Moving Integrated Product Development to Service Clouds in the Global Economy
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Product Development Model for Application in R&D Projects of the Brazilian Electricity Sector

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Abstract. Through a broad approach about reputable methodologies of Product Development Process (PDP), this paper proposes a model of development to be considered in designing and management of R&D project of the Research and Development Program of the Brazilian Electricity Sector regulated by the Brazilian Electricity Regulatory Agency (ANEEL). Such projects, guided by the search for innovative products and technologies in response to technological challenges of the power sector, are well defined by PMBOK Guide of Project Management Institute as "a temporary endeavor undertaken to create a product, service or result". This means that, for a R&D project to fulfill the principle of temporariness, its management should seek to achieve pre-established goals, following appropriate processes, technologies and teams involved in problem solving principles for development until it gets the achievement of the planned product. In this sense, the objective of this work is to demonstrate that, as in the industry, PDP methodologies may be also suitable for these R&D projects, ensuring better adaptation of the results to customer needs and strengthening the relationship between university and industry in the R&D process of the electricity sector. This research addresses a compilation about several PDP models already established by the industry with a view to creating a suitable development model to the R&D projects of the electricity sector. The model emphasizes the constructive interaction between the various stages of development methodology (concepts of Concurrent Engineering) and multidisciplinary teams fully integrated with the innovation process. The proposal shows to be promising to induce to the reduction of the typical limitations of segregated and sequential activities observed in many of the projects in R&D of electric sector.

Keywords. Product development process model, R&D projects, electricity sector

Introduction

ANEEL (Brazilian Electricity Regulatory Agency) is the agency that regulates the *Brazilian Electric Sector R&D Program* [1] which has the purpose of development and technological qualification of the companies related to the sector.

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Product development was not foreseen by ANEEL in its *R&D Program*, it happened only in 2008 with the inclusion of categories of *HS (Head Production Series), PL (Pioneer Production Lot)* and *MI (Market Production Insertion)* in its *Innovation Chain* [2] (Figure 1).

Figure 1. ANEEL Innovation Chain [2].

ANEEL announced that 4,487 R&D projects had been made since the beginning of the *R&D Program* until the implementation of the new resolution in 2008. However, after this date, from the 1,915 new projects registered until 2009, only 117 had involvement with the *Innovation Chain* new stages [3], and the success of these projects as products market happened for dealers who sought, in the industrial sector, knowledge of the *Product Development Process (PDP)* required for the fulfillment of the Innovation Chain.

It is a fact, however, that for this sector, it is possible to identify multiple models that systematize the PDP [4,5]. Another verification is that the *ANEEL R&D Program* is an object of analysis with little academic reference, explaining the lack of knowledge about PDP by most of R&D project managers [6], justifying that, despite advances in implementing the more robust projects, it is verified the lack of a proper development model to R&D projects with effective potential of entering the market [7].

In this sense, and through a PDP comprehensive approach, this paper proposes a specific development model for the *Brazilian Electric Sector R&D Program*, whose objective is to reduce recurring limitations observed in R&D projects and finally accelerate the return on investments in benefit of society through the generated products quality and consequently the services provided by energy companies.

1. Research Methodology

The strategy of this research was the case study with a qualitative approach. The analysis unit was the management processes of R&D projects of the Companhia Paranaense de Energia - COPEL (that is the Paraná electrical power company) under the ANEEL R&D Program.

As a technical procedure, it was initially considered the literature review about *ANEEL R&D Program* and its criteria, followed by exploratory study on PDP models. From the synergy between them, it was sought to define a development model suitable to the context of *ANEEL Innovation Chain*. Next, in order to confirm its effectiveness, the proposed model was applied in the preparation of a R&D project that could be compared with the actual counterpart project, recently executed by COPEL.

It is worth noting that the using of a single unit of analysis in this research does not make it particular or less comprehensive. The proposed model is generic and can be applied by any utility that is liable to the ANEEL criteria.

