Transdisciplinary Engineering Methods for Social Innovation of Industry 4.0
M. Peruzzini et al. (Eds.)

doi:10.3233/978-1-61499-898-3-431

New Application of Product Development Model Oriented to the R&D Program of Brazilian Electrical Sector for Planning a Product Project

João Adalberto PEREIRA[a,1], Maurício PENHA[a], Osiris CANCIGLIERI JÚNIOR[b], Rodrigo Bueno OTTO[c] and Vilson Rodrigo MOGNON[d]
[a] *COPEL – Companhia Paranaense de Energia*
[b] *PUCPR – Pontifícia Universidade Católica do Paraná*
[c] *FPTI – Fundação Parque Tecnológico Itaipú*
[d] *Institutos LACTEC – Instituto de Tecnologia para o Desenvolvimento*

Abstract. As of 2008, the R&D Development Program of Brazilian Electricity Sector (Brazil, Law nº 9.991/2000) regulated by the Brazilian Electricity Regulatory Agency (ANEEL) started to contemplate the Product Development Process (PDP) in its innovation chain, a fact that not only stimulated the transfer of innovative technologies from the research of the electric sector to the industry, but generated the need for specialized knowledge to manage these projects. In view of this, MoR&D, acronym for "Integrated Product Development Model Oriented for R&D Projects of the Electric Sector", aims to assist in the planning of projects to transform the results of the electric sector research into ready-to-market products. The MoR&D is the result of compilation of PDP models, theirs tools and concepts. It is composed of macro-phases, phases, stages and activities, correlated with the needs of the typical ANEEL projects. This paper presents a case study of the planning of a Head Production Series design for electronic equipment, illustrating the MoR&D application process. Their contribution can be concluded as a key step for effective participation of the industry in the process of generating solutions to problems that afflict the electric sector. The model is the result of a doctoral thesis sponsored by Companhia Paranaense de Energia (COPEL) in favor of best practices applied to the management process of its processes, which, now shared, may contribute to the various energy concessionaires in Brazil and in the world that excel for the quality of its services.

Keywords. Research and Development, Electric Sector, Innovation Chain, Head Production Series, Product Development

Introduction

Brazilian Electricity Regulatory Agency (ANEEL) regulates the Research and Technological Development Program of Brazilian Electricity Power Sector (ANEEL R&D Program), established in the year of 2000 [1].

[1] Corresponding Author, Mail: joao.adalberto@copel.com.

This Program stipulates that national electric power companies must invest in research and development (R&D) projects, aiming scientific and technological development in electric power sector through the creation of innovative technologies and products.

However, until 2008, the Product Development Process (PDP) was not contemplated in ANEEL R&D Program. After some years it is observed that the success of a few projects were given to the concessionaires which look at in the industry necessary knowledge for the PDP to be fully implemented [2].

It is a fact that in industrial sector there are several models that systematize the PDP, but "despite the advances in the implementation of more robust projects (resulting from the 2008 resolution), there is still a lack of a development model conducive to R&D projects of the National Electric Power Sector with effective potential of insertion in the market" [3].

Integrated Product Development Model Oriented for R&D Projects of the Brazilian Electricity Sector, MoR&D [2, 4], is presented as a new tool for planning projects of the ANEEL R&D Program, directing its results to products innovators, fulfilling its main objective, which is "the search for innovations to meet technological and market challenges of electric power companies" [5].

This paper presents the concepts that underpin the MoR&D and a case study to illustrate the process of planning of the stages of a product development project for innovative equipment conceived in the context of the ANEEL R&D Program [6].

1. Research methodology

The research strategy for the MoR&D development was the case study with qualitative approach, having as unit of analysis the ANEEL R&D Program and, as technical procedures, the compiling of the literature about the PDP, its models and support tools, from whose synergy was possible to structure this model [2].

2. About the Brazilian Electric Sector R&D Program and the PDP

In late 1990s, with increasing competition in face of increasing energy demand, several actions were taken to effect the technological development of the electric sector in Brazil. Among them, energy companies were encouraged to invest in R&D programs [3]. ANEEL provides the Procedimentos do Programa de Pesquisa e Desenvolvimento[2] (PROP&D) as guidelines for R&D projects elaboration [5].

