Reorganization of KM-Oriented Medium Voltage Power System Planning Process

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Abstract**—**The planning of medium voltage power systems has been so far carried out in a limited way. Apart from the purely technical aspects, other issues as relevant as the task of planning must be identified and defined. The methods currently available are based solely on mathematical principles and computational techniques applied to the schematic representation of power systems. The organization of the planning process proposed here stems from a cognitive approach that associates intrinsic knowledge with planning activities and other relevant aspects. A description of the organization of the planning process is preliminary presented so that the other aspects inherent to this activity are identified. From a systemic perspective, the re-organization of the planning process is proposed taking its efficacy into account. Finally, the reorganization of the planning process is evaluated so that its properties are identified along with its efficiency. Undoubtedly, the planning of medium voltage power systems requires improvement. The optimization of this process transcends classical and purely technical problems with power systems, which leads us to propose a reorganization of the planning process, focusing on knowledge management (KM) as the main paradigm of investigation.

Keywords-Process Management; Planning of Power Systems; Knowledge Management

I. INTRODUCTION

This paper discusses the planning of electric power distribution systems, more specifically the planning of a medium voltage distribution system. The re-organization of this planning process based on knowledge management is the main purpose of this study.

The Brazilian national electric power industry has been considered one of the best in the world in terms of reliability and operational costs [1]. With some rare exceptions, the electrical power distribution system has always presented supply quality levels compatible with those demanded from the consumer market.

In general, the interconnected system receives the energy generated by hydroelectric, eolic and thermal plants. The whole process occurs in accordance with rules established by various regulating agencies. In this context, Agência Nacional de Energia Elétrica – ANEEL [National Agency for Electrical Energy] has as a mission to provide favorable conditions so that the electrical energy market develops in a sustained and balanced way among its agents and for the benefit of society [2].

The electrical power system consists of three interconnected components, each one with very distinct features: generation, transmission and distribution. The distribution systems, so called due to the fact they operate on voltage equal to or lower than 138 kV, distribute energy to all classes of consuming clients.

In accordance with PRODIST [3] the distribution system can be classified as: High Voltage Distribution System (HVDS) with nominal voltage between 138 kV and 69 kV; Medium Voltage Distribution System (MVDS) with nominal voltage between 13.8 kV and 34.5 kV; and Low Voltage Distribution System (LVDS) with nominal voltage between 440 Volts and 110 Volts. The distribution systems are interconnected by means of distribution substations (DSs) which aim to transfer vast amounts of power at more adequate voltage levels to distribution in accordance with urban specificities. Fig. 1 displays an electric power distribution system.

The MVDS, a primary network segment in Fig. 1, aims to supply electric power from the DSs to low and medium voltage clients, which include large companies, industries, commercial clients and residences located in the rural and urban areas. This preliminary study focuses exclusively on the planning of a MVDS.

It is argued here that the planning activities carried out by electric utilities need improvement, since there are difficulties in meeting regulatory goals concerning supply quality problems and in justifying investments. Ultimately, a planning activity requires approaches suitable for the scientific paradigms that support the management processes of modern organizations.

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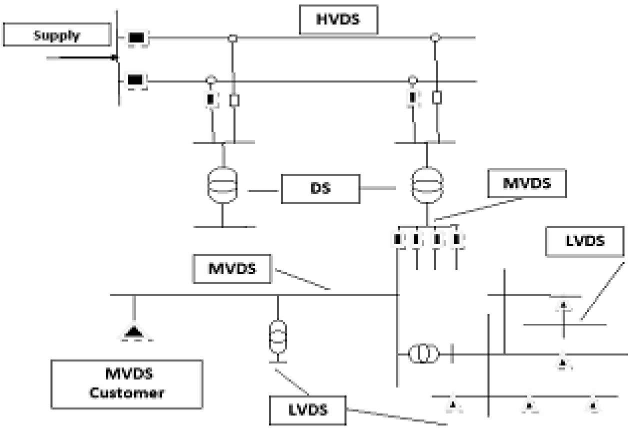

Figure 1. Representation of an electric power distribution system.