2. Brazilian Electric Sector R&D Program

By the late '90s, the increasing competition facing the growing demand of the energy market showed that actions to effectuate the technological development in the Brazilian electricity sector should be taken [8]. In this context, ANEEL began requiring from the electricity companies to invest in annual programs of R&D and Energy Efficiency (EE) [9], thus creating the *Research and Development Program of the Brazilian Electricity Sector* (*ANEEL R&D Program*).

Over the years and the increase of representativeness, the projects have evolved not only in quantity but also in complexity. And although there is still much debate about the efficiency of *ANEEL R&D Program* [10,11], it is verified that with this, unprecedented collaborative relationships among energy companies, academia and industrial sector [9] were created. On the other hand, it is noticed that there is still a lack of maturing by companies in relation to the R&D development activities, remaining a lot of work to do for the program to be an effective success [12].

The conditions for submission, implementation, evaluation and monitoring of R&D projects are set by ANEEL through the *Manual for Research and Development Program for the Brazilian Electric Sector* [13], where activities related to the execution of R&D projects *"are those creative or entrepreneurial nature with scientific-technical foundations and aimed at generating knowledge, or its innovative application for the investigation of new applications"*.

The global references which define *Innovation and R&D* are the *Oslo Manual* [14] and the *Frascati Manual* [15]. For the Brazilian Electric Sector the ANEEL own *Manual for R&D* [2] defines these activities [16] and, differently from *Oslo Manual,* emphasizes that the social-economic factor that comes from the innovative process should be considered as part the project's results. On the other hand, while the *Frascati Manual* groups R&D activities into three categories *(Basic Research, Applied Research and Experimental Development)*, *ANEEL R&D Manual* classifies them into six categories according to the *Innovation Chain* (Figure 1), making clear the intention of stimulating, not only the generation of technological innovations, but also, and from them, the development of practical solutions for the everyday of energy companies.

3. R&D Projects

According to *ANEEL R&D Manual,* projects are grouped into six categories: *Directed Basic Research* (BR), *Applied Research* (AR), *Experimental Development* (ED) which require a high degree of technological innovation, while the improvements with a view to industrial producing are the focus of *Production Head Series (HS), Pioneer Production Lot (PL) Product and Market Insertion (MI)* [17,18].

The merit of a R&D project is defined by ANEEL through four criteria, namely: *Originality, Applicability, Relevance and Cost Reasonableness*. Of these, *Originality* is exclusionary factor for projects of BR, AR and ED being assessed according the requirements of *Challenges*, *Advance and Products*. For the *Applicability* it is considered the criteria of *Application Context*, *Scope* and *Results Confirmation*. The *Relevance* criterion is analyzed from the viewpoint of *Professional and Technological Training* as well as *Socio-Environmental and Economic Impacts* of the project. For the *Cost Reasonableness* criterion must be proven the *Economic Feasibility* of planned investment in a particular project.

The formalization of R&D project proposals should be done through documents that, in general, include a project description, a sheet of disbursements and a pattern file that should be sent to ANEEL [19]. The first document aims to present the proposal with the purpose of its approval. In the disbursements worksheet must be detailed the R&D project expenditures, supporting the management team in the project execution. Finally, a file in XML (eXtensible Markup Language) format formalizes the proposal by the regulatory agency [19].

4. Product Development Process

There are several definitions in the literature for the PDP. For Pahl & Beitz [20] "*is multifaceted and interdisciplinary activity that has as a result ... the final product documentation*". For Smith [21] "*is the process that converts customer needs and requirements into information in order that a product or technical system can be produced*". Rosenfeld *et al*. [22], comprehensively, states that the PDP "*is a "business process" where "develop products consists of a set of activities through which it is sought, from the needs of the market and technological possibilities and constraints and considering the company's competitive and product strategies, get to design specifications of a product and its production process ... involves the activities of accompanying the product after the launch ... "*.

The idea of using product development models to structure R&D projects is justified by the principle that R&D projects should generate products and therefore the use of its concepts to build the new model which corroborates the statement that *"R&D and project are so often mingled in contemporary technological language that sometimes it becomes difficult to differentiate them"* [23].