Over time, “R&D projects have evolved not only in quantity but also in complexity, which has led to the creation of unprecedented and irreversible collaboration relationships between energy companies, academy and industry” [3]. However, despite all the effort, there is a lack of maturation by the energy companies and academy regarding the process of insertion of the PDP into the context, evidencing a long way to ANEEL R&D Program to reach the expected success.

[2] Research and Development Program Procedures, in english.

3. ANEEL R&D projects

Activities related to R&D projects execution are of creative or entrepreneurial nature, with a technical-scientific basis, aiming generation of knowledge or the innovative application of pre-existing knowledge, including for the investigation of new applications. Differently from pure academic research, characterized by freedom of research, projects defined in PROP&D [5] must present well defined goals and results [7], having as main goal the convergence of the discovery (innovation) in practical application.

The PROP&D [5] is based on global references that define the R&D activities [8, 9] and group research activities into six types of projects with intention to reach the entire production chain [10], as shown in Figure 1.

The possibility of developing projects aimed at improving products considering production and commercialization reinforces the intention of ANEEL R&D Program to stimulate not only the development of technological innovations but also, and from these, practical solutions for the daily life of energy companies [2].

The merit of this R&D projects must be justified by four primary criteria, which are: Originality, Applicability, Relevance and Cost Ratio. The formalization of R&D project proposals is usually done in specific forms that include description, financial disbursements and XML[3] file to register the project in ANEEL [4, 5].

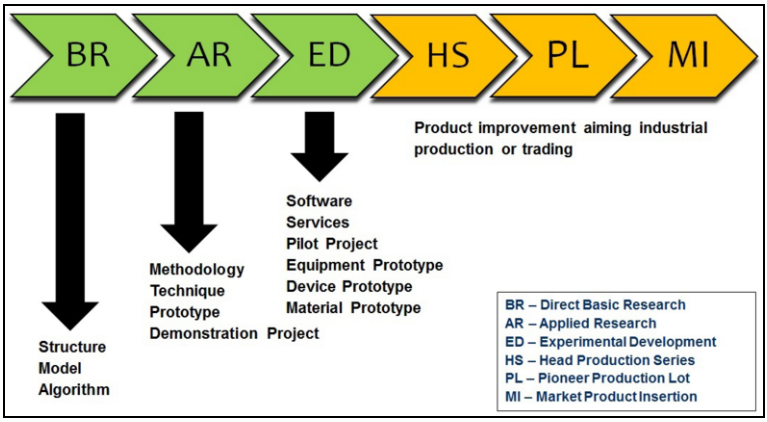

Figure 1. ANEEL Innovation Chain.

4. Product Development Process (PDP)

One of the most comprehensive definitions of PDP is advocated by Rosenfeld et al. as "a set of activities through which its seeks, from the needs of market and the possibilities and constraints of technology... to reach design specifications of a product and its production process... involves the activities product follow-up after launch" [11].

For these activities it is possible to identify several approaches, defined according to the type of company or product, thus characterizing the different models and concepts considered to compose the MoR&D [2], of which we highlight: Asimow

[3] an acronym for "eXtensible Markup Language"

Model (1962), Cooper Model (1993), Pahl & Baitz Model (1996), Unified Model (2006), Cascade Model (1970), V Model (2011) among others, and concepts such as: Multidisciplinary Projects, Concurrent Engineering, Stage-Gate, Product Based Business and Integrated Product Development [2] in addition to the various support tools, such as: QFD (Quality Function Deployment), WBS (Work Breakdown Structure), FAST (Function Analysis System Technique), FMEA (Failure Modes and Effects Analysis), DFX (Design for X) and RB (Robust Design) [2].

5. The MoR&D

Using the concepts, models and tools of PDP to plan R&D projects in electric power sector is justified by the fact that such projects must result products (finalized or not), consequently, the use of these to compose MoR&D. “In practice, R&D and new product design are so intertwined that sometimes it becomes difficult to” [12].

To compose MoR&D methodological structure it was considered 38 PDP models of the most renowned authors [6]. Its structure is composed of 14 steps, 6 phases, 3 macro-phases and 2 management activities. It is also considered the application of tools of the PDP as well as a flow with several activities that characterize the project development process (Figure 2).

