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KNOWLEDGE CAPTURE FOR THE UTILITIES

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ABSTRACT

The scientific methodology for capturing, preserving, and sharing knowledge (Hoffman & Lintern, 2006) developed during the era of "expert systems." Today, it takes on special importance with regard to the loss of expertise in knowledge-based organizations, a cohort effect known as the "gray tsunami" (Moon, et al., 2009). Senior leadership at utilities throughout North America cite statistics that 45-65 percent of senior engineers are at or are nearing retirement. The palette of knowledge elicitation (KE) methods includes forms of structured interview, techniques for work analysis of on-the-job performance, and methods for proficiency scaling (Hoffman, et al., 1998; Hoffman & Militello, 2008). Empirical comparisons of KE methods have highlighted their strengths, weaknesses, and appropriate applications (Hoffman, et al., 1995). Certain combinations of methods are particularly useful and efficient for eliciting knowledge that is critical to the organization and remains undocumented ("tacit" knowledge). IHMC researchers, in collaboration with Perigean Technologies LLC, have conducted demonstrations and training workshops on KE with participants at numerous utilities. Knowledge modeling efforts have focused on domains ranging from business relations to steam turbine repair. The KE methods we have used include Concept Mapping and the Critical Decision Method. In this presentation we will describe these methods and will illustrate some of the knowledge models we have developed. An additional focus of our work has been to carry the knowledge capture effort over into training. In collaboration with EPRI, we are converging on a methodology to demonstrate the "accelerated learning" of expertise. We provide recommendations for utilities and nuclear personnel considering knowledge capture efforts.

Key Words: Expertise, knowledge elicitation, tacit knowledge.

1 INTRODUCTION

In all complex sociotechnical workplaces, knowledge and skill have become widely recognized as a critical asset. Expertise is a "must" for proficient performance in these domains, and yet many of the most knowledgeable personnel are nearing retirement. An outright panic attack comes when an organization realizes that it does not have a plan in place to capture the valuable knowledge before it is lost (Hoffman & Hanes, 2003). Widespread recognition of the problem is shown in the current popularity of "knowledge management." Over the years since the publication of Gary Klein's seminal paper, "Using Knowledge Engineering To Preserve Corporate Knowledge" (1992), numerous trade books have appeared bearing such titles as: *If we only knew what we know: The transfer of internal knowledge and best practice* (O'Dell & Grayson, 1998), *Working knowledge: How organizations manage what they know*

(Davenport & Prusak, 1998), *The knowledge evolution: Expanding organizational intelligence* (Allee, 1997), *The knowing organization: How organizations use information to construct meaning, create knowledge and make decisions* (Choo, 1998), and *Corporate memory: Strategies for knowledge management* (Brooking, 1999).

For a variety of reasons including downsizing in the 1990s and early 2000s, loss of expertise has become a critical issue in the electric utilities. An EPRI survey found that 92% of 37 respondents representing 21 electric utilities reported that loss of unique valuable expertise would pose a problem within the next five years. However, only 30% of the respondents indicated that a planning effort is in place to address this problem of retaining knowledge from experienced workers in a manner that would make it accessible and usable by new or replacement members (Gross, Hanes & Ayres, 2002; Ziebell, 2008). In our collaboration with EPRI, we suggested that utilities:

- Identify employees who possess valuable undocumented knowledge;
- Evaluate whether the knowledge is worth capturing;
- Elicit and preserving the valuable knowledge;
- Share this knowledge with other personnel as needed.

Generic guidelines were developed as a major component of the first project performed as part of the EPRI Strategic Human Performance Program (Gross, Hanes & Ayres, 2002; Hanes & Gross, 2002). The goal has been to develop detailed process and methods guidance that knowledgeable utility personnel—to include nuclear experts—can apply to elicit valuable knowledge from experts within their organizations, and to prepare knowledge modules for use.