As noted, a lack of product development models in R&D projects of the electric sector has generated the need for specific knowledge [24]. In this sense, based on a comprehensive literature research, initially composed by reference as [4,5,25,26], it was sought to develop an appropriate development model for *ANEEL R&D Program*.

5. Model for the R&D

Aiming to meet the entire range of projects covered by the *Innovation Chain* in the preparation of the *Integrated Product Development Model Oriented for R&D Projects of the Brazilian Electric Sector* (MOR&D) it was considered, besides the guidelines of the R&D Program [13], recurrent product development concepts, such as: *Concurrent Engineering* [27,28, 29]; *Stage Gate* [30]; *Integrated Product Development* (IPD) [31]; *V Model* [32]; *Product Based Business* [33,34], among others. It was also considered their tools in order to assist in the PDP [18,22,28,29,35]. It was compiled 38 different PDP models resulting in a structure with 14 *Stages*, 6 *Phases*, 3 *Macro-Phases* and 3 Management activities [36], as illustrated in Figure 2.

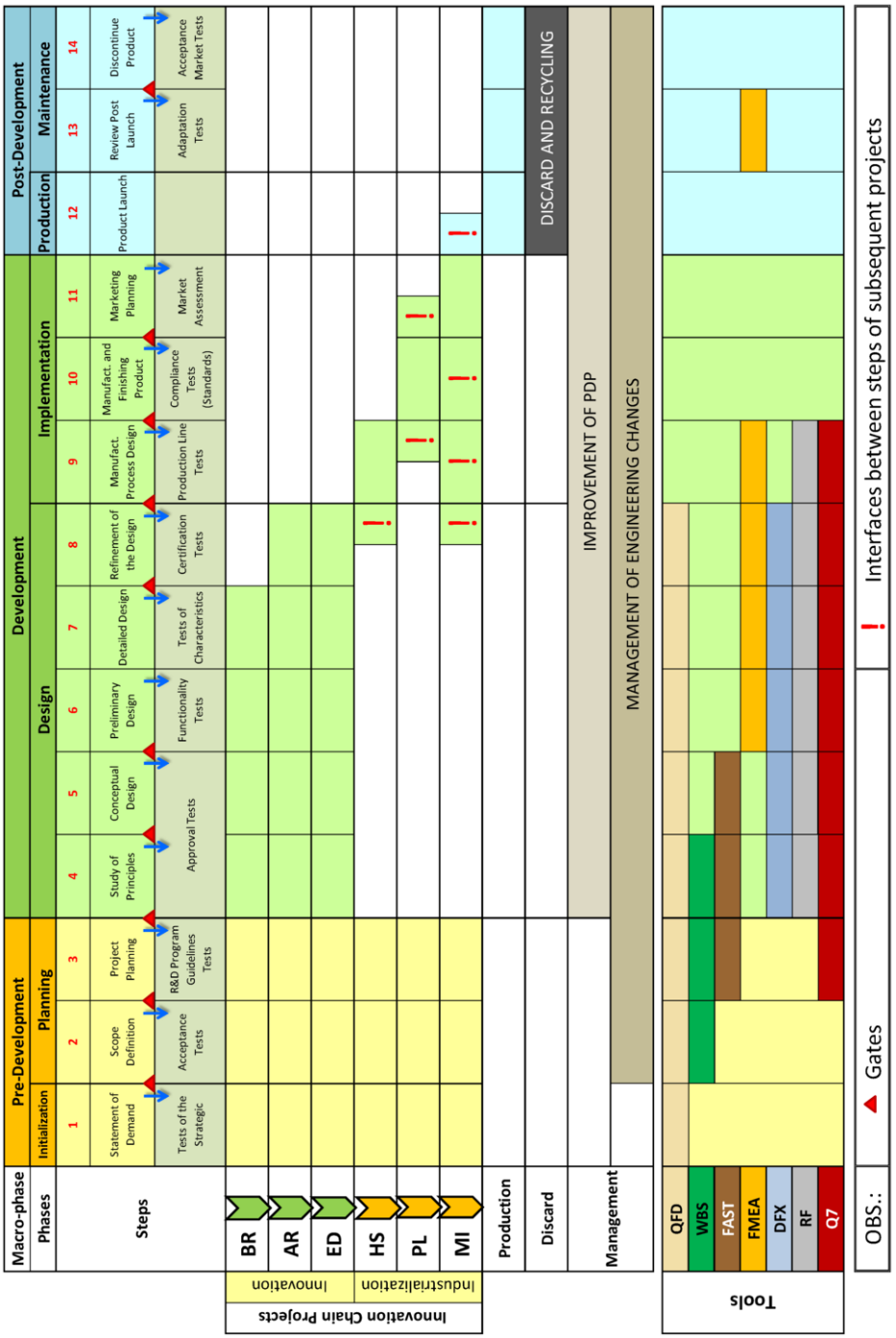


Figure 2. Integrated Product Development Model Oriented for R&D Projects of the Brazilian Electric Sector - MOR&D.

