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Improving Operator Training and Knowledge Transfer at Swissgrid

Hanqing Zhao
Worcester Polytechnic Institute

Kenneth Andrew Swanson
Worcester Polytechnic Institute

Logan Edward Brown
Worcester Polytechnic Institute

Sabbrin Shweiki
Worcester Polytechnic Institute

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Logan Brown, Sabbrin Shweiki, Kenneth Swanson, and Hanqing Zhao

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Advisers:
Professor Kathi Fisler
Postdoctoral Scholar Daniel DiMassa

Sponsors:
Patrick Favre-Perrod
HES-SO University of Applied Sciences and Arts of Western Switzerland
Antonios Papaemmanouil
Swissgrid Ltd.

swissgrid

WPI

Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences and Arts Western Switzerland

Abstract

Swissgrid, Switzerland's Transmission System Operator (TSO), has a major role in guaranteeing uninterrupted services; therefore their current initial and continuing training programs need to be as effective as possible so their operators remain updated and proficient at their daily tasks. This project looks at improving training and knowledge transfer at Swissgrid. We interviewed operational experts at a variety of companies within and outside of the power industry. We compared and analyzed present industry best practices in knowledge management and operational training with those applied at Swissgrid. With the answers obtained from the interviews and further independent research, we generated a set of recommendations that Swissgrid could potentially implement for their future trainings.

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Executive Summary

The current and future needs of the Swiss electrical grid make it imperative that Swissgrid's operators be prepared for as many situations as possible and be given the tools to succeed. We were asked to investigate industry best practices in continuous training and knowledge management to identify deficiencies in Swissgrid's current practices. Swissgrid's knowledge management system contains their trainings and explanations on how to run system operations, meaning their continuous training program is intrinsically linked to their knowledge base because the training is contained in the knowledge base. These two systems provide a way for knowledge to be transferred between individuals in the company and across the group of operators as a whole.

To gather our data, we interviewed companies both inside and outside the power industry. These companies were chosen to yield a variety of sources to get a better idea of the wider trends of training and knowledge management across multiple industries. The main data we collected came from distribution system operators in Switzerland and other transmission system operators in Europe and in the United States. These other electrical transmission companies have a comparable respon-

sibility to what Swissgrid does and give us a reference to what current trends are in the electrical field. Other companies included gas transmission, railway systems, and networking companies, which all involved integrated knowledge management and extensive continuous training programs similar to Swissgrid. In our interviews, we asked questions about how they conduct continuous training and how they manage their knowledge in an effort to collect as many views on these practices as possible.

We separated our data into two main categories to help our analysis of Swissgrid's needs. For the knowledge management practices, we used a chart of our own creation adapted from a textbook on knowledge management systems to map each company's knowledge management practices and their potential deficiencies. Swissgrid itself was missing the transfer of knowledge from the operator to the semantic memory base, meaning operators did not have the ability to put what they thought was important or pertinent information into their system for storing methods, facts, and figures. Using the other completed charts and interview data, we could find alternative ways of creating this process for Swissgrid. The most effective strategy we found through our research is for Swissgrid to allow operator modification of documents to ensure minimum loss of knowledge.

Our second set of research involved investigating each company's continuous training programs and their methods of assessing the effectiveness of their training programs. Swissgrid was interested in the viability of an E-learning platform for parts of their training, and we investigated how other companies utilized online learning platforms and what Swissgrid could use one for to improve their training and assessment. Several interviewees raised concerns in our early research about how

much information operators retain after training sessions and the job effectiveness after running through new trainings. Swissgrid's current evaluation of their training involves quizzes and trainer evaluations of the trainee, but there is no way for operators to give feedback on how useful the training is in operations. Additionally there is no way to measure how effectively they retain the training, meaning they could forget it in a short period of time even if they pass the evaluation. An E-learning platform can serve as a solution to the issue of retention, as Swissgrid can run smaller, more frequent refresher courses to make sure operators remember what the training taught them without having to have operators leave their stations or meet at a central location for trainings. To address the issue of job evaluation, we recommend the use of operator feedback in the form of questionnaires and interviews in addition to performance tests both before and after the training sessions.

Overall, we suggest that Swissgrid implement the following four improvements: Introduce a method for operators to input their knowledge into the company's database of facts and figures, create an E-learning platform for use across all facilities, introduce operator feedback and performance tests to increase evaluation of the effectiveness of training, and introduce a program to help operator retention after they finish training programs.

Chapter 1

Introduction

The goal of this project is to compare and analyze present industry best practices in knowledge management and operational training with those applied at Swissgrid. Swissgrid, founded in 2005 and headquartered in Laufenburg, is the Swiss Transmission System Operator (TSO) [Swissgrid AG, nd]. Swissgrid has since been responsible not only for the operation of Switzerland's transmission grid but also for its maintenance, renewal, and expansion. In its capacity as owner of the transmission system it ensures the secure, reliable, and cost-effective operation of the Swiss high-voltage grid. Using state-of-the-art technology and a high level of automation, Swissgrid controls all transmission system substations [Swissgrid AG, 2015a]. As a member of the European Network of Transmission System Operators for Electricity (ENTSO-E), it is also responsible for the coordination and grid usage in the cross-border exchange of electricity in Europe, making it a strong partner and an established brand in the European electricity market [Swissgrid AG, 2015b]. Thanks to continuing process

optimization, it is one of the five leading grid operators in Europe [Swissgrid AG, 2015a].

As Swissgrid is responsible for the expansion planning, operation, and financing of the entire Swiss high-voltage grid, it is crucial to assure that their workers are fully capable of handling their duties within the company. With approximately 430 employees, 60 specifically being operators, they need to ensure that their professionals are kept up to date on the latest tools and policies [Swissgrid AG, 2015b]. Also, to accomplish this grid expansion, their operators are required to continuously update their knowledge before new technologies are in practice and receive the necessary training on the respective — so that frequent operations can continue unhindered.

This IQP has been sponsored by Patrick Favre-Perrod with the HES-SO University of Applied Sciences and Arts of Western Switzerland and Antonios Papaemmanouil with Swissgrid. Patrick is a member of the licensing committee for Swissgrid's operators, so he gets to see a lot of the inner workings of how these operators are trained and is well versed in the requirements for licensing. Antonios is the operational training manager at Swissgrid, so he manages all of the training, both initial and continuing. Together, they represent a large body of knowledge, very useful for our team to incorporate into.

In spite of their well-developed initial and continuous training programs, Swissgrid aims to keep improving and would like to see if there is anything they can do better. With this objective in mind, our sponsors have asked us to conduct research on other companies' practices in the hopes of obtaining recommendations and further ideas on best implemented industry processes. Therefore, our methodology

is focused on determining how a company like Swissgrid can make its continuous training program for their professionals more effective. In order to do so, an extensive research was done on companies with duties similar to Swissgrid — those who maintain and operate critical services and may require continuous training of their operators. Once identified, our team got in touch with and interviewed professionals from each of those companies. These interviews entailed a set of questions that helped the team better understand the company and particularly how they manage knowledge and training. Alongside with the interviews, additional research from websites, and books were conducted on those topics. Overall, our focus was narrowed to target the following research questions:

- What companies have similar knowledge management requirements and how do they manage knowledge and training?
- What content needs to be conveyed in training? More importantly, does the type of content affect the way knowledge and training are managed and dispensed?
- Is an online E-learning platform applicable to Swissgrid? What is the need for online learning? How can Swissgrid benefit from it?
- How can Swissgrid's operational training be assessed more thoroughly?
- Could an exchange program for operators be implemented at Swissgrid? Do other European TSOs show interest for its implementation?

In general, looking for methods of continuous training and knowledge management that Swissgrid has not yet tried gave us a broader range of options for potential implementations. Quantifiably determining the advantages and disadvantages of different training practices will allow Swissgrid to make an informed decision when choosing how to train their operators. Also, learning what content needs to be conveyed in a training program is of the utmost importance to implementing a successful training system. Beyond that, we looked at existing methods for teaching the required content. Different methods of teaching can be more effective at conveying certain types of information. By answering these questions, through the interviews and research, we were able to evaluate the strengths and weaknesses of various methodologies, analyze their potential applicability to Swissgrid, and deliver a set of recommendations.

Chapter 2

Literature Review

2.1 The Power System

Acquainting ourselves with the power industry was a major component of our preparation and research. None of us are power systems engineers, nor do we have prior experience with the industry. We began our research by reading about the administrators of the European power distribution, focusing primarily on Transmission System Operators — henceforth referred to as TSOs — as this is Swissgrid's role in the system.

A TSO is defined by the European Parliament as:

> *A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet rea-*

> *sonable demands for the transmission of electricity.* [European Parliament, Council of the European Union, 2009]

In other words, a TSO is a person or corporation that owns and operates the high-voltage transmission grid in a country (although in practice, there are no individuals that own transmission grids). They are also responsible for the maintenance and upgrades to the grid to ensure continuous service. This puts a lot of responsibility on a TSO as they are the singular entity responsible for the transmission of power in a country. Smaller companies known as Distribution System Operators (DSOs) are responsible for the distribution of power to a region, but these DSOs rarely have enough local power generation capacity to serve their customers. They must therefore rely on the TSO to provide access to power generation.

A TSO's duties are much more diverse than is implied by "*operating, ensuring the maintenance of and, if necessary, developing the transmission system*". "*Because electricity can only be stored in limited amounts, it needs to be used as soon as it is generated. At the heart of the power system, [TSOs] are responsible for keeping the balance between supply and demand*" [RTE France, 2015]. A TSO must coordinate with power generation companies to guarantee that enough power is produced to meet needs, while minimizing waste by ensuring there is as little excess of power as possible. This role is complicated by the relatively recent addition of small scale renewable power into the system. In previous years, a TSO could more easily make assumptions about power requirements, since their customers only had one source for power. With the addition of wind and solar energy, a TSO must now consider far more variables in their forecasting [Swissgrid AG, 2015a].

In 2003, the European Commission passed legislation for the first part of the European market liberalization [European Parliament, Council of the European Union, 2009]. The goal of market liberalization is to allow a consumer to choose where they purchase their electricity from. In contrast, traditional distribution models have a consumer that purchases electricity from their local distributor and then the distributor purchases electricity from whomever they like. This model gives the consumer virtually no choice in where they buy electricity from. The disadvantage of market liberalization is that it makes the job of the TSO harder. More electricity is being traded across borders, which requires operators to have a greater understanding of the European market and how their actions directly affect it. They also have to upgrade transmission lines to enable greater power flow in and out of Switzerland and to ensure grid security with the more dynamic loads caused by market actions. This in turn requires a more comprehensive SCADA (Supervisory Control And Data Acquisition) system and a more advanced grid simulation software to ensure n-1 (meaning that no single failure will disrupt service) grid security.

2.2 Swissgrid's Role

Swissgrid is the Swiss national TSO and a key player in the European power market. Due to Switzerland's geographic location, power from many countries flows through its transmission grid. Approximately two-thirds of Switzerland's power grid was built in the 1960s [Swissgrid AG, 2015b] and was designed simply to transport electricity from generation sites to consumption sites. This has proven to be inad-

equate; today's consumers are demanding more electricity and electricity is being supplied from different places. Swissgrid has 46 connection points to other countries which allows for the purchase of electricity from a myriad of sources [Swissgrid AG, 2015a]. In addition, other countries buy power and Swissgrid acts as an intermediary, carrying power across Switzerland without consuming it. The complexity of today's electrical market makes thorough and effective training critical to safely secure electricity.

Furthermore, Swissgrid is in constant coordination with other parts of the electrical system. They are continuously working in synchronization with power generation facilities to ensure stable voltage and frequency on the grid. They coordinate with DSOs to ensure that necessary agreements and contracts are in place to guarantee reliable and non-preferential usage of the transmission grid. Neighboring TSOs must be contacted frequently in order to coordinate congestion management (more load than a line can carry), market operations, and other various activities. Today's operators have to be more than just technically competent: they have to be excellent communicators.

