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Industry-Academia Collaboration Applied in Research of Power Systems and Components

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***Abstract*— The establishment of partnerships and cooperation between academic institutions and companies is of paramount importance in fostering innovation and societal progress. The existing literature has examined many models of managing the connection between Industry and Academia. However, the current understanding of this subject is incomplete and lacks clarity. Hence, it is imperative to investigate and provide novel management frameworks for the Industry-Academia collaboration, aiming to augment the competitive edge, foster innovation, and facilitate socioeconomic progress within a nation. This paper presents a fresh model for establishing relationships between industry and universities. The establishment of this model was achieved by collaborative efforts between two universities, resulting in the successful development of a range of research initiatives. In the projects, the participating enterprises have leveraged the human resources and physical assets of the universities to successfully address previously deferred or undetected issues, which were ultimately resolved through combined efforts. The acquired findings have demonstrated that the proposed technique effectively handles the many stakeholders from industry and academia, and successfully generates answers to practical challenges provided by the participating companies.**

***Index Terms*—Industrial relations, laboratories, power systems, power system simulation, research and development, test facilities.**

I. INTRODUCTION

The relationship between industry and academia is a very significant topic, as it has the potential to greatly influence a country's technological advancement [1]–[3]. In the present era of a global economy driven by knowledge, there has been considerable focus on cooperation between industry and academia. This has garnered substantial interest from various stakeholders, including policymakers, industrialists, and researchers [4]. The significance of transferring knowledge and the utilization of academic research has been acknowledged by these stakeholders, who have aggressively advocated for the transformation of the university's conventional strategy, which primarily focuses on teaching and research [2], [4], [5]. The existing research has examined many models of managing the Industry-Academia interaction. However, it is important to note that the current understanding of this topic is incomplete and lacks coherence [4], [6]. Hence, there is a need to investigate and suggest novel management frameworks for the Industry-Academia collaboration, with the aim of augmenting a nation's competitive edge, fostering innovation, and promoting socioeconomic progress [4].

The topic of relations between industry and universities is not a recent subject and has undergone transformations alongside the growth of universities, the advancement of the industry, and the implementation of public policy measures [5]. The significance of the Industry-Academia relationship gained prominence in the 1980s as a result of the rise of the concept of "innovation" as a catalyst for economic growth [2], [3]. In contemporary times, colleges have assumed a multifaceted role that extends beyond the mere development and transmission of knowledge. They have also become actively involved in the process of commercializing knowledge [3]. Universities employ diverse strategies to foster societal advancement, concurrently engaging in research and the development of novel technologies. They play a pivotal role in supporting both public and private enterprises and facilitating industrial progress. Furthermore, universities have increasingly incorporated explicit environmental criteria into their endeavors.

Regardless of the specific framework for Industry-Academia partnership, there are inherent problems and potential conflicts that may arise [1]. Despite the emergence of concerns over possible conflicts of interest when academics engage with industry in roles such as consultants or scientific advisors, it is important to acknowledge that these worries should not hinder the progress of such collaborations, as they have the potential to yield significant positive synergies [7]. However, it is crucial for both industry and academia to proactively identify possible causes of conflict and resolve them in advance as part of the preliminary efforts to form collaboration agreements [6]. The objectives, cultures, and working practices of industry and academia differ, necessitating adjustments to facilitate a fruitful relationship.

Numerous scholarly investigations have examined the link between the industry and academia. The study conducted in reference [3] aimed to identify and understand the distinct motives of industrial and academic participants involved in joint activities. The primary objective was to determine the specific benefits that these participants wanted to get from such collaborations. The motives mostly consist of research-driven inquiries and analyses pertaining to the applicability and impact of conducted research, as well as public policy considerations. According to the source cited as [8], the interaction between the industry and academia has primarily been approached from a transactional perspective rather than a relational one. This can be attributed to the emphasis placed by universities on their responsibility of disseminating research findings to many stakeholders in society, including companies, organizations, and other entities. However, the authors argue that the relationship between industry and academia can encompass alternative models, such as those involving closer collaboration through joint initiatives. In reference [5], the university's mission is delineated as an institution that fosters the advancement of a nation. Therefore, the authors suggest that colleges should adopt a clear focus on addressing the particular and/or broader requirements of a nation, encompassing those pertaining to the industrial sector. The article [4] introduces the notion of co-creation as a framework for guiding the collaboration between the industry and academia. The researchers assessed the manner in which academic and business entities collaborate to generate value through their involvement in research endeavors.

