Business Intelligence and Data Analytics (BI&DA) to Support the Operation of Smart Grid

Business Intelligence and Data Analytics (BI&DA) for Smart Grid

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Abstract: Smart Grid is the modernization of electrical networks using intelligent systems and information technologies. The growing interest that the smart grid is attracting and its multidisciplinary nature motivate the need for solutions coming from different fields of knowledge. Due to the complexity, and heterogeneity of the smart grid and the high volume of information to be processed, Business Intelligence and Data Analytics (BI&DA) appear to be some of the enabling technologies for its future development and success. The aim of this article is proposed a framework for the development of BI&DA techniques applied to the different issues that arise in the smart grid development. As case study the paper presents the applications of BI&DA in database of processes security for Distribution System. The goal is to have available and timely information to make better decisions, to reduce the number of accidents and incidents. This work is therefore devoted to summarize the most relevant challenges addressed by the smart grid technologies and how BI&DA systems can contribute to their achievement.

1 INTRODUCTION

In the last decade the Electric Power Utilities (EPUs) industry has undergone major changes in terms of liberalization, increased competition, efforts to improve energy efficiency, in a context of environmental sustainability.

This situation has led governments and the scientific community to look for solutions that allow an efficient, reliable and responsible use of energy, appealing to an optimized and more flexible conception of the electrical grid (Mejia 2009).

The modernization of the electrical grid is known as the Smart Grid. The NIST defines as smart grid how a modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications (NIST 2010). Smart Grid is the convergence of information technologies, sensors and intelligent systems to monitor and manage power generation, transmission, and distribution. Despite the highly diverse nature of the technological challenges, they share a common set of features that need to be considered as the starting point to propose solutions based on Information Tecnology (IT).

The EPUs need a way to collect, correlate and analyze information from multiple sources, for different task, such as: processes optimization, planning, prediction, diagnosis, make decision, and re-evaluate the situations to determine whether further actions are required (Khanna et al, 2015).

Due to the complexity and challenges in the design, optimization, scheduling and management of smart grids, IT and computational intelligence techniques (CIT) have proven to be a good alternative to achieve these goal (Morais et al, 2009). Two of these techniques are Business Intelligence and Data Analityc (BI&DA). The opportunities associated with data and analysis in different organizations have helped generate significant interest in BI&A, which is often referred to as the techniques, technologies, systems, practices, methodologies, and applications (Chaudhuri et al, 2011). BI&DA transforms the raw, massive data collected by various sources into useful information. BI&A includes business-centric practices and methodologies that can be applied to various high-impact applications such as electric market intelligence, planning, make decisions and

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cyber security, among others.

The aim of this paper is to present a proposed framework for the application of BI&DA in smart grids environment. In section 2 a brief of smart grids concept and challengers for the information management is shown. Section 3 presents a resumen of BI&DA techniques. Section 4 shows the proposed of a framework for BI&DA applications. Section 5 presents a case study of application of BI&DA in database of processes security for Distribution area. Finally, Section 6 summarizes the most relevant ideas presented in this paper.

2 SMART GRID

An EPU is a complex environment. The structure of traditional power grid comprises different stages: generation, transmission, distribution and commercialization of electricity, see figure 1. The first stage is the power generation that takes place in large power plants or renewables power plants; the second stage is the transmission that transports energy to the areas where it will be consumed; the third stage is the distribution that delivered energy to the end user. To support the electrical grid operation information systems needed for management and control the processes of generation, transmission, distribution and trading.

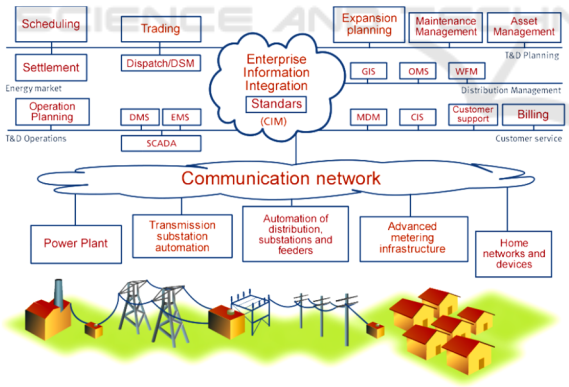

Figure 1: Main Processes and its information systems of EPU.

