery infrastructure. Given limited time available for responding to emergency situations what would come to his rescue would be his experience, values, insight and grounded intuition.

A model of human performance at control centres as discussed in the report by CIGRE working group 39.03 indicates that there are numerous individuals and environmental factors that contribute to job performance. The operator's skills and knowledge (the fact that they know 'how to perform') is clearly an important factor in the quality of operating performance. The report also mentions that detailed symptom-based procedures ("If this is observed, do that...") have only limited applicability in system operation because of the complexity of power systems and the impossibility of anticipating every event.

PSO falls under the realm of essential public service and is presently being carried out within the government set up and under regulatory oversight. The activities have to be limited within a code of discipline and commercial rules specified by the regulators. A diverse constituency has a stake in power system operation. This includes generating utilities, transmission utilities, distribution companies, consumers, manufacturers, market intermediaries, academic institutions, technologists, economists, lending agencies, planners, administrators, government authorities, regulatory bodies, legislature, judiciary and many others. Decisions have to evolve after a considerable formal and informal interaction among stakeholders and system operators are subject to heightened value-laden expectations for neutrality, fairness, transparency and accountability. This makes power system operation a multidisciplinary in nature and calls for an understanding of all related areas apart from the technical aspects. Considering the diversity of expertise required a control centre, expecting a single individual to have proficiency in every area would be unrealistic. Therefore pooling of expertise and effective knowledge management appear to be the most practical alternative to achieve the desired objective.

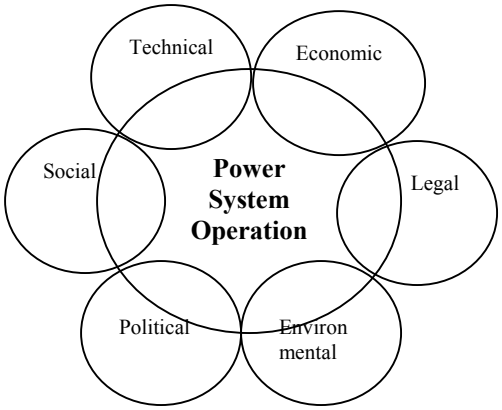

Figure- 5: Multidisciplinary aspects of PSO

KM practices presently adopted in PSO

All organizations overseeing PSO in India are awash with 'represented' and 'tacit knowledge but much of that knowledge is not even visible since other members of the organization, or customers of the company are not even aware of its existence. Knowledge transfer takes place primary through sporadic personal interactions, meetings and conferences. Officials from the administrative strata generally attend gatherings. Formal training programmes are few and far between. Most of these programmes are organized in metros and considered to be more as an

occasion to relax than an opportunity to learn and share. Pressure to economize on employee cost in a tight regulatory regime has resulted in downsizing and a corresponding slowdown in fresh recruitments. This has made the matter worse because those who are nominated in the training programmes are either those who can be easily spared or those who manage to get themselves nominated for other reasons.

The control centres at the regional as well as state level operate round the clock with the help of a small team of system operators. Apart from the occupational stress, the job involves immense physiological stress arising from frequent disruption of natural circadian rhythms and exclusion from daily business activities. All this also has a bearing on the performance of system operators. Unlike in 24x7 customer care service centres, the absence of a critical mass in terms of number of personnel in one control centre makes it slightly difficult for the management to address the physiological problem.

The output of control centre operations is highly intangible. The organizations consider it a low priority area. Incentives for enhancing performance are difficult to design. The control centres have to be run within a given framework of administrative processes with elaborate internal rules and reporting systems. The rewards and status of the system operator position in India is generally considered to be incommensurate with their level of responsibility. Further there is a general lack of awareness about the importance of system operation in power sector. Liberalization has opened a large number of avenues for job-seeking youngsters and the number of talented engineers willing to serve in this area is gradually diminishing. The problem is particularly acute in state level control centres. Employees past their prime age are posted in the control centres. These personnel neither have the motivation in acquiring the skill nor adequate time to comprehend the nuances of system operation. Process of hiring, firing, disciplining and financially rewarding employees are highly constrained.

The situation at the regional control centres is slightly better. They have greater exposure and better mechanisms of knowledge acquisition and sharing. However the rapidly changing environment in India and particularly in the power sector has made the situation difficult even for them. Time available for thinking, acquiring and acquiring new knowledge vital for achieving the strategic objectives has shrunk drastically. The increased mobility of the workforce in general and retirements has also led to diminishing knowledge reserves.

In the ongoing reforms in India the focus has once again shifted to the infrastructure sector such as transport, telecom and power. At the regional level conscious efforts are being made to enhance the productivity and performance of control centres. Debriefing sessions are conducted after major contingencies to analyse the event and identify deficiencies. Focussed programmes are being conducted to revitalize the theoretical concepts with the help of academic institutions. Need-based short training modules on different focus areas are organized. Operators from the state level are also invited to take part in these sessions. Libraries are being gradually upgraded with relevant publications. Reading habits of individuals are being improved by encouraging them to take specific research areas and make short presentations. This is also helping them in polishing their public speaking skills. Employees of all levels and all departments attend these group talks to enable cross-fertilization ideas. Knowledge creation through systematic documentation of operator experience in the form of papers is being encouraged. Seminars, workshops, conferences and exhibitions are being organized to provide opportunity to operators to share and enlarge domain knowledge. Internet access has been provided to every executive to enable them to take advantage

of the information available online. Web-groups with different focus areas have been formed to facilitate interaction between operators posted at different control centres. Major issues are debated through videoconferences.