This paper presents a novel conceptual framework that establishes a connection between the electrical sector and academia through the implementation of a collaborative research method. The model has been formulated and implemented inside the Electric Energy Departments of the Technological Institute of Costa Rica (TEC) and the University of Costa Rica (UCR). The industry encompasses various participants, including providers of electrical analysis software, electrical machine repairs and assessors, utilities, and electrical equipment manufacturers. The aim of this study is to establish a comprehensive analytic and modeling framework for electrical power systems (EPS) in order to address practical challenges encountered in the industry. This research endeavors to leverage the collective expertise and experiences of all parties involved, with each individual adding their unique skills and knowledge. The findings thus far have facilitated the electrical industry in conducting investigations utilizing various simulation and calculation tools. This enables a comprehensive comprehension of diverse phenomena and intricate difficulties, hence leading to complex solutions. This endeavor has facilitated the academic institution in conducting research that culminates in scholarly publications and equips students with comprehensive expertise in their respective fields of study, so enabling them to undertake their graduation projects with proficiency.

This paper is organized as follows: Section II presents a review of different models of collaboration between Industry and Academia. In Section III the proposed collaboration model Electrical Industry-TEC/UCR is presented. In Section IV a summary of projects is presented along with a case study. Finally, the conclusions are presented in Section V.

II. Models to establish Industry-Academia research collaborations

The origins of research in modern universities can be traced back to the latter half of the 19th century. During this period, academic research began to incorporate several key principles. Firstly, the generation of knowledge was recognized as essential for the effective functioning of universities. Secondly, academic work encompassed professional training across various fields of knowledge. Thirdly, the pursuit of research necessitated a framework built upon diverse disciplines. Lastly, universities established organizational structures and legal statutes to support their research endeavors [5]. Based on these premises, it is evident that the university holds national recognition as an institution inside a particular country, and its goal is highly regarded as integral to the advancement of the nation. The statement pertains to the evolutionary trajectory of the university institution.

The perception of universities in society has undergone a notable transformation, wherein there is now a heightened recognition of their importance and an increased expectation for them to make a more tangible contribution to national development [2]. The insufficiency of research funding in basic sciences to drive technological advancements necessary for a country's development and the resolution of national issues prompted a reevaluation of relationships, both internal and external, including interactions with the industry. In circumstances characterized by limited government funding allocated to support research endeavors within universities, the initiatives that received financial backing in previous instances were predominantly aligned with national interests. In light of the stipulations imposed by government financing, universities are compelled to seek out additional means of assistance, while also exploring alternative sources and adopting novel research management frameworks [2].

In this sense, Industry-Academia relationship presents different models and forms of interaction, such as [3]:

- Collaborative research.
- Research centers.
- Contract research.
- Academic consulting.
- Patents.
- Informal information exchange.
- Publication and reports.
- Hired graduated.
- Licenses.
- Temporary personnel exchange.
- Joint research.
- Public meetings and conferences.

In every model that encompasses the link between the industry and academia, it is imperative to adopt an interactive approach to innovation that involves various stakeholders. The interactive model of innovation entails a departure from the conventional linear perspective on innovation, in favor of a collaborative approach including various stakeholders engaged in research [2]. The use of a collaborative approach fosters the facilitation of learning processes among participating students. This method is not limited to academic institutions, but is also extended to various businesses. Furthermore, scholars have long been interested in the benefits of cultivating partnerships with a diverse range of stakeholders.

The link between industry and academia can be understood from an economic theory perspective, as it pertains to the pursuit of achieving the most efficient allocation of resources for the purpose of knowledge generation [5]. The primary objective of economic theory is to optimize the allocation of investments to maximize societal returns. The complexity of this element arises from the characteristic of knowledge as a public good, which gives rise to questions regarding the way the returns generated from it are appropriated. To prevent disagreements and issues among the parties involved, it is imperative to establish confidentiality agreements in accordance with the university statutes [9].