2.3 Operators

One bit of terminology that confused us early on was the difference between a Transmission System Operator, and an operator. A Transmission System Operator is a corporation whereas an operator is an employee at a TSO. An operator is responsible for ensuring the duties of a TSO are executed swiftly and correctly. Depending

on their position, these duties vary and include (but are not limited to) coordinating with generation facilities, de-energizing lines so maintenance may be performed on the lines, troubleshooting outages, and planning switching operations to respond to any potential failures. In order to ensure constant voltage and frequency, the amount of power being fed into the grid must closely follow the amount of power being drawn from the grid. This is done on a schedule based on forecasts derived from historical data. Any time maintenance needs to be performed on lines or equipment, those lines or equipment need to be "*de-energized*" (meaning that the circuit is disconnected). An operator is responsible for making sure those lines are properly disconnected and that the maintenance is complete and everyone is safe before reconnecting the line to the grid. The lives of the maintenance workers are in the operator's hands: if something is not properly disconnected or gets reconnected before maintenance is completed, those workers could easily lose their lives. Operators must be able to handle stressful situations like that and react quickly and correctly. This is why operator training is so critical to the safe operation of the grid.

2.4 Training Requirements

European TSOs have minimum requirements for training provided by the European Network of Transmission System Operators for Electricity, more commonly known as ENTSO-E. ENTSO-E published *Policy 8: Operational Training* [ENTSO-E, 2008] in 2008 which establishes minimum requirements on what must be covered in training and makes recommendations on how training should be performed. *Policy*

8 defines a training program as "*a planned, organized sequence of activities designed to prepare individuals and teams to perform specific jobs and to maintain or improve their performance. It describes the training process on the basis of the needed qualification (selection, activities, training requirements, etc.) and consists of an initial program and a continuous program*". Operators must have an initial training and accreditation program, continuous training provided on a regular basis, and periodic accreditation renewals (frequency at the discretion of the TSO). Initial training must cover the basic components of the grid, theoretical operation of the system, and operational tools. Additionally, initial training must incorporate practical experience, with on-the-job training and simulator sessions. Continuous training is designed to provide both refreshing of previously learned information, as well as information about new conditions, rules, and procedures. Additional simulator training is provided as well, with scenarios that include insecure grid conditions, emergency situations, and inter-TSO disturbances.

Policy 8 further defines requirements on languages. Operators should have some knowledge of the languages of neighboring countries so that effective communications may take place. A working knowledge of English is also a requirement so that all TSO operators share a common language in which they can communicate. Exercises in English may be used so that operators are able to communicate clearly in an emergency situation, work with foreign operators, and resolve misunderstandings in communications. English training is not mandatory, but it is recommended.

Assessing training needs and training outcomes are important parts of a training program; *Policy 8* does not specify requirements on assessment. A training needs

assessment looks at the trainees' knowledge and skill levels so that potential improvement could be found for training [United Nations Human Settlements Programme, 2012]. Assessing the outcome of trainings is important for the quality of future trainings as well as security of the grid. By understanding how their operators retain training materials, Swissgrid can optimize the frequency and content of trainings, both saving time and money.

2.5 Training Assessment

Training evaluation is used to qualitatively or quantitatively determine the result or outcome of the training program and it helps to identify whether the benefit of the training program outweighs the cost. In addition, the evaluation can measure the effectiveness of the training program and provide improvements for future training cycles. There are four levels of evaluation in an organization: *participant reaction, individual learning, job performance, and organizational performance* [United Nations Human Settlements Programme, 2012]. Participant reaction evaluation looks for trainees' opinion and attitude towards the training event. Individual learning evaluation looks at how well trainees learned specific objectives. Both job and organizational performance evaluations look at what the changes of actions and behaviors are, and how well the learning transfers into application as an individual or as a group. Participant reaction and individual learning can be evaluated immediately after the training. Job and organizational performances are evaluated after a longer period of time since the training happened. Although the first two levels are much more

frequently used in companies, further evaluations are essential to ensure the bridge between learning and application [United Nations Human Settlements Programme, 2012].

2.5.1 Participant Reaction Evaluation

There are various reasons to have training participant reaction evaluation for Swissgrid. The most important one is positive participant reaction, as it can encourage learning to occur in training. If a trainee has negative attitude towards training, they could learn very little and potentially affect group learning in a harmful way. Also, trainers can get a sense of whether the training is relevant by knowing trainees' reaction so that they can decide whether to include or improve the activity in future trainings. In addition, participant reaction evaluation can possibly provide understanding for further assessment. For example, a disagreement on the content introduced in training from an operator could be the reason his or her job performance is not improved.

A successful participant reaction evaluation should include questions from three aspects: training content, training delivery, and training support [United Nations Human Settlements Programme, 2012]. Questions on training content should focus on its relevance and value, according to the trainee's feelings. Questions on training delivery should target their attitude towards the way the training has been delivered. Questions on training support should ask how easily trainees felt they could get help during training and the general training atmosphere such as room condition, speakers, etc.

2.5.2 Individual Learning Evaluation

Individual learning is the most crucial part of training. If actual learning never takes place, training can be considered useless and there will be no outcomes. Therefore, evaluation for individual learning is a must for Swissgrid in order to determine how well the knowledge and practices have been transferred. Specifically, quizzes and questionnaires are given for classroom type training which is the most common and efficient way to test knowledge-based objectives. Simulation training evaluation is a very effective way to test skills and knowledge learned from training either individually or as a group.

2.5.3 Job Performance Evaluation

Job performance evaluation plays an essential role in training evaluation because it is the only way to find out if learning has been applied. Just as WPI's motto: "*Lehr und Kunst*" (Theory and Practice), it is necessary to ensure that what is taught is being put into use. Great individual learning does not necessarily guarantee an increase in job performance. Trainees may not necessarily know how to apply what they learned from training, as changing behavioral pattern is a lot more difficult than learning. Therefore, a thorough job performance evaluation can help Swissgrid ensure the link between learning and application.

Interviews and questionnaires are two methods to get employees' feedback on how training affects their work. When developing questions for interviews or questionnaires, they should not be misleading or biased (suggesting one answer is better than the other) so that trainees can provide neutral opinions. Interviews and question-

naires should both be conducted in a relaxed and less formal atmosphere in order to get natural answers out of the trainees. However, the value of information generated from these methods is limited. These methods only provides trainees' opinions which could differ from actual job performance.

Another method is *Job Shadow Performance Testing* [United Nations Human Settlements Programme, 2012]. This test determines how well the trainees remember and apply learning into their daily tasks. An evaluator joins the trainee on-the-job and observes their work before and after the training; then, compares results to look for change in behavior and application of lessons learned. When conducting the test after training, here are some questions worthy to answer [United Nations Human Settlements Programme, 2012]:

- How well does the trainee remember the training?
- How well does the trainee apply learning into work?
- Does the trainee share the learning to colleagues?
- Does the trainee have a plan of action written? Does the plan get implemented during work? How successful it has been? If not, does the trainee give up or modify the learning? And why?

The evaluator will get a good sense on the impact of training by figuring out the answers to these questions. If the evaluator is satisfied with the results, the current training program can potentially remain intact. If little change has occurred on individual job performance level, or learning has not been applied, the trainers

need to investigate the reason rather than feeling disappointed. Potential reasons for this problem are [United Nations Human Settlements Programme, 2012]:

- Trainee may not agree on a new process introduced in training.
- They do not agree that the learning from the training could benefit job and organization performance.
- They do not know how to apply learning.
- The trainers should work together and make adjustments to unexpected job performance.

2.5.4 Learning from Training Outcome

It is very important to learn from the training evaluation in order to guarantee an effective training program. A useful tool is action learning cycle [United Nations Human Settlements Programme, 2012] which has four levels of questions:

- What have we done?
- What happened? What went well? Not so well?
- What new knowledge, ideas, understanding or concepts can we draw from the experience?
- How can we incorporate the learning into our next round of activities?

By using the action learning cycle, the trainers can identify the successful and unsuccessful parts of the training so that the future cycles can be enhanced.

2.6 Knowledge Management

Taking a step back from the specifics of training makes it obvious that training is just a subset of a larger organizational problem: knowledge management. Knowledge in a company is the skills that are needed to run the system based both on an operator's experience as well as required facts and figures. Effectively managing an organization's knowledge is key to making sure that the company is able to compete in the future. Building a knowledge base allows a company to quickly and effectively respond to market change and crisis situations [Irma Becerra-Fernandez, 2008]. Swissgrid's response to crisis situations is essential to the security of the grid and a well implemented knowledge base helps to prevent situations from arising. By building organizational knowledge, mistakes that could impact the security of the grid can be prevented. Also, transferring experiences and best practices among workers are key aspects of applying and accessing knowledge, allowing the organization to operate more efficiently [Handzic, 2004].

A Knowledge Management System (KMS) comprises three core principles: externalization, internalization, and direction [Irma Becerra-Fernandez, 2008]. Externalization turns tacit knowledge into a comprehensible form that others can understand. In other words, turning what someone knows in their head to instructions others can follow. Internalization takes explicit knowledge and turns it into tacit knowledge. How does someone turn the instructions on paper into something they know implicitly and can perform without hesitation? Direction involves guiding another party without transferring the underlying knowledge between the two parties. Operators are not trained on all operations but operators need to be aware of their existence.

Any implemented KMS must help facilitate these three core principles in order to be effective.

2.7 E-learning Platform

According to the article *Choosing An Online Learning Platform: Which Makes Sense?* [Burns, 2014], there are various platforms to consider for E-learning implementations. Now, which one would be good for Swissgrid? As we intend to answer those questions, this article provided us a brief introduction on existing platforms and how they can be effectively incorporated into an industry, giving us a perspective into their possible applicability to Swissgrid.

The most critical pieces of information in choosing an online system are typically the most obvious and overlooked questions: (1) What do you want learners to know and be able to do? (2) What platform can best help them attain these learning goals? There are four options for choosing an online learning platform.

The most common option for teaching online is through a Learning Management System (LMS). A LMS is a software application for the administration, documentation, tracking, reporting and delivery of electronic educational technology (also called e-learning) education courses or training programs [Ellis, 2009]. It is extremely important to choose the LMS carefully and to allow users (teachers and students) — for this case trainers and trainees — to use the system before committing to it. LMSs function as an online classroom where instructors can hold discussions, upload readings, show videos and play audio, carry out learning activities, make announcements,

and assess and grade student work. LMSs store and deliver materials developed in a variety of different formats — everything from documents to videos and third-party applications. They support synchronous (real-time) and asynchronous (not simultaneous) interactions between faculty and students and among students themselves. Online learning management systems can be hosted locally (i.e., kept on a server physically located at an educational institution) or remotely, "in the cloud" wherein the LMS company manages all server-related issues [Ellis, 2009]. Wherever they reside, LMSs demand high-speed connectivity and strong bandwidth [Ellis, 2009]. LMSs also act to augment the lessons the teacher is giving in a brick and mortar environment, not just replace them. This is the sort of platform that Dr. Thilo Krause, professor we interviewed, mentioned that he would like it to be implemented, as he believes it is a great potential platform for his power system students.

Corporate training departments not only use LMSs to deliver online training, but to automate record-keeping and employee registration as well. In addition, LMSs serve many functions, but it is best to think of them as a repository or vehicle for learning, not the learning itself. LMSs lack functionality in the most critical areas of teaching—content and instruction. An LMS does not teach an online course, the instructor does that through the LMS. In this case, Swissgrid needs to take into account their trainers: their availability and willingness are key aspects. They should also be responsible for initially creating, updating, and maintaining the content within the LMS.

Free social media networks can be an alternative to an LMS. Edmodo, for example, is a free educational social networking application. If the idea is to have learners

teaching each other in an open environment (versus the traditional instructor in the "walled garden" of an LMS), this option can be a good way to go. With regards to Swissgrid, operators can discuss among themselves their knowledge, ensuring that they are all at the same page and level of understanding. This could also help stimulate a friendly working environment — while not something they are struggling with, it is good to maintain.