5.1. Pre-Development

Macro-phase applied to all types of *Chain Innovation* projects, since it is here where it is sought to align the company/product strategic planning to the R&D project planning. It begins with the *Initialization* phase, where from a technological need of strategic interest of the company is defined the *Demand Definition* as a R&D project. After demand is approved through the *Strategic Directives Tests*, the *Planning* phase of the R&D proposal is started. First with the stage of the *Scope Definition* in the contextual of the *R&D Program Criteria and Acceptance Testing* by customers, and after that *Project Planning* is performed, which if in accordance with the *R&D Program Criteria*, the *Formatted Proposal* can be submitted to the enrollment and authorization by ANEEL. Figure 3 illustrates the steps mentioned and their correlation with the stage of the project life cycle; and Figure 4 shows the dynamics of the activities involved.

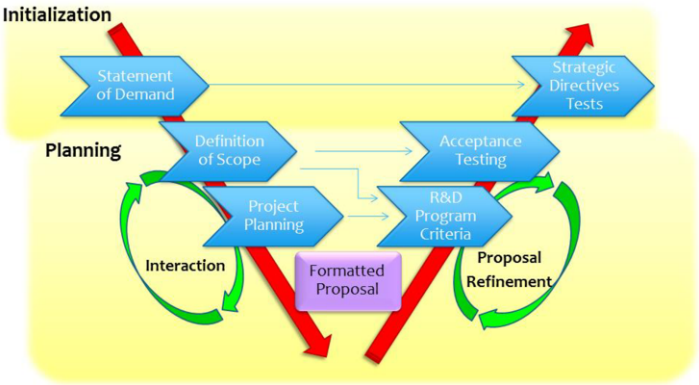


Figure 3. Pre-development Macro-phase.

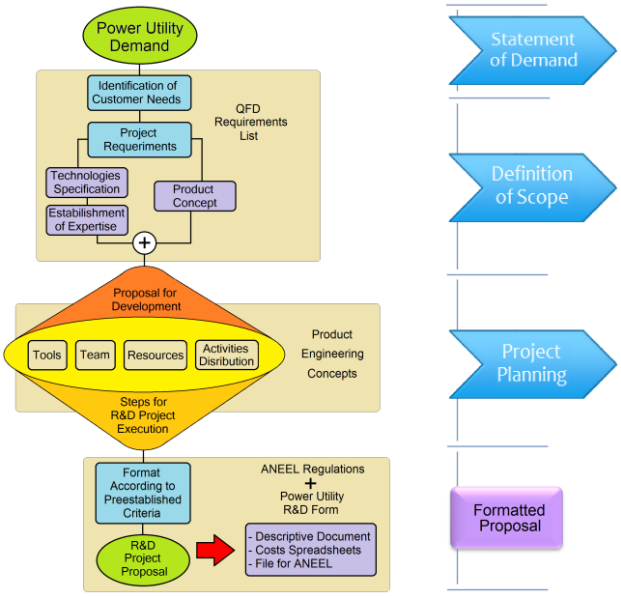


Figure 4. Activities involved in the Pre-development Macro-phase.