Another aspect to consider in the context of the interaction between industry and academia is the involvement of scientific collaboration institutions as a distinct participant from the academic sector. There exist two primary entities for scientific cooperation, namely researcher networks, which can be either local or international, and research laboratories. One notable development in the field of scientific research is the increasing level of collaboration among researchers. This upward trajectory has the potential to bring about significant transformations in the way scientific activity is conducted on a global scale [5].

The provision of government funding aimed at facilitating collaborative efforts among diverse academics, both domestic and international, serves to foster the development of extensive research initiatives. Conversely, the establishment of research laboratories by researchers enables them to secure funding from universities or public institutions, which can be utilized for laboratory infrastructure and research project financing.

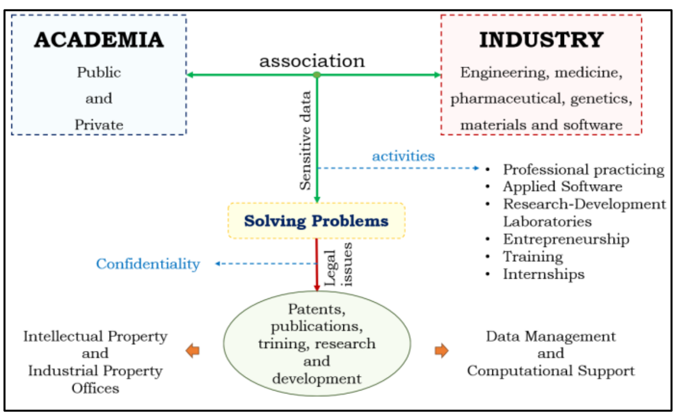

Fig. 1. Industry-Academia outreach process. Based on [9]–[12].

Therefore, it is imperative to closely monitor the progression of scientific collaborations to assess their influence on the connections between industry and academia. The exponential growth and expansion of knowledge-intensive enterprises in contemporary times necessitates acknowledging the significance of linkages and the function of development and research within the networks of knowledge [5].

As previously discussed, the relationship between the industry and academia has evolved over time, adopting various models. These models include shared research and development activities, which involve close collaboration between different stakeholders to generate synergistic outcomes. Additionally, the traditional approach of technology transfer, where research findings are transferred from academia to industry, has also been observed [8]. Figure 1 shows summary of the findings of the literature review.

The collaboration between academics and industry should ideally involve a mutually beneficial partnership where both parties share in the gains, as illustrated in Figure 1. The academic sphere encompasses both the public and private sectors, whereas the industry is predominantly associated with the private sector.

This alliance encompasses a range of disciplines, including engineering, medicine, biotechnology, materials science, and software development, among others. The availability of many choices for cooperative project development in the sector is contingent upon the academic offers. Illustrative examples of such alternatives encompass professional activities, application development, and internships, among a myriad of other possibilities.

A critical factor to be considered in this cooperation pertains to the effective handling of data, given that the establishment of trust between the two sectors is important for the sustained prosperity of collaborative endeavors. The issue at hand can be effectively resolved by implementing confidentiality agreements, since the consideration of legal factors becomes relevant during this phase. To address such challenges, it is possible to utilize various measures such as patents, publications, and analogous mechanisms. Intellectual property can play a significant role in the management and treatment of data.

III. TEC/UCR PROPOSED MODEL TO ESTABLISH INDUSTRY-ACADEMIA COLLABORATIONS

This section aims to elucidate the collaborative paradigm between the Electrical Industry and TEC/UCR, within the context of seeking resolutions for specific technical issues within the industry. The four actors involved in the model are as follows: i) Professors and researchers from the TEC and UCR, ii) Manufacturers of electrical equipment and software for electrical grid analysis, iii) Companies involved in electrical generation, transmission, and distribution, and iv) Companies specializing in diagnostic and repair services for electrical machines such as motors, generators, and transformers. The idea is grounded in a collaborative research framework, involving the active involvement of research laboratories from both universities and the electric sector. The salient facets of this relationship between the industry and academia are expounded upon in the subsequent sections.

A. *Steps to build the collaboration between Electrical Industry and Universities*

Figure 2 depicts the sequential procedures used for establishing the proposed collaborative endeavor. The following section provides a full explanation of each step depicted in Figure 2.