One alternative to the standard online course (via an LMS) or a social networking site is an online conferencing system that allows for webinars and online meetings (web-conferencing applications can also be used together with an LMS). Web conferences mimic the traditional lecture one finds in university or classroom - the instructor can lecture, share notes or a presentation and students can even virtually raise their hands, ask questions, and communicate through voice or chat. The danger here is that unless faculty are highly creative and determined to be different, this can promote very instructor-lead, didactic, lecture-based instruction.

A final option is to use two-way video for one-to-one coaching and tutoring (for example, Microsoft Skype or Google Hangouts). This is an extraordinarily powerful form of online learning because it can provide intensive one-to-one (or one-to-many) instruction and support and make E-learning less impersonal and more face-based. And of course, seeing someone and talking with them one-on-one is very essential to developing rapport — and when online learners develop a rapport with their online instructor they are more likely to persist in an online course of study.

Background research has given us a solid frame for our data analysis. We learned what a TSO is, what its duties are, and the role of an operator in fulfilling those

duties. We gained an understanding of what the minimum requirements of TSO trainings are and the importance of assessing those trainings. Training was put in the grander scope of knowledge management, and how it integrates with the core concepts of a Knowledge Management System. Familiarizing ourselves with those concepts and how they relate helped facilitate our analysis.

Chapter 3

Methodology

In order to evaluate other industry's continuous training practices for applicability at Swissgrid, we first examined how Swissgrid performs training. From there, we compared how other companies perform their continuous training. We did this via in-person interviews wherever possible, using telepresence methods only as a fallback. After that, we reviewed their methods, determined where they differed from training methods at Swissgrid, and assessed whether those differences could be applicable at Swissgrid. We additionally determined why certain methods are useful for teaching different concepts so that we can draw sound conclusions. This was done primarily by interviewing teaching professionals, with additional background research done on specific methods. Finally, we drew conclusions from our data about which methods could potentially improve training at Swissgrid.

3.1 Interviews

We chose in person interviews as our primary research method as it is a very effective method to acquire qualitative answers to our research questions. Interviews allow us to acquire in-depth information about a topic and ask follow up questions since precise wording can be tailored to ambiguous responses and the precise meaning of questions can clarified. The interviewer actually works with the interviewee, which allows for a much more personal touch than a questionnaire or survey. This also gives the interviewee more freedom in their responses: it becomes a conversation about a topic that leads to information that they would not have necessarily divulged through other means. People are more willing to talk to other people — especially about sensitive topics like shortcomings in their activities — than they are to write things down.

Any training methods we looked at had to meet the needs of Swissgrid. As a Transmission System Operator (TSO), Swissgrid has a responsibility to make sure that their employees are well trained, both for safety purposes and to comply with European regulations pertaining to TSOs. Understanding these requirements provides us a context in which to evaluate all other methods. Without this context, we have no way of limiting the scope of our research. We researched this in two ways. We took a tour of the facilities to get an overview of operations and provide us some base knowledge to form further research questions on. Secondly, we met with one of our sponsors to seek answers to those questions. By doing this, we got a thorough understanding of the requirements any potential training solution has to fulfill. The established interview questions used for this project can be found in Appendix A.

3.2 Interview Other Companies

By interviewing representatives from a myriad of companies similar to Swissgrid, we gained concrete information on training methods that could potentially be applicable at Swissgrid. This information is the primary source for our analysis. We selected companies that also operate critical services as these companies have duties similar to Swissgrid and therefore training is most likely performed to meet similar goals. By limiting ourselves to those companies, we made it easy to make direct comparisons to Swissgrid, which improved the quality of our results.

Our industry sources were each chosen due to their involvement in their respective organizations' training operations. Marco Reis is a training specialist at the Distribution System Operator Groupe-e — one of the largest DSOs in Switzerland. They run a control center staffed by operators similar to operators at Swissgrid. Raymond Cettou is an engineer at SIG. SIG is also a DSO, but they are significantly smaller as they exclusively operate in the canton of Geneva. This requires a slightly different approach to training, but should still be relevant to our goals. We spoke with Romain Birbaum, Head of Grid and System Management, about Alpiq's training and interactions with Swissgrid. Alpiq was formed in 2009 by the merger of two smaller DSOs, and is a large multinational power generation and distribution company. Our most directly comparable interview was with Gaznat — one of the largest Swiss natural gas TSOs. Their duties are nearly identical, which suggests that their training needs should be very similar. To confirm this, we spoke with their Head of the Control Center, Pierre-André Rossat. Swiss Federal Railways — usually shortened to SBB CFF FFS — is the corporation responsible for the operation and maintenance

of the Swiss railway system. Not only are they a transportation company with all the duties and operations involved, but they also run a transmission system for their trains, trams, and busses. From SBB CFF FFS, we interviewed Hansruedi Korner, Head of Dispatching, who provided us insight on how SBB's operations somewhat resemble those of a TSO. These companies provided an excellent foundation for further research.

Certain interviews came with the secondary benefit of helping us understand Swissgrid's position in the Swiss power market. They shed light onto the interactions between DSO and TSO and what the implication on training might be. In addition to the aforementioned interviews, we also discussed the topic with our sponsor Patrick Favre-Perrod. Patrick is a professor at HES-SO and has been working with Swissgrid to develop a Certificate of Advanced Studies (CAS) for power system operators. He also works as part of a licensing committee that assures that Swissgrid operators are properly qualified and licensed. Understanding Swissgrid's role in the industry helped us further identify the needs its training must fulfill.

About halfway through the project, our preliminary data looked rather inconclusive. None of the power companies we had spoken to had offered any information on training that was relevant to Swissgrid. These companies do not operate at anywhere near the same scale as a TSO. After speaking with our advisers and sponsors, we decided to expand our scope to include several companies from other industries, as well as some foreign TSOs. One of our team members has some experience with the training programs offered by Juniper Networks, a multinational corporation specializing in enterprise networking equipment. Through a contact at WPI, we were

able to reach out to Dr. Jim Fuller, Sr. Director of Technical Training at Juniper, to discuss their training programs. We had a phone meeting with Ángel Carbonero from the Talent Management Department at Red Eléctrica de España (REE), the Spanish TSO, to discuss their training programs. We conversed via email with Sylvain Rommel (Head of Service Performance) and Laurent Rosseel (Deputy Director) from Réseau de Transport d'Électricité (RTE), the French TSO. Additionally, we had a phone conversation with Glen Boyle, Manager of System Operator Training at PJM Interconnection. PJM is a regional transmission organization (RTO) in the United States, in charge of coordinating the movement of wholesale electricity in various states. These companies were able to give us additional insight on training at companies on a similar scale to Swissgrid.

3.3 Further Research

Once we identified industry training practices and what Swissgrid's requirements are, we needed to analyze the data we collected. A major component of doing that was understanding why certain training methods work for certain content. We researched this topic primarily by conducting interviews with education professionals. Dr. Thilo Krause is a professor at ETH Zurich that teaches Certificate of Advanced Studies (CAS) and Masters of Advanced Studies (MAS) courses in power systems. We interviewed him to find out how he teaches his courses and why he has chosen methods. As a professor at HES-SO specializing in power system operators, Patrick Favre-Perrod was also a reliable source of information. Interviews with professionals

in the education field gave us a better theoretical understanding of training.

Going beyond interviews, we also had to do background research on training techniques. Our interviews are only an hour to ninety minutes, meaning that we have limited time to get information from our subjects. Our subjects are also not native English speakers which can make it hard to convey some of the nuances. Studies like the one documented in *Modeling Training Effects Using a Human Performance Taxonomy* [Meador and Hill, 2011] look specifically at how people learn. By doing further research on the teaching methods discussed in the interviews, we ensured that we have a thorough understanding of teaching processes.

Information retention was another subject that required further research. Several interviewees were concerned about how long an operator retained knowledge after being trained on it. This is a critical factor in how frequently training is performed. If a company finds that operators retain knowledge very well, they could potentially reduce the frequency of training. The inverse is also true: If a company finds that operators do not retain knowledge very well, they can increase the frequency of training or look for other methods to help improve retention. Understanding how certain factors affect the retention of knowledge helped us form recommendations for our conclusion.

Chapter 4

Data and Analysis

4.1 Introduction

As per our methodology, we conducted interviews with training experts at a variety of companies within and outside of the power industry. These companies were: Groupe-e, SIG, Gaznat, Alpiq, PJM, Red Eléctrica de España (REE), Réseau de Transport d'Électricité (RTE), Juniper Networks, and the Swiss Federal Railway (SBB CFF FFS). With this selection of companies, we believe that we have given ourselves a broad view of training and knowledge management practices not only in the power industry, but also in other corporations that have similar roles in providing critical infrastructure as well.

Per the wishes of some of these companies, we anonymized all data in this report. These companies shared detailed, proprietary information on their knowledge management practices, with additional focus on their initial and continuous training

programs. We randomly assigned companies a letter; they will be referred to as Company A through Company I. This protects the reputation of companies involved and allowed us to use the data to its fullest potential.

The information gleaned from our interviews was compared to our information on Swissgrid's knowledge management practices, and evaluated on a chart of organizational knowledge management practices that we are using as our primary evaluation metric. This chart was adapted from *Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues* [Alavi and Leidner, 2001] and demonstrates the components that a complete knowledge management system must contain.

Per our sponsor's wishes and our preliminary research, we targeted several additional topics for research and analysis. Early discussions suggested that the multilingual nature of Switzerland might result in linguistic obstacles in training. Preliminary interviews revealed a potential lack of training assessment and evaluation. Our sponsor was particularly interested in the potential implementation of an exchange program between Swissgrid and other European Transmission System Operators. Our later interviews focused more heavily on these topics in addition to our general questions about knowledge management and training programs.

4.2 Analysis

In this project, we have relied heavily on a textbook entitled *Knowledge Management: An Evolutionary View* [Irma Becerra-Fernandez, 2008]. This book contains a

diagram that very clearly laid out the components of a complete Knowledge Management System, which was adapted from *Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues* [Alavi and Leidner, 2001] . We adapted this diagram for our own purposes, and have used it as our primary metric for comparing Knowledge Management practices.

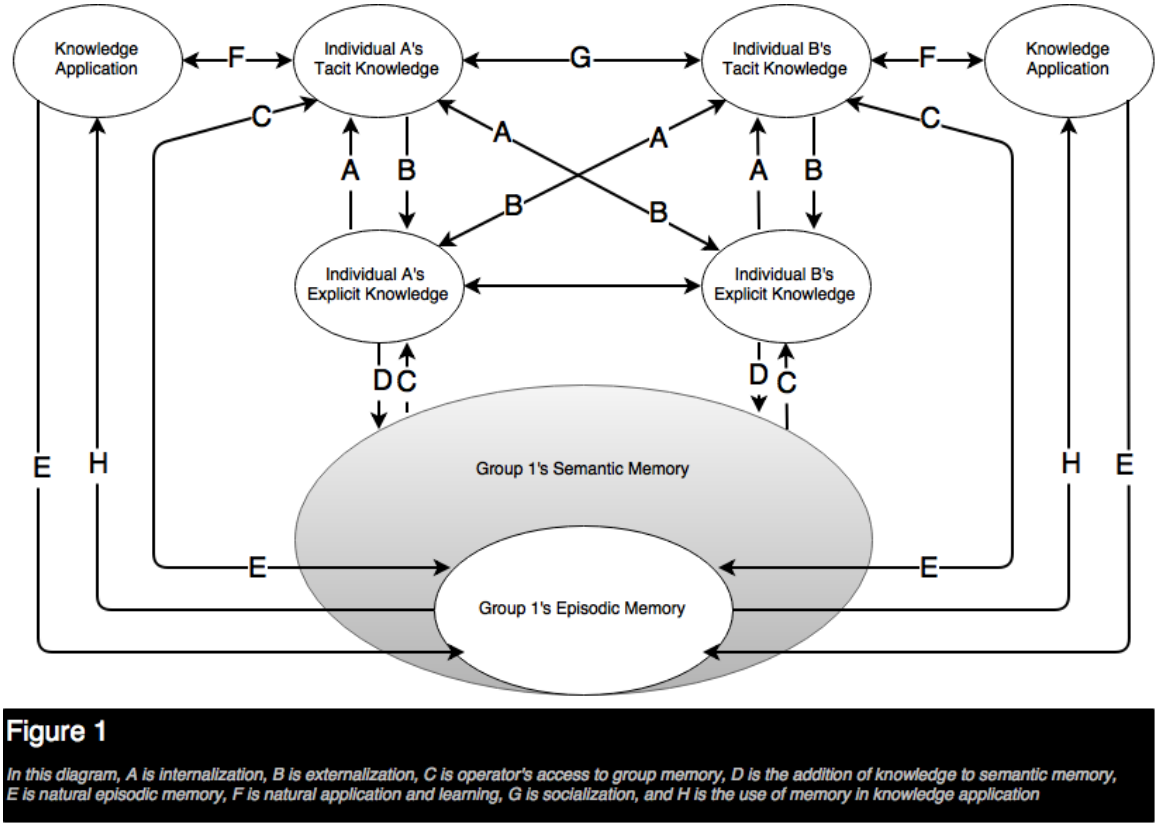

Figure 4.1: Generic Diagram

Figure 4.1 shows how the three processes — *internalization*, *externalization*, and *socialization* — and the two types of knowledge — *tacit* and *explicit* — in an organization interact. The diagram has a number of arrows, each representing a specific