5.2. Development

In *Development* macro-phase, it was sought to solve the research's problem, synthesizing solutions, configuring and standardizing the product and registering all information in the technical documentation. This macro-phase begins with the *Design* phase (Figure 5), where the *Study of Principles* involved in the scope of the desired product are defined in the *Conceptual Project*, *Preliminary Design* and *Detailed Design*, simultaneously with *Refinement of the Design*. The activities inherent to this phase are shown in Figure 6. Projects of *Directed Basic Research*, *Applied Research* and *Experimental Development* are attended by these steps, allowing achieving robust prototypes that are ready for more demanding tests and directed to the production process.

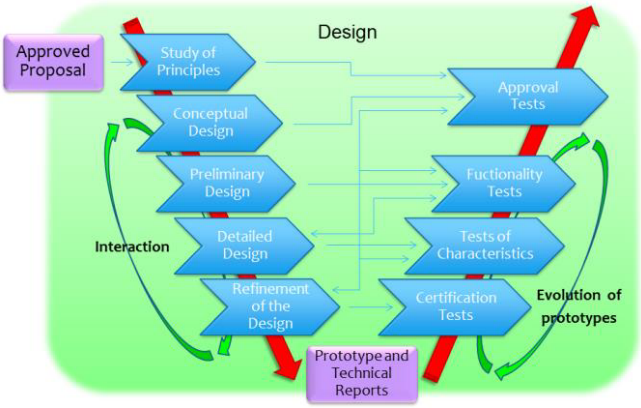


Figure 5. First part of the Development macro-phase (Design phase).

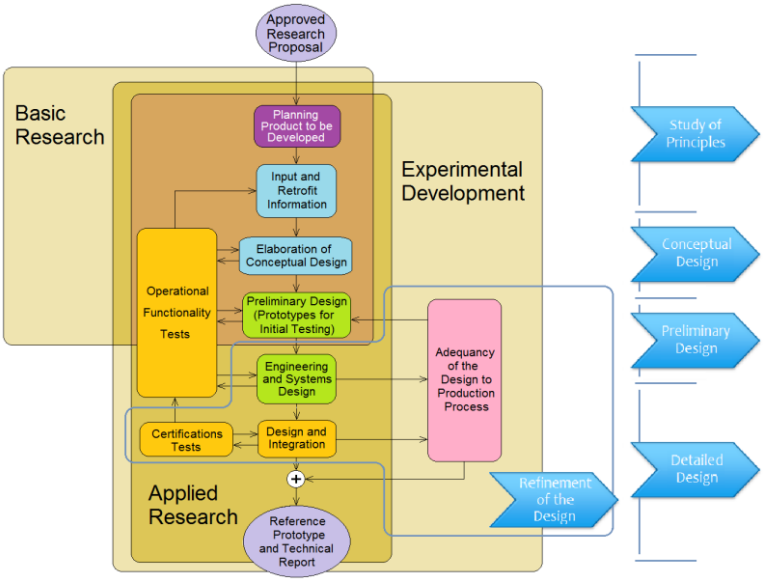


Figure 6. Activities assigned to the Design phase.

The model, yet within the *Development* phase, follows with the *Implementation* phase (Figure 7), where the suitability of the new technology to production processes is performed. In this phase are held activities relating to the *Manufacturing Process Design, Manufacturing and Finishing Product*, which defines the final characteristics of the product as well as the *Marketing Planning* for the final product, reporting to the *Refinement of the Design* stage always that some technical feature difficult the process or increase the final cost of the product (Figure 8).

Projects such as *Head Production Series, Pioneer Production Lot* and *Market Product Insertion* (Figure 1) are eligible for this stage of the development process.

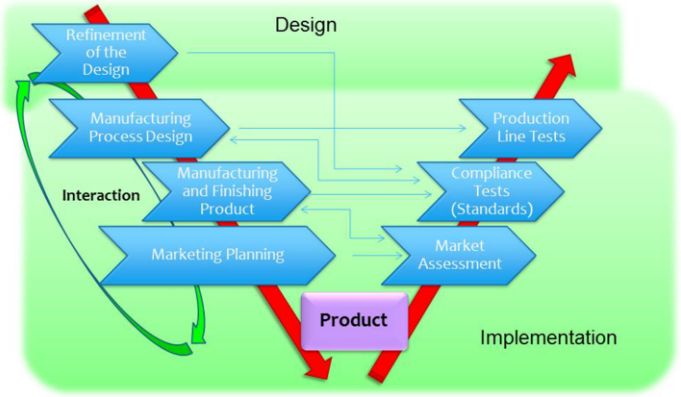


Figure 7. Second part of the Development macro-phase (Implementation phase).