2 METHODOLOGY

2.1 Concept Mapping

The primary KE method we utilize is Concept Mapping, or "Cmapping." Concept Maps are meaningful diagrams that include concepts (enclosed in boxes) and relationships between concepts or propositions (indicated by labeled connections between related concepts). Concept Mapping has foundations in decades of research and application (Cañas, et al., 2004; Gordon, 1992; Moon, et al, in press; Novak, 1988). The technique is being used world-wide and throughout education, academia, and the private sector. The advent of *CmapTools*, IHMC's free Concept Mapping software, has encouraged the spread of Concept Mapping, and enabled easy creation and sharing of Concept Maps across the Internet. (For more information and the free download of CmapTools, see http://cmap.ihmc.us.)

In the standard KE procedure involving a single domain expert, one researcher serves as the "Facilitator" while another researcher—the "Cmapper"—uses *CmapTools* to create the Concept Map that is projected on the screen. Beginning with a "focus question," the facilitator helps the domain practitioner build up a representation of their domain knowledge, in effect combining KE with knowledge representation. This is one reason the method is relatively efficient. Full details on the procedure appear in Hoffman (2006).

The typical two-day session can result in as many as 30 Concept Maps, each having somewhere in the neighborhood of 45 propositions. The method generally meets the benchmark for efficiency in KE, of more than one informative proposition per task minute (see Hoffman, 1987). We have also used variations on the standard procedure, particularly when operational needs do not afford extended time of the participating expert, or when we have developed composite Concept Maps across multiple experts on a single focus question. In these cases, we spend the time with the expert eliciting the primary concepts and begin to sketch the structure of the Concept Maps. These sessions are audio recorded, enabling us to return to the Concept Maps at a later time and create links and additional structure based on the verbalizations of the Expert. These refined Concept Maps are then provided back to the expert for additional refinement.

Concept Mapping can also be used by teams or groups, and can be used for purposes other than KE (e.g., brainstorming, consensus formation). Teams can be structured in a variety of ways, and can make and share Concept Maps while geographically separated (see Cañas et al., 2004).

Figures 1 through 4, in the Appendix, are Concept Maps that we have developed using the procedure with utilities personnel. They represent a diversity of topics. The ability to hyperlink digital "resources" such as text documents, images, video clips and URLs is another significant advantage provided by computerized means of developing Concept Maps. *CmapTools* indicate hyperlinks by the small icons underneath concept nodes. Hyperlinks can connect to other Concept Maps and sets of Concept Maps hyperlinked together are known as a "knowledge model." Note especially in Figure 4 how icons appended to nodes represent the "stitching together" of multiple Concept Maps into a knowledge model. The icons indicate hyperlinked resources provided by the participating experts, including images, documents, and also video clips of interviews with experts.

2.2 The Critical Decision Method

In drilling down into the expert's knowledge, reference is often made to a previously-encountered tough case. Such cases are often significant for indicating the expert's information requirements and reasoning strategies. Typically during a KE session using Cmapping, the expert will be struggling to explain a concept and will say something like "Well, let me give you an example of...." What follows is a recollection of a very instructive case. In addition to their being a rich source of additional knowledge tapping the expert's wisdom and reasoning, the cases can be used to populate the knowledge models, as cast stories or vignettes.

We enable this recollection using the Critical Decision Method (CDM) (see Crandall, et al., Hoffman, et al., 1998). The CDM is multi-pass retrospection in which the expert is guided in the recall and elaboration of a previously-experienced difficult case. The CDM leverages the fact that domain experts often retain detailed memories of previously-encountered cases, especially ones that were unusual, challenging, or in one way or another involved "critical decisions." The CDM does not use generic questions of the kind, "Tell me everything you know about x," or, "Can you describe your typical procedure?" Rather, it guides the expert through multiple waves of re-telling and prompts recall through the use of specific probe questions (e.g., "What were you seeing?") and 'what-if ' queries (e.g., "What might someone else have done in this circumstance?"). The CDM yields time-lined scenarios, which describe decisions (decision types, observations, actions, options, etc.), and aspects of decisions that can be easy or difficult. It can also yield a list of decision requirements and perceptual cues—the information the expert needs in order to make decisions. Given its focus on decision making, the strength of the CDM is its use in the creation of models of reasoning (e.g., decisions, strategies).