In sequence, the dynamic of MoR&D structure is described in a synthetic way, based in its three macro-phases: “Pre-Development”, “Development” and “Post-Development”. For more details consult references [2, 4].

5.1. Pre-Development macro-phase

This macro-phase (Figure 2) applies to all Innovation Chain projects (Figure 1) to align project and product planning to the company's interests. It begins with “Initialization” phase, where, from a technological need, “Statement of Demand” (Step 1) is adopted as research goal.

With the approval of the demand through the “Tests of the Strategic”, the “Planning” phase of the R&D project proposal begins, firstly with the implementation of Step 2, “Scope Definition”, in accord with “Acceptance Testing” by customers. Next, the “Project Planning” (Step 3) is executed in compliance with the “R&D Program Guidelines Tests”. The result of which is the formal document that represents the project and which must be submitted to the evaluation process, approval, contracting and homologation at ANEEL.

5.2. Development macro-phase

In this macro-phase (Figure 2) researchers seek to solve the research problem by developing solutions, configuring and normalizing the product and recording the acquired experiences. It begins with the “Design” phase where, from the “Study of Principles” (Step 4) involved in projetct scope, “Conceptual Design” (Step 5) is defined, the “Preliminary Design” (Step 6) and the “Detailed Design” (Step 7) that occur simultaneously to the “Refinement of the Design” process (Step 8) where are applied Concurrent Engineering and Multidisciplinary Projects concepts [2].

Projects like BR, AR and ED (Figure 1), whose products are prototypes for validation of the new concepts, can use these steps.