The NIST defines as smart grid how a modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications. The Smart Grid integrates electricity and communications in an electric network that supports the new generation of interactive energy and communication services and supplies digital quality electricity for the final customer. In this sense, the smart grid can be defined as a system that employs digital information and control technologies to facilitate the deployment and integration of distributed and renewable resources, smart consumer devices, automated systems, electricity storage and peak-saving technologies. The most common applications of Smart Grids are shown in the figure 2 (Gulich 2010).

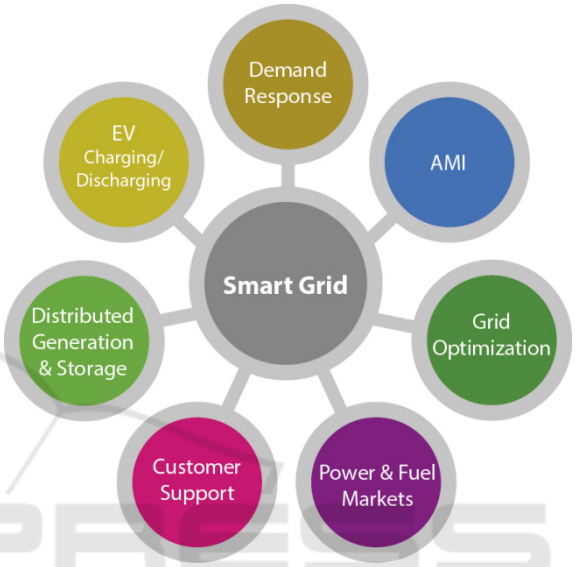

Figure 2: Applications of Smart Grid.

Advanced Metering Infrastructure (AMI). Remote Meter Reading, Remote Disconnect/Connect, Theft Detection, Customer Prepay, Mobile Workforce Management.

Demand Response. Advanced Demand Maintenance and Demand Response; Load Forecasting and Shifting.

Grid Optimization. Self-healing Grid: Fault Protection, Outage Management, Remote Switching, Minimal Congestion, Dynamic Control of Voltage, Weather Data Integration, Centralized Capacitor Bank Control.

Distributed Generation & Store. Monitoring of Distributed Assets.

EV Charging and Discharging. Application Data Flow for PHEVs.

Customer Support. Application Data Flow to/from End-User Energy Management Systems.

Electricy Market. Real Time Energy Markets.

Smart Grid will integrate all the components of power system to enhance the performance of the grid. Much of the integration of components relates to communication systems, IT systems, and business

processes. To satisficed this challenges for Smart Grid, the IT involved include the following:

- Integrated communications across the grid.
- Advanced control methods.
- Intelligent sensing, metering, and measurement.
- Advanced grid components
- Decision support and human interfaces
- Business Intelligence, Data Analytics and Big Data.

3 BUSINESS INTELLIGENCE AND DATA ANALITYC

The term intelligence has been used by researchers in artificial intelligence since the 1950s. Business intelligence became a popular term in the business and IT communities only in the 1990s. In the late 2000s, business analytics was introduced to represent the key analytical component in BI. More recently big data and big data analytics have been used to describe the data sets and analytical techniques in applications that are so large (from terabytes to exabytes) and complex (from sensor to social media data) that they require advanced and unique data storage, management, analysis, and visualization technologies (Chen, 2012). Business intelligence and data analytics (BI&DA) is an unified term and treat big data analytics.

BI&DA is a collection of decision support technologies for gathering, providing access to, and analyzing data for the purpose of helping enterprise users (executives, managers and analysts) make better and faster business decisions (Obeidat, 2015). The term implies having a comprehensive knowledge of all of the factors that affect the business. It is imperative that companies have an in depth knowledge about factors such as the customers, competitors, business partners, economic environment, and internal operations to make effective and good quality business decisions. Business intelligence enables firms to make these kinds of decisions. Enterprise aimed at enabling knowledge executives, managers and analysts to make better and faster decisions (Yeoh, 2010).

The typical components of Business Intelligence architecture for an Enterprise are shown in the figure 3:

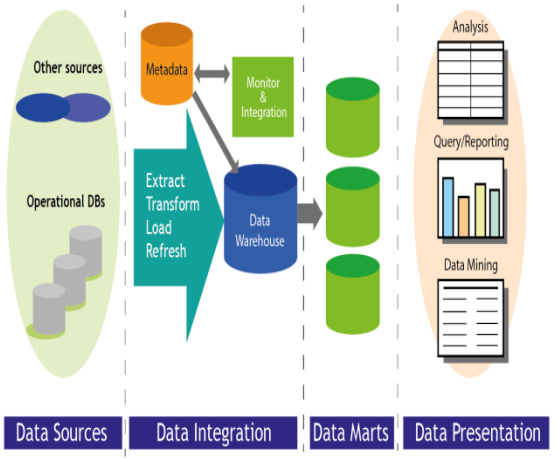

Figure. 3: Typical BI architecture.