process, and a number of bubbles, each representing a form of knowledge, storage, or application. *Tacit knowledge* is knowledge that is difficult to transfer. It is something an operator knows either from experience or training that can't be simply explained. *Explicit knowledge* is knowledge that can be easily transferred, such as methods and procedures. This type of knowledge can also be easily stored for later retrieval. *Internalization* is the process of how someone converts explicit knowledge into tacit knowledge. Training is the simplest example: the employee turns transferable knowledge like instructions into a deeper understanding of what needs to be done and why. *Externalization* is the process of turning tacit knowledge into explicit knowledge that can be conveyed to others. This is essential for an employee to explain methods or procedures to another person. *Socialization* is how tacit knowledge is shared between two employees. If two employees work together, they can learn from each other without having to externalize, convey, and internalize information. These five concepts form the core of how knowledge is formed, transferred, and managed within an organization.

We evaluated each company's knowledge management practices by determining if each component was present in their practices, and how effective it was relative to other companies. Practices that are present in a company are indicated by black arrows, while practices that are missing are indicated by light gray arrows. In situations where we were unable to ascertain the existence of a practice, the practice is marked with a large unshaded arrow. This gave us an excellent visual representation of the strengths and weaknesses within each company.

4.3 Swissgrid

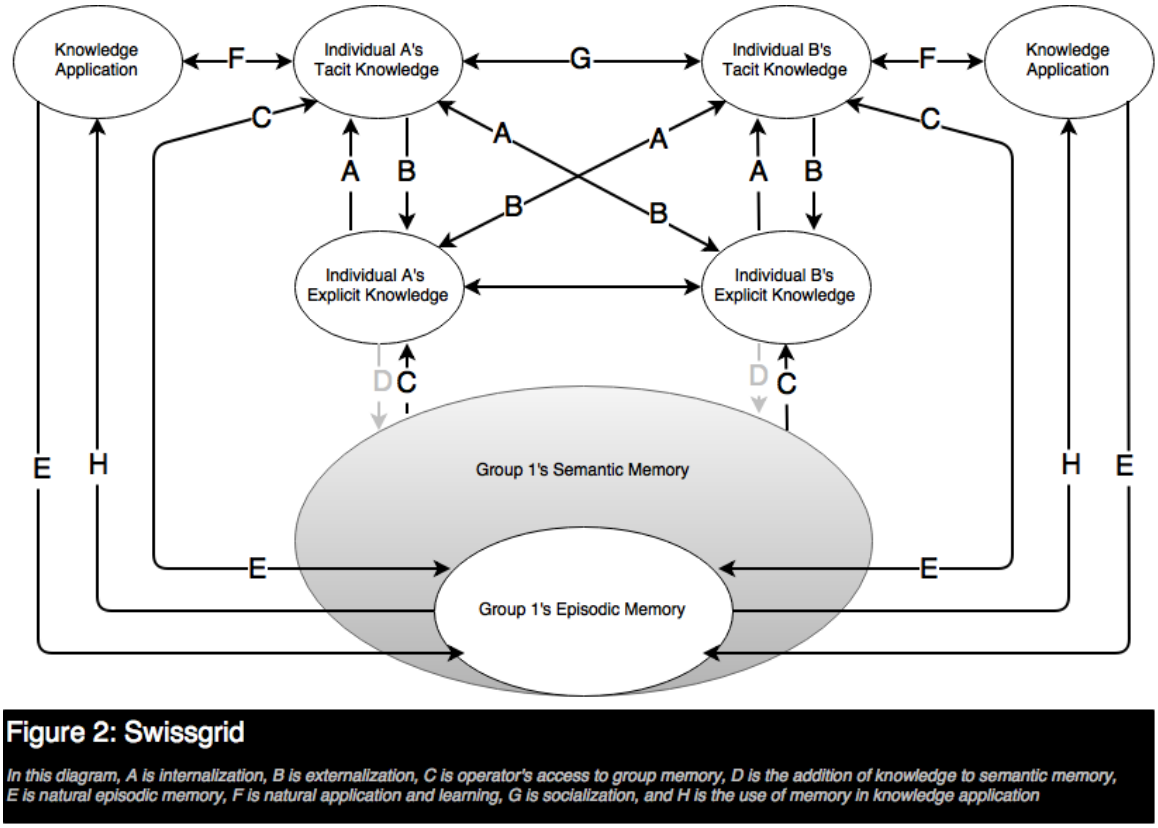

Figure 4.2: Swissgrid Diagram

Swissgrid is our project's sponsor and as such, the primary focus of our research. The company was formed as a part of the liberalization of the European transmission network. As part of ENTSO-E, they are bound by a set of policies, including *Policy 8* which establishes baselines for operator training which are detailed in the Literature Review. Swissgrid's training programs not only meet those requirements, but exceed them in several areas.

Looking at Figure 4.2, one can see that Swissgrid has most processes involved in

knowledge management. Per *Policy-8*, any new operator must undergo a minimum of six months of initial training, including on the job and in simulator training. Swissgrid's initial program consists of a six month theoretical training course, followed by six months of on the job training with an experienced operator. After this training, they are eligible for licensing. The theoretical training course is delivered in cooperation with HES-SO University of Applied Sciences and Arts of Western Switzerland and does not factor into their knowledge management practices. However, the on-the-job training facilitates socialization and the transfer of tacit knowledge from the more experienced operator to the trainee. In addition to the initial training program, *Policy 8* also specifies the implementation of a continuous training program which is to include continuing theoretical training as well as further simulator training. Continuing theoretical training is conducted by the most experienced operators, which allows some operator knowledge to be externalized and then internalized by less experienced operators. The operators have required workshops throughout the year which typically run one or two full days, followed by a day of simulator training. The materials from these trainings are also archived online, storing them in the group semantic memory. These archived trainings are available online to all operators, along with plentiful documentation.

One major component that is missing from Swissgrid's knowledge management is a way for operators to store their explicit knowledge (Arrow D, Figure 4.2). An operator that is working as a trainer can externalize their knowledge for trainings, and then those trainings become part of the group semantic memory. Operators that do not act as trainers have no such method. This is a crucial part of knowledge

management, without which, an operator has no way of sharing their knowledge other than explaining it face-to-face, and no way of storing it for posterity. This is one of the issues we address in our recommendations.

4.4 Company A

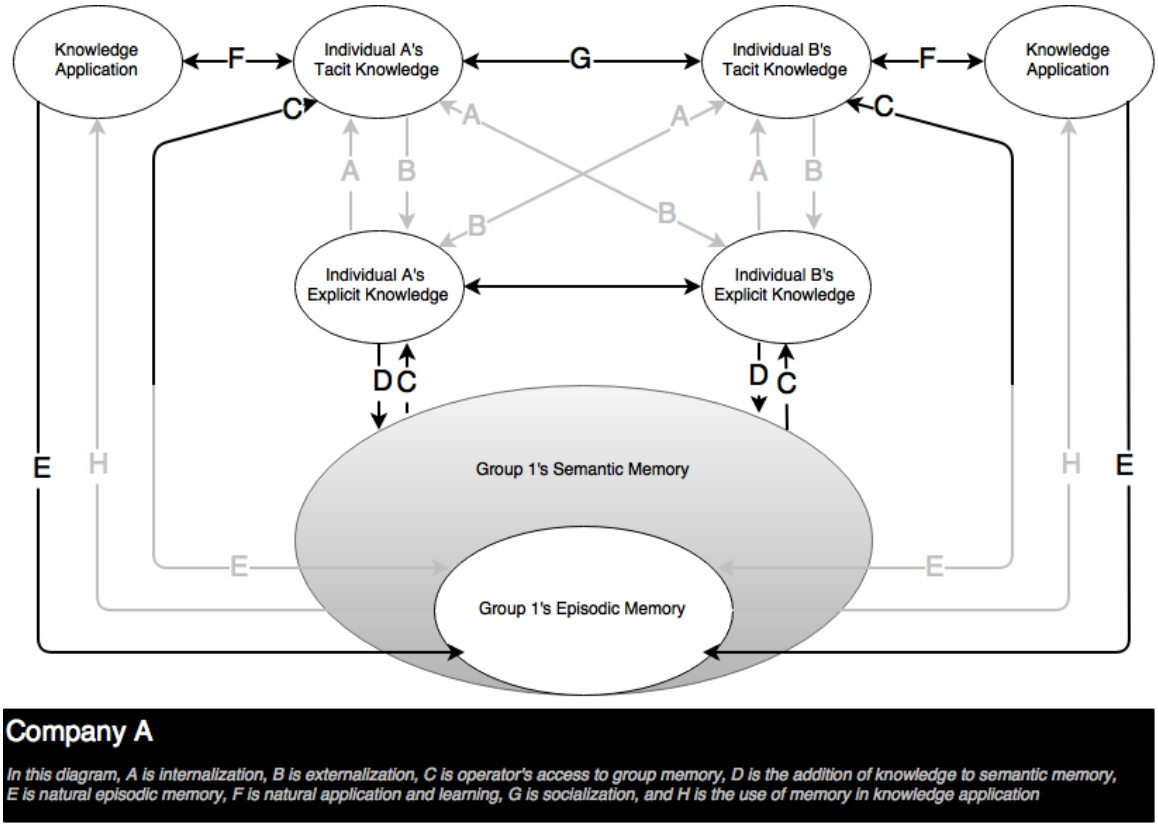

Figure 4.3: Company A Diagram

Company A operates in the energy industry. Their operators start as apprentices and learn a trade, after which they can begin working as back office operations support. During their time in the back office, they help with inspections and travel

to facilities to examine the equipment. This gives them an understanding of the system they will be operating. They are given initial instruction on how to perform system procedures and proper usage of the software systems at their disposal, after which they are allowed to work in the control room. There is no licensing process and no continuous training is given. Operators have access to a knowledge base — which serves as group semantic memory — of facts and procedures which they can draw from in their work. They have no ability to put their own knowledge into the knowledge base, limiting their ability to share their experiences with their fellow operators. Company A has a rather small staff of operators: only four people are in charge of operating the system 24/7, which somewhat mitigates the lack of structured training.

