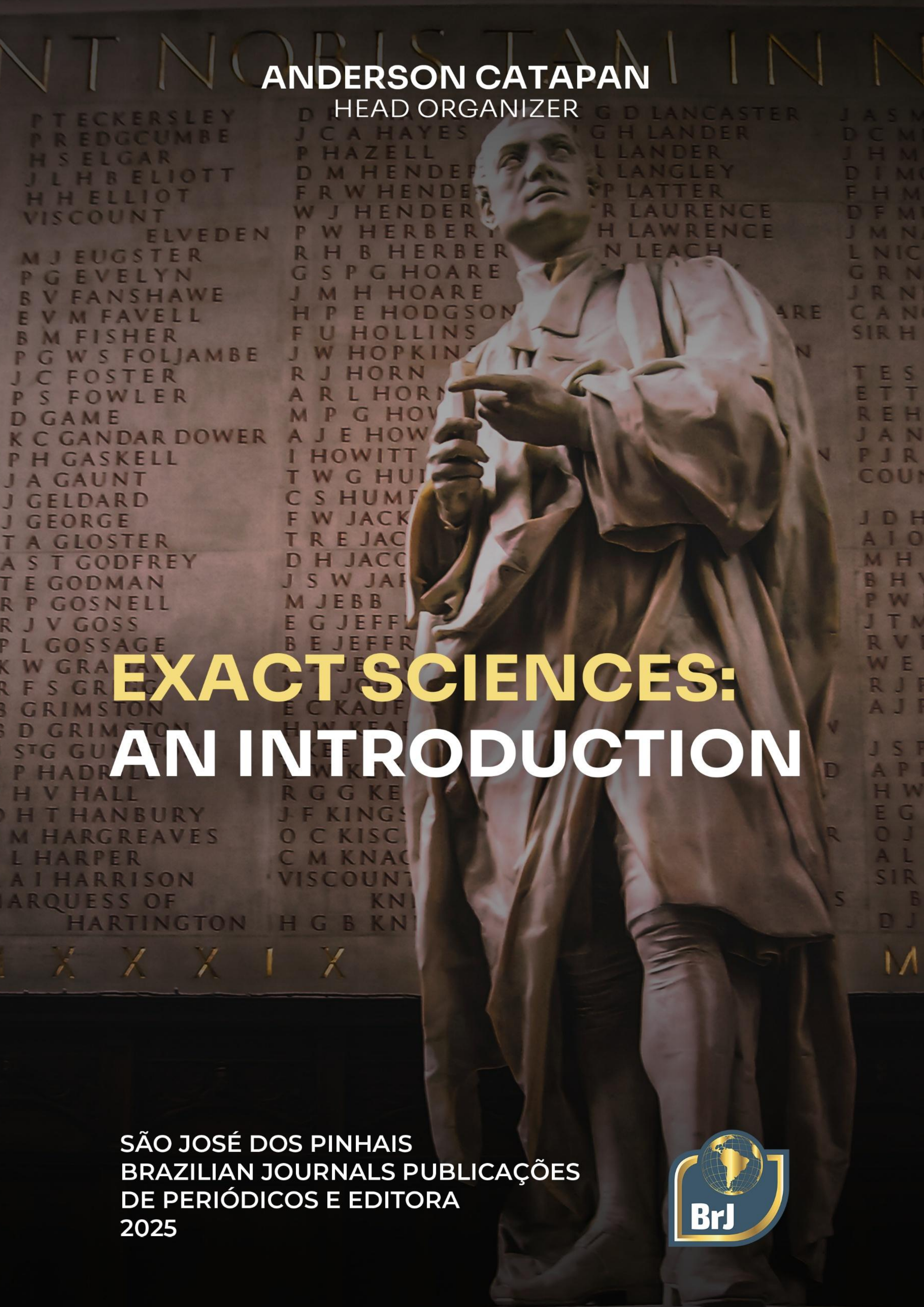

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EXACT SCIENCES: AN INTRODUCTION

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PRESENTATION

The exact sciences play a central role in the advancement of human knowledge, providing the foundation for technological development, the understanding of natural phenomena, and the construction of rational solutions to everyday challenges. Rigor, logic, and precision are hallmarks of this field of study, which is in constant dialogue with innovation and global transformation.

Exact Sciences: An Introduction is recommended reading for students in training, educators committed to teaching, and professionals who wish to strengthen or update their understanding of the fundamental principles that underpin the exact sciences.

More than just technical content, this work invites reflection on the value of critical thinking, structured analysis, and the practical application of knowledge in various spheres of academic and professional life. It is an engaging and accessible starting point for anyone who wishes to delve into—or reconnect with—the world of the exact sciences.

SUMMARY

CHAPTER 1

PARTICULARITIES OF INVERTER-BASED GENERATORS SHORT-CIRCUIT CURRENTS AND THEIR IMPACTS ON ELECTRIC POWER DISTRIBUTION NETWORK PROTECTION

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ABSTRACT: Despite its many benefits, the Distributed Generation (DG) can adversely affect some aspects related to the operation performance of distribution networks, still no so deeply explored in the literature, mainly regarding to the inverter-based DGs and their interaction with the distribution system protection. This paper shows the particularities of inverter-based generators currents to different types of faults. The impacts of these generators on distribution network protection schemes are also investigated. The results show that depending on characteristics such as penetration level, operating capacity, location and fault endurance the short-circuit current of the generators behave in different ways, also causing impacts on the distribution networks as protection miscoordination.

KEYWORDS: inverter-based generators, short-circuit current, distribution system protection, protection coordination.

RESUMO: Apesar de seus inúmeros benefícios, a Geração Distribuída (GD) pode afetar negativamente alguns aspectos relacionados ao desempenho operacional das redes de distribuição, ainda pouco explorados na literatura, principalmente no que se refere às GDs baseadas em inversores e sua interação com a proteção do sistema de distribuição. Este artigo mostra as particularidades das correntes de geradores baseados em inversores para diferentes tipos de faltas. Os impactos desses geradores nos esquemas de proteção da rede de distribuição também são investigados. Os resultados mostram que, dependendo das características, como nível de penetração, capacidade operacional, localização e resistência à falta, a corrente de curto-circuito dos geradores se comporta de maneiras diferentes, causando também impactos nas redes de distribuição, como descoordenação da proteção.

PALAVRAS-CHAVE: geradores baseados em inversores, corrente de curto-circuito, proteção do sistema de distribuição, coordenação da proteção.

1. INTRODUCTION

The number of installations of distributed generation (DG) units has grown significantly in Brazil over the last two years. This is mainly due to the creation of ANEEL Normative Resolution (NR) 482/2012 and its update NR 687/2015. The norm established the general conditions for micro and mini-generation access to electricity distribution systems. The number of connections of DG units surpassed the 10,000 mark in May 2017, with solar photovoltaic (PV) accounting for 99% of the total number of installations. ANEEL's new projection points to 886,700 installations and 3.2 GW of capacity for DG units by 2024.