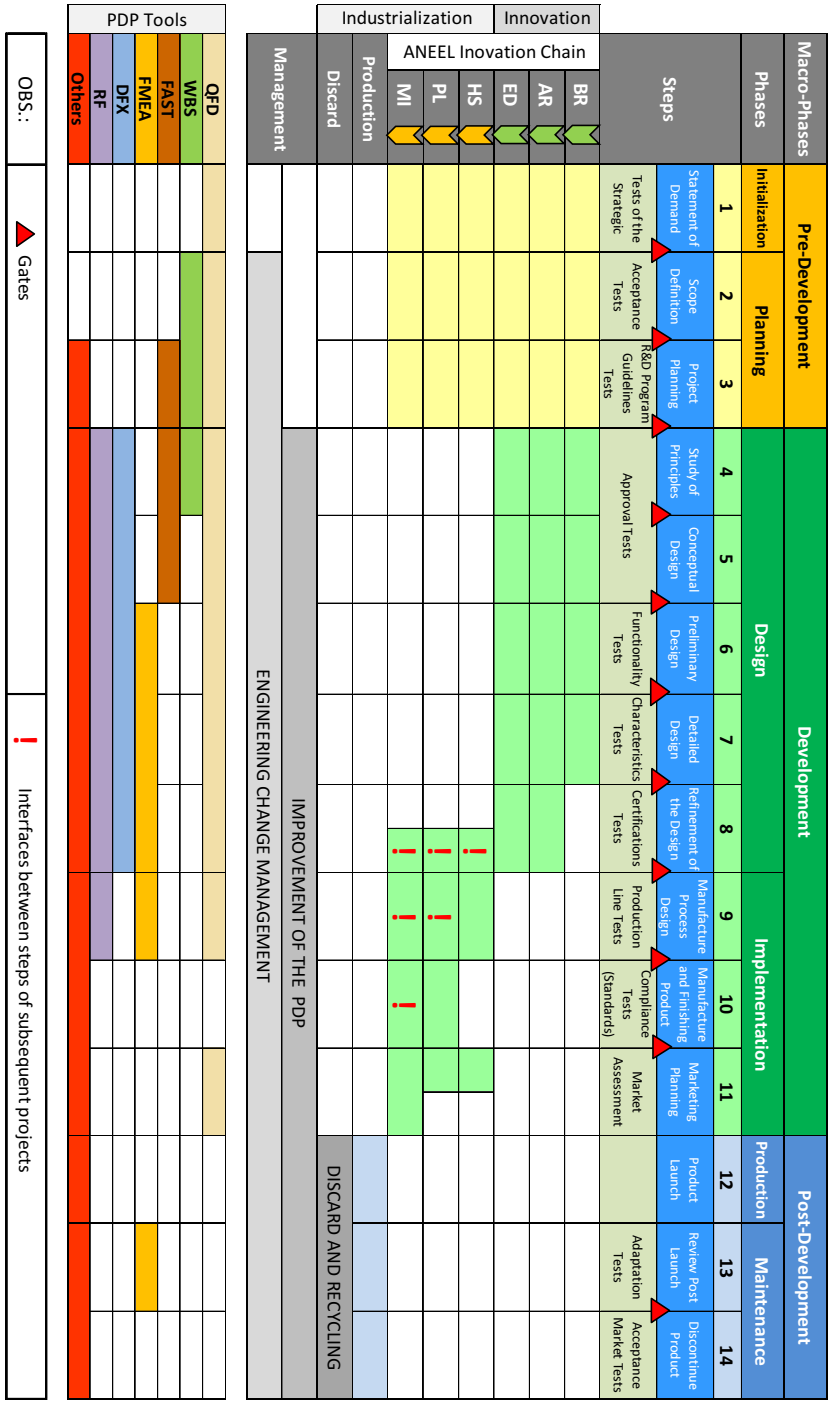

Figure 2. MoR&D conceptual structure.

Following the "Development" macro-phase, in the "Implementation" phase, adaptations of the new technology to the production process are done, which ocurr through activities related to the "Manufacturing Process Design" (Step 9), "Manufacturing and Finishing Product" (Step 10), where the characteristics of the product and its "Marketing Planning" (Step 11) are also defined, referring to the "Refinement of the Design" (Step 8) whenever something hinders the process or costs the product.

Projects such as ED, HS, PL and IM of Innovation Chain (Figure 1) justify these steps, since they aim at the adequacy of prototypes or new concepts to the production process.

5.3. Post-Development macro-phase

This macro-phase is not explicitly addressed in Innovation Chain (Figure 1), however, as part of the planning process for new product development, it encompasses activities related to production planning, such as launching, monitoring, maintenance and discontinuity of product.

"Post-development" macro-phase begins with the "Production" phase, which includes the "Product Launch" (Step 12), followed by the "Maintenance" phase, which is composed by "Review Post Launch" (Step 13), for which product updates are performed, and "Discontinue Product" (Step 14), process which, in practice, must be previewed during the design steps and in the production development process.

The company must always be prepared to execute the end-of-production plan, since the life of a product depends on customer satisfaction or economic or strategic advantages do that measured through the "Adaptation Tests" (Step 13) and "Acceptance Market Tests" (Step 14).

6. Case study

6.1. Contextualization

The performance of a transmission line depends on the power factor, whose correction is carried out by capacitor banks located in power transmission substations. These banks are composed of associations of capacitive elements, whose failure or degradation compromises the correction of the power factor and, consequently, the quality of the energy transmitted.

The usual procedure adopted by concessionaires to identify defective capacitors involves disassembling the bank to carry out measurement of each element individually, incurring in unavailability of the system for a period that can arrive to weeks.

Commercially there are two specific equipment for these functions, but both with restrictions on their use, because of their high costs, have low accuracy, do not allow analyzes with frequency sweep and are difficult to transport because of their weight. A third alternative is the use of laboratory equipment, which is fragile for field work and does not normally have the ability to scan frequency.

Based on the need to carry out preventive maintenance in capacitor banks in a more agile and precise way, in order to reduce the unavailability of the power transmission system, specific equipment, called MEDCAP, was conceived through an ED R&D project (Figure 1), executed by LACTEC Institutes for COPEL [6], whose

prototype (Figure 3) demonstrated performance beyond expectations due to its excellent accuracy, reliability, practicality and low operating cost to diagnose the damaged element.

Given the success of the new technology, a new HD project (Figure 1) comes with the intention of defining the technical characteristics of the product (Figure 4) and its production line making it commercially viable, as prescribed by the R&D ANEEL Program.

In this sense, the MoR&D was applied to the planning the development stages of the HS project for the MEDCAP equipment, identified in ANEEL by the code PD-06491-0403/2015 [13].