In this context, it is important to highlight that the organizations that make use of old-fashioned paradigms show organizational deficiencies in which the main reasons can be [4]:

- Lack of focus on the client;
- Lack of clear, well-defined and disseminated objectives and concepts;
- Processes and activities are not registered or optimized;
- Professionals who do not know the organization's role and do not participate of processes, actions and solutions to problems;
- Lack of ways to constantly measure and evaluate the processes.

Although there are good prospects for the quality of electricity supply in relation to a medium voltage distribution system, there is much to be done in terms of improving the planning process:

a) operationally, long and successive energy supply interruptions and problems of voltage regulation occur in MVDSs and LVDSs, resulting in damages and regulatory fees. Additionally, these problems detract the company's image in a significant way.

b) tactically, organizational problems associated with indefinite processes often occur. There is some difficulty in integrating and standardizing procedures and Technologies.

c) strategically, planning experts are questioned about their reasons for technical alternatives and requests for resources, which are not convincingly justified. There is much uncertainty and generally decision-makers, who act strategically, do not obtain the necessary information to make effective decisions due to lack of appropriate computational tools and processes.

From a historical perspective, investments have not followed the demands for market expansion. In addition, experts face difficulties in articulating good investment justifications; the regulatory rigor is strong; financial resources are short; consumer market is demanding; ultimately, decision-makers need to know the organizational processes, that is, they need knowledge. It is believed that these issues would be attended to if a reorganization of the MVDS planning process was effectively implemented and supported by appropriate knowledge management.

In line with [23], R$ 75 million was spent nationwide on fines resulting from problems of power quality supply between 2008 and 2009. Furthermore, it is highlighted that some electric utility companies going in the opposite direction of the regulatory framework signal an investment reduction, which implies a risk to distributors. ANEEL shows that investments must be justified and when approved they must be carried out in their integrity under penalty of the utility companies being discounted in the next tariff cycles [23].

In order to acquire a real picture of this process, in 2009, CELESC Distribution S.A., a state electric power distribution company in Santa Catarina state, provided electric power to approximately 2,256,178 consumers and invested more than R$ 66 million in LVDS and MVDS distribution networks [21].

In order to stay competitive in the market, the electricity distribution companies need systematically develop an investment plan consistent with reality. Technical data, information about electric systems and the market, ultimately, knowledge of this process is indispensable. In this sense, [18] affirm that within information economy, pivotal knowledge-based competencies represent the organization's greatest asset. Knowing how to do things effectively is the greatest differentiator of success.

Another fundamental aspect when organizational issues are discussed has to do with the need to evaluate all the component parts of a process from various points of view. According to [24], systems thinking enables professionals to understand that a process consists of parts dependent on the whole and that these parts should not be analyzed in isolation. Systems thinking leads us to always evaluate the whole, considering the other disciplines of which it is comprised.

In Sections 2 and 3, the current process of planning a power system is presented along with a brief introduction to knowledge management connected with the systems view, which is an intrinsic foundation to the study being developed. In Sections 4 and 5, the reorganization of the planning process is proposed with a view to knowledge management. Finally, conclusions and recommendations are offered.

II. The Current MVDS Planning Process

Organizational efficiency has been an object of research due to its relevance to the economic context. Production with the highest possible quality and lower costs is the goal of any company that intends to stay competitive in the market.

According to [13], as large companies perceive that one of the greatest competitive advantages of organizations is the production of intangible assets, knowledge of business processes becomes increasingly critical. In [12] view, these processes represent to modern organizations the essence to enable their existence, especially when the analysis of an organization emphasizes the evaluation of its processes and not only the results of these processes.

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Still according to [13], much of the literature defines a process as a set of sequential tasks that receive input, process value-adding functions, and provide customers with a product or service. Therefore, an organization has within itself a set of processes that constitute it, and some processes can be more efficient and effective than others.

With a vast bibliography, the planning of distribution systems counts on a set of methods and computational techniques that have been developed for decades. Module 2, which refers to the PRODIST, establishes the guidelines for the expansion planning of the distribution system. Either for a regulatory or financial reason, the level of demand increasingly imposes that electric utility companies continue to improve their results.