Unlike what happens with rotating generators, as for example in [1], [2], and [3], there are few bibliographical references that comprehensively address the contributions of short-circuit currents from generators connected to the electricity grid by means of inverters (such as PV sources). Furthermore, due to their inherent overcurrent limitations, the fault current portion of inverter-based generators is generally neglected when compared to synchronous or induction generators.

When it comes to distributed generators made up of rotating machines and connected directly to the electricity distribution networks, as is the case with most installations with synchronous and induction generators with squirrel-cage rotors, there are numerous studies on their impact on short-circuit levels, which can be analyzed with some reliability using various programs specializing in short-circuit analysis.

Over the years, research efforts have focused on these types of generators because they are the first and main machines used in primary distribution networks as DG, as well as having inertia (rotor) and field winding current supplied by an external source, factors that make their short-circuit current much higher and with a longer duration than generators connected via inverters.

However, there has been an increase in the number of inverter-based generators in power distribution systems around the world. This expansion is set to grow and is being driven by the large-scale production and continuous improvement of semiconductor materials and microprocessors, which are the basis of photovoltaic cells and inverters, respectively, providing faster responses to transients and a more attractive cost-benefit ratio for consumers, who also find flexibility in implementation (due to their small size) and recent regulatory incentives an additional incentive to purchase the system.

However, the high penetration of PV generators in distribution networks, particularly in medium and low voltage, introduces new technical issues in the operation of these networks. The effects are mainly on voltage and angle control, short-circuit levels, protection settings, etc.

Within this context, this article investigates the short-circuit currents of generators connected via inverters and their particularities. The study was carried out using time domain simulations in the DIgSILENT Power Factory software using the electromagnetic transients model. An equivalent 13.8kV distribution network with typical IEEE data was used. The effects of different PV generator locations and the contribution of their fault currents were investigated, considering various fault conditions with different values of operating capacity, degree of PV penetration, fault resistance and other factors that modify the PV generator current. The proposed study also analyzes the impact of PV generator penetration on the protection of electricity distribution networks. A simulation is carried out on part of a real 34-bus IEEE distribution system, showing the loss of protection coordination in the recloser-fuse scheme.

2. LITERATURE REVIEW

Studies on the short-circuit level and obtaining fault current values are essential for planning and operating a power distribution system. Although there is not yet a large number of references related to the study of the behavior of inverter-based generators under fault conditions, some studies promote discussions and presentations of tests and results on the subject.

According to [3], in short-circuit studies involving inverter-based generators, the calculation of the initial value (effective and peak values) of the short-circuit currents is based on the assumptions set out in the IEC60909 standard for induction motors driven via inverters. According to this standard, the short-circuit current of inverter-driven motors is limited to three times their rated current. However, for non-rotating inverter-based generators, this assumption may be conservative.

Generators based on rotating machines have dynamic behavior and electromagnetic characteristics that cause electrical transients (voltage and current) and also require a longer time to adjust their energy supply (response time) to occurrences or changes (load input or output) in the electrical system to which they are coupled [4]. Unlike generators connected via inverters which, due to the use of power electronics, are not subject to these characteristics.

In [5], it was hypothesized that the expected short-circuit current of an inverter-based generator is at most equal to its rated current. However, this value depends on the behavior of the inverter, which in turn depends on the characteristics of the devices used and the control strategy adopted. In this article, the impacts on the short-circuit level in a distribution network due to the installation of a synchronous generator and an inverter-based generator were also compared. The results showed that the contribution of the inverter-based generator is around seven times less than that of a synchronous generator, both of the same size.

In [6], work was done to determine the fault current contributions of inverter-based generators. The main objective of the work was to evaluate what the industry adopts as the standard fault current contribution for inverters, which is approximately twice the inverter's rated current. The tests were conducted by the National Renewable Energy Laboratory (NREL) and by inverter manufacturers.

The tests conducted by NREL considered a 1 kW single-phase generator interconnected to a small electrical system by means of a current-controlled inverter. Short circuits were applied to this system and the results showed that the peak current value varied between four and five times the inverter's nominal current, over an interval of 1.6 ms (approximately 0.1 cycle). These results represent practically double the values practiced in the technical literature, which, according to the authors of this work, is twice the nominal current.

The tests carried out by the inverter manufacturers had similar test procedures to those reported for NREL. However, they used a three-phase circuit and the measurements were made for two-phase faults. The records showed that the duration of the faults is around 1.1 to 4.25 ms and the peak values of the fault current reached values around two to three times the nominal current of the inverter.

Other important approaches to the subject are made by [7]. In this work, the difference in the inverter's response time during a short-circuit was observed as a function of the control mode adopted. In this case, under voltage control, both the initial peak of the fault current and the re-establishment of normal conditions were faster than under current control.

In [8], the impacts on the current of a distribution system with an inverter-based generator due to the occurrence of short circuits are evaluated. In this work, it is found that variations in system current depend on the level of penetration of distributed generators and also on the type of control of these generators.

Reference [4] analyzes the influence of inverter-based distributed generators on the three-phase short-circuit current in a power distribution system, and its simulations show that their contribution to the value of the fault current does not exceed twice their nominal current.

It can be seen that the inverter's current and response time limitations in the event of a short-circuit are mostly linked to the control devices. However, the diversity of control modes and the different dynamic responses of inverters to different types of short circuits and scenarios make it difficult to reach a general conclusion about the behavior of this type of generator. This increases the need for research into the behavior and consequences of distributed generators in systems under fault conditions.

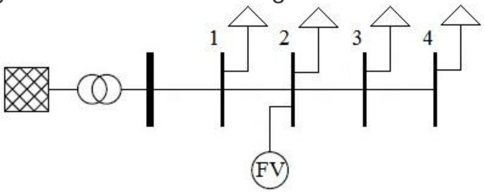
3. PECULIARITIES OF SHORT-CIRCUIT CURRENTS IN FV GENERATORS

With the expansion of PV generators, it is essential that technical aspects relating to the short-circuit currents of these generators, among other technical factors, be further investigated. It is worth noting that there is no technical document available to date that presents a comprehensive analysis involving various types of faults with generators connected via inverters.

In addition, the technical literature has not addressed the inclusion of their currents in short-circuit calculation programs that provide conservative results that are consistent with the behavior of inverters in the face of faults. Researchers generally adopt the 2.0 p.u. contribution as a convention, which is considered conservative.

The time domain simulations presented in this section were carried out using the electromagnetic transients model in the DIgSILENT program. The equivalent distribution network in Figure 1 was used, with typical IEEE data of 13.8kV. Transient three-phase short circuits, from 0.1s to 0.2s, with different values of operating capacity, degree of PV penetration, fault resistance and other factors that alter the PV generator's fault current, were applied to the line between bars 3 and 4, in order to gain a brief understanding of the PV contribution.

Figure 1. System for Understanding PV Generator Fault Current



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3.1 DEGREE OF PENETRATION

In order to analyze the aspect of the PV generator fault currents in terms of the degree of penetration of the distributed generation system into the grid, three-phase faults were applied and the injected active power set at 80% of the inverter's nominal capacity, moments before the fault. Figures 2, 3 and 4 show the generator currents at 10% (165.6 kVA), 30% (561.03 kVA) and 50% (935.05 kVA) PV penetration, respectively. The degree of penetration of a DG can be defined as the share of power delivered to the grid by the DG, taking as a reference the total power demanded by the loads in the system under analysis.