4.5 Company B

Company B is another company in the power industry we interviewed with. Operators are given an initial training that is specifically tailored to their existing knowledge, after which they are certified to work in the control room. Unlike other companies we interviewed with, operators at Company B are less technical. Instead, they rely on on-call engineers in the case of major system malfunctions. The operators are expected to provide customer support outside of normal business hours. This leads to their training programs being less technical and more tailored towards customer support and communications. Trainings are given in person, and are supplemented with simulations when needed. Operators have access to an inter-

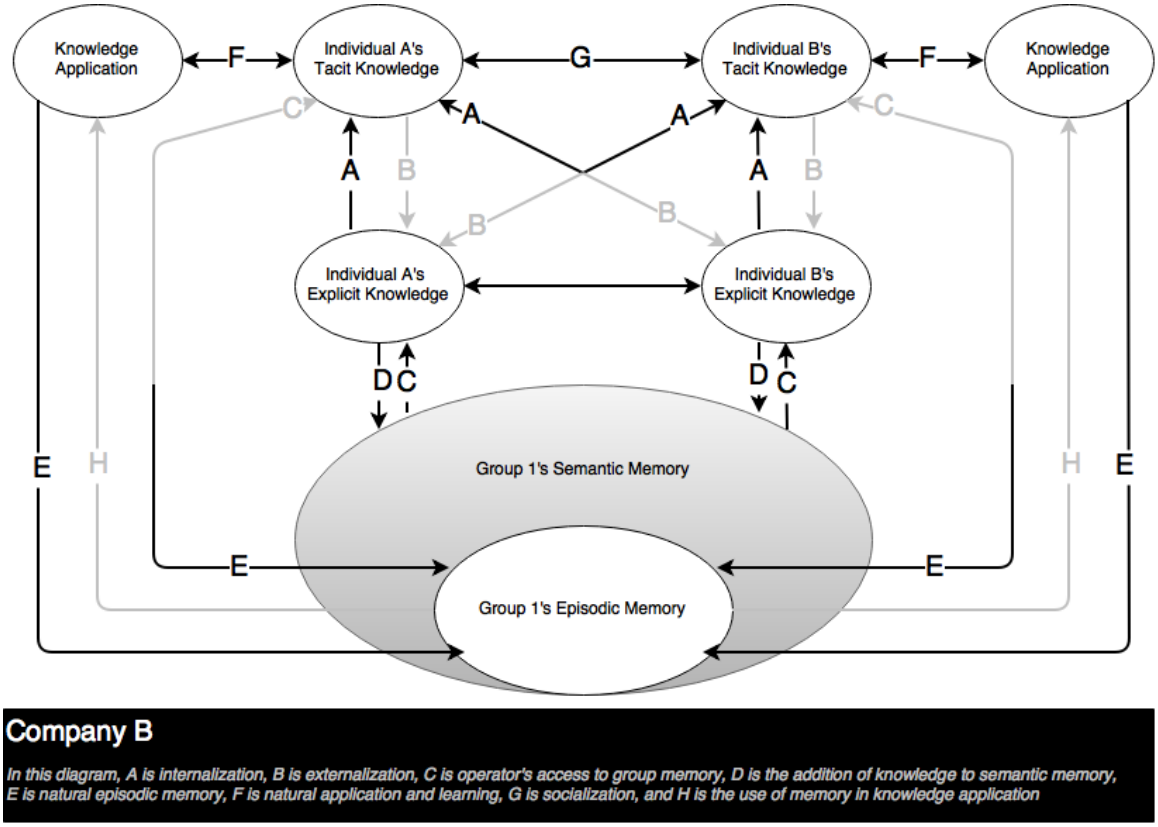

Figure 4.4: Company B Diagram

nal knowledge base that contains system schematics and figures, giving them access to the group semantic memory. Because of the factual nature of the knowledge base, operators do not have a need to be able to input information into it; engineers are responsible for updates. Company B — like Company A — has a very small staff of operators, with only 8 at the time of writing.

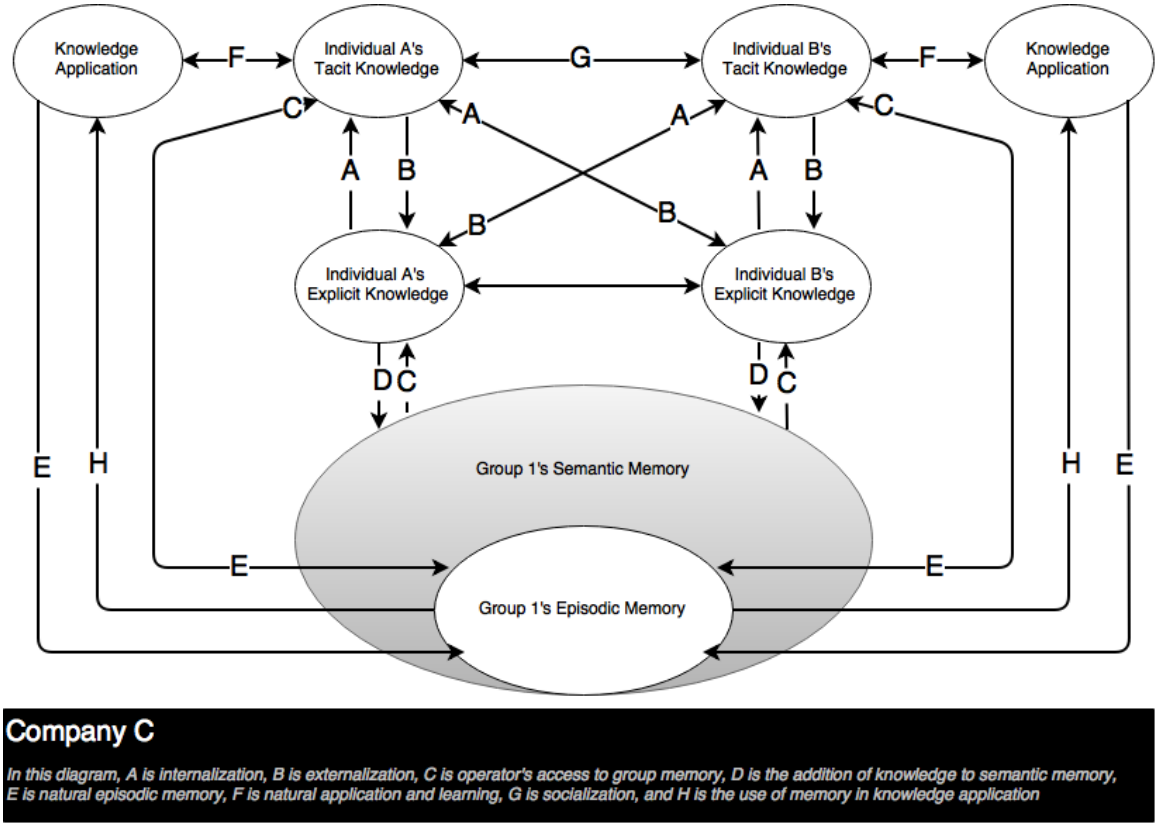

Figure 4.5: Company C Diagram

4.6 Company C

Company C had the most robust knowledge management system of any of the companies we interviewed. Like Swissgrid, they are bound by policy that defines minimum training requirements. Company C's training is designed systematically; each job is defined in terms of the tasks a person in that position is responsible for performing. These tasks are analyzed in terms of required tools, how often they need to be performed, and how critical they are. New operators are trained specifically for all of the tasks they will be performing. This training is delivered in a myriad of

ways, including self-study courses, simulator training, and on the job training. After they have completed their training, operators get certified to work in the system. Certifications must be renewed every three years; this is done by accumulating 200 continuing training hours over the three year period. Continuing training occurs on a rotation with six teams of operators (around 60 operators total), so every operator spends one week out of every six weeks in training. This is repeated on a cycle 8 times per year, so each operator spends 8 weeks per year in training. Content for continuous training varies by cycle, with some cycles repeated yearly due to their critical nature. These training weeks are comprised of two days of lectures, eight hours of online training, and a full day of simulator training. This ends up being around 150 hours of training per operator per year, or about 450 hours over three years (far more than the mandatory 200 hours required to renew a certification).

Company C evaluates their training programs quite rigorously. Every class includes a testing portion and each online module includes a multiple choice quiz. Simulation sessions are evaluated by trainers and operators are scored based on performance. These evaluations showed that the material was learned, but later quizzing revealed that operators tended to forget a lot of what was covered in training only a few weeks after. In an attempt to combat this, Company C implemented an interval learning program using a tool called Axonify.

Interval learning or spaced repetition is the process of repeating information at regular intervals to ensure long-term retention. Axonify is a platform that is designed to turn the interval learning process into a game, thus increasing participation and simplifying implementation. Company C simply has to maintain a collection of

questions, and the platform quizzes operators. If an operator has an issue with a particular question or topic, it comes up more frequently, and if they answer a question correctly, it will appear less frequently. Using this method, Company C has seen a 15% increase in retention among operators that use it. Unfortunately, they are struggling somewhat with participation. Only about half of their staff of operators are using the platform and they are attempting to increase that without making the program mandatory. That being said, other than the participation issues, Company C is very happy with the program.

Company C also has a very thorough knowledge base that operators can both access and add to. This is drastically different from most other companies we have talked to, where the operators are exclusively users of the knowledge base. The knowledge base is split into two parts: one is a library of archived trainings that are not editable, but are a resource that operators can draw from, while the other is operator maintained. They can post procedures and other information for all other operators to view. This gives operators a way to contribute to the group semantic memory, which is an important part of knowledge management.

4.7 Company D

Company D is yet another company in the power industry we interviewed. Like Company A, Company D does not have a continuous training program, instead relying on extensive initial training and a thorough knowledge base integrated into their control systems. Initial training covers all procedures and tools needed to

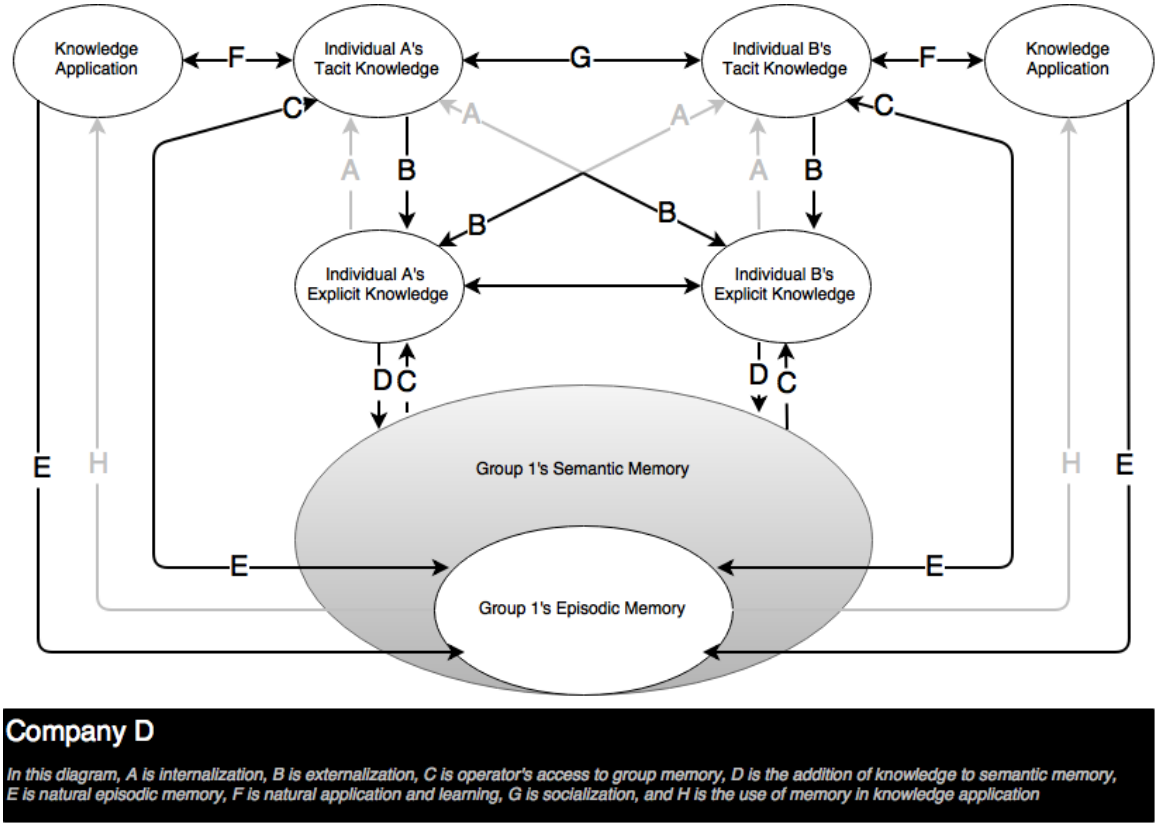

Figure 4.6: Company D Diagram

operate the system. Any updates that need to be made are put in the knowledge base and critical updates are made via email. The knowledge base is maintained by back office staff, who are also responsible for email updates. Company D has a small operations staff, around 13 operators, which seems to negate the lack of continuous training programs.