In the initial phase, the primary methodologies are established and the composition of the working group is determined. The initial stage involves gathering information regarding the potential for collaboration, as well as acquainting the relevant individuals with the subject matter. The execution of this phase is overseen by experienced experts hailing from the research laboratories of both universities. It is imperative to commence the process by undertaking an examination of diverse perspectives pertaining to the initiatives that are to be undertaken.

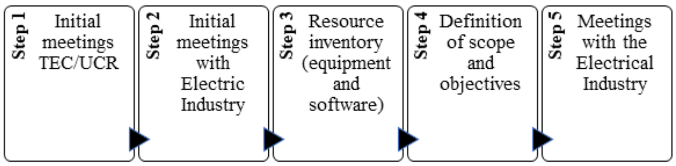

Fig. 2. Four-step procedure to build collaboration Industry-Academia.

In the second step, it is imperative to gain a comprehensive understanding of the underlying context in which the projects will be undertaken. This entails familiarizing oneself with the distinctive issues and features associated with the potential situations that the electrical sector aims to address. These elements are essential prerequisites for meaningful engagement and the development of a sustainable long-term plan. This entails an assessment of the requirements within the electrical industry, which necessitates careful consideration yet frequently encounters limitations in terms of manpower, equipment, or time constraints for its execution. This process is achieved by the conduct of official meetings.

Upon achieving the objectives of the initial stages, step 3 involves the examination of the inventory of equipment and software tools accessible in academic institutions. This analysis will serve as a foundation for undertaking research on industry-related concerns. Furthermore, the inventory of equipment that is both accessible for utilization and eligible for donation and will be utilized in the advancement of the projects, is obtained from the industries involved in the initiative.

Step 4 involves the establishment of the scope and the definition of objectives for the collaboration between the industry and academia, specifically within the chosen topic of research. One of the factors to be considered when determining the extent and goals of a project is the requirement for confidentiality as stipulated by the companies involved. It is crucial to define this aspect at the outset of the collaboration. This is also evaluated in accordance with the regulations of the universities.

Ultimately, in the fifth step, the project is initiated by a formal gathering with the various stakeholders. During this meeting, the elucidation of the relationship model is provided, with the aim of ensuring that each participant comprehends their own roles and duties. The collaboration model between the Electrical Industry and TEC/UCR is specifically designed to facilitate research on issues that are commonly encountered within the electrical industry. This model will be further elaborated upon in the upcoming section.

The depicted approach in Figure 1 has been built in a linear fashion to facilitate the implementation of new requirements within a company. By adhering to the outlined phases, a recent collaborative project can be effectively established.

B. Proposed model of Electrical Industry-TEC/UCR relationship

To address the requirements identified by the Industry-Academia partnership, we have put up a collaborative research framework, as seen in Figure 3. The next section provides an explanation of the suggested model.

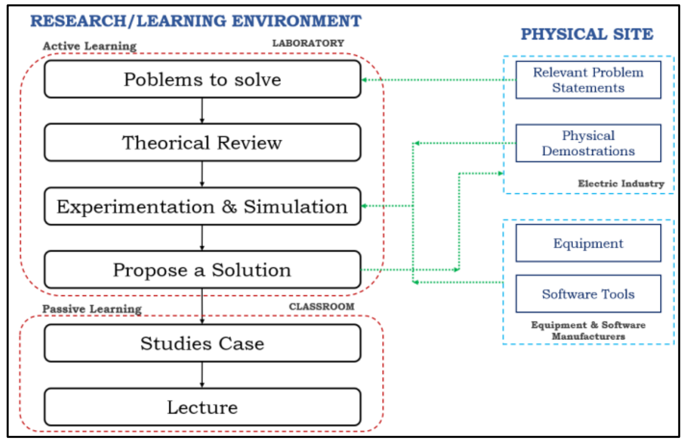

Fig. 3. Proposed model of collaboration. Adapted of [13].

Figure 3 depicts two distinct and well-defined locations that function collaboratively and synchronize their activities. These locations can be described as follows: i) an academic setting dedicated to research and learning, situated within universities such as TEC and UCR; and ii) a tangible site within the electric industry where manufacturing activities take place. Within the institution, there exist two distinct spaces that serve as venues for diverse activities, mutually contributing to each other's growth and development. One of the anticipated advantages of engaging in collaborative endeavors with the industry is the utilization of the executed projects as exemplars for case studies. Case studies are an invaluable pedagogical resource that enhances the learning processes within the conventional curricula of institutions.