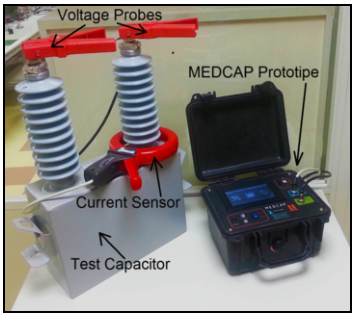

Figure 3. MEDCAP prototype.

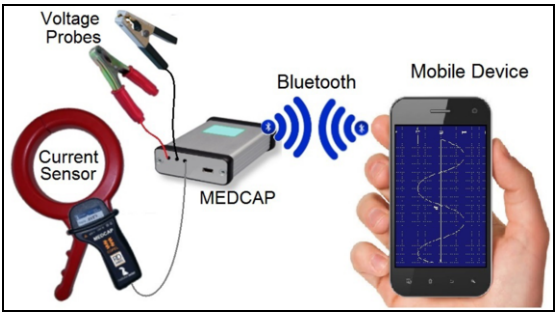

Figure 4. Concept for the MEDCAP product.

6.2. The project

The project planning and its execution were based on Steps 1, 2, 3, 8, 9 and 11 (Figure 5), as suggested by MoR&D for Head Production Series projects (Figure 2). Starting from the "Initialization" phase, from the "Pre-Development" macro-phase, it was sought to meet the technical need of the concessionaire, at which time the "Statement of Demand" (Step 1) was identified for the new project.

	Macro-phases	Pre-Development			Development		
	Phases	Initialization	Planning		Design	Implementation	
Industrialization	Steps	1	2	3	8	9	11
	ANEEL Inovation HS	Statement of Demand	Scope Definition	Project Planning	Refinement of the Design	Manufacture Process Design	Marketing Planning
		Tests of the Strategic	Acceptance Tests	R&D Program Guidelines Tests	Certifications Tests	Production Line Tests	Market Assessment
	Management				IMPROVEMENT OF THE PDP		
			ENGINEERING CHANGE MANAGEMENT				

Figure 5. MoR&D applied to Head Production Series (HS) project.

In this Step 1, the formalization of demand took place through technical meetings between managers, executors and clients, following the "Planning" phase of the project where, based on the survey of the requirements for the product and available technologies, the definition was set of the "Scope Definition" (Step 2) and, depending on this, for the details of the guidelines for "Project Planning" (Step 3), where the

adequacy of the new technologies was considered; work in multidisciplinary teams; scaling and simultaneity between project stages (schedule); allocation of Gates (strategic decisions) and allocation of resources (Human Resources, Permanent Materials and Equipment, Consumables, Third Party Services, Travel and Daily and Others [6]).

The migration of customer requirements to product requirements, in accord with the company's strategic plans and the ANEEL R&D Program, were addressed in the "Scope Definition" step (Step 2), where the use of modern wireless communication technologies, battery packs with small volume and high energy storage capacity, visual interface through mobile applications (smart phones, tablets, etc.) and possibility of online operation of the equipment in sync with a company operations center (Figure 3).

The demands for the research project development were then considered in the team's expertise definition and in the technological solutions to be employed in the "Development" macro-phase which, in turn, goes through the stages "Refinement of the Design" (Step 8), "Manufacture Process Design" (Step 9) and "Marketing Plannig" (Step 11).

The methodology behind the design steps as presented in Figure 6 are derived from the "Development" macro-phase and were structured according to the MoR&D template, suggested by the authors, for HS projects (Figure 1) [14].

The colors indicated in the project "Activities" column (Figure 6) correspond to the colors that make up the activity flowcharts in the literature [2, 4, 14, 15].

The activities of the "Refinement of the Design" step should be carried out by the team of researchers who developed the previous Experimental Development (Figure 1) project [6] supplemented by manufacturing company members (selected in the project planning), product engineering experts and marketing planning professionals who, in simultaneity, will direct the project of the product and its production line.

The formalization of the R&D project for submission of technical and legal approval by the concessionaire is done through the preparation of the descriptive document of the project according to the criteria defined by ANEEL [5], a financial disbursement forecast worksheet and a standard XML file for submission of the project to ANEEL, thus closing the "Pre-Development" macro-phase.