Figure 2. Three-Phase Fault Current of the PV Generator with 10% Penetration

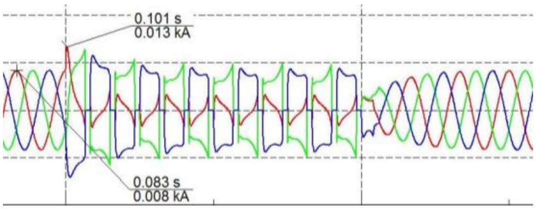

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Figure 3. Three-phase Fault Current of the PV Generator with 30% Penetration

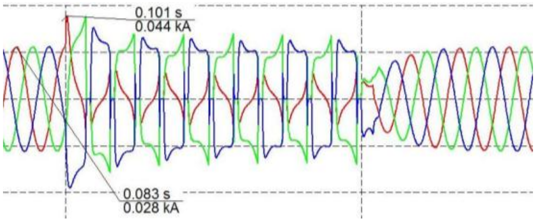

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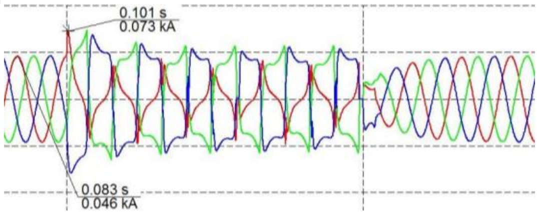
Figure 4. Three-phase Fault Current of the PV Generator with 50% Penetration



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There is no great influence of the degree of penetration on the variation of the post-fault currents, as a percentage of the currents in the permanent regime. At 10% penetration there is a variation of 62.5% in relation to the pre-fault current, at 30% penetration there is an increase of 63.64%, and at 50% penetration the current varies by 58.7%.

The results show that there is no linear relationship between the short-circuit current of the generator connected via the inverter and its degree of penetration into the system. Although the current variation for 50% penetration is lower, its absolute value is higher, due to its higher power injection, interfering more severely with the power grid.

3.2 OPERATING CAPACITY

In order to measure the influence of operating capacity on the fault currents of the PV generator inverter, three-phase short circuits were also applied to the three cases of generator operation: 20% (187.01 kW), 50% (467.52 kW) and 80% (748.04 kW) of its nominal capacity, for a penetration degree set at 50% (935.05 kVA). Figures 5 to 7 show the behavior of the short-circuit currents for the respective percentages.

The analysis of the short-circuit currents of the PV generators in terms of their nominal capacity at the time of the fault is significant due to the intermittency of their source, sunlight. The greatest increase in the short-circuit current in relation to the pre-fault current occurred when the generator was operating at the lowest simulated capacity, 20%. There was a 3.75-fold increase in its post-fault current, while for faults with the generators operating at 50% and 80% of their capacity there was a short-circuit current 2.14 and 1.72 times greater, respectively.

The results suggest that the greater the difference between the power injection of the PV generator at the time of the fault and its nominal capacity, the greater the contribution of the short-circuit current compared to the current of the same generator moments before the fault.

Figure 5. Three-Phase Fault Current of the PV Generator Operating at 20% of its Rated Capacity

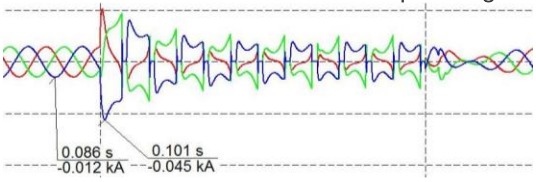

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Figure 6. Three-Phase Fault Current of the PV Generator Operating at 50% of its Rated Capacity

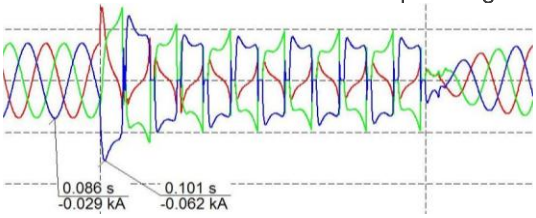

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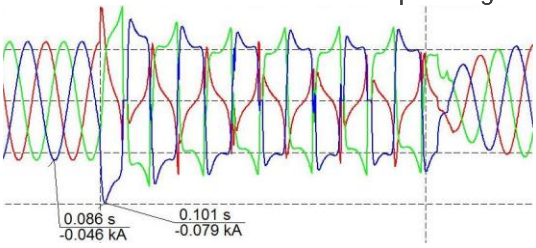
Figure 7. Three-phase Fault Current of the PV Generator Operating at 80% of its Rated Capacity



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Although the greatest increase in current was seen in the generator operating at 20% of its capacity, its absolute value remained lower than in the other simulations due to its low power injection just before the fault. Although this current in fact affects the grid less, it can cause greater damage in an adaptive protection system based on the pre-fault current at the inverter connection point.

3.3 RESISTANCE AT THE FAULT POINT

The resistance formed by the short-circuit at the point of the fault is one of the factors that has a significant influence on the short-circuit currents of PV generators. To examine this, three-phase short-circuits were applied with fault resistance (RF) values equal to 0.1Ω, 1.0Ω and 10.0Ω and shown in Figures 8, 9 and 10, respectively.

The degree of penetration was kept at 50% (935.05 kVA) and the pre-fault injected active power was also kept at 50% (467.52 kW).

Figure 8. Three-phase Fault Current of the PV Generator with RF = 0.1Ω

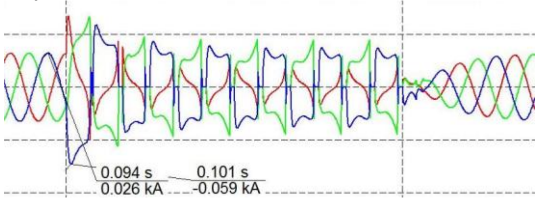

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Figure 9. Three-phase Fault Current of the PV Generator with RF = 1.0Ω

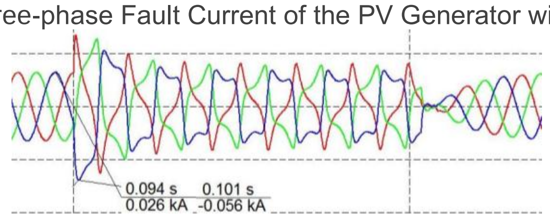

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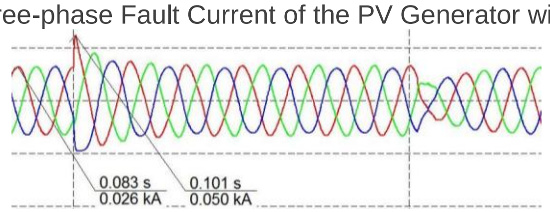
Figure 10. Three-phase Fault Current of the PV Generator with RF = 10.0Ω



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There is a relationship between the results: the value of the short-circuit current in the inverter increases as the resistance at the fault point decreases. For faults with RF = 0.1Ω, there is a 2.17-fold increase in the post-fault current compared to the steady-state current, for RF = 1.0 Ω a 2.15-fold increase and at RF = 10.0Ω a 1.92-fold increase.