3.1 Data Sources

Data sources can be operational databases, historical data, external data for example, from market research companies or from the Internet), or information from the already existing data warehouse environment. The data sources can be relational databases or any other data structure that supports the line of business applications. They also can reside on many different platforms and can contain structured information or unstructured information. Thus the problems of integrating, cleansing, and standardizing data in preparation for BI tasks can be rather challenging.

3.2 Data Integration

Extract-Transform-Load (ETL) refers to a collection of tools that play a crucial role in helping discover and correct data quality issues and efficiently load large volumes of data into the warehouse.

3.3 Data Warehouse and Data Marts

The data warehouse is the significant component of business intelligence. It is subject oriented, integrated. The data warehouse supports the physical propagation of data by handling the numerous enterprise records for integration, cleansing, aggregation and query tasks. A data mart is a collection of subject areas organized for decision support based on the needs of a given department. The key difference is that the creation of a data mart is predicated on a specific, predefined need for a certain grouping and configuration of select data (Watson, 2007).

3.4 Data Presentation

BI&DA includes several tools for the data analysis. It refers to the way in which business users can slice

and dice their way through data using sophisticated tools that allow analytical processing and advance analytics. Online analytic processing (OLAP) provides multidimensional, summarized views of business data and is used for reporting, analysis, modeling and planning for optimizing the business. OLAP tools provide the common BI operations such as filtering, aggregation, drill-down and pivoting. Advanced analytics is referred to as data mining, text analytics, forecasting or predictive analytics and artificial intelligence algorithms, this takes advantage of statistical analysis and artificial intelligence techniques to predict or provide certainty measures on facts.

There are several popular frontend applications through which users perform BI tasks: spreadsheets, enterprise portals for searching, performance management applications that enable decision makers to track key performance indicators of the business using visual dashboards, tools that allow users to pose ad hoc queries, viewers for data mining models, and so on. Rapid, ad hoc visualization of data can enable dynamic exploration of patterns, outliers and help uncover relevant facts for BI.

A high-level diagram depicting the interrelationships among the various BI&DA technologies and their applications in the different subsystems of power grid is shown in Figure 3 (Zeyar, 2013).

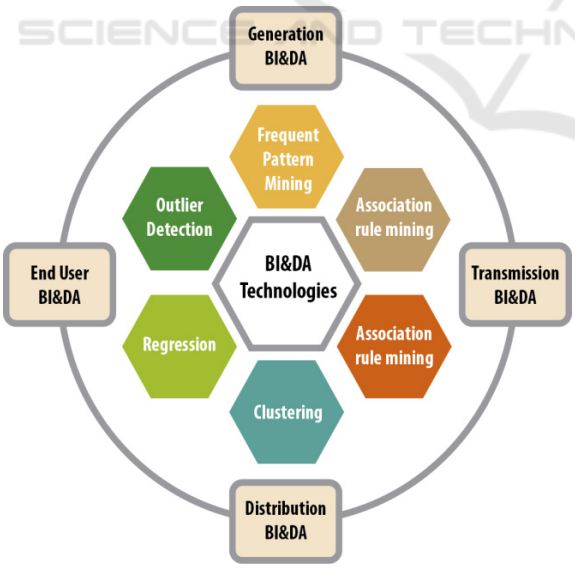

Figure 4: BI&DA applications for Smart Grid.

In addition to the traditional BI&DA paradigm on static and centralized data, there are new paradigms distributed data, data stream, and time-series data are much relevant to the smart grid because of its very nature of distributiveness and having to deal with numerous data streams and time series data from various data sources: smart meters, sensors, and power system machinery.