Along with [11], the expansion planning of distribution systems consists of proposing, analyzing and selecting expansion alternatives to meet the increasing demand, respecting guidelines, restrictions and the criteria for the quality of electric power supply. The lower cost alternatives, which meet the established criteria, are selected and integrated into a work plan for the study period here established.

Generally speaking, the planning of distribution systems can be understood as follows [10]: Be it a distribution system meeting the demands of an electric power market comprised of consumers. The demand associated with electric power consumption is dynamic and varies in space and time. The increase of demand requires the expansion of the distribution system that can be translated in general lines by the following actions: build substations, increase the capacity of transformation, build new lines and/or change lines (i.e. reconducting). Develop a work plan taking into account network operation costs, and at the same time meeting a set of regulatory, economic and operational restrictions constitutes a planning problem.

Various studies have dedicated to the analysis of distribution network planning ([14][15][16][20]). Most of these studies, however, have an exclusive focus on the development of mathematical and algorithmic models based on schematic representations of a power system, which by considering restrictions and technical criteria enable experts to propose solutions to the identified problems. The search of an "optimal solution" is always a goal to be reached; however, the kinds of work to be carried out are selected most of the time by considering planning experts' knowledge and intuitions.

The MVDS planning is carried out considering five years of annual periodicity. The following study year receives special attention from experts. Additionally, from a purely technical perspective, experts consider the demand forecast, criteria and studies on planning, in accordance with the procedures set out in PRODIST.

More specifically, the MVDS planning has been carried out along with electric utility companies in a matrix and analytical way. Generally, the experts identify the technical problems, analyze information and after technical discussions with experts from other areas that integrate the electric power distribution system, power flow studies are carried out. According to the available budget, computational tools and mathematical methods for analysis of variables, works with the best cost-benefit ratios are prioritized.

Fig. 2 illustrates the procedures for the MVDS planning carried out along with electric power utility distribution companies.

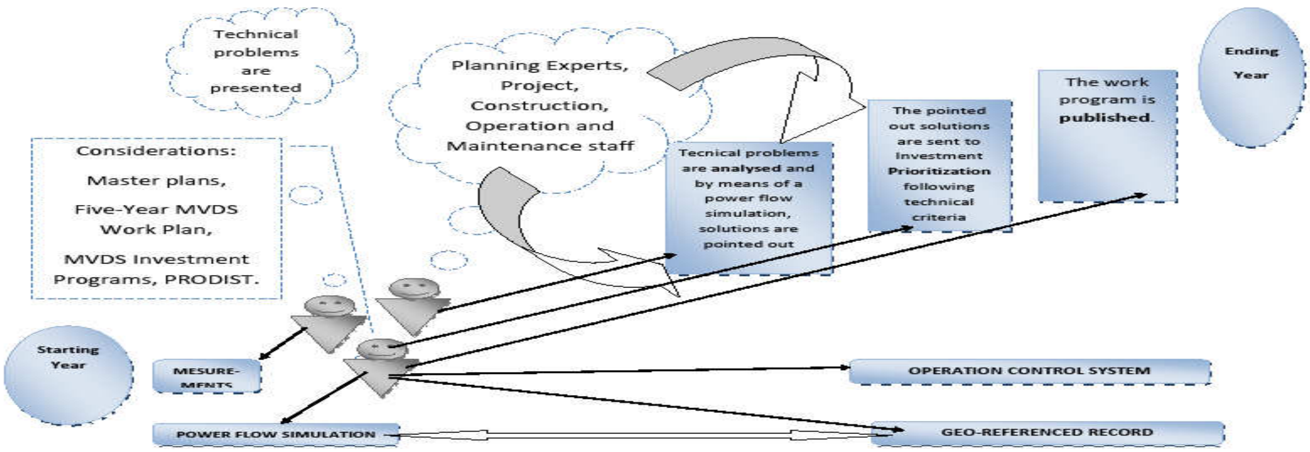

Figure 2. Representation of the current MVDS planning process.