The relationship exists, but it is not linear. As the resistance values at the point of the fault increase, the ratio of the short-circuit current to the pre-fault current decreases considerably. For resistances lower than RF = 0.1Ω, the post-fault current increase remains at 2.17 times the pre-fault, i.e. the maximum value of the fault current for the imposed conditions is 2.17 times the pre-fault.

3.4 FAULT LOCATION

The distance of the fault, also analyzed in more detail in [9], influences the inverter's output current. In order to confirm and measure the effect of the distance of the short-circuits on the currents of the PV generators, three-phase short-circuits were carried out on bars 2 and 4 of the system in Figure 1, at distances of 0.3 km and 4.3 km, respectively, and illustrated in Figures 11 and 12. The degree of PV penetration was kept at 50% (935.05 kVA) and the active power injected moments before the fault was also kept at 50% (467.52 kW).

Figure 11. Three-phase Fault Current of the PV Generator for a Short in Bus 2

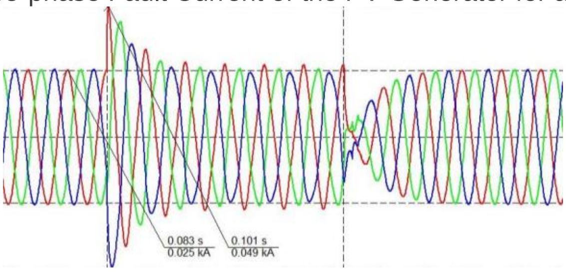

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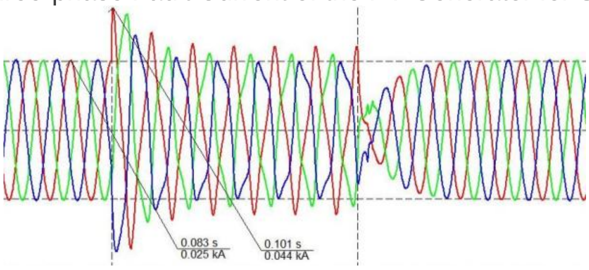
Figure 12. Three-phase Fault Current of the PV Generator for Short in Bus 4



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For the short-circuit applied close to generation, in bus 2, there was a 96% increase in the fault current in the PV generator inverter compared to the pre-fault current. For the same short-circuit applied away from generation, in bus 4, the post-fault current value reached 76% of the pre-fault current. The simulations therefore prove that the closer the generator is to the fault, the more it will contribute to it.

4. IMPACTS ON DISTRIBUTION NETWORK PROTECTION

Selective protection is protection designed and adjusted in such a way that for any type of fault only the protection device closest to the fault location (protective device) acts, isolating the faulty section [10].

Coordinated protection, on the other hand, is designed and adjusted in such a way as to eliminate transient faults through the automatic reclosing of the rear protection device and permanent faults through the operation of the device closest to the fault point [10].

For protection systems involving a recloser-fuse combination, with the recloser connected on the source side and the fuse on the load side, the link must withstand all fast recloser operations without damage. When permanent faults occur, the recloser must operate for a time that is sufficient for the link to fuse completely, avoiding possible mismatch problems. In this case, the opening(s) in the fast curve try to remedy the fault and if this does not happen, the link must merge before the first operation of the slow curve, preventing the recloser from becoming blocked [11]. In recloser-fuse coordination (recloser upstream of the fuse), the recloser's fast turns must act before the link is fused and the recloser's slow turns act as back-up protection.

The loss of sensitivity of the protection devices basically occurs because the PV source alters the system's current balance, i.e. by contributing to the fault current, the distributed generation source means that the upstream devices are not sensitized by the fault, or take longer to act. Depending on the magnitude of this source's contribution, the fuse will trip before the recloser, causing mismatch and unnecessary consumer disconnections.

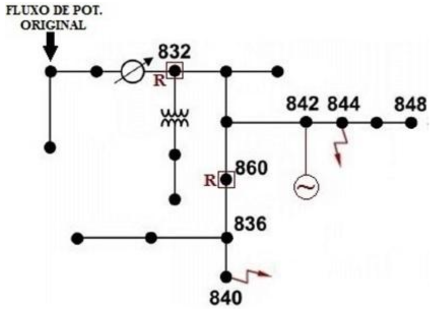
Another possible consequence for coordination is when the DG is upstream of the recloser. In this case, in addition to the loss of coordination, it has the capacity to cause unnecessary tripping of the recloser when there is a peak in demand, for example.

Also, when there is a fault on a feeder adjacent to the one containing the DG, loss of selectivity can occur. Currents can increase to such an extent that series protection devices on the adjacent feeder lose selectivity, as the network was not designed to be selective at this new short-circuit level. This phenomenon can occur between reclosers and fuses, as well as between fuses.

The test feeder corresponds to the IEEE 34-bus model that is part of the distribution system of the state of Arizona, in the United States of America. This model has been suggested by the IEEE committee in charge so that researchers can use it as a reference in their studies of distribution systems. For the sake of simplicity and understanding, the studies of recloser-fuse coordination are carried out on just one part of the system, on bars 832-844 and 860-840, as shown in Figure 13.

The simulations carried out consider the PV unit installed on bus 842. The PV generator's interconnection with the grid has a unity ratio, power factor equal to one, with 50% penetration and operating at 50% of its rated capacity at the time of the fault.

Figure 13. Part of the IEEE 34 Bus Test Distribution System Analyzed



Source: Author

The reclosers installed are on busbars 832 and 860, which coordinate with all the fuses on their respective downstream busbars. Single-phase and three-phase faults were applied to busbars 840 and 844, both with 0.1 Ω fault resistances, as shown in Figure 14 to Figure 17.

4.1 FEEDER WITHOUT PV INSERTION

Figure 14. Coordination between bars 832-844 (recloser-fuse) after three-phase (left) and single-phase (right) short-circuit on bus 844

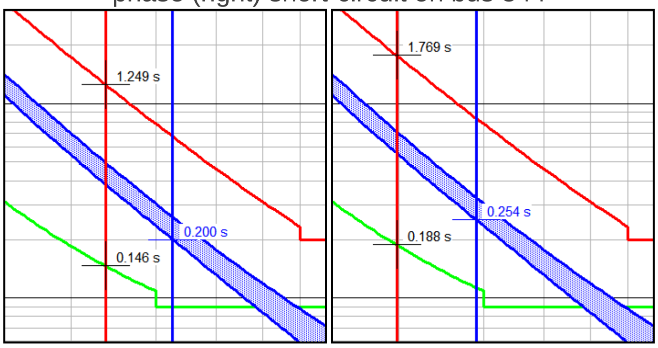


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Figure 15. Coordination between busbars 860-840 (recloser-fuse) after a three-phase (left) and single-phase (right) short-circuit in bus 840

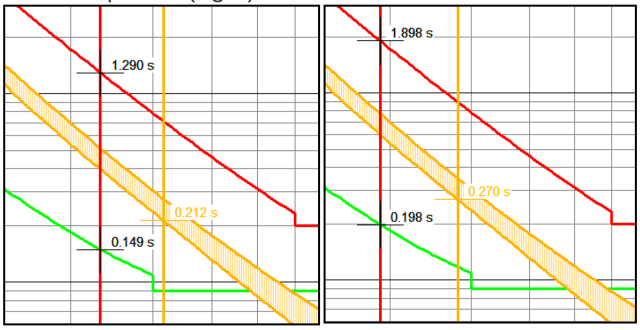

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Figure 14 and Figure 15 show the proposed recloser-fuse coordination well used for the original system (without DG) under study. In all cases, the fast recloser curve (green) acts before the minimum fusing time of the fuse link (blue and yellow), leaving good margins, even after severe faults, with low fault resistance and close to the bars protected by the fuse link, where the current experienced by the link is higher than that of the recloser.