The laboratory environment facilitates the development of industry-sponsored projects undertaken by students engaged in their graduation projects. These students receive help from laboratory assistants, while the technical staff provides collaboration and supervision. Moreover, the sector can contribute by offering tangible demonstrations. During this procedure, producers engage in collaboration with technical support personnel for their equipment and software tools, actively participating in the analysis of the obtained results. Ultimately, the recommended resolution to the examined issue is conveyed to the organization. Another potential outcome of this research is the potential dissemination of the findings, either in their entirety or in part, through publishing in academic publications and/or presentation at conferences. The matter is examined individually, considering each case separately.

C. Resources (physical) involved in the model Electrical Industry-TEC/UCR relationship

To facilitate any collaborative framework between universities and industries, the presence of technological resources is important. A collaborative project offers players the opportunity to access technical resources that may be unavailable or limited in their own capacities.

Universities can achieve cost reduction by refraining from procuring equipment that is readily accessible in the industry for research initiatives or is donated to participating laboratories. Universities may encounter challenges in accessing sufficient resources for the development of specific research due to budgetary constraints. However, these obstacles can be overcome with the help provided by the industry.

In the present study, the term "resources" include laboratory equipment, industrial equipment, software tools, and access to authentic facilities for conducting tests and measurements. The resources engaged in the collaborative paradigm between the Electrical Industry and TEC/UCR, known as "resource-sharing," encompass the following elements:

1. *University Resources.*

Available in the Energy Laboratories:

- Simulation and calculation software for the development of electrical studies and simulations off-line (MATLAB/Simulink from Mathworks, Mathematica from Wolfram).
- Access to research databases (digital libraries available: IEEE Xplore, ScienceDirect, ASTM, others).
- Real-time simulation equipment (OPAL-RT) with different software tools and the ability to make configuration type hardware-in-the-loop.
- Monitoring equipment for different variables (electrical, thermal, mechanical, meteorological variables, others).
- Electrical machines (transformers, generators, motors, dynamometers, others).

2. *Industry Resources*

Donated to the Energy Laboratories of the universities:

- Different types of protection relays and accessories.
- Different parts of electrical equipment to do test and analysis (windings, cables, insulators, others).
- Specialized technical equipment (automatic controls of generators, regulators, others).

Available in the industry facilities:

- Access to real tests on generators, transformers, substations, etc.
- Access to specialized laboratories to do test and analysis (quality control laboratories, destructive and non-destructive testing laboratories).

3. *Manufacturers Resources*

Donated to the Energy Laboratories of the universities:

- Computer labs equipped with simulation software and specialized calculations (ETAP, PLECS, EMTP).
- Different types of protection relays and accessories.
- Different parts of electrical equipment in order to test and develop analysis (windings, cables, insulators, others).

Available in the manufacturer facilities:

- Specialized test equipment (monitoring of condition, protection relay testing equipment, others).

With part of the indicated resources above, together with the participation of the personnel in charge, the following projects have been completed, to explain the way in which the proposed model was applied.

IV. Summary of Completed Projects and Case Study

We first present a list of completed projects, with some details on each one. Thereafter, a detailed case study is presented, which has not yet been published.

A. List of completed projects

Table I displays the projects that have been successfully concluded, resulting in the publication of findings in either a journal or a conference. Table I provides a comprehensive overview of the project descriptions, the specific electrical industry sectors involved, the resources contributed by the industry, and the corresponding published citations.

In the context of universities, the resources and personnel allocated for the advancement of various projects encompassed the following elements: i) students engaged in their final research endeavors and laboratory aides; ii) professors possessing specialized expertise in the respective fields under investigation; iii) facilities equipped for conducting tests; iv) databases dedicated to research; and v) software tools designed for analysis and simulation purposes.

This section provides an account of a project conducted in collaboration with an electrical generating firm, whereby a protective coordination study was conducted utilizing two software tools.