3. KNOWLEDGE ELICITATION ACTIVITIES IN THE UTILITIES

3.1 Workshops

An initial activity was a collaboration with EPRI in 1999 to review and survey alternative knowledge elicitation methods. This contribution was formative of an EPRI report on knowledge capture methodology (Hanes, 2000).

Our subsequent KE activities have included workshops at which methods of knowledge elicitation and representation are explained and issues of expertise, workforce, and knowledge management are discussed. The workshops have held been in a collaboration with the Electric Power Research Institute. Nuclear and utilities experts, personnel in human resources, and personnel in knowledge management are given guided practice at conducting methods of knowledge elicitation. Training on knowledge management methodology has been provided to individuals from organizations including Progress Energy, EPRI, Southern Company, South Texas Project Electric Generating Station, Rochester Gas and Electric, TXU Energy, DTE Energy, Ontario Power Generation, TVA, Public Service Company of New Mexico, Nebraska Public Power District, Exelon, Detroit Edison Enrico Fermi-2, Southern Nuclear/Farley, CANDU Owners Group Inc., Entergy/Waterford-3, the Institute of Nuclear Power Operations, Diablo Canyon, Energy Northwest/Columbia Generating Station, Gulf Power, and the New York Power Authority.

3.2 Knowledge Elicitation and Modeling

We have conducted knowledge elicitation and modeling projects for utilities and their vendors, including Southern Nuclear, Southern Company, the Tennessee Valley Authority, New York Power Authority, and Westinghouse Electric Company. The utilities and vendors each identified one or more experts who possessed critical and undocumented knowledge. Then, in a series of KE sessions ranging from four to forty hours, Concept Maps were created, refined and hyperlinked together to form knowledge models, and critical incidents were captured. Subsequently, the Cmaps were resourced with various supporting media, such as procedural documents, images, etc. In some cases, the content created through KE populated the organization's own knowledge management systems.

A broad spectrum of topics have been modeled, including: the design of reactors and plants, nuclear plant construction and component manufacturing, reactor, plant and systems design, the nuclear fuel cycle, licensing and operation of complex nuclear facilities, regulation of nuclear facilities, similarities and differences among plants, telecommunication technology, utility relations with the Federal Communications Commission and Public Services Commissions, maintenance and overhaul of steam turbines, nuclear chemistry, environmental monitoring and testing, and power distribution and coordination.

3.3 Roadmapping Knowledge Management for the Utilities

Our early KE activities contributed to the establishment of a general KE methodology that is appropriate for the utilities, for capturing tacit knowledge (see Hanes, 2000; Hoffman & Hanes, 2003). Our more recent KE activities have contributed to a notion of "accelerated expertise," that is, the establishment of knowledge bases that can be used to help workers achieve high levels of proficiency in less time that in commonly takes (on the order to 10 years to achieve expertise in some sub-domains) (Ziebell, 2008). IHMC and Perigean Technologies LLC supported a series of workshops for EPRI to help define a research and operational roadmap for accelerating the achievement of expertise within the utilities industry. The workshops introduced cognitive scientists and knowledge elicitation experts to nuclear and utilities industry personnel, and resulted in a series of publications outlining programs for knowledge elicitation and transfer, and an EPRI report on knowledge management issues (Ziebell, 2008).

4 RECOMMENDATIONS FOR CONSIDERING KNOWLEDGE CAPTURE EFFORTS

In our experience, in order for knowledge capture to be successful a number of conditions must be established. First, the leadership of the utility must appreciate the difference between what is widely called "knowledge management" and the empirical foundations of actual knowledge elicitation activities.

In other words, it is critical to distinguish knowledge management in the sense of IT infrastructure and training, from knowledge elicitation as a specific process for capturing and preserving undocumented knowledge.