4.2 FEEDER WITH PV GENERATION AT BUS 842

Figure 16. Coordination between busbars 832-844 (recloser-fuse) after a three-phase (left) and single-phase (right) short-circuit in bus 844

Source: Author

Figure 17. Coordination between busbars 860-840 (recloser-fuse) after three-phase (left) and single-phase (right) short-circuit in bus 840

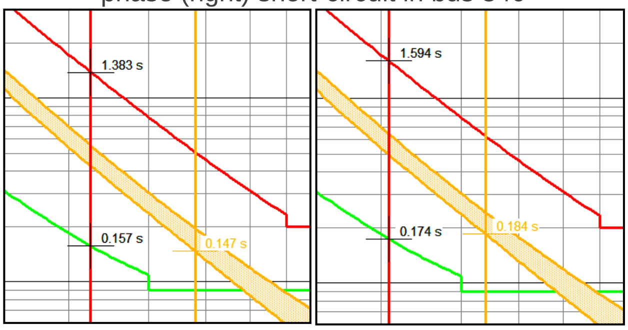

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Figure 16 shows the impact on protection coordination caused by inverter-based generators. In the case of a three-phase short-circuit, in addition to an increase in the current in the fuse, there is a drop in the current experienced by the recloser, causing the section to become uncoordinated for this type of fault. For single-phase faults, in this type of scenario, the system still remains coordinated, but with a very narrow and dangerous margin.

In the coordination between bars 860-840, Figure 17, there is also a slight lack of coordination for three-phase faults, proving that PV systems cause imbalances in current flows that are detrimental to coordination, even when installed upstream of the recloser. In Figure 17, special attention is also drawn to the fact that PV generators, even if not installed close to the faults, also have an impact on coordination.

5. CONCLUSIONS

As can be seen, inverter-based generators, and especially PV generation, have been introduced as a potential agent capable of increasing short-circuit currents in the electrical system in which they are installed. This increase was not significant before the installation of a few PV generators, but a massive insertion of this type of system can cause a marked change in the short-circuit level of the electrical system.

It is true that DG has already been installed in the world in a minority but consolidated way. It has spread rapidly around the world due to its numerous environmental, economic, social and technical impacts, which were initially seen as beneficial. However, with the increase in research and investment to boost DG, these impacts, especially with regard to technical aspects, have now become worrying and debatable, especially with regard to the protection of feeders and the DG units themselves. As such, the installation of PV generators in distribution networks must necessarily be accompanied by a set of studies to assess the possible impacts that may occur in electrical systems with these generators and their future configurations in the short, medium and long term.

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CHAPTER 2

DATA ANALYTICS AND BUSINESS INTELLIGENCE AS A DRIVER FOR ACADEMIC DEVELOPMENT

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ABSTRACT: The relationship between Business Intelligence and Data Analytics can improve strategic decision making within educational institutions. The aim of the research was to compile from various sources the main contributions of various authors on both concepts; The nature of the research was non-experimental (observational), whose study approach was qualitative, descriptive transectional; The method was field (empirical) from various documentary sources (bibliographic). Among the main results, it can be noted that Business Intelligence and Data Analytics take advantage of data collected in educational environments to extract valuable information and generate significant insights. These technologies allow informed decisions to be made to improve school management and the quality of education. Data Analytics goes even deeper, applying algorithms to identify hidden patterns and trends in large data sets, helping to anticipate academic problems, adjust teaching strategies, and personalize learning to meet individual student needs. As these technologies evolve, it is crucial to find a balance between educational innovation and protecting student privacy.

KEYWORDS: business intelligence, data analytics, decision making.

RESUMEN: La relación entre la Inteligencia de Negocios y la Analítica de Datos puede mejorar la toma de decisiones estratégicas dentro de las instituciones educativas. El objetivo de la investigación fue recopilar de diversas fuentes las principales aportaciones de diversos autores sobre ambos conceptos; la naturaleza de la investigación fue no experimental (observacional), cuyo enfoque del estudio fue cualitativo, transeccional descriptivo; el modo fue de campo (empíricos) a partir de diversas fuentes documentales (bibliográficas). Entre los principales resultados se puede comentar que la Inteligencia de Negocios y la Analítica de Datos aprovechan datos recopilados en entornos educativos para extraer información valiosa y generar *insights* significativos. Estas tecnologías permiten tomar decisiones informadas para mejorar la gestión escolar y la calidad de la educación. La Analítica de Datos profundiza aún más, aplicando algoritmos para identificar patrones y tendencias ocultas en grandes conjuntos de datos, ayudando a anticipar problemas académicos, ajustar estrategias de enseñanza y personalizar el aprendizaje para satisfacer las necesidades individuales de los estudiantes. A medida que estas tecnologías evolucionan, es crucial encontrar un equilibrio entre la innovación educativa y la protección de la privacidad estudiantil.

PALABRAS-CLAVE: inteligencia de negocios, analítica de datos, toma de decisiones.

1. INTRODUCTION

Today, using data to demonstrate that an educational institution provides value is no easy feat. Higher education collects an exorbitant amount of information that can be used to measure the performance of students, faculty, facilities, and the institution as a whole. Education needs performance metrics that can be tracked, measured, and analyzed. And so the educational institution will be able to understand how a program, department, course or even a student is progressing towards its goals.

There is a strong call from the international education community for governments around the world to engage in data collection projects to build key performance indicators for educational processes for monitoring purposes.

Over the past decade, education systems around the world have undergone considerable reforms and changes, all seeking to improve the quality and management of education. A key feature of this change has been the frequent review of policy style and approach, especially in the area of performance indicators, with an important emphasis on evaluating and monitoring student learning outcomes, in fact, current policy activities related to "results-based" educational performance indicators and their links to the growing demands for accountability, standards monitoring, benchmarking, school effectiveness and reform are widespread and well established in many developed countries.

2. METHODOLOGY

Through an exhaustive systematic review of the literature in areas such as Business Intelligence, Data Analytics, Academic Analytics, Learning Analytics and Data-driven Decision Making, the framework for the development of research in these domains and their essential conceptual foundations was established. Analyzes of articles from the most influential scientific publications in both English and Spanish languages were carried out. Subsequently, we proceeded to examine and recognize both in the specific literature of each field and in that which addresses these fields jointly, the elements of relevance to understand the relationship between Business Intelligence and Data Analytics in the educational context. Emerging perspectives from this review were considered with the aim of identifying key factors at this intersection.