7. Conclusion

The model MoR&D is robust and flexible to meet the entire Innovation Chain stipulated by ANEEL [5] and considers the dynamic interaction between the stages of a project with the use of multidisciplinary teams that, as in industry, result in projects that are methodologically adapted to clients needs and industrial production requirements.

Its contribution to the state of the art lies in the fact that product development models are common in the industrial sector, however, with regard to scientific research for the development of new technologies, there is no evidence of models linking scientific methodology to PDP concepts, characteristic which directly benefits the Research and Scientific Development Program of the Brazilian Electric Energy Sector.

Not only applied to the development of series head designs, as demonstrated, MoR&D serves the entire Innovation Chain (Figure 1) with its versatility confirmed by the application in several other reported cases [2, 4, 13, 15].

As a result, a significant reduction of segregated activities is observed, as well as a better targeting of design results to an innovative product in response to customer and market needs.

The next step, in under way, is the development of a web tool which will allow the dissemination of MoR&D to all companies electricity sector, benefiting everyone in general.

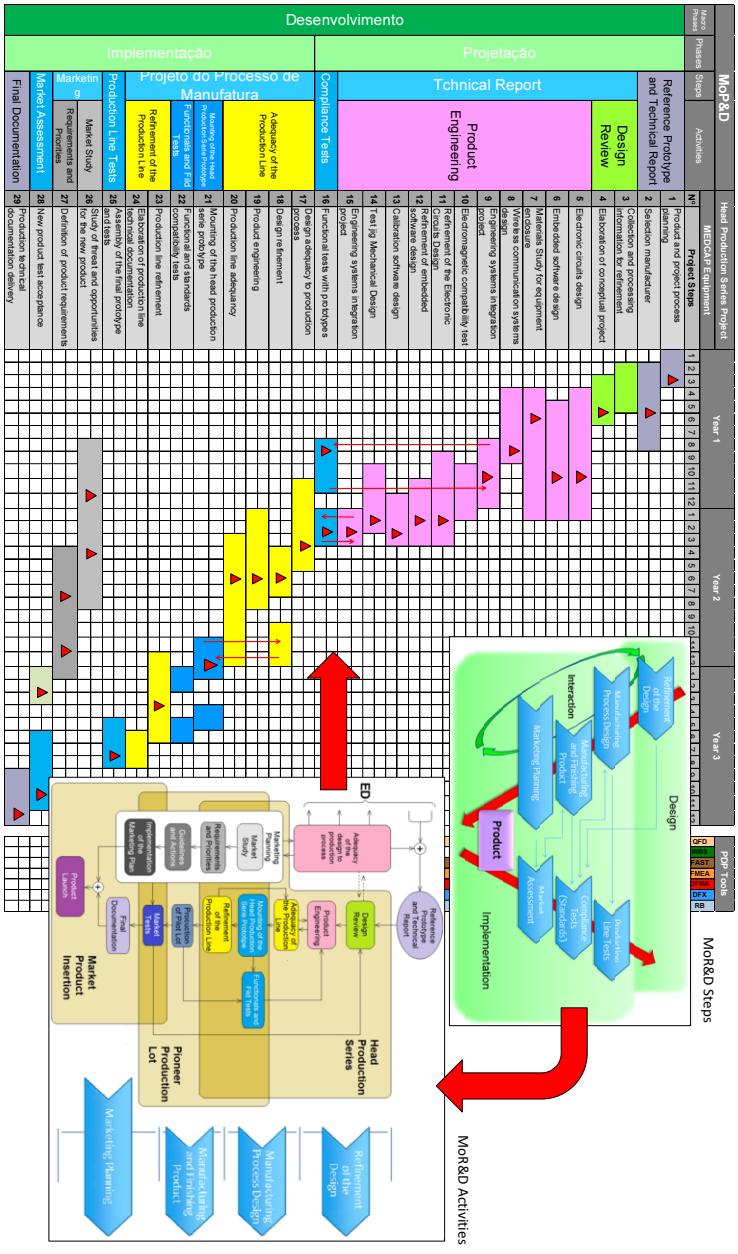

Figure 6. Head Production Serie project steps for the MEDCAP equipment.