A second condition is that the utility's program for knowledge capture, preservation and re-use has significant support from leadership, and significant inducements for personnel to participate. While consultant elicitors such as ourselves can be employed to conduct the KE, we prefer to simultaneously train utilities personnel in the methods. In our estimation it would take hundreds of Concept Maps to capture all of the critical knowledge possessed by a domain expert. Job designations for knowledge elicitors, and programs for training the knowledge elicitors, must be part of the program.

Elicitors themselves need to develop certain skills and come to the KE role with some appropriate background in interviewing. No matter how much detail is provided about the conduct of a KE procedure there is no substitute for practice. The elicitor needs to be comfortable in adapting on the fly to individual differences in style, personality, individual agenda and goals. In "breaking the ice" and establishing rapport, the elicitor needs to show good intentions and needs to be sensitive to possible concerns on the part of the expert. To be good and effective at knowledge elicitation, one must attempt to become an "expert apprentice"—experienced at, skilled at, and comfortable with going into new domains, bootstrapping efficiently and then designing and conducting a series of knowledge elicitation procedures appropriate to project goals.

A final note is in order with regard to the costs of doing knowledge capture, and the costs and risks of *not* doing it. There is no magic bullet that can make the knowledge capture process move at light speed. No hyped software tool can eliminate the burden of deeply understanding the meanings and concepts that experts possess. But can any company afford to take its best experts away from their main job so that they can engage in, say, a month's worth of knowledge capture? Can any company afford to routinely bring their retired experts back as consultants, so that knowledge capture can be accomplished? On-going research in the field of KE is addressing these problems of costing, business modeling, and KE efficiency. For now, we offer the following exercise.

Business Case Modeling Exercise

Think of five people in your organization who have knowledge that is critical to the organization and yet remains undocumented. For each person, think of five critical job functions they perform. For each of the five functions, ballpark the frequency with which it has to be performed, and the approximate time it takes for the expert to accomplish the primary goals.

Calculate this: *What is the total operational cost of achieving all the critical functions?*

For each of the functions, list five consequences to the organization if the function were lost.
Calculate this: *When would my revenue stream dry up if the organization lost that expertise?*

For each of the experts, how many years of salary and training costs did it take the organization to grow the expertise in the first place? Calculate this: *Looking out ten years, what would be the total cost of re-growing that expertise?*

If your identified experts are all age 50 or greater, these sums will allow you to estimate how long your organization has to exist in a worst case (upper bounds) and dangerous case (lower bounds) of loss of expertise.

Finally, estimate this: *What does it take to have a trained, full-time knowledge elicitor?*

The utilities as a whole need a technology innovation program aimed at helping them mitigate the challenges of knowledge loss by developing effective solutions for knowledge capture, transfer, and repurposing. The problems associated with the loss of expert knowledge and skill will only grow in severity under the strains of dramatic labor-force shifts that will see as many as 40-70% of the workforce retiring over the next 5-10 years. The aforementioned EPRI report highlighted an integral piece of this problem facing the utility business:

> … many technical positions are held by outstanding experts, recognized as having a grasp of their field that far exceeds that of others. They are depended upon for mission-critical problem solving and difficult and high-value technical judgments… EPRI's observation of experts in utility domains affirms that it takes a long time to achieve expertise, but also that "extraordinary" experts who conduct mission-critical activities are recognized as having achieved their extraordinary respect and value after 25 to 35 years of experience (Ziebell, 2008, p. 2-2).

What are the defining characteristics of "super-experts" in the utilities? What are the characteristics of the utilities domain that shape the subdomains of expertise, that impact the nature of expertise, and that affect processes of knowledge management? What is most likely to work for accelerating the achievement of expertise, and can methods adapted from fields such as Expertise Studies be effectively deployed in the utilities? Our final recommendation is to encourage the industry to tackle these questions.

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APPENDIX

(Note: Concept Maps are meant to be viewed full screen and at high resolution.)