Evaluating the current planning process (Fig. 2), some relevant issues can be identified as follows:

a) There is no distinction as to task execution. The identification of problems, development of studies and choice of alternatives are not realized in a structured way;

b) Studies are carried out, but there is no register of problems, studies and alternatives in a computational environment.

c) Conceptual indefinitions make it difficult to categorize problems, technical solutions and classify investments;

d) There is no structured register of studies, consequently, there is no management of the studies carried out, making it difficult to improve the process;

e) The problems are not well-defined and there are no systems to facilitate the composition of precise diagnosis as well as adequate solutions, considering the other points of view that integrate the MVDS technical problems.

Still in relation to Fig. 2, it is possible to observe that the planning procedure is carried out annually. Alternative-oriented studies are carried out, but they are not recorded in a computational environment. The computational tools are specific for the optimization and they are not integrated into a management environment.

Planning depends on other factors. The mathematical procedures currently diffused and associated with computational tools are not sufficient for the planning composition to propitiate an investment plan that is really efficient and consistent with reality.

The management of works, the supervision of the power system according to its dynamics, consensus in the selection of concepts for the identification of technical problems, structured record of proceedings, the diagnosis, and definition of problem-solution patterns; ultimately, all kinds of knowledge related to planning development are relevant for an efficient work plan to occur.

In line with [8], one of the most difficult things to be understood at present is the fact that if we do something that is good, continue to do that does not necessarily mean to get the best solution. In other words, companies cling to the paradigms that have kept them alive until the present time, safe in the knowledge that this will enable them to face new market challenges, especially competition increment and regulatory scrutiny.

III. KNOWLEDGE MANAGEMENT (KM)

In the mid-90's, knowledge management emerged as a key concept to organizations, as the basic economic resource was no longer the capital, but knowledge [9].

For Rodrigues and Helena [22], knowledge society is based on the value of intangible assets, which makes it imperative for companies to focus on knowledge management. Companies must also create ways to accumulate intangible assets, produce knowledge, transfer it, and also recognize the kind of knowledge that adds value to the company. In this scenario, organizational and entrepreneurial management must comprehend the concept of knowledge and make an effort to structure all the necessary activities to deal with the organization's intangible assets. It is, then, essential to understand how knowledge is built.

According to [19], there are two types of knowledge: tacit knowledge and explicit knowledge. Tacit and subjective knowledge kinds of knowledge are skills inherent to a person. It is a system of ideas, perception, experience that is difficult to be formalized, transferred and explained to another person. Explicit knowledge, on the other hand, is relatively easy to codify, transfer and re-utilize, as it is formalized in texts, graphs, tables, figures, drawings, schematic representations, diagrams, etc, which are easily organized in data banks and general publications either in hardcopy or electronic format.

In accordance with [25], an adequate experience of KM systematization must consider that knowledge exists in two formats: (i) people's mind and (ii) various kinds of records; therefore, information technology has a relevant part on KM, which involves its formalization, refinement and sharing. According to [19], there are four modes of knowledge conversion: (i) socialization (from tacit knowledge of an individual to another); (ii) externalization (from tacit knowledge to explicit knowledge); (iii) combination (from explicit knowledge of an individual to a group) and (iv) internalization (from explicit knowledge to tacit knowledge).

Nevertheless, implementing knowledge management requires cultural change. Apart from recognizing knowledge as an object of inestimable value, experts still need to perceive all aspects related to the vital processes of organizations. In this sense, a systemic approach stands out among others due to its peculiar ubiquity and synthesis. In view of the complexities involved, understanding the whole through a systemic approach is indispensable [6].

In this context, two postulates [6] can be highlighted:

1) Everything that exists at an abstract or concrete level is systems, components or potential components of a system; and

2) A system must be understood as a set of interconnected components that relate to each other in order to achieve a purpose.

Seen as a system, an organization can be evaluated as a system consisting of various subsystems. It can also be highlighted that systems as well as complex problems should not be analyzed in isolation as the whole is always larger than a sum of its components and presents a systemic characteristic that its components do not have [6].