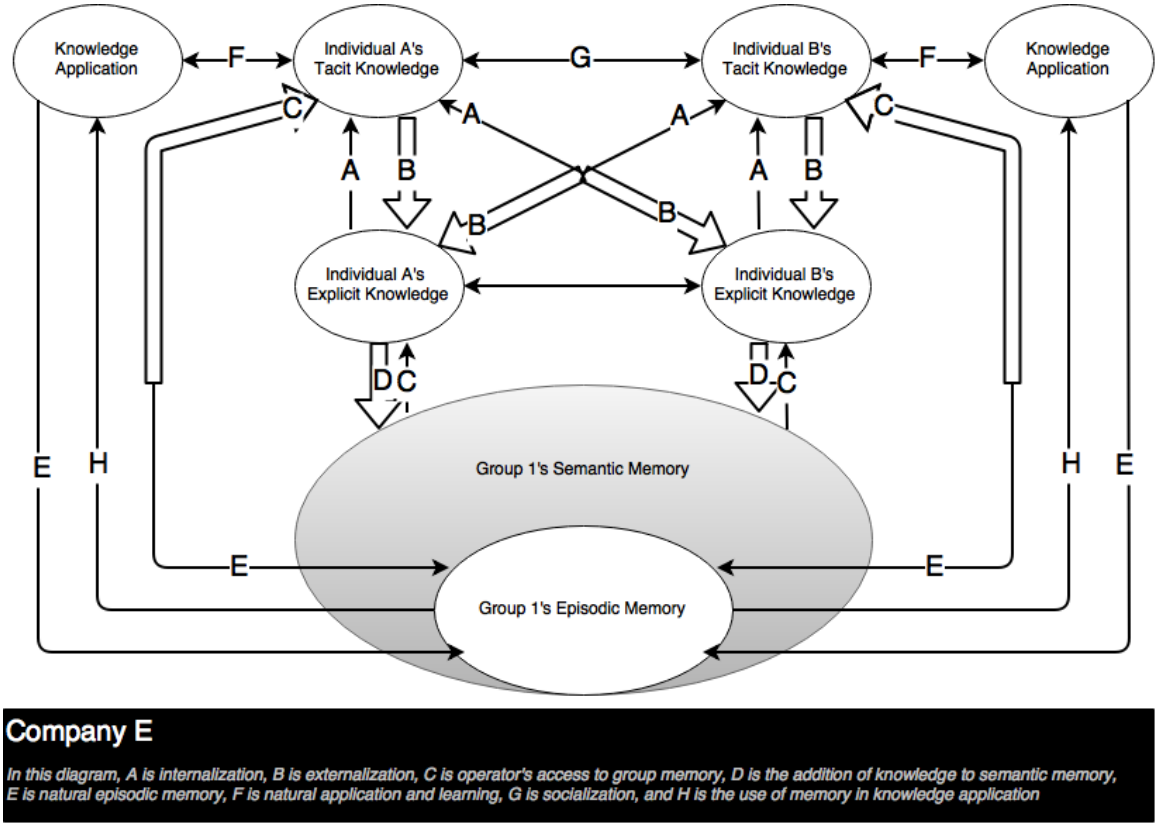

Figure 4.7: Company E Diagram

4.8 Company E

We spoke with Company E over the phone, and due to connection issues and a language barrier, we were unable to ascertain certain information about their knowledge management procedures. Knowledge management components we are unclear on are indicated by the large unshaded arrows. Company E's operators are given an extensive initial training that lasts about 8 months, and includes a certificate program at a local university on electrical engineering, extensive simulator training, and a month of on the job training with another operator. After initial training, they are

given a test and if they pass, they are licensed to operate the systems. Continuous training takes place twice a year, in two week-long sessions. One session takes place in a simulator, where operators have to practice tasks like system restoration. The other session reviews system operation, including essential skills, control systems, and other tools at the operator's disposal. Some basic information is covered in online modules. If they pass both sessions, their license remains valid and they are able to continue working as an operator. All documentation and trainings are stored in a centralized knowledge base, which operators have access to. We do not know if operators have the ability to put their own knowledge into the knowledge base.

4.9 Company F

Company F is quite new to conducting their own operations, having only started in 2014. Previously, they worked and trained with a larger company, but with changing regulations, they were required to separate operations. As such, their training programs are still undergoing development. When an operator is recruited, they undergo 6 months of initial training, followed by an evaluation period where they work under the supervision of an experienced operator. This component of training is important, because it allows for the socialization component of knowledge management to take place, as operators normally work in the control room alone. Company F does not perform any other testing or licensing as a part of their training. Operators go to a simulator facility for training exercises once or twice a year, but other continuous training is not performed. This has not been a significant issue as

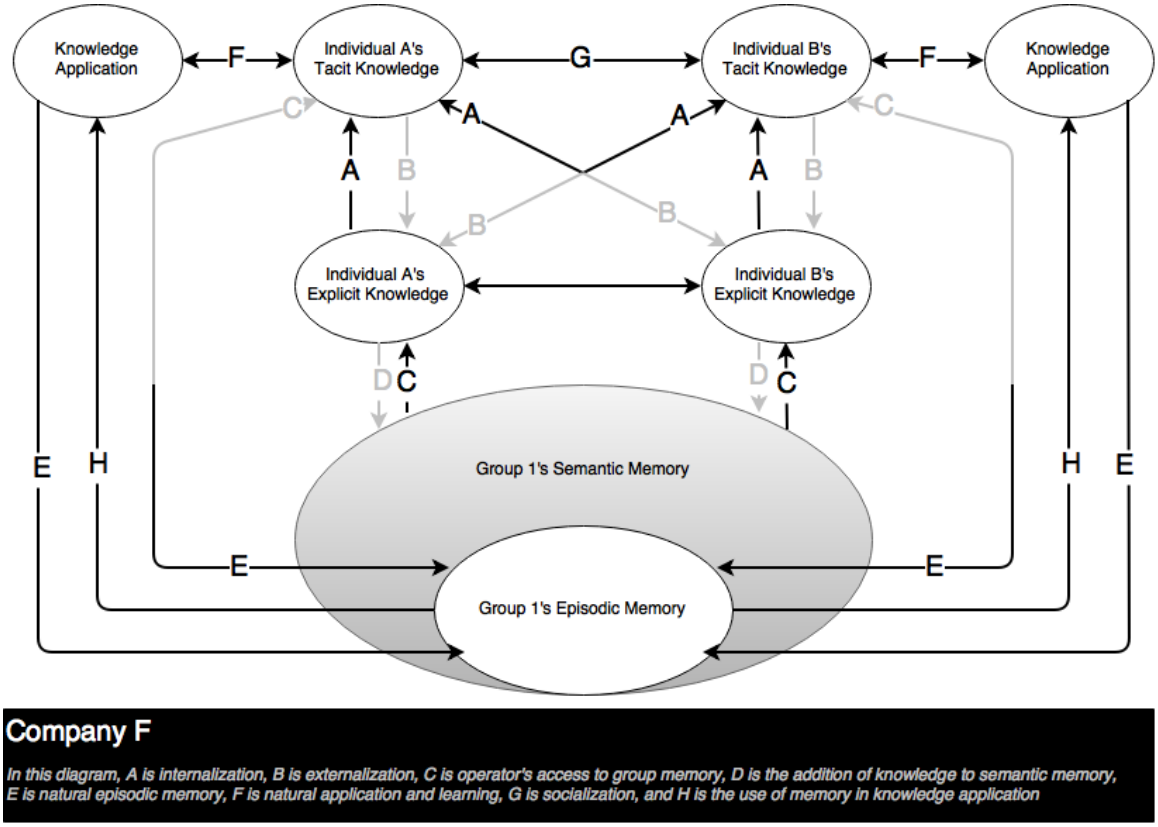

Figure 4.8: Company F Diagram

unlike other companies, being an operator at Company F is usually not a long term position. Operators frequently move to another position in the company after a few years.

4.10 Company G

Company G is another company we interviewed over the phone, and our call was once again subject to technical issues. This company is somewhat different from our other interviewees in that they have training programs for their customers, as well

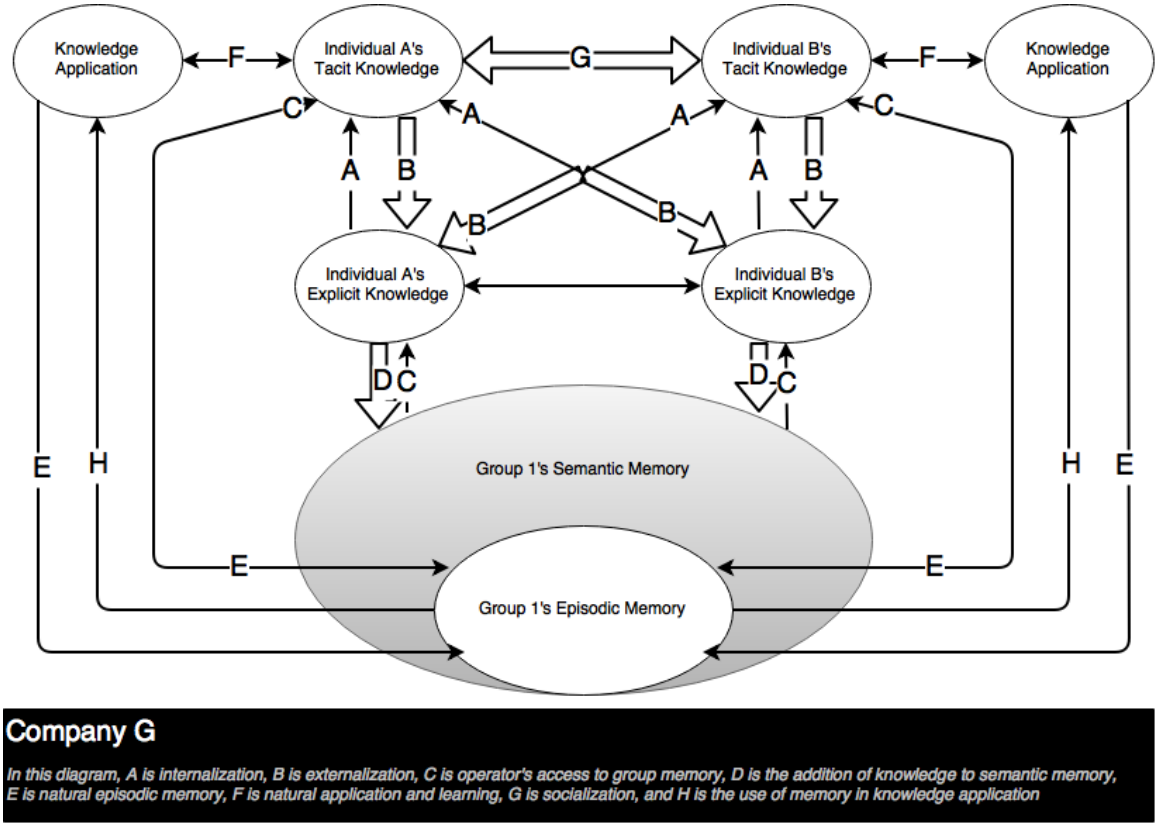

Figure 4.9: Company G Diagram

as their own employees. As such, Company G devotes a large number of resources and staff to training. When speaking with Company G, we focused mostly on how their employees were trained as it is more relevant to Swissgrid. When an employee is first hired, they undergo a training program during the first year. Once initial training is completed, employees have twice yearly meetings with their managers where employee goals are reviewed and training programs are designed to meet those goals. Technical training is offered in four levels and is specific to the segment of the company the employee is working in. The training is provided in three primary

ways: lectures, labs, and online modules. Online modules are delivered by a custom platform that Company G has developed.