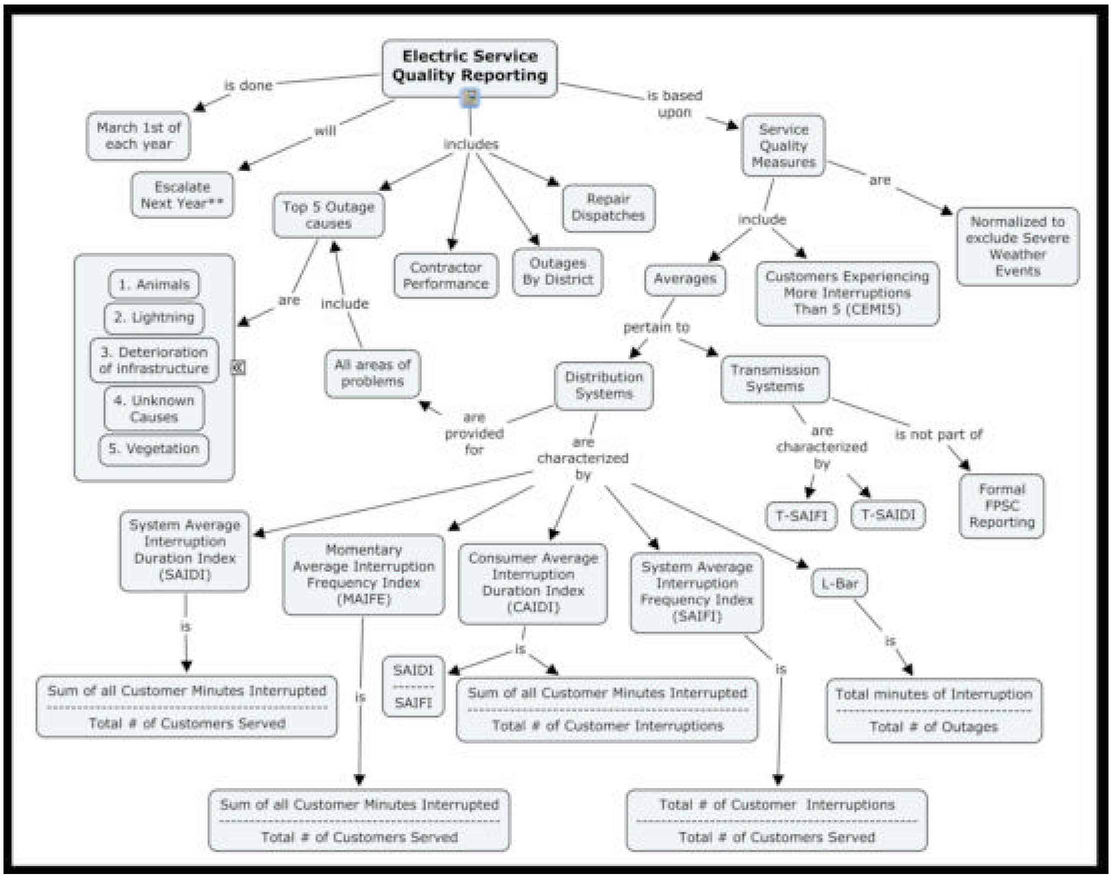

Figure 1. A Concept Map about electric service quality reporting.