Acknowledgement

To Companhia Paranaense de Energia [4] (COPEL), Intitutos LACTEC [5], Parque Tecnológico Itaipú[6] (PTI) and Pontifícia Universidade Católica do Paraná[7] (PUCPR) by the financial and technical support. Also to all the engineers and researchers who dedicated themselves so that this work could be realized.

References

[1] Lei nº 9.991 de 24 de julho 2000. In: *Diário Oficial da União*. Brasília, DF, Brazil, 2000.
[2] J.A. Pereira, *Modelo de desenvolvimento integrado de produto orientado aos projetos de P&D do setor elétrico brasileiro: MoP&D*. Tese de doutorado, Pontifical Catholic University of Paraná, Curitiba, PR, Brazil, 2014.
[3] ANEEL, Avanços tecnológicos no setor elétrico. In: *Revista Pesquisa e Desenvolvimento*, n. 4, Brasília, DF, Brazil, 2011.
[4] J.A. Pereira and O. Canciglieri Junior, *Modelo de desenvolvimento integrado de produto orientado aos projetos de P&D do setor elétrico brasileiro - MoP&D*, 1 ed., Novas Edições Acadêmicas, Alemanha, 2016.
[5] *Procedimentos do programa de pesquisa e desenvolvimento (PROP&D)*. Agência Nacional de energia Elétrica (ANEEL). Available at: http://www.aneel.gov.br/pt/programa-de-p-d. Brasília, DF, 01/01/2017.
[6] M. Penha, Projeto de P&D ANEEL código PD-6491-0233/2012: Pesquisa e desenvolvimento de equipamento para análise e diagnóstico de bancos de capacitores de alta tensão (MEDCAP). *Relatório Final de Projeto*, LACTEC/COPEL, Curitiba, PR, Brazil, 2015.
[7] J.A.V. Barbosa Júnior et al., Agências executivas: conceitos, fundamentos e atuação: 2008. *Trabalho de Conclusão da Disciplina Democracia e Tecnologias de Informações*, Universidade Estadual Paulista Júlio de Mesquita Filho, Araraquara, SP, Brazil, 2008.
[8] *Oslo Manual: Guidelines for collecting and interpreting innovation data.* 3. ed. OECD (Organization for Economic Co-Operation and Development), Paris, France, 2005.
[9] *Frascati Manual: Proposed standard practices for surveys on research and experimental development.* 6. ed. OECD (Organization for Economic Co-Operation and Development), Paris, France, 2002.
[10] A.F. Cabello and F.M. Pompermayer, Impactos Qualitativos do programa de P&D regulado pela ANEEL. In: *Inovação tecnológica no setor elétrico brasileiro: uma avaliação do programa de P&D regulado pela ANEEL*. 1. ed. IPEA, Brasília, DF, Brazil, 2011.
[11] F.A.H. Rozenfeld, at al. *Gestão de desenvolvimento de produtos: uma referência para a melhoria do processo*, 1 ed., Saraiva, São Paulo, SP, Brazil, 2006.
[12] M. Asimow, *Introdução ao projeto de engenharia*, Mestre Jou, São Paulo, SP, Brazil, 1968.
[13] M. Penha, Cabeça de série de equipamento para análise e diagnóstico de bancos de capacitores de alta tensão (MEDCAP), *Relatório de Projeto PD-06491-0403/2015*, LACTEC/COPEL GeT, Curitiba, PR, Brazil, 2015.
[14] J.A. Pereira and O. Canciglieri Junior, *MoP&D - Modelo de Desenvolvimento Integrado de Produto Orientado para Projetos de P&D do Setor Elétrico Brasileiro: Planilha e templates.* Availeble at: https://issuu.com/moped_joaoadalberto/docs/mop_d.
[15] J.A. Pereira at. al, Product Development Model for Application in R&D Projects of the Brazilian Electricity Sector, In: J. Cha et al. (eds.), *Moving Integrated Product Development to Service Clouds in the Global Economy*, IOS Press, Amsterdam, Netherlands, 2014, pp. 33-45.

[4] Paraná Electrical Power Company (http://www.copel.com/hpcopel/english/)
[5] LACTEC Institutes: Institute of Technology for Development (http://www.institutoslactec.org.br/en/)
[6] Itaipú Technological Park (https://www.pti.org.br/en)
[7] Pontifical Catholic University of Paraná State (http://en.pucpr.br/)