B. Case Study

The hydroelectric production plant necessitates an upgrade of its protection system, which is responsible for monitoring the transmission line connecting the plant to the national electrical grid. The pertains to the recent regulations implemented by the regulatory authority governing the electrical system, specifically pertaining to power producing facilities that are interconnected with the grid. The electric company extends an invitation for collaboration on the project, resulting in the joint efforts of two students and their supervisor to produce a solution that effectively fulfills the newly established criteria. Upon the conclusion of the project, our next course of action will involve the establishment of the technical standards for the acquisition of protective relays, along with the determination of their respective settings.

The hydroelectric facility is classified as a "run-of-river" type and possesses a power generation capacity of 18 MW. The plant is equipped with a modest daily regulatory dam. Table II presents the primary attributes of the hydroelectric plant, including mechanical and electrical properties, including water flow, turbine types, rotor rotation speed, minimum and maximum generation capacities, and other pertinent factors.

When conducting an adjustment and coordination of line safeguards, it is imperative to consider the following criteria, which are encompassed within the guidelines for connecting power facilities to the electrical grid:

- To effectively safeguard the protected equipment, it is imperative for every failure protection system to incorporate a backup mechanism that operates with sufficient speed to prevent faults from beyond the damage threshold.
- To ensure the reliability and safety of the power system in a generating plant, it is necessary to implement a minimum of two distinct protection mechanisms for all equipment. These protections, along with their respective fault elimination systems, should operate independently of each other to prevent common mode failures. One protection system should serve as the primary safeguard, while the other functions as a backup protection.
- The required protective equipment should consist of numerical relays equipped with oscillographs and event recording capabilities.
- The line protection functions will be optimized to efficiently detect and isolate faults occurring within the line, minimizing the time required for fault identification and isolation. Furthermore, it is imperative for individuals to possess the capability to discern and recognize instances of malfunction inside electrical systems, commonly referred to as off-line failures. Moreover, it is crucial for them to take appropriate measures to mitigate the adverse effects caused by these irregularities.
- The primary protective functions must detect internal line failures within a maximum time frame of 100 milliseconds, while backup functions must respond within a maximum time frame of 500 milliseconds.
- The analysis considers the upper and lower limits of fault currents that may be experienced. The worst-case scenario is considered when analyzing the system.

The proposed line protection scheme, wherein the inclusion of line differential protection is emphasized as the key protective measure. Existing are distance protection relays.

The transmission line of the power producing facility operates at a voltage of 34.5 kilovolts (kV) and is linked to the substation through the utilization of a circuit breaker. The current substation is equipped with a voltage output of 230 kilovolts. The primary attributes of the interconnection line of the power producing facility must be considered when determining the necessary modifications to the protection system that will be implemented.

The ETAP software is utilized to input the physical attributes of the electrical grid, resulting in the acquisition of impedance measurements with enhanced precision. The data will be utilized in further computations and simulations. One of the computations performed involves the analysis of short circuits, which is a crucial step in the first process of setting protective measures.

Initially, the feature will be activated for two distinct protection zones, namely zone 1 and zone 2. A tolerance of 15% is deemed acceptable for the maximum inaccuracy in the impedance values obtained through measurements. It is crucial to note that in the context of a short-distance transmission line, the shunt conductance and capacitance can be considered unimportant. Therefore, the impedance in series can be determined by solely considering the resistance and inductance along the entire length of the line. The adjustment of Zone 1 will encompass an impedance range equivalent to 85% of the overall impedance of the transmission line. This characteristic considers the potential mistakes associated with measurement transformers, as previously stated at a rate of 15%. Similar to the methodology employed in the first zone, the correction for zone 2 is determined by utilizing a protection range that encompasses 120% of the line impedance.

Additionally, the calculations are performed in order to determine the operational characteristics of the line differential relay. The establishment of a minimum threshold value is important to account for measurement mistakes in instrument transformers and residual flux. The number, as per the utilized laws, often falls within the range of 15% to 20% of the base current. It is necessary to assess the region in which the transformers exhibit no saturation in their cores, commonly referred to as the K1 Slope, characterized by a 30% slope.