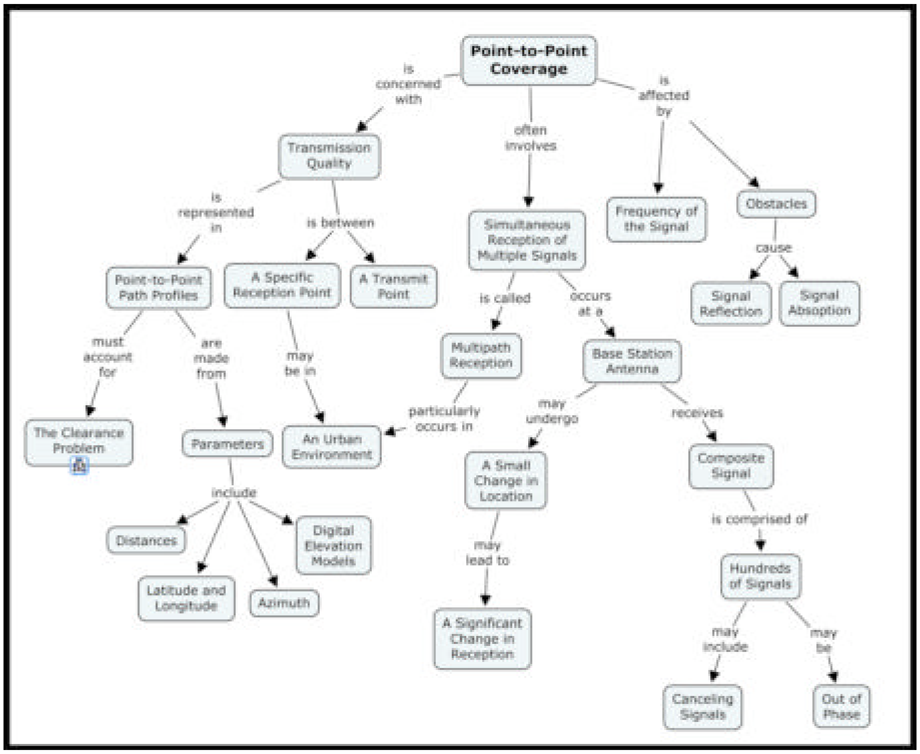

Figure 2. A Concept Map about point-to-point coverage in a utility's radio communications system.

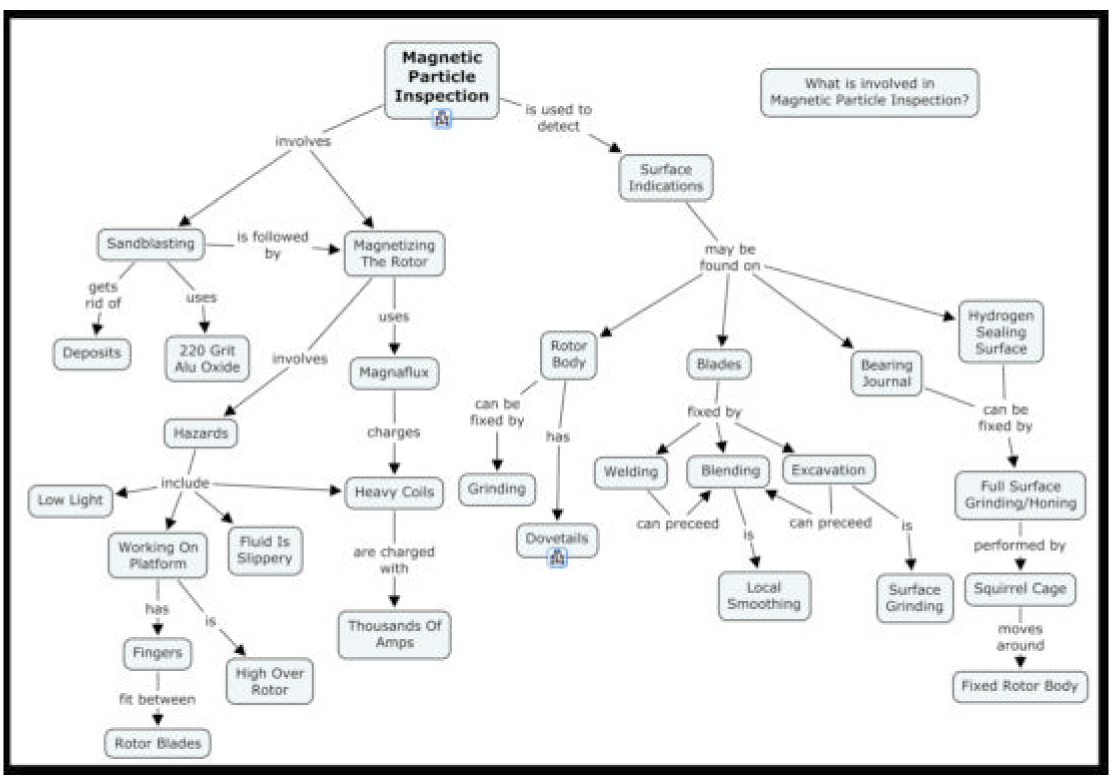

Figure 3. A Concept Map about magnetic particle inspection in steam turbines.