4.11 Company H

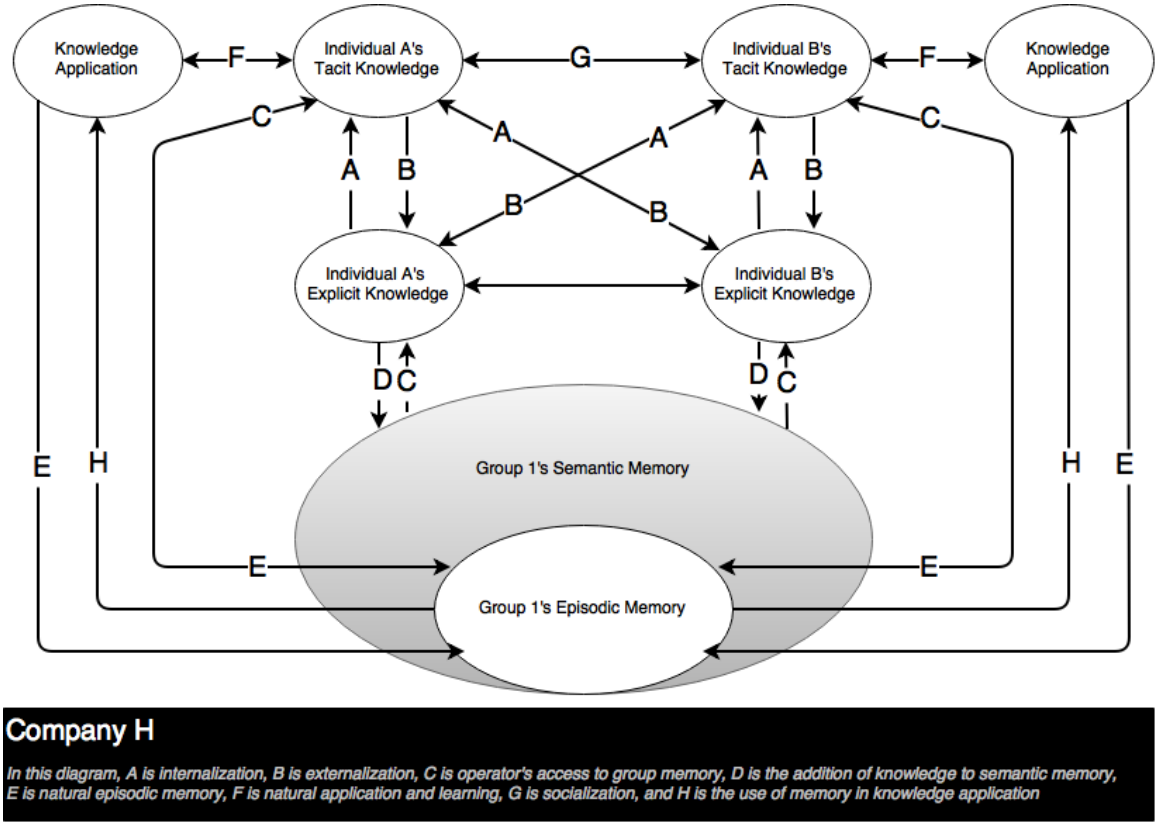

Figure 4.10: Company H Diagram

Company H was one of the final companies we interviewed. They are somewhat new to the implementation of continuous training, and as such their program is not fully established. They have mostly designed the program, and are in the process of implementing it. Currently, they have a very extensive initial training program

that brings a new operator up to speed over the course of a year, which is followed by two months of working alongside an experienced operator. Company H has two operator roles, and while an operator eventually learns both roles, they start out in the lower-stress role so that they can become acquainted with the environment. After some time working in the first role, they begin learning the second role. Once they are fully versed in both positions, they switch between the two on a monthly basis. Each component of Company H's operations has a set of documentation available both in print and electronically. This information is validated and updated every 3-5 years by the operators. During this procedure, operators have the option to add their own knowledge about the system to the documentation.

4.12 Company I

Due to scheduling conflicts, we were unable to meet or call Company I. Instead, we corresponded via email and got answers to our interview questions. Like several other companies we have talked with, they are bound by regulations on their training programs. At Company I, training is split up between a centralized department responsible for the training of all employees at the company and local training at each operations center. Initial training is specialized to the operator's position, which includes both theoretical parts as well as several weeks of simulator training. After initial training is completed, operators are able to work on a provisional basis under direct supervision. This allows trainers to evaluate their progress and determine what additional topics need reinforcement. These topics are addressed during several

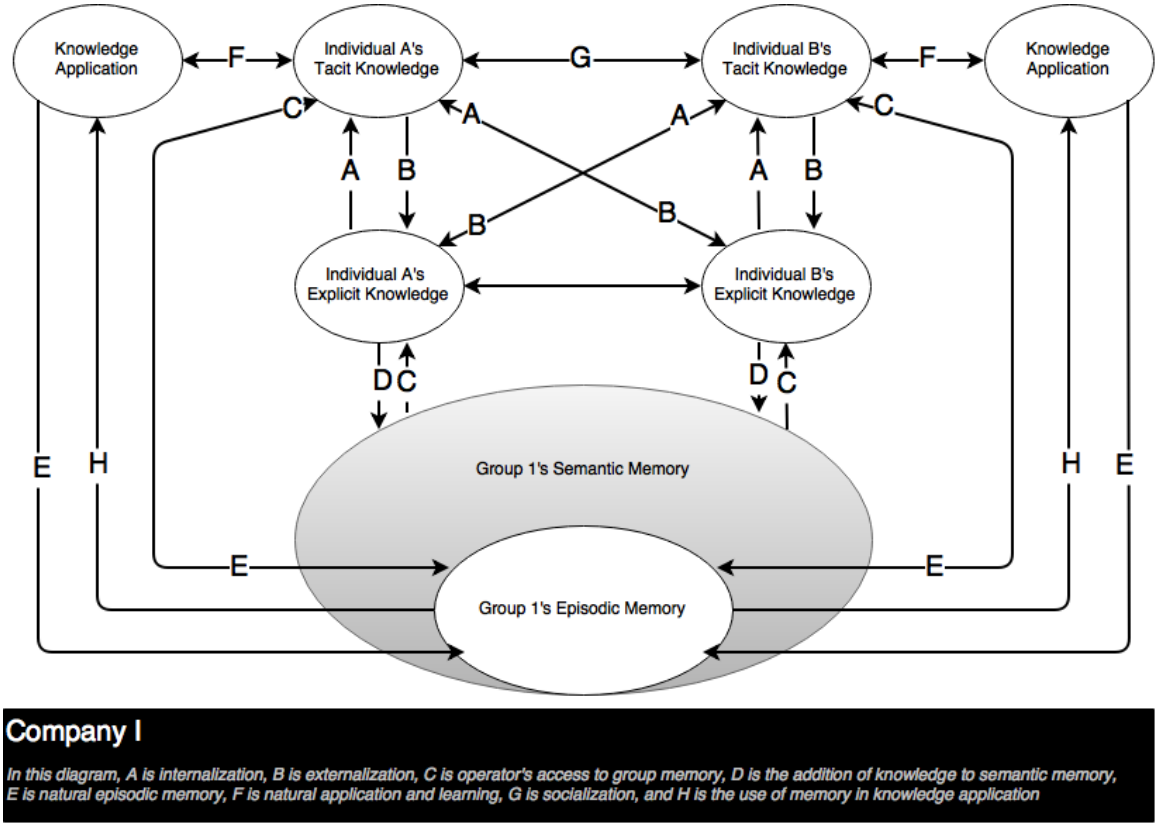

Figure 4.11: Company I Diagram

months of on the job training, after which a second evaluation is performed and the operator is licensed. Several mandatory continuous training courses are given every year, which an operator must attend to keep their certification. Training materials are archived alongside their knowledge management system. The knowledge base is split, part of it is specifically for training documents and the other part was described as a "sharing site" that all operators have access to.

4.13 Trends

Looking at the data from these different companies, several trends start to emerge. Some of these are unsurprising due to the nature of our interviewees, but several of them were more than a little shocking. The biggest indicator of how thorough knowledge management practices were at these companies was the number of operators they employed. Companies with less than a dozen operators tended to have a much more laid back approach to training and knowledge management in general, whereas companies with more operators tended to have more rigorous practices.

Every company we spoke with had some form of knowledge base, which makes sense: a company with more than a few employees can not run effectively without some place to store information. The major differentiating factor in these systems was whether operators had the ability to contribute to the knowledge base, or were strictly users. In a complete knowledge management system, operators must have the ability to share their own explicit knowledge with the semantic memory stored in the knowledge base. If this is not possible, the company risks serious knowledge loss when an operator moves from the job or retires. This is a facet of knowledge management that is missing in Swissgrid's current practices, and should be addressed.

Almost every company we spoke to had a fairly extensive initial training program. It usually covered both technical and operational topics, and was often a part of a certification program. The only company that had no standardized initial training program was Company A. Instead of training, they relied on an operator's apprenticeship with the company and on the job knowledge transfer. While this certainly would not work with a company like Swissgrid with its large operator staff, it has

been working out fairly well for Company A as they only employ 4 operators at any time. Initial training does not appear to be an issue at Swissgrid; they have a CAS program with HES-SO that is extremely thorough and a minimum period of 6 months spent with an experienced operator.

One negative trend we noticed that is not really conveyed by the diagram is a lack of retention evaluation. Every company we spoke to with a continuous training program had some sort of quiz or exam at the end of a class, but almost none of them have a way of evaluating how long their operators hold onto that knowledge. This is a topic that was not even brought up in our earlier interviews, but was heavily emphasized by Company C. They started evaluating how well their operators retained information learned in trainings, and noticed that a lot of information was lost as quickly as two weeks after a training session. To combat this, Company C introduced an interval learning program based on Axonify, and have since seen a 15% increase in retention compared to those not using the program. We believe that interval learning could potentially be a valuable tool for Swissgrid as it not only helps to increase retention, but the results could be used to improve their continuous training programs.

Continuous training practices were somewhat diverse in their frequency. Out of the nine companies we interviewed, two did not have continuous training programs and saw no particular need to implement one. Out of the other seven companies the frequency varied a lot, even among similar companies. Some companies performed training on a yearly basis, Company C performed training every 6 weeks, Company B performed training “as-needed”, decided by their trainers. During interviews, none

of our interviewees were able to explain the motivation behind training schedule, unless it was dictated by a policy. The results from an interval learning program as described in the previous paragraph could be used to measure the effect of training intervals on operator learning and retention, thus allowing Swissgrid to optimize the frequency of their training.

One thing that was mentioned a few times in our early interviews was E-learning as a tool for continuous training. This is something our sponsor Antonios expressed deep interest in as well. We tailored several questions in our later interviews towards E-learning practices. We found that many companies did not employ E-learning in their continuous training. Those that did employ it used it exclusively for training on topics that the operators had been previously trained on. Company C and Company G have both invested time into optimizing their platforms based on their training needs.

Current continuous training at Swissgrid is done in multiple sections due to operators working multiple in multiple 8 hour shifts. All operators can not possibly attend a single training session as at least one team has to be working at all time. This is tedious for the organizers and trainers, who need to teach the same material two or three times to ensure everyone sees it. Swissgrid could easily use E-learning to reduce the amount of time trainers need to spend teaching and allow operators to study theoretical content when it is more convenient for them. An E-learning platform also gives trainers another way to evaluate how well operators are learning the content.

4.14 Improving Training Assessment

We adapted our knowledge management diagram for Swissgrid and labeled how its various continuous training methods impact knowledge transfer, as well as the potential loss of knowledge over time. In Figure 4.12, we color coded each arrow based on the method used. Blue is accomplished by lecture-style training, Purple is done by simulation training. Red is natural application and learning which is not done by any particular training but by the operators themselves. Green is the loss of knowledge over time, and Orange is the potential for memory to be regained through interval learning.