Moreover, [5] explains that in any field of knowledge current problems have become very complex; solutions require interdisciplinary and systemic approaches. Like other systemic authors, [5] also warns that problems should be analyzed in isolation as specific parts of a process does not enable us to know effectively a process or complex problem. Nevertheless, if the set of components of a system and the relationship between them are known, then high levels of understanding are obtained by means of the systems [5].

Therefore, by analogy it is assumed that the process consist of components, have specific functions and systemic features. The organizational change with a view to knowledge management presupposes a systemic approach.

An interesting approach is still proposed by [7], focusing on the model and systems description. According to this proposal any system can be structured in accordance with the following attributes:

1) Composition: collection of component elements;

2) Environment: collection of items that are not part of a system, but act or suffer an action of any component;

3) Structure: collection of links between components and between these and other Items of the environment;

4) Mechanism: collection of processes that generate qualitative novelty, that is, they promote and obstruct transformations causing the emergency or submersion of the system or any of its properties.

Table1 shows some examples of CESM models, which can be natural, social, technical or mixed.

TABLE I. EXAMPLES OF CESM MODELS IN EXISTING SYSTEMS. SOURCE BASED ON BUNGE (2000)

System	C Composition	E Environment	S Structure	M Mechanism
Atom	Associated particles and fields comprising an atom.	Things (particles and fields) with which an atom interacts.	The fields that keep an atom together with environment items.	Processes of emission and absorption of light, combination, etc.
Company	Personnel and Management.	Market and government.	Work relationships between company members and between members and environment.	Activities that result in company products.
Solar System	Sun, planets and asteroids.	Milky Way Galaxy and other universe celestial bodies.	Gravitational forces.	Translational motion of components in orbits that enable the continuity of a system (with no dispersion or collapse) due to inertia.

According to this model, any system can be represented so that its relevant features are described. The technical properties as well as functions, combined with the description of components, structures, environments and mechanisms of the system, provide effective knowledge and enable to evaluate the capacity of the system to keep its basic properties or even (sub)emerge.

By analogy, as long as evaluation processes are understood as systems, a complete evaluation of the proposed system in accordance with the CESM model can be carried out [7]. Concomitantly to this approach, explanations related to the properties of the system associated with its mechanisms can qualify the efficiency of the proposed reorganization process.

IV. REORGANIZATION OF THE MVDS PLANNING PROCESS

As occurs in most Brazilian companies in the electricity distribution sector, CELESC Distribuição S.A. decentralized its operations to optimize the achievement of their business goals. Each of these operating units, located in regions with distinct cultural characteristics, has developed particular ways of interpreting, therefore achieving those goals, the same occurring with the planning process for the SDMT. Reflecting that unique circumstance, the company created an organizational culture that, according to [26], allowed to adjust its operations as a small business, even in the case of a large corporation. On the other hand, it made implementing corporate solutions difficult, damaging the company's organization and appropriateness to the interests of the regulator (ANEEL), in particular the question of the planning process that could no longer fulfill its role.

Consistent with [27], processes must be defined and modeled concurrently to the human tasks. The process should also consider the underlying infrastructure of the organization considering the interface with users so that interactive tasks can be defined and created.

Most importantly, the planning process is crucial to the business of an electric power distribution company, and the reorganization of the planning process-oriented knowledge management is recommended.

A KM-oriented reorganization of a planning process presupposes the restructuring of a system that has knowledge as its main paradigm. Therefore, the reorganization of a planning process starts to be understood as a system with its respective components, structure, environment and mechanisms that relate between themselves in order to achieve its purposes [7].

It is important to identify the intrinsic knowledge related to the planning system and its respective components before proposing a new MVDS planning process.

Evaluating the planning process by means of a systemic approach and identifying components individually without losing track of the system as a whole. The following dimensions are highlighted:

1) People have competencies and attributions; the ability to properly plan depends directly on the experts who need motivation, continuous training and evaluation of the results of their work;

2) The process consists of activities and tasks in accordance with norms, instructions and a timetable; in addition to the planning process itself, other processes must be structured in order of formalization, implementation, refinement and dissemination of knowledge;

3) The technology consists of methods and techniques that are most of the time used by means of computational tools; emphasizing that the knowledge employed by the planning process requires a transactional and knowledge systems, which are essential tools to keep track of the work and search for better investment alternatives respectively.