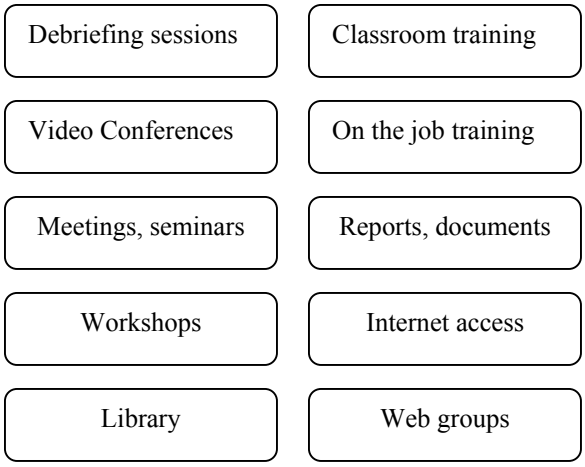

Figure-6: Present KM initiatives in Regional PSO

The new recruits are groomed with the help of classroom training; on-the job training and industrial visits. Junior executives are included in the team from the control centres that meet stakeholders at regular intervals.

Suggestions

The knowledge management (KM) initiatives presently being pursued are steps in the right direction for capability building in PSO. However, the participation in these initiatives is still lukewarm mainly on account of cultural prejudices and a natural resistance to change. These could be addressed through suitable interventions. Individual counselling and behavioural workshops could be found useful in tackling personality and culture related issues. Special attention needs to be given for improving reading and communication skills.

On the KM front more focussed initiatives on the lines of SECI model of socialization; externalisation, combination and internalisation could also be considered. Standard KM techniques such as knowledge portals and mentoring techniques could be also explored. Electronic performance support systems (EPSS), embedded hypertext based helps, multimedia or other technologies could be extensively deployed.

Organizations performing system operation function would have to move beyond narrow interests and create shared infrastructure for training, capability building, R&D and KM. Effective networking between system operators in different control centres through formal and informal channels would help in developing trust and technical solidarity. This would also help in nurturing the profession in India. Efforts are also required towards developing a metrics for measuring the impact of KM initiatives. Capability Maturity Models similar to those used in software industry could be developed in PSO to assess the gap between the present and desired maturity level.

Concluding Remarks

Running any system is very much a question of playing against the odds. There is a lot to be gained by stacking odds in your favour. Being aware of what is going on and then making the

right intervention at the most opportune time can make the difference between survival and profitability, or failure and loss. Effective knowledge management policies would not guarantee success or survival. They simply improve the odds in favour of the system operator. KM initiatives could help in integrating various efforts in the direction of enhancing the performance of system operators. Cooperation from internal as well as external stakeholders would be essential in making realising the collective vision of a near perfect power system.

Productivity of knowledge activities is key to competitiveness and success. It demands sound strategy implementation on wise choices. Strategic choices on implementation approaches will play a critical role in leveraging KM for competitiveness (Ganeshraj and Momaya, 2006). Organizations in India need to move much beyond technology (often IT)-centric approaches of KM to people/culture-centric KM approaches where knowledge creation and use becomes a joyful way of life.

Acknowledgements
The authors would like to thank the practicing engineers at various control centres in India for providing valuable insights to the subject. Authors are also grateful to POWERGRID management for encouragement and support for this research.

Reference

CIGRE working group39.03, '*Improving Human Performance in the Control Centre*', ELECTRA No. 174, October 1997

Gamble P. R. & Blackwell J., '*Knowledge Management- A State of Art Guide*', ISBN 0 7494 3649 2, Published by Kogan Page, 2001.

Gupta V. et. al., '*Business Policy and Strategic Management- Concepts and Applications*', ISBN-81-81-203-2862-0, Prentice Hall of India Private Limited, New Delhi, 2005

International Energy Agency, '*Energy Market Experience-Learning from the Blackouts- Transmission System Security in Competitive Electricity Markets*', Organization for Economic Cooperation and Development, 2005

Overbye, Thomas, '*Reengineering the Electric Grid*', American Scientist, , Volume: 88, Number: 3 Page: 220, May-June 2000

Senge P. M., '*The Fifth Discipline*', Published by Currency, 1994

Soonee S.K., Narasimhan S.R. and Pandey V, '*Significance of Unscheduled Interchange Mechanism in the Indian Electricity Supply Industry*', Proceedings of International Conference on Power System Operation in a Deregulated Regime, Institute of Technology, Banarus Hindu University, 2006

Soonee S.K. and Pandey V., '*Transparency in Power System Operation in India*', published in CANDOUR, an in house journal of Power Grid Corporation of India, 2007

Umamaheshwari R. and Momaya K., 2006, Strategy and Implementation Approaches to Knowledge Management, Productivity, 47 (1-2), April-Sept., p. 9-15.