BI&A is an unified term and treat big data analytics. In the case of smart grid there are some potential applications of this technology, see figure 4:

- **Frequent Pattern Mining:** to discover some sub-patterns or motifs those occur frequently in a dataset.
- **Association Rule Mining:** to uncover which causes usually lead to which effects in a dataset. The association rules can generally be derived from the frequent patterns described above.
- **Classification:** to classify instances in a dataset into pre-defined groups (called class labels). Classification is a supervised learning process.
- **Clustering:** to organize similar instances in a dataset into groups which are not predefined. Clustering is an unsupervised learning process in which we do not know the class labels of all the instances in the data set in advance.
- **Regression:** to predict the value of the target attribute (called dependent variable) of an instance based on the values of other attributes (independent variables). Regression is also a type of supervised learning which works in the similar way as classification.
- **Outlier Detection:** to identify anomalous instances, which might be interesting or indicate errors and require further investigation. It can be supervised, unsupervised, or semi-supervised learning.

4 FRAMEWORK OF BI&DA FOR SMART GRID

The framework proposed provides the methods and tools for assisting in the acceptance, production, use and maintenance of BI&DA implementation. It is based on TOGAF framework; an iterative process model supported by best practices and a re-usable set of existing architecture assets, see figure 5.

For a successful BI implementation is to be applied formal methods for managing information and fully understand the operation of the organization.

- **Project Definition:** The first is to have clearly defined the purpose of the application of BI&DA aligned business vision and mission;

fully understand the strategic objectives of the organization.

- **Business and IT Architecture:** An Enterprise Architecture (EA) is a scheme whereby represented through models, the business of the company (strategy, objectives and processes), the needs of information (data and applications) and the technologies that support it. The BA determines that the government provides to the business of information technologies (IT) and how are you must be aligned with strategic business goals.
- **Business Process Mapping:** It requires mapping the processes and technological applications involved in the definition of the data to develop BI&DA applications. The data quality is critical for success of the application of BI&DA.
- **IT Applications:** The IT applications must be the automation of the business process. The IT applications are the origin of the data.
- **Data Quality:** For a successful BI&DA applications, you must ensure that the data are available and reliable.
- **B&DA Techniques:** Design of data marts and tools for extraction, transformation, and load (ETL) are essential for converting and integrating enterprise-specific data. Database query, online analytical processing (OLAP), and reporting tools based on intuitive, but simple, graphics are used to explore important data characteristics.
- **Front End & Applications:** Front-end-applications can be the most relevant because it show the result of BI&DA applications. In addition to these well-established business reporting functions, statistical analysis and data mining techniques are adopted for association analysis, data segmentation and clustering, classification and regression analysis, anomaly detection, and predictive modelling in various business applications.
- **Results and Improvements:** Finally the results have to analyser in order to improve the BI&DA applications.

BI&DA is a matter not only of technology, it is necessary that the company deploys a Business and IT technology strategy that is executed by the BI&DA Centre and this requires an infrastructure of software and hardware as well as organization and models.

Figure 5: Framework for BI&DA.

5 CASE STUDY

The goal of BI&DA is to provide new knowledge to the company, from the automated exploitation of historical information for business actions are taken to be better supported. The results obtained by applying techniques of BI&DA to the database of industrial safety of Mexican Electric Utility are shown in this section.

The benefits it will bring to the implementation of business intelligence technologies are mainly:

a) Accessing security information in a timely and reliable, which allow reducing the time in making and decisions, creating more effective decisions to have the information available.
b) Display detailed information of the security process, making further analysis as a result of having consolidated historical information and current information.
c) Allow delivery of data in a flexible, dynamic and in many cases to solve unplanned queries.
d) As result of above: having a decrease in the number of injured or dead; having a decrease in the economic impact caused by accidents and Decrease the number of days lost due to accidents.

Today there are many tools that offer similar products to both large and small organizations. BI vendors propose solutions both horizontal and vertical and the best choice will depend on the specific need of each organization. With horizontal

solutions from scratch by an application tailored to the need. Vertical solutions are aimed at an industry already developed components and only fit specific needs. In this case the implementation of BI tools for the industrial security was done by development proprietary tools under Windows platform and a solution horizontal. For the design and development of BI tools take in count the following queries:

Project Definition. Goal alignment queries: the application of BI tools has the aim to reduce the number of accidents and incidents.

Business & IT Architecture. The enterprise architecture meets the information needs related to the process. The elements of the entreprise architecture are bussines architecture and IT architecture. The business architecture includes the strategic plan definition and the **BP mapping**. The technology architecture includes the definition of the data set and data flow; the information systems applications management, the communication definition, the enterprise bus, the drives, the security system and soon. The figure 6, shows the Enterprise architecture.