3. RESULTS

3.1 BUSINESS INTELLIGENCE

In the last decade of the 20th century, decision support systems (DSS) were the dominant concept in business administration and a totally new discipline known as Business Intelligence was beginning to be used, which has been evolving and gaining strength and in which DSS has been included, since the central initiative revolves around the data of organizations, their conversion into knowledge so that, after the corresponding study, they support business decision-making. At present, information systems are considered the backbone of organizations and their daily support and the axis on which business intelligence systems are structured (Joyanes, 2019).

And it was IBM researcher Hans Peter Luhn in 1958, who first published in the IBM Journal the concept of Business Intelligence to allude to a system that is automatic, which obtains information and distributes it in a timely manner to the appropriate sites. By the year 1990, Howard Dresner is regarded as the father of Business Intelligence and idealizes it as the concepts and procedures to optimize decision-making in the company through the use of fact-based systems of support. Business Intelligence leads the company to competitive superiority through insider information and leads to the resolution of the organization's problems (Garcia et al., 2021).

It can be said then that, Business Intelligence, are those administrative and business resources that recent and modern companies have the possibility of having to get the most out of the information they have both from their consumers and from their suppliers and even from the competition, all with the purpose of achieving competitive advantages in a hostile and quite dynamic market. The performance of information management, administration and control as a strategic weapon, belongs to Business Intelligence, supported by technological and analytical tools that help companies maximize their performance generating operational effectiveness. Likewise, knowledge management helps to have a better understanding and knowledge of the field and processes from our experience as individuals and companies.

Thus, Business Intelligence, in addition to being the group of tools and applications for support to decision-making, allows the interactive, analytical and multiplication of the critical assignment corporate information. These applications provide a cherished understanding of operational information, identifying drawbacks and business opportunities. With them, users are able to access huge amounts of information to engage and examine collaborations and understand trends that will ultimately support business decisions.

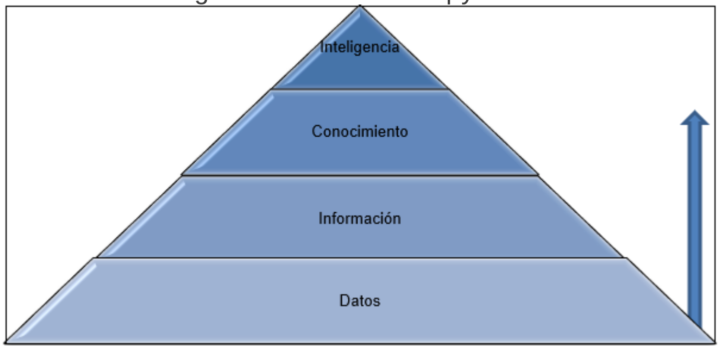
Therefore, there are resources that remain quite correlated with Business Intelligence, such resources are: reasoning, data and information. Data becomes information and is in parallel in understanding. Therefore, data is considered to be the smallest semantic unit, and they correspond to primary information resources that alone lack meaning and are not useful as support for decision-making. Moreover, they have the possibility of seeing themselves as a group of values, which lack meaning about why things happen and are not used for action.

Consequently, information can be conceptualized as a collection of structured data that contain meaning (relevance, objective and context), and that therefore is of great help to who should make decisions, by reducing uncertainty.

Therefore, knowledge is a combination of experiences, principles, information and skills acquired through experience or education, theoretical or practical understanding of a subject (Muñoz et al., 2016).

To illustrate better, these resources are expressed graphically as the informational pyramid, which represents the interrelationships between data, information, knowledge and intelligence. Each block is a step towards a higher degree: in the first instance it is the data, then the information, then the knowledge and finally the intelligence. Each step answers different questions about the initial data and adds value to it. The more enriched our data is, the more knowledge and insights we gain from it so that the right data-driven decisions can be made. In Figure 1, the flow for knowledge generation is observed (Davenport & Prusak, 1998).

Figure 1. Informational pyramid.



Source: Davenport & Prusak (1998)

In the special case of educational institutions, in addition to automating their general processes such as registration, payment, qualification management, teaching management, among others, they must integrate information technology in their educational processes and incorporate it into the learning plan. An example is the use of a learning management system (LMS Learning Management System), which allows students to interact with a variety of synchronous and asynchronous tools.

In this sense, the creation of information in an educational institution is permanent and the management of your data is absolutely necessary. Technological advances have resulted in access to a large amount of information that must be included in reports with updated information and disseminated almost in real time. Therefore, good data management is a complex but essential function of a good strategic direction of an educational institution.

Thus, the understanding of Business Intelligence as a resource for educational organizations arises from the current need for information to make a decision based on data obtained from different organizational processes. It should also provide relevant metrics to measure learning outcomes, have important and reliable information to monitor the vital functions of the institution, as it is considered a key piece for academic management. The monitoring of academic and learning management through the use of Business Intelligence systems becomes a reality thanks to the improvements of key performance indicators or KPI's (Alvarez, 2021).

Another aspect is data management, which includes analyzing different types of data of the institution and the environment in which it is located, through the use of information technologies, which allows the application of Business Intelligence, providing the necessary tools to take advantage of stored data transactions and use the information to support decisions.

To face the new challenges and opportunities that are available, educational institutions around the world need to use innovative approaches. In general, education authorities don't know what is happening in every department or area and it can take years to solve these problems and improve performance, but competition can go faster.

In this context, it is of paramount importance that institutions have a formal analytical process that can facilitate the decision-making process. Business Intelligence tools play an important role in this process of competition in which they are today, because they allow modeling multidimensional structures to create concise queries through a dashboard that helps as support to generate reports. Educational institutions that use Business Intelligence to make decisions collect small pieces, keep them simple and focused to provide immediate and critical benefit, demonstrate the value of data-driven decisions (Santos & Benites, 2020).

3.2 DATA ANALYTICS

To be sure, the automation of processes, the wave of changes in technology and the constant increase in the volume of transactions of organizations have led to the storage of a significant part of their information in their systems. Often, such information is not considered as such, let alone analyzed because it is misunderstood to be false, and believed to be difficult to obtain or labor-intensive to process, unlike the benefits it provides. However, in recent years companies have noticed that this information can be very valuable for organizational empowerment. In this context, data analysis processes and/or techniques emerge, along with access to internal and/or external (quantitative and qualitative) information, allowing managers to view their organization's management in a more meaningful way (Condor, 2019).

In this way, Data Analytics is a discipline focused on extracting knowledge from data, including analysis, collection, organization and storage of data, as well as the tools and techniques used to work with them, its main objective is to employ technologies and statistical analysis on data to find trends and solve problems. Increasingly important in business as a way to analyze and design processes, as well as to improve decision-making and results. It draws on a variety of disciplines, including computer programming, mathematical models, and statistics, to perform data analysis in order to describe, predict, and improve performance. To ensure robust analytics, data analysts employ a variety of management techniques, including data mining, data cleanup, data transformation, data modeling, and more (Olavsrud, 2019).