In an individualized way, components and their respective main attributes are highlighted in terms of the three aforementioned dimensions.

TABLE II. SYSTEMIC VIEW OF THE MVDS PLANNING SYSTEM.

Dimensions	MVDS Planning System	
	Components	Attributes
People	experts, engineers, managers and directors	motivation, tacit knowledge, explicit knowledge, attributions and established functions
Process	activities, tasks	PRODIST, planning instruction, budget, master plan, environment norms, calculation of losses, specific resolutions, technical notes
Technology	computational tools, computational agents	optimization methods, prioritization techniques, techniques for evaluation and market projection, artificial intelligence, knowledge agents, ontologies, data warehouse, transactional computer systems, knowledge systems

Table 2 shows that the planning system consists of the following components: experts, engineers, managers, directors, activities, tasks, computational tools and knowledge agents. For each of these components, their respective attributes are observed.

It is highlighted that an adequate planning presupposes the development of a work plan optimized and consonant with budget restrictions. Moreover, the planning shall consider federal, state and municipal norms and carry out studies following optimization techniques in accordance with the systemic approach, which enables to propose solutions considering all issues that influence the planning context. Economic scenarios, weather aspects, future regulatory rigor, new technologies; ultimately, all issues that direct or indirectly influence the planning environment must be systematically taken into consideration.

Moreover, with the aim of proposing a new process, Fig. 3 presents the reorganization of the KM-oriented MVDS planning process.

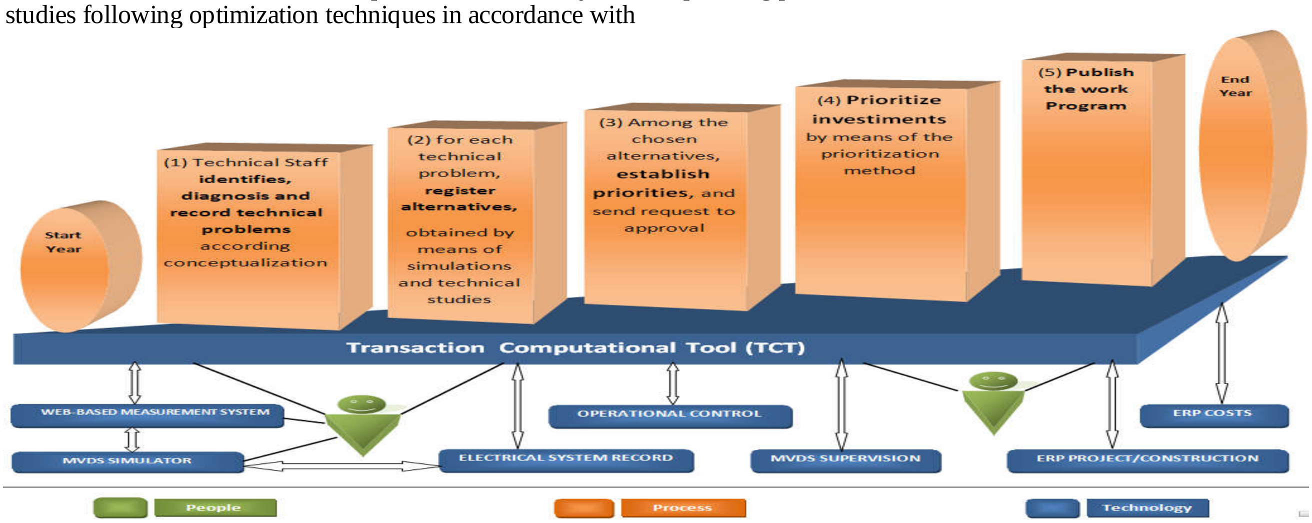

Figure 3. Reorganization of the KM-oriented MVDS planning process.