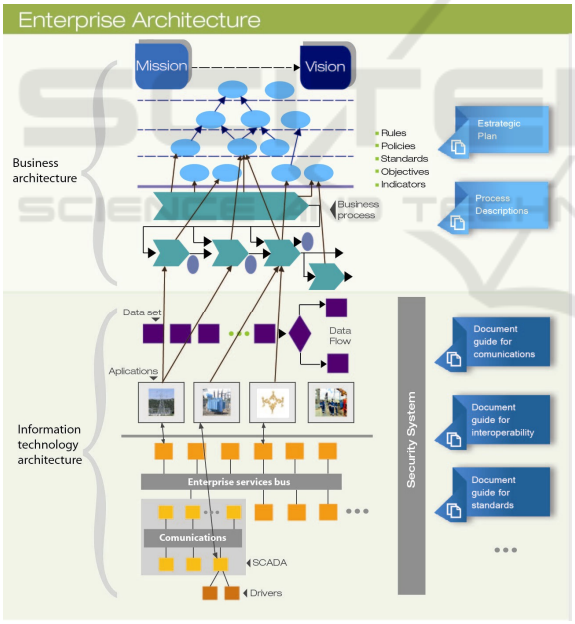

Figure 6: Enterprise Architecture.

IT Applications. Baseline queries: the source of information is generated by security information system (in Spanish, Sistema de Integral de Seguridad y Salud en el Trabajo –SISST). The system manages three areas of industrial safety for power system processes: accident, infrastructure safety and health protection; and safety management (Jacome et al, 2011).

Customer and stakeholder queries: There three kinds of users: operative, analytical and executive.

Metric-related queries: the metrics was defined by the security expert. The metrics includes: security indicators, and related variables. A success factor for the development of BI&DA applications is the definition of metrics.

Data Quality. The operational variables are load by the security information system. There are procedures and methodologies defined by the company for the variables and its load frequency.

BI&DA Techniques. The architecture of BI&DA techniques considers the construction of a single enterprise data warehouse and from it will emerge Data Marts (small units of analysis), with an overall vision of the company. The figure 7 shows the BI&DA-SISST architecture.

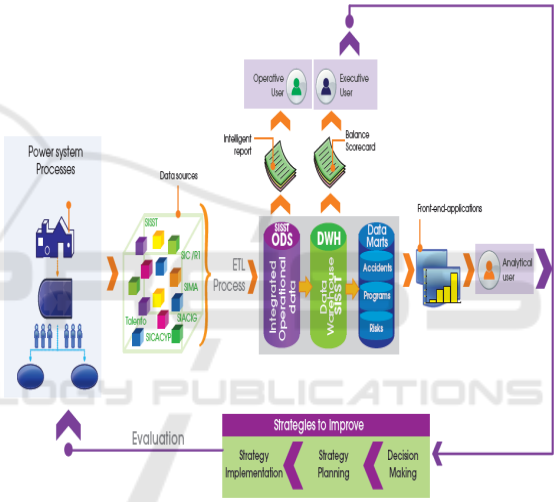

Figure 7: BI&DA-SISST architecture.

The primary tasks include gathering, preparing and analyzing data. From operational database of industrial security system, extract the most relevant data to the user through an ETL process, which loads and makes the necessary transformations and data cleansing. These are the integrated operational data (ODS-SISST) of the security system. The data itself must be of high quality.

Once the data is complete and clean, they pass through another ETL process to data warehouse (DWH-SISST). Finally, data marts are created for accidents, safety programs and hazards. From these data were carried out the data analysis, through multidimensional analysis and consulted manager dashboards.

Front-end Applications. The results of the BI application are the front-end-applications through of dashboards. The Dashboard should provide the

executive with a tool for navigating through company's information. The figure 8 shows the accident frequency by area with pie contribution and table of results with goal and indicator state. Also shows the severity by area.

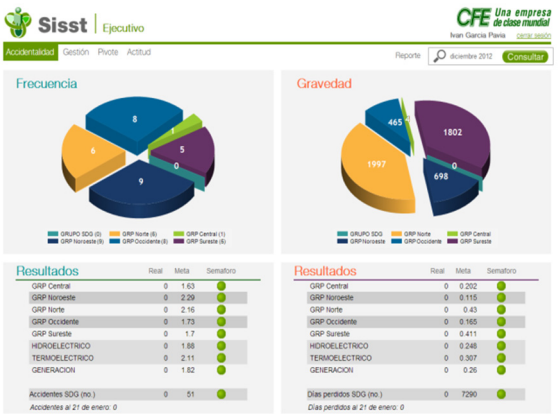

Figure 8: Accident frequency and severity.