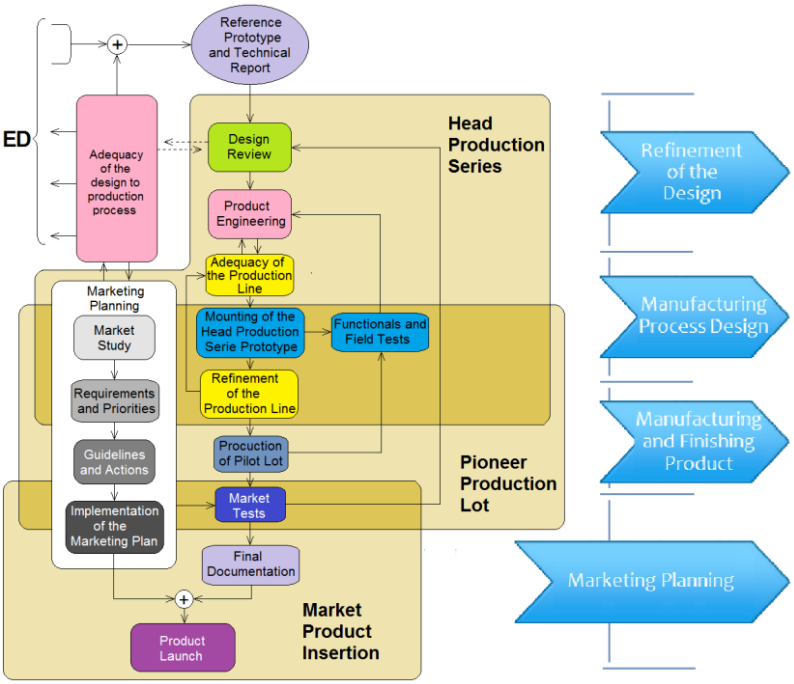


Figure 8. Activities assigned to the Implementation phase.

5.3. Post-Development

This macro-phase does not include *Innovation Chain* projects, however, it must be part of the R&D projects planning process that aim the launching of new products. As illustrated in Figure 9, it includes activities related to the production, monitoring, maintenance, release and withdrawal of the product from market.

The *Post-Development* begins with the *Product Release* step, followed by the *Post-Release Review* step, for which the product and manufacturing process updates are performed in order to customers services. These activities must occur simultaneously to the *Discontinue Product* step, which, in practice, starts during the production process. The company should always be prepared to execute the end of plan, since the useful life of a product depends on the satisfaction of its client and / or when no longer present economic or strategic advantages.

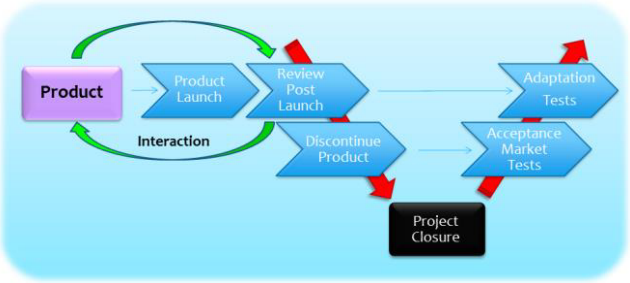


Figure 9. Post-Development macro-phase.

Figure 10. Activities assigned to the Post-Development macro-phase.

6. Case Study

In this case study the MOR&D was applied in the restructuring of a recently finalized R&D project aiming to estimate its efficiency based on the correlation of results. Characterized as ED in the *Innovation Chain*, this reference project was the development of an electric field sensing equipment to serve as accessory of a safety helmet to alert the electrician when excessive proximity to the energized electrical network [37,38]. Table 1 shows the distribution of the project's execution steps. In the left column we have the stages sequence according to the MOR&D (Figure 6) and in the right column, we have the steps according to the R&D project design at the time it was planned. [37].