So, Data Analytics provides organizations with tools and methodologies to examine all their data (real-time, history, data with or without structure, quantitative, qualitative, etc.) to identify models and create knowledge to notify and, in some cases, automate decisions, linking intelligence and actions. The best existing solutions support the analytics process, from data access, preparation and analysis, to analysis and monitoring results. It allows organizations to transform their business into a digital culture, become more creative and forward-thinking, for decision-making. In addition to monitoring and generating traditional KPI reports to find hidden models in the data, organizations that are powered by the use of algorithms are considered to be innovative and leading in their field. By modifying the model, organizations can create a personalized customer experience, create connected digital products, streamline operations, and increase employee productivity.

Using Data Analytics, organizations enable everyone to contribute to the company's success, from engineers and data scientists, to the organization's analysts and programmers, as well as experts and organizational leaders. Encourage people inside and outside the organization to collaborate. For example, data scientists can work closely with customers to help them solve their problems in real time using cooperative user interfaces.

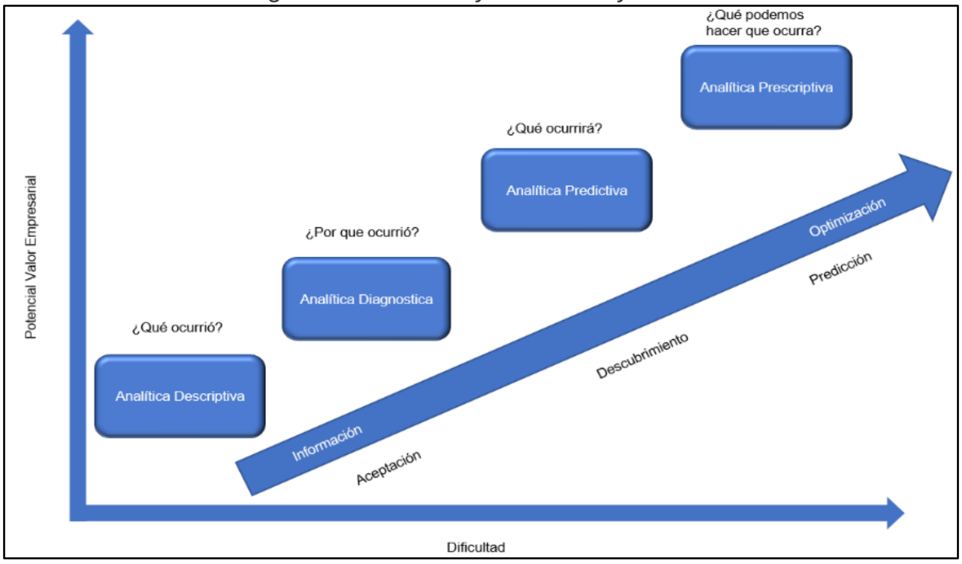
In this sense, Data Analytics allows the organization to move forward through the introduction of algorithms in all its areas, to optimize important business processes, applies to all industries, including financial services and insurance, production, energy, transport, tourism, logistics, health, etc. It can help predict and manage disruptions, improve routes, provide proactive customer service, deliver smart mass offers, anticipate imminent equipment failures, manage inventory, optimize prices and report fraud (Hesse, 2021).

Data Analytics consists of several stages, ranging from data capture to the production of results, so that companies obtain optimal business value. There are four types of Data Analytics (Joyanes, 2019).

In recent years, Data Analytics has been a hot topic. Many authors talk about why organizations should use Data Analytics. With the amount of value that Data Analytics can bring, it's tempting to get in right away and try to make a quick profit. But without the right foundations, it is impossible to achieve these results. So, what is the first step in gaining this valuable knowledge?

Understanding the progression of Analytics and starting in the right place will help ensure success with Data Analytics. Figure 2 explains the maturity model of Data Analytics (Kalsbeek, 2020).

Figure 2. Data Analytics maturity model.



Source: Douglas (2019).

Hence, Descriptive Analytics is the process of using current and historical data to identify trends and relationships. It is sometimes called the simplest form of data analysis because it describes trends and relationships, but does not delve into them. Descriptive Analytics is relatively accessible and probably something your organization uses on a daily basis. Basic statistical software, such as Microsoft Excel or data visualization tools, such as Google Charts and Tableau, can help analyze data, identify trends, relationships between variables, and display information visually. Descriptive Analytics is especially useful for communicating changes over time and uses trends as a springboard for more detailed analysis to drive decision-making (Cote, 2021).

In fact, Descriptive Analytics is closely related to Business Intelligence, which uses techniques such as regression modeling, data modeling, and visualization. For these reasons, it is allowed to know some of the following activities (Joyanes, 2019):

- Discover which products are the best sellers and the geographical areas in which the organization is developed.

- Observe the historical evolution of the demand for a product or service in certain periods of time.
- Identify the most influential people or companies in the business division of the organization.
- Visualize the news of the press, radio, TV, social networks of greater repercussion, as well as its geographical location, segments of population, etc.

After asking the main question of what happened?, you may want to dig deeper and ask why it happened? This is where Diagnostic Analytics comes in. The Diagnostic Analytics takes the information obtained from the descriptive analyzes and delves into finding the cause of that result. Organizations make use of this type of analysis, as it creates more connections between data and identifies patterns of behavior.

It is necessary to emphasize that a critical aspect of Diagnostic Analytics is the creation of detailed information. When new issues arise, you may have already collected certain data related to the issue. Having the data at your disposal, you end up having to repeat the work and make all the problems interconnected (Gibson, 2021).

Next, Predictive Analytics is a classification of Data Analytics focused on forecasting the possibility of future results based on past data and methods of analysis, including statistical modeling and machine learning. Predictive Analytics can create forecasts with substantial accuracy, allowing organizations to use the past and present data to project patterns and behaviors days, months or years in advance. For every organization, big or small, the ability to anticipate the future is the key to sustainable growth and sometimes even the very existence of the organization depends on it.

Patterns are used to build a model that tracks key trends after the collected data has been analyzed. Decision makers can then use the result to propose steps to get the best result (Funmilola & David, 2019).

Some of the tasks that Predictive Analytics allows are (Joyanes, 2019):

- Anticipate customer requirements at different points of sale.
- Detection of fraudulent bank transactions.
- Identify interest groups that share similar characteristics: demographics, geography, product preferences, and more.

Finally, Prescriptive Analytics allows to "prescribe" a set of different possible actions and direct them to the solution. Simply put, these reviews are meant to provide advice. Descriptive analysis attempts to determine the impact of future decisions to provide advice on possible outcomes before making a decision. At best, Predictive Analytics not only helps predict what will happen, but also why, and provides forecast-based recommendations for action. This type of analytics goes beyond descriptive and predictive analytics by suggesting one or more possible courses of action. Basically, they predict multiple futures and allow organizations to evaluate many possible outcomes based on their actions. Prescriptive Analytics uses a variety of techniques and tools, such as business rules, algorithms, machine learning, and computer modeling processes. These methods apply to input from a variety of data sets, including historical, transactional, real-time data sources, and Big Data. It is worth noting that Prescriptive Analytics is relatively complex to manage and most organizations have not yet used it in their daily operations. When done correctly, it can have a big impact on how a company makes decisions and its business results. Large organizations successfully employ Prescriptive Analytics to improve production, planning and inventory in their supply chain to ensure the right product is delivered at the right time and improve the customer experience (Bachar, 2020).