The figure 9 shows the historical, real and forecast accident bye year and by moth. This information is obtained to accident module.

The main indicators of the security have presented in the figure 10. The definition of indicators is an important task to ensure the success of business intelligence. This dashboard shows the security maturity in terms of identification of hazards, legal requirements, compliance of security programs, safety forms, incidents and acts of government.

With the business intelligence is possible to combine different information. For example it is possible to relate the accident with the attitudes.

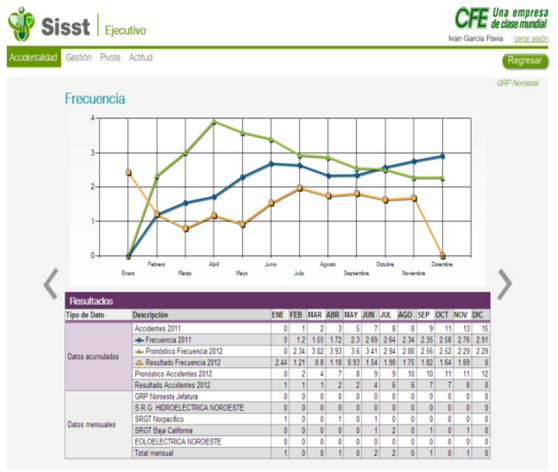

Figure 9: Accident frequency: historical, real and forecast.

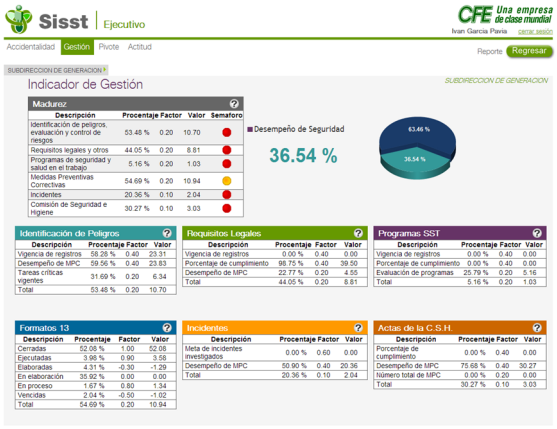

Figure 10: Management indicators.

For this case, the figure 11 presents the relations between the accidents with attitudes. Also, it is possible to classify the kind of attitudes: learning, knowledge and responsibility. This means that the an accident occurs can determine if the accident occurred due to lack of training, lack of knowledge or lack of responsibility. For the case of incidents also it is possible determinate if occurred by lack of training, knowledge or responsibility.

BI&DA-SISST system is a traditional business intelligence application with back-end database and front-end user interface, software that processes the information and reporting systems.

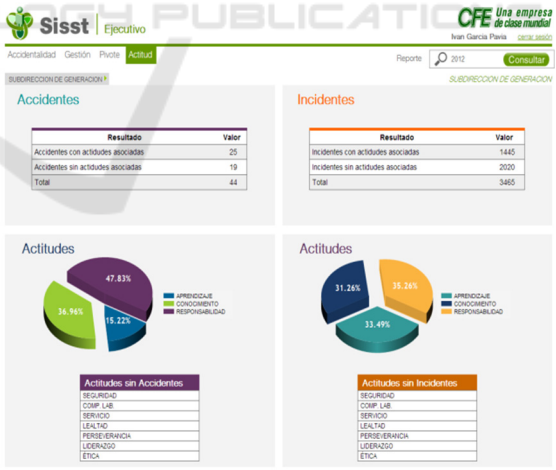

Figure 11: Relationship between accidents and incidents with attitudes.

6 CONCLUSIONS

BI&DA as a concept is becoming more common in everyday business life. BI&DA incorporates people,

process, and also knowledge as an end product. The implementation of BI&DA is a complex undertaking requiring considerable resources.