With a view to relating the dimensions identified in Table 2 to the reorganization process proposed in Fig. 3, the experts are represented in green. The relationship of experts with the process occurs by means of the TCT (Transaction Computational Tool) and demands competencies from these professional in order to carry out their activities. Technology and its components, represented in blue, are integrated with the TCT, facilitating the execution of activities, especially by adopting methods, modern techniques, dominion ontologies to provide semantic consensus, and so on. Finally, the process represented in brown shows the reorganization in specific tasks that are carried out successively.

Fig. 3 shows that the MVDS planning process here proposed is structured by means of interconnected components that relate to each other in order to promote the MVDS planning. The planning task, which was previously carried out in a general way, starts to be performed in a structured way in accordance with the following sequence of tasks: identification record, problem diagnosis, studies, alternatives, prioritization, and publication of the investment plan. Moreover, norms and instructions govern and guide the execution of tasks respectively.

The TCT supports the whole process, providing experts with evaluation facilities and record of all tasks. The problems are diagnosed with the support of knowledge systems and application of methods and optimization techniques occur in an integrated way as the TCT relies on these implemented functions.

It is also important to emphasize that the TCT is critical for the reorganization of the proposed process. The interconnection of information systems that comprise the process occurs through the TCT. It is through this computational tool that the information flow occurs due to its integration with other computer systems that make up the process, like the construction management systems, operation, maintenance and ERP costs. The computational agents like knowledge system, data warehouse and artificial intelligence techniques complement the information flow in order to support the decision maker in the planning process.

Due to the reorganization of the planning system oriented towards people, processes and technology, it is noticed that the components are organized, which in turn enables the understanding of representation tasks, refinement and application of knowledge in terms of the development of an efficient work plan. It is important to highlight that the efficiency of the planning process starts to be evaluated because by means of the categorization of problem patterns, engineering actions and investments, the experts with the passing of time will be able to refine the knowledge related to the MVDS planning concomitantly with the performance of the power system.

According to [7], it is possible to verify along with the proposed system a set of mechanisms essential to the maintenance of its properties as well as its emergency condition. The CESM model is then applied to the new process in order to evaluate the reorganization of the proposed planning (see Table 3).

TABLE III. APPLICATION OF THE CESM MODEL TO EVALUATE THE REORGANIZATION OF A MVDS PLANNING.

System	C Composition	E Environment	S Structure	M Mechanism
MVDS Planning System	people computer tools, computer agents	PRODIST, MVDS, methodologies, market, building site, maintenance and operation, investors, directors, administrative council	processes, norms.	provide a work program trainings, process evaluation, motivation, formalization, representation, and refinement of the knowledge related to planning

Table 3 displays a set of mechanisms that were identified along with the proposed process reorganization. These mechanisms provide the planning system with efficiency as the investments programs start to be evaluated concomitantly with knowledge management as well as the other attributes that comprise the process. The planning system oriented towards people, process and technology facilitates the identification of the knowledge required to the execution of KM-oriented tasks.

V. CONCLUSION

The current planning process of a power system exclusively oriented to technical analysis must be re-evaluated, especially in the strategic area, which lacks compelling arguments for the development of investment plans.

Preliminarily, the current planning process was described so that its main aspects and deficiencies were identified. The reorganization of the process was proposed taking into consideration three knowledge dimensions: people, process and technology. The CESM model was used to evaluate the process reorganization that started to be understood as a system. It is important to highlight that the reorganization of the KM-oriented planning process enables the representation tasks, refinement and knowledge application to be understood. Taking into account the expertise acquired by means of the evaluation of the planning processes analyzed, experts provided with refined knowledge will effectively justify the necessary investments.

According to this proposal, the association of knowledge management with MVDS planning starts to occur in a regular way along with organizations that implement this kind of reorganization. New studies, however, will have to be consistent with the definition of knowledge systems, ontologies and motivational aspects with a view to achieving planning efficiency. It is recommended to carry out scientific research on the application of knowledge agents to the development of precise diagnosis for MVDS technical problems.

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