This evaluation considers factors such as the precision of the current transformers and the precision of the current transformers. Regarding the relays. The established zone is defined as a threshold beyond which the core is not deemed fully saturated. In the context of this study, the threshold is set at twice the magnitude of the base current. The establishment of the region referred to as K2 Slope has been accomplished. This work pertains to the phenomenon of core saturation resulting from the application of very high currents. The evaluation of saturation values involved assessing percentages of the restraint currents within the range of 67% to 200%. In this particular instance, a slope value of 150% will be adopted. The adjustment parameters of the protective relays involved are created in this manner. The assessment of the configuration is now being extended through the utilization of short-circuit investigations and simulations. The adjustment parameters of the protective relays are formulated in this manner. The evaluation of the arrangement is currently being expanded by incorporating short-circuit tests and simulations. To enhance the outcomes of dynamic simulations, which aim to accurately depict physical systems, a comprehensive analysis is conducted within the HYPERSIM software of OPAL-RT (real-time simulation). This analysis involves the incorporation of pertinent data and attributes pertaining to power generation units, including time constants, voltage regulation system parameters, and speed governor adjustments. The electrical generation firm provided all of the data. The generating plant underwent two types of testing, namely the island test and the grid linked test, to validate its proper operation throughout the simulation. These tests were conducted using the HYPERSIM programming system and after adjusting all the control systems.

TABLE I

LIST OF COMPLETED PROJECTS THAT HAVE PUBLISHED RESULTS

No	Description	Type of industry involved	Resources provided by the company	Publication
1	Development of a dielectric health index for diagnosis of medium and low voltage industrial electric motors.	Repair of rotating electrical machines	• Testing at company facilities. • Support of the technical staff of the company.	[14]
2	Development of a dielectric health index for diagnosis of power transformers.	Power transformer assessment and diagnosis	• Testing at company facilities. • Support of the technical staff of the company.	[15]
3	Development of a methodology for life-span estimation of power transformers from the evaluation of its dielectric materials.	Power transformer assessment and diagnosis	• Testing at company facilities. • Support of the technical staff of the company.	[16]
4	Development of a FMECA methodology for a doubly-fed wind turbine.	Power generation	• Generator operating data. • Support of the technical staff of the company.	[17]
5	Motor bearing failures detection by using vibration data.	Rotating machines assessment and diagnosis	• Electric motor vibration data. • Support of the technical staff of the company.	[18]
6	Characterization of partial discharges (PDs) in slots and by vibration in stators of hydrogenators.	Power generation	• Testing at company facilities. • Generator PDs data. • Support of the technical staff of the company.	[19]
7	Residual lifespan estimation index in power transformers based on condition.	Power transformer assessment and diagnosis	• Testing at company facilities. • Support of the technical staff of the company.	[20]
8	Development of a methodology to assess the condition of electrical power transformers based on a health index.	Power transformer assessment and diagnosis	• Testing at company facilities. • Support of the technical staff of the company.	[21]

Initially, the island test encompassed the assessment of the producing plant's performance while subjected to abrupt load fluctuations while running independently from the main power grid. In this experiment, the functionality of the voltage and frequency control systems was assessed. A simulation of 60 seconds was conducted using the HYPERSIM software, during which the behavior of the generators was monitored and recorded. The study revealed that the excitation system modulates the field voltage to maintain voltage regulation at the terminals when the load is connected. Upon analyzing the voltage control loop, it is evident that the fluctuation in the field voltage is contingent upon the disparity between the reference voltage and the measured value.

In continuation of the island test, an assessment was conducted on the performance of the speed governor, responsible for regulating the output frequency. In this scenario, the speed regulator adjusted the gate opening signal based on the reference electrical power and speed, with the objective of aligning the output power with the reference power. Furthermore, the grid-connected experiment involved the interconnection of the power generation facility with the electrical grid, followed by the implementation of load variations. An evaluation was conducted on the performance of the voltage regulator and the speed governor. All the results produced in the simulations were deemed to be within the permissible ranges, therefore enabling the continuation of the other aspects of the protection research.

TABLE II

MAIN CHARACTERISTICS OF THE POWER GENERATION PLANT

Quantity of units	*2*
Turbine type	*Francis*
Shaft arrangement	*Horizontal*
Turning speed	*600 rpm*
Elevation	*100 m*
Pipe diameter	*3 m*
Pipe length	*450 m*
Annual energy generated	*78 GWh*
Power per unit	*9 MW*
Output voltage	*13.8 kV*
Connection line length	*25 km*

The study involved conducting simulations using various fault types at different sites along the link line between the generating facility and the national electrical system. The aims of these simulations encompassed the following objectives: The objectives of this study are twofold: firstly, to validate the efficacy of the suggested protection mechanism, and secondly, to conduct a comparative analysis of the simulation outcomes generated by two software tools employed in the project, namely ETAP (utilized for offline simulation) and HYPERSIM (utilized for real-time simulation).