Table 1. Project steps comparison: MOR&D X Real Project [37].

Steps	Conceptual Planning Steps (MOR&D - Figura 6)	Real Project Steps (Project documentation [39])
1	Development planning process	Acquisition/evaluation of sensors
2	Processing of input data	Establishing of the safety distance
3	Conceptual equipment proposition	
4	Electronic circuits Design	Electronic device Development
5	Embedded software design	
6	Study about materials to enclosure	
7	Communication systems design	
8	Systems engineering design	
9	Systems Integration	
10	Functional laboratory testing	Laboratory and field evaluation
11	Electromagn. compatibility testing	
12	Standards Based Tests	Standardization of the new device
13	Project aiming at industrial design	
14	Refinement Design	
15	Assembly of reference prototype	
16	Delivery of technical reports	Transfer of technology
17	Project closing	Conclusion of the project

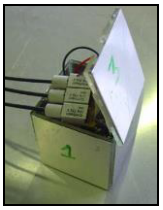
Table 2 lists the necessary expertise to the research team, with the left column, according to the schedule indicated in MOR&D (Figure 4) and in the right column, the expertise allocated as design adopted will then defining the proposal.

Table 2. Expertize comparison: MOR&D X Project conducted [37].

Conceptual Expertise	Project conducted Expertise [39]
Physics expert	Physics expert
Electronics engineer	Electronics engineer
Electrotechnical engineer	Electrotechnical engineer
Mechanics engineer	
Electromagnetic compatibility expert	Electromagnetic compatibility expert
Software designer	
Industrial designer	
Safety engineering expert	Safety engineering expert

In Table 3 are shown the results expected and done for both discussed planning lines. At first, based on MOR&D, the final object would be a robust prototype, with traces of own design for direct application in field tests which coincides with the predicted target for the conducted project [37]. In the second column, it is illustrated the actual prototype obtained [38], a direct result of the project conducted.

Table 3. Final objective comparison: MOR&D X Project conducted [37,38].

Conceptual Prototype	Project conducted Prototype [39]
	

7. Considerations

The research has allowed important conclusions on the application of MOR&D, contributing to its improvement as well as showing the importance of having a proper planning in R&D projects elaboration that aim to market products.

From the comparison between the two projects, it can be concluded that the projected steps based on MOR&D are more comprehensive than those of the executed project. It was predicted, for example, steps aimed at adapting the prototype to the design criteria (ergonomic and industrial), and due to this, it was necessary industrial projects specialists and designers. This fact, not foreseen in the real project was crucial to the completion of a robust prototype, as it should be (Table 3). It is also observed that despite the team that carried out the project was composed of experts in materials engineering, it has not proposed a step for the design of the enclosure that would house the equipment. This, in practice, forced an emergency realignment during its execution, delaying the project completion and adding extra costs to what was predicted.

On the other hand, the MOR&D in practical application has shown that it would be interesting adding to the flowchart of Figure 6 a "*Field Tests*" step, before finishing the final prototype with a branch feedback for "*Input and Retrofit Information*" stage in case of need for corrections or adjustments.

8. Conclusion

From the initial literature review on ANEEL R&D Program, it was found the lack of a model with systematic configuration of specific activities for conducting R&D projects in the Brazilian electric sector, fact that characterizes the original contribution of this work. In this sense, through analysis of established product development processes models, it was sought to compose a comprehensive model serving as a framework for R&D projects elaboration of the ANEEL R&D Program.

The proposal showed promising since it allows the reduction of the segregated and sequential limitations, typical of R&D projects carried out so far, leading to efficient

development process which enables the realization of superior quality products in competitive time and prices.

However, it is known that only a practical application of the proposed model, as demonstrated here, is not enough to make it fully applicable. In this sense, other ANEEL R&D projects were and has been structured [18,35,36,39] having the MOR&D as background, which results and conclusions are contributing to the model refinement.

9. Acknowledgments

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