3.3 DATA ANALYTICS IN EDUCATION

Data has been dubbed “the new oil,” and organizations around the world are scrambling to exploit the data repositories they hold, in an attempt to extract actionable information that could give them an edge over the competition. But Data Analytics is not unique to the world of big business. Educational institutions around the world are also joining in. Its adoption of Data Analytics and predictive modeling will have a significant impact on the way courses and institutions are marketed, curricula are structured, and students are monitored and supported (Henebery, 2019).

Most managers of education institutions understand that using Data Analytics can significantly transform the way they work by enabling new ways to engage current and future students, increase student enrollment, improve student retention and completion rates, and even increase teacher productivity and research. However, many school and university managers remain unsure how to incorporate Data Analytics into their operations and achieve the expected results and improvements. What really works? Is it a bet on new talent, technologies, or operating models? Or all of the above?

Transformation through Data Analytics can be difficult for any organization. In education, the challenges are compounded by sector-specific factors related to governance and talent. Education leaders cannot simply talk lip service to the power of Analytics; they must first address some or all of the most common obstacles. In many educational institutions, there is little incentive (and a lot of reluctance) to share data. As a result, most education institutions lack good data hygiene – that is, established rules on who can access various forms of data, as well as formal policies on how they can share that data across departments. Transformation through Data Analytics is possible when managers of educational institutions strive to change both operations and mindset (Krawitz, 2018).

Analytics is a critical enabler for helping educational institutions solve difficult problems, but education institution leaders must devote as much energy to acting on data information as to enabling data analysis. Implementation requires significant changes in culture, policy, and processes. When outcomes improve because one educational institution successfully implemented change, even in a limited environment, the rest of the institutions notice. This can strengthen the institutional will to move forward and begin to address other areas of the organization that need improvement (Litman, 2019).

Nowadays, educational institutions are using two forms of Data Analytics: Academic Analytics and Learning Analytics, Academic Analytics is the application of Business Intelligence tools and strategies for decision making in educational institutions, reflects the role of data analysis at the institutional level, Learning Analytics is the analysis and reporting of student data to facilitate the teaching-learning process, also emphasizes the use of data intelligently.

Table 1. Comparison between Academic Analytics and Learning Analytics.

Academic Analytics	Learning Analytics
Academic Analytics is associated with Business Intelligence.	Learning Analytics is associated with the collection, measurement and analysis of data about the learner and their learning process.
It can be applied at four different levels: institutional, regional, national or international.	Can adapt to the whole process Teaching – learning.
The main beneficiaries are administrators and educational authorities.	The main beneficiaries are the student and instructor.
It helps managers to ensure optimal utilization of resources.	Help students and instructors understand the pattern of success or failure.

Source: (Moore, 2019).

In other words, Learning Analytics is more specific than Academic Analytics. The first focuses on learning, a process that includes analyzing the relationship between student, content, institution and educator, while Academic Analytics involves students and the institution. Table 1 provides a comparison of the two types of Analytics (Long & Siemens, 2020).

3.4 BUSINESS INTELLIGENCE AND DATA ANALYTICS IN EDUCATION

True, education is becoming increasingly demanding, both in terms of running schools as a business and providing the resources to educate young minds. School administrators and boards are often expected to do more with less, with funding tied to tuition fees charged, academic results, student population size, class size, average daily attendance, after-school program offerings (languages, music, fine arts, sports, etc.), and a variety of other measures that detail overall school performance.

Schools' ability to attract new students and satisfy parents, government groups, educational authorities, and government regulations becomes more difficult each year. Schools have long been required to report to stakeholders and under increasingly harsh operational conditions, as this is a time-consuming activity and uses significant administrative resources. But schools have an opportunity to reduce this burden and even expand operational knowledge that can improve business function and academic performance. How, by directing the large volume of naturally collected data to a Business Intelligence system.

While not as large as universities, schools of basic and upper secondary education share many of the same commercial and reporting problems. In countries where private schools are popular, it is not uncommon for private schools' annual operating budgets to reach the tens of millions. This makes the functioning of these institutions complex.

Education institutions are increasingly embracing Business Intelligence and Data Analytics to reduce the complexity of management and uncover important facts about their businesses. A competition that can boost academic, administrative, and workforce-related outcomes and help publicize those achievements. Figure 7 shows a basic business intelligence and academic analytics scheme (Combita et al., 2018).

4. FINAL CONSIDERATIONS

In an educational environment, Business Intelligence tools are used to measure, collect and analyze the activity of the entire institution. Data Analytics in education, it's not just about technology, it's about completely redefining who uses the data and how. If colleges or universities have not used these tools, it is time for them to make a culture shift towards data-driven decisions. What they need is an easy-to-use, customizable, cloud-based solution with actionable intelligence that doesn't require complex coding (Sriram, 2017)

There are several educational institutions that have used data models to make decisions and with that, increase student retention, provide transparency of financial reports, improve space management, security and protection, provide real-time operations visualization and, above all, support for data-based decision-making. To cite one example, better retention of students can lead to higher graduation rates. When educational institutions use data to manage, they save money, shorten enrollment to graduation, and have more transparent ways to track successes and improve forecasts (Pomeroy, 2014).

This being said, there is a growing interest in educational institutions to have a data-driven analytics model to raise decision-making and improve performance. Having an educational management system driven by analytical data will offer a gold mine of data that can impact curriculum design, course delivery, students, and institution growth.

Business Intelligence and Data Analytics are powerful tools that, when used together, can significantly improve strategic decision-making in educational institutions. Through data collection, analysis, and presentation, Business Intelligence provides valuable insights that enable leaders to better understand their organization's performance and make informed decisions. By combining Business Intelligence with Data Analytics, organizations can effectively identify and monitor the most relevant indicators for the organization. This allows them to assess performance in real time and make strategic adjustments as needed. Business Intelligence provides a comprehensive view of data and helps identify patterns and trends, allowing organizations to anticipate and quickly adapt to market changes. The use of Business Intelligence and Data Analytics also fosters a data-driven culture within the organization. By basing decisions on objective data and deep analysis rather than intuitions or assumptions, the likelihood of costly errors is reduced and more accurate and informed decision-making is promoted. However, the effective use of Business Intelligence and Data Analytics presents challenges. The quality and availability of data are critical for accurate and reliable results. In addition, a leadership mindset is needed that values and promotes the use of Business Intelligence and Data Analytics across the organization. In conclusion, the use of Business Intelligence in combination with Data Analytics offers educational institutions a competitive advantage by improving strategic decision-making. By harnessing the power of data and quantitative metrics, organizations can quickly adapt to market changes, optimize their performance, and achieve their goals more effectively.

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