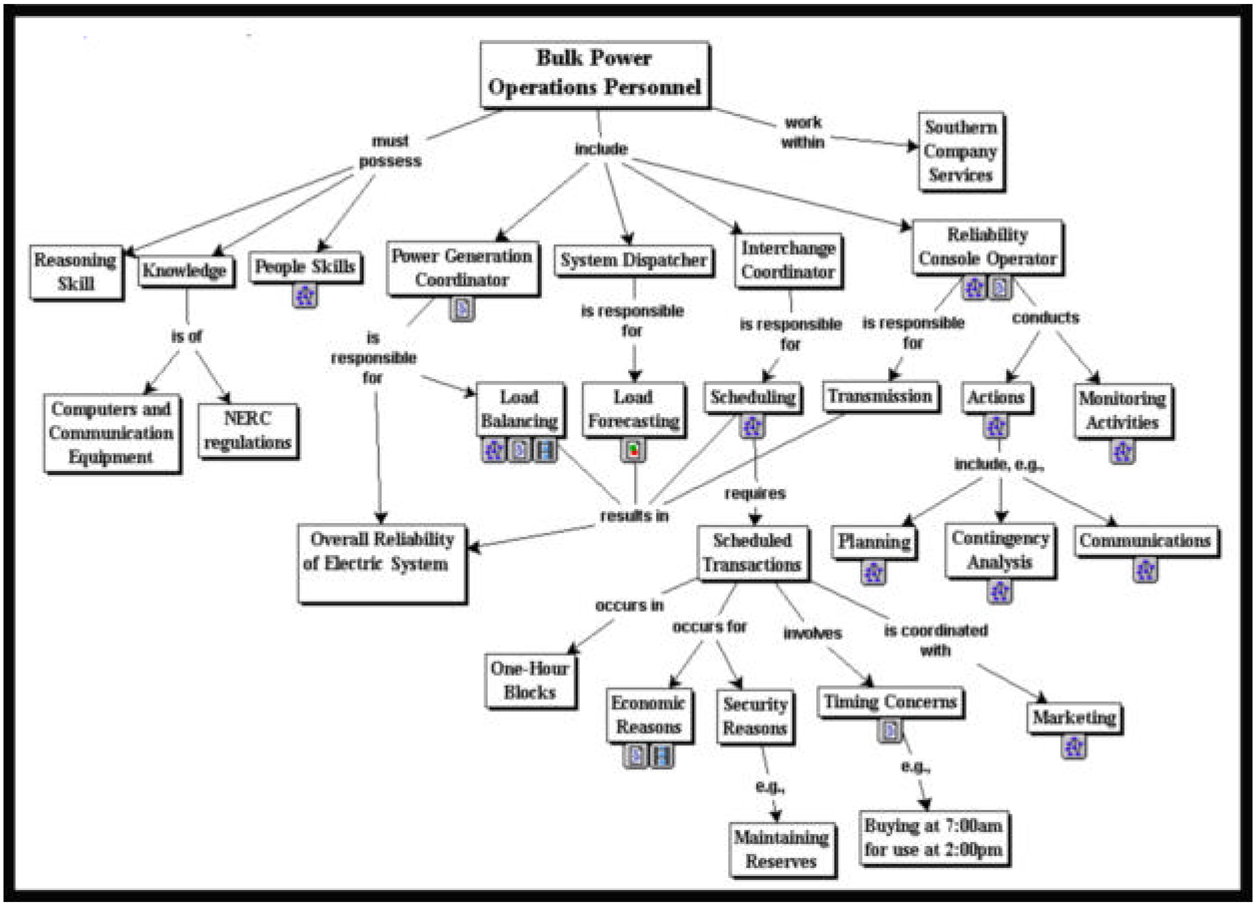

Figure 4. A Concept Map that integrates a number of other Concept Maps into a knowledge model about the domain of bulk power operations.