Looking at Figure 4.12, one can see Swissgrid already employs exams and feedback for lecture training, and simulator training is a way to evaluate the application of knowledge, but they lack qualitative assessment for simulator training. They also do not have any way to measure how long operators retain what they have learned. Operator retention is critical in emergency scenarios where lives might be on the line and operators can not waste precious seconds researching a procedure. Current Swissgrid simulator training is graded on a pass/fail basis. By developing a further set of metrics to assess operator performance in the simulator, operators could receive additional review on topics they struggled with, improving the effectiveness of training. Company C solved this issue by scoring operator performance in the simulator. A similar method might work for Swissgrid. Additionally, after-action meetings can be very useful by giving operators immediate feedback on their performance.

Similar in nature to simulation evaluation is *Job Shadow Performance Testing* [United Nations Human Settlements Programme, 2012]. Essentially, an operator is

surreptitiously evaluated by a trainer before and after training, to determine what if any effect the training had on the operator's daily activities. This gives the trainer a better understanding on how the operator absorbed information and potentially how well the operator retained said information. The trainer could then use his improved understanding to assign additional review work for the operator, or modify their own lectures to better fit the needs of operators.

Operator knowledge retention was an interesting topic for us, because it was brought up by Company C about halfway though our project. Our contact indicated that operator retention was an issue that they solved by adding an interval learning course. Their course identified which operators struggled with which concepts and gave them further review questions to compensate. It also provided trainers with feedback on this process, allowing trainers to further improve their courses. For Company C, interval learning was both the assessment and the solution in one package.

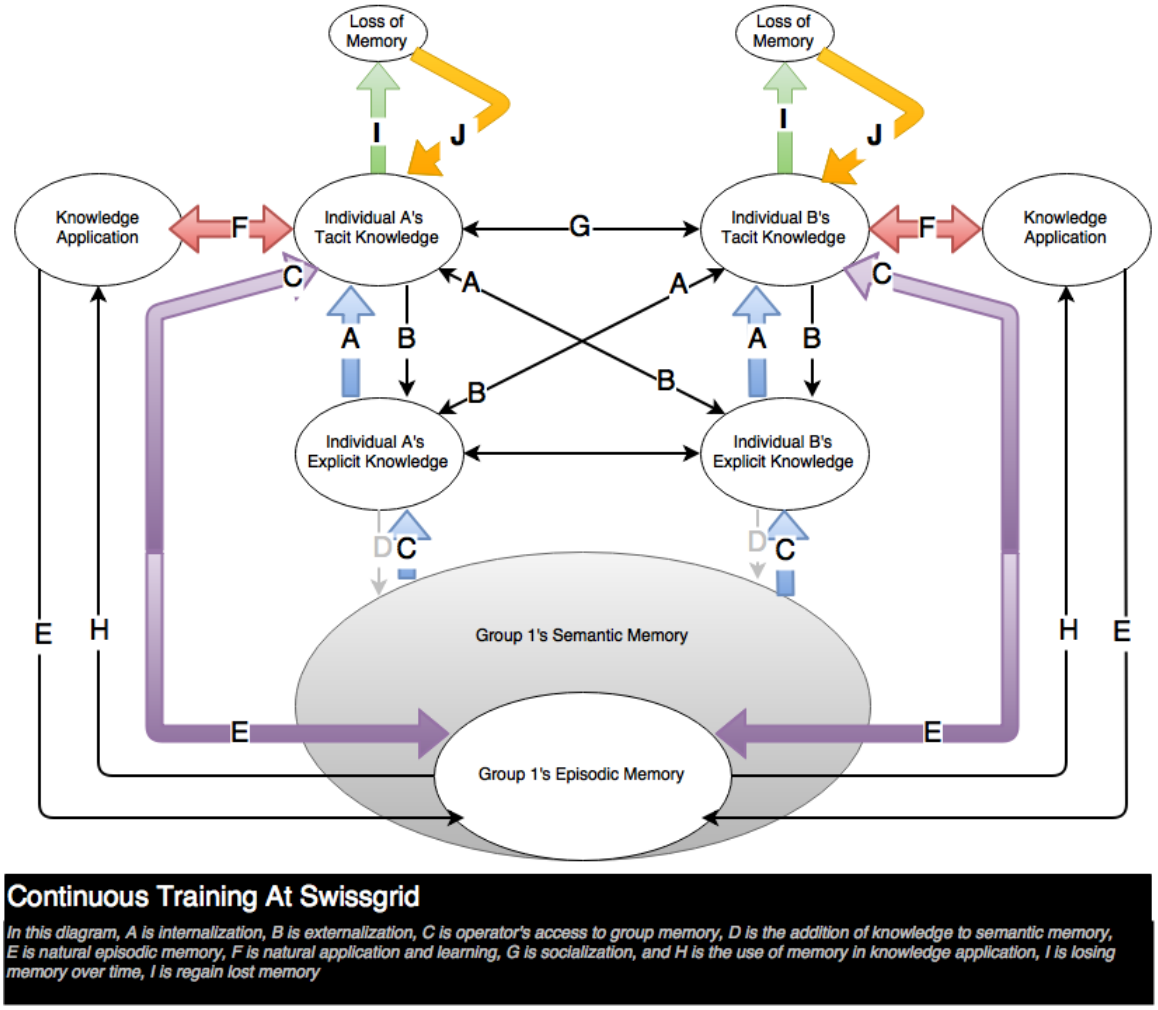

Figure 4.12: Swissgrid Training Methods

Chapter 5

Conclusions and Recommendations

After conducting research on continuous training and knowledge management practices in companies inside and outside of power industry, we came to the conclusion that Swissgrid's current continuous training program for operators and knowledge management system are sufficiently effective. However, we identified some potential improvements for Swissgrid, and synthesized several recommendations on how they can be implemented.

5.1 Conclusion

Swissgrid's current continuous training programs should satisfy the growing needs of Swissgrid's grid operation. Operators are well trained in grid operations and are fully able to complete their assigned duties. The training program meets all the requirements defined by ENTSO-E *Policy 8*. Operator training programs are well structured and more thorough than most similar companies. The training schedule

is rigorous and learning objectives are well defined. There is an evaluation program to back up training and measures individual learning. Their yearly job reviews ensure operators meet license renewal requirements and gauge needs for training. Swissgrid's knowledge management system works sufficiently within the organization. Knowledge can be stored and flow in most directions if needed.

Despite Swissgrid's well established training program and knowledge management system for operator training, we identified several potential improvements based on our research. Implementing an E-Learning platform could help make current training programs more efficient and potentially alleviate some of the burden of running multiple trainings on every topic. It could also include interval learning to increase operator retention. A more thorough evaluation system could gauge the efficiency of current training program from more perspectives and help indicate further improvements. Applying a method for increasing the knowledge retention of operators in the training program could help individual learning in the long term. Swissgrid's current knowledge management system could be improved by implementing a method for operator knowledge to be introduced to the semantic memory base so that potential knowledge loss can be avoided when an operator retires.

5.2 Recommendations

5.2.1 E-learning

An E-learning platform could be a great tool for conducting certain operational training at Swissgrid. It could help solve one of their main issues with regards to

gathering all the operators together in one place in order to provide them their required training. With this platform, each operator can learn from their location at a time convenient to them. Additionally, an E-learning platform allows for trainer-trainee interaction and interactive questions and answers. Online testing is another of its benefits. This is not only a more environmentally friendly option - as it avoids for the need of papers and pencil as currently done - but allows for faster and easier results of training assessment. The initial application of this E-learning platform may seem tedious as it requires time, dedication to content creation, and getting workers transitioned to it, but once it is applied and "people get used to it", it becomes a feasible way to conducting operational training.

5.2.2 Training Assessment

We recommend that Swissgrid implement metrics for simulation training assessment. Some form of scorecard could be used for evaluating individual operator performance. In addition, after-action discussions can provide operators a chance to communicate and receive immediate feedback on their performance.

A *Job Shadow Performance Test* allows a better evaluation of an operator's job performance. Changes in behavior resulted from the training can be detected by performing this test. Further investigation of the test outcome can allow Swissgrid to identify the transition between learning and application for operators.

Figuring out a way to evaluate operators' retention will allow trainers to identify topics that need to be reintroduced or reviewed by the operators in order to refresh their memory. This assessment can be integrated into the E-learning platform if

Swissgrid implements one in the future.

5.2.3 Knowledge Management System

Current knowledge management practices at Swissgrid could be improved by setting aside time outside the control room to review and or update documentation and procedures in the knowledge base. Other Swissgrid knowledge practices are either sufficient, or improved in other sections of our recommendations. By giving operators a set time to work with data and materials they use, they are able to ensure that practices are efficiently explained and methods/figures are up to date. Additionally, this helps prevent the issue of loss of operator knowledge when an experienced operator leaves the company, as they would have been updating the knowledge base with their knowledge before they depart. How much time they spend in the office working on knowledge maintenance would have to be determined by Swissgrid, to ensure that they did not spend too much time away from their primary operations tasks. Other companies we interviewed with that employed this technique usually had their operators spend 2-3 hours per week on knowledge maintenance.

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Appendix A

Interview Questions for Companies

Below is the full list of questions we used during our interviews. We included a brief introduction at the beginning of the interview describing why we were interviewing them.

We are conducting a project for Swissgrid concerning their continuing training programs and knowledge management systems. From our understanding, your company operates critical services and conducts continuing employee training. We intend to learn about your training procedures and knowledge management.

Questions for Interview

Continuous training program

1. Is there any continuous training program applied to your organization? Could you give us a brief description of the program?

2. What kinds of contents (for example, policies, procedures, facts, etc.) do you train on?

3. Does the type of content being trained affect the methods of training used or is the training conducted the same way regardless of content?

4. Are there features of your continuous training program that you are proud of that could be a model for other organizations?

5. Do you use an E-learning platform for training (both initial and continuous)?

   (a) If so, what program?

   (b) How effective is it in comparison to non-online training?

   (c) Is there any method to assure retention?

Training Results Evaluation

1. Are there participant/operator reaction evaluations? An evaluation asks how trainees like the training?

2. How is individual learning evaluation performed?

3. Is there job performance evaluation? How is it conducted to find behavior changes from work resulted from training?

4. How do you test retention of each operator? Is there any way to maintain individual knowledge?

Knowledge Management System

1. How do you handle loss of knowledge when an experienced employee leaves?
2. Do you have a centralized knowledge management system?
   (a) How do workers have access to it and interact with the content?
   (b) Is your KMS integrated with training or are they two separate resources?
3. Is there any content that they are not currently trained on, and if so, how are the methods transferred between employees?
4. Is there a way for operators to put their own individual knowledge into the system?

Operator Exchange Program

1. Have you ever implemented exchange or training programs with other companies? If so how did you do it?

Is there anything about continuing training and knowledge management that we haven't asked that you believe is useful for us to know?

Appendix B

Interview Questions for Thilo Krause

Below is the full list of questions we used during our interview with Thilo Krause. We included a brief introduction at the beginning of the interview describing why we were interviewing them.

As we mentioned in our email, we are conducting a project for Swissgrid concerning their continuing training programs and knowledge management systems. We believe that talking to you will help us understand effective education programs that are applicable to operators. We will proceed to questions.

- How long have you been teaching?
- What experience do you have with continuing education?
- Tell us about your teaching methods with regards to operators.

  - What has been successful, what has not?
  - Are power systems courses taught differently from other classes?
  - How have classes on power systems changed during your tenure with ETH? In terms of content and techniques.
  - Are there particular topics you find more challenging to teach to participants?

- What are some teaching tools or techniques that you want to explore or may be useful?
  - Which ones seem good but fail in practice?
- Does education happen in various languages?
  - How do participants from different language backgrounds interact with each other?
  - Say someone who solely knows French with someone who solely knows German.
- Is there a difference when providing continuing education to those of more experienced than those who are new?
- Different methods for trainers than for normal employees?
- Knowledge management
  - We can tell him we want to do research in knowledge management and ask him how often his courses are updated and how they are updated?

- What are the methods for KM of his courses? e.g. books? archives?

Is there anything about continuing education that we havent asked that you believe is useful for us to know?