There are two distinct categories of power system simulation software: offline simulation and real-time simulation. The utilization of both categories of simulation tools can contribute to the enhancement of calculations and the generation of more accurate projections, particularly when employed in conjunction with one another, as is the case in this particular project. Moreover, it is crucial to underscore the merits and drawbacks of each technique, while also acknowledging the promise of an integrated framework that enables accurate and adaptable simulations.

The distinction between simulation types is contingent upon the sampling interval and the acquisition of outcomes [22]. In the context of real-time simulation, temporal progression occurs in discrete increments of uniform duration. Consequently, the length required for the system to produce an outcome inside each increment is referred to as the sampling time. Real-time simulation offers the advantage of facilitating the incorporation of sophisticated setups, including Hardware in the Loop (HIL), which enables the execution of performance evaluations for electrical power system protection devices, among other applications. In contrast, offline simulation employs a sampling margin that is both variable and delayed, making it suitable for handling non-linear systems. However, it is important to note that this approach may yield less precise outcomes.

Tables III and IV present a set of comparative findings between the two simulation tools. These findings were derived from the operating sequence of events reports provided by each tool.

TABLE III
OPERATION TIMES OF THE DISTANCE RELAYS WITH FAULTS AT 80% OF THE CONNECTION LINE

Fault type	**HYPERSIM**		**ETAP**	
	Signal time (ms)	*Breaker opening time (ms)*	*Signal time (ms)*	*Breaker opening time (ms)*
Single-phase	35.97	92.18	21.70	71.70
Bi-phase	32.94	85.71	21.70	71.70
Three-phase	33.40	84.70	21.70	71.70

TABLE IV
OPERATING TIMES OF DIFFERENCE RELAYS WITH INTERNAL FAULTS IN THE CONNECTION LINE

Fault type	**HYPERSIM**		**ETAP**	
	Signal time (ms)	*Breaker opening time (ms)*	*Signal time (ms)*	*Breaker opening time (ms)*
Bi-phase	30.61	86.56	20.00	70.00
Three-phase	29.51	83.85	20.00	70.00

The differences in running timeframes between the two software programs may be observed in Tables III and IV, namely in terms of the duration from the formation of the opening signal to the complete opening of the circuit breaker. The observed variations were anticipated due to the utilization of distinct modeling methodologies. The important consideration is that both outcomes fall within the parameters stipulated by national regulations.

Throughout the course of this project, a comprehensive array of investigations, computations, and simulations were conducted employing the designated software tools. These endeavors successfully validated that the configurations of the protective relays functioned in a synchronized manner, thereby guaranteeing adherence to the stipulated criteria of all protection systems, namely sensitivity, selectivity, reliability, and speed.

V. CONCLUSIONS

The partnership between industry and academia has experienced a notable increase in recent years. This growth can be attributed to the demand for innovation and the pursuit of solutions to various difficulties encountered by nations. Universities are responsible not just for the development and transmission of knowledge, but also for engaging in the commercialization of knowledge. Historical data suggests that relationships between industry and universities have played a crucial role in facilitating the advancement of disruptive innovations. Furthermore, the collaborative dynamics observed in these instances are contingent upon the capabilities of both academic institutions and industrial entities, as well as their inclination towards embracing technological advancements. Hence, it is imperative to disseminate the skill sets possessed by each participant, together with their respective technological capabilities, and utilize them in support of joint endeavors.

This paper presents a fresh model for establishing relationships between industry and universities. The establishment of this model was achieved by collaborative efforts between two universities, resulting in the successful development of a range of research initiatives. In the projects, the involved enterprises have used the human resources and physical resources of the universities, thereby successfully addressing previously deferred or undetected issues that were only identified and resolved through collaborative efforts. A number of these literary works have successfully made their way into university curricula as subjects of analysis, serving as case studies. Additionally, they have been disseminated through publication in reputable academic publications and presented at scholarly conferences.

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