An important factor to build BI&DA applications is the information management. BI&DA requires reliable and timely information and generates summary information for the operative and strategic decision making. In addition, the implementation of a BI&DA is often associated with the following challenges: underlying original back-end systems and processes which were not adapted for BI&DA applications; poor data quality derived from source systems that can often go unnoticed until cross-systems analysis is conducted; and the maintenance process that tends to be vague and ill-defined

To attack this problem is necessary to implement enterprise architecture with its two main components: business architecture and technological architecture can help ensure that the data source will be reliable.

The BI&DA tools developed for the industrial security have had good results. The information displayed through dashboards make career choices have led to the decrease of accidents. In particular the relationship between accidents and attitudes has been a great help to generate preventive actions to avoid accidents. Also indicate if the accident occurred due to lack of training, knowledge, or lack of responsibility.

As many research challenges remain in all aspects of BI&DA, several new open research challenges appear on horizon for recent technologies, such as Cloud Computing, Near Real-Time BI, Enterprise Search, distributed data mining, data stream mining, time-series data mining, information security and more.

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REFERENCES

Zeyar Aung, “Database Systems for the Smart Grid”, Book Smart Grids: Opportunities, Developments, and Trends, *Sringer Verlag, pp 151-168, 2013.*

Victor Chang, Yen-Hung Kuo, Muthu Ramachandran, “Cloud computing adoption framework: A security framework for business clouds”, *Future Generation Computer Systems, Volume 57, Pages 24–41, 2016.*

S. Chaudhuri, U. Dayal and V. Narasayya, “An Overview of Business Intelligence Technology”, *Communications of the ACM, Vol. 54, No. 8, pp: 88-98, August 2011.*

Oleg Gulich, “Technological and Business challenges of Smart Grids”, *Msc Theses, Lappeenranta University of Technology, 2010.*

Hsinchun Chen, Roger H. L. Chiang and Veda C. Storey, “Business Intelligence and Analytics from Big Data to Big Impact”, *MIS Quarterly, Vol. 36, No. 4, pp: 1165-1188, December 2012.*

N. Jacome-Grajales, G. Escobedo-Briones and E. Guadarrama Villa “Inteligencia de Negocios en el area de seguridad de la CFE” (In Spanish), *Congreso Internacional sobre Innovación y Desarrollo Tecnológico, pp. 677-685, 2011.*

Manju Khanna, N. K. Srinath, and J. K. Mendiratta, “Data Mining in Smart Grids-A Review”, Vol. 5, No. 3, pp: 709-712, 2015.

I. Martin-Rubio, A. E. Florence-Sandoval, J. Jimenez-Trillo, and D. Andina, “From Smart Grids to Business Intelligence, a Challenge for Bioinspired Systems”, Lecture Notes in *Computer Science, Vol. 9108, pp 439-450, 2015.*

M. Mejía-Lavalle, G. Arroyo-Figueroa, E. F. Morales, “Innovative applications of diagnosis, forecasting, pattern recognition, and knowledge discovery in power systems”, *IEEE Power & Energy Society General Meeting PES’09, Otawa Canada, pp. 1-9, 2009.*

J. Morais,, Y. Pires,, C. Cardoso, A. Klautau “An overview of data mining techniques applied to power systems. In: *J. Ponce, A. Karahoca (eds.) Data Mining and Knowledge Discovery in Real Life Applications. I-Tech Education and Publishing, 2009.*

NIST Framework and Roadmap for Smart Grid Interoperability Standards N. S. P. 1108., Release 1.0, January 2010.

M. Obeidat, M. North, R. Richardson V. Rattanak and S. North, “Business Intelligence Technology, Applications, and Trends”, *International Management Review, Vol. 11, No.2, pp: 47-55, 2015.*

Sarvapali D. Ramchurn, Perukrishnen Vytelingum, Alex Rogers, and Nicholas R. Jennings, “Putting the ‘Smarts’ into the Smart Grid: A Grand Challenge for Artificial Intelligence”, *Communications of the ACM, Vol. 55, No. 4, pp: 86-97, April 2012.*

William Yeoh, Andy Koronios, “Critical Success Factors for Business Intelligence Systems”, *Journal of Computer Information Systems, pp:23-32, 2010.*

H. Wang, and S. Wang, “A Knowledge Management Approach to Data Mining Process for Business Intelligence,” *Industrial Management & Data Systems, Vol. 108, No. 5, pp: 622-634, 2008.*

H. J. Watson, H. Barbara Wixom, The current state of business intelligence, *Computer, Vol. 40, No. 9, 96-99, 2007.*