Dynamic Model of Operational Information Flow on Electric Power Distribution Systems

Modelo dinámico de flujo de información operacional en sistemas de distribución de energía

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ABSTRACT

In many cases, when considered to automate an operational process, methods allowing to guide such automation in a scaled way, are not taken into account. The main objective of this article is to present a dynamic methodology of operational information flow allowing to guide the decision making related to operational process automation, thus, shortening uncertainty. The application of the operational information flow methodology is presented as a study case in order to improve the current restoration process within the electric power distribution system of CODENSA.

Keywords: Operational Information Flow, Business Process Management, Process Automation and Electric Power distribution Systems.

RESUMEN

En muchos casos, cuando se desea automatizar un proceso operacional no se tienen en cuenta métodos que permitan guiar dicha automatización de forma escalada. El objetivo principal de este artículo es presentar una metodología dinámica de flujo de información operacional que permite guiar la toma de decisiones relacionadas con la automatización de procesos operacionales reduciendo la incertidumbre. Como caso de estudio se presenta la aplicación de la metodología de flujo de información operacional para mejorar el proceso actual de restablecimiento en el sistema de distribución de energía de CODENSA.

Palabras clave: Flujo de Información Operacional, Gestión de Procesos de Negocio, Automatización de Procesos y Sistemas de Distribución de Energía.

Introduction

Ahead of carrying out the automation of a manual process, it is necessary to perform a deep study allowing to picture the benefits of such automation as well as to identify its potential risks.

It is intended through this article to bring forward a guided-by-stages methodology enabling to objectively choose one or several automation options, thus, shortening the risks of such automation. The main stages of this methodology are listed below:

Modeling, Feasibility, Engineering and Development.

The operational information flow methodology will be presented as a study case to improve the current restoration process within the electric power distribution system of CODENSA.

The article content is organized as follows. The section 2 introduces the theoretical concepts being related to the addressed issue. The section 3 presents a dynamic methodology to general-ly set up the operational information flows. Finally, the section 5 puts forward some conclusions as well as the future work.

Theoretical Framework

This section introduces the theoretical concepts being related to the addressed issue.

Information Flow Models.

The information flow models represent how the information flows through the processes as well as how it turns into as it tours via a system. The system receives different inputs transformed by hardware elements, software elements or humans to lead an output [Pressman, 2002].

The information flow models are embedded in a business process. "[…]; when we peer under the top layer of that model, what is exposed is the model for how both information and control are propagated through the business application." [Loshin, 2003].

Business Process Models

A business process "a collection of activities whose final aim is the production of a specific output that is of value to the customer. A business process has a goal and is affected by events occurring in the external world or in other processes" [Aldin, 2009].

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A business process model is an abstract rendering of the organization processes allowing to identify the agents involved within the business and how they perform the organization activities. Within this model, each of the process tasks can be represented as well as only those being essential to render the offered service or product.

Processes Automation

The processes automation is the replacement of traditionally manual tasks by automatic tasks (machines, robots, or any other kind of automatism).

The processes costs, service and quality are improved through automation [Jiménez, 2003]. The work is done faster and does not require of operators that were previously needed.

Electric Power Distribution Systems

Different departments are involved within an electric power distribution system. Each of these departments have tasks aimed to a specific contribution [Turan Gönen, 2014].

The distribution companies specialized the tasks through four departments to the restoration process in order to optimize the process itself.

Control Center: the control center is responsible for supervising, operating and controlling the electrical system at high-tension and medium-tension in real time.

Telecontrol Center: the telecontrol center is responsible for maintaining, operating and improving the telecommunications system allowing the proper functioning of the control center operational processes, such as the communication with the equipment.

Low-tension Control Center: it is in charge of supervising, controlling and operating the low-tension electrical system that includes the lines connecting the transformers on the transmission towers to the users' electric power meters. As the alarms and operations are not automatized at low-tension, the user is the one in charge of identifying and warning of the failures by calling to the customer service line.

Information Management: this department is responsible for the distribution system technical information management, keeping the system information updated online. Thus, the control center can make choices without falling into mistakes due to not updating the system. When the control center or the low-tension control center restore the service, they must report on the repaired failure to the information management department.

Dynamic Methodology to set up the Operational Information Flow

This methodology allows to make choices related to operational processes' automation. Such methodology includes 4 stages. Fig. 1.
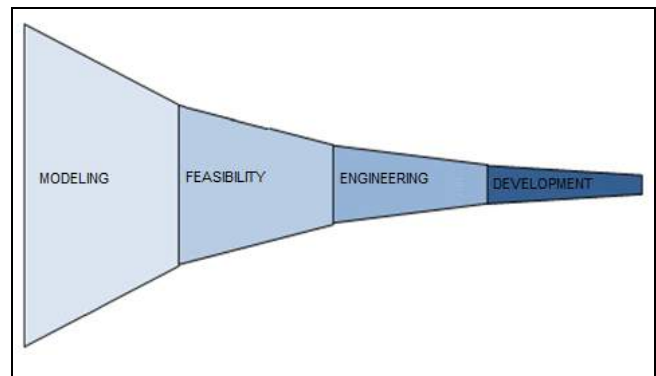

Figure 1. Information dynamic model stages.

Modeling Stage

The sub-processes and the existing dynamic of a specific issue or area are identified in this stage. Detailed information of each sub-process as well as the damage level are obtained in this stage that is divided into 3 phases:

Processes' Setting-up Phase: the main goal of this phase is to identify the macro-processes involved in the issue (issue general idea).

Current Process Modeling Phase: modeling each of the macro-processes previously identified, is intended in this phase. The activities, logic gates and events existing in each macro-process have to be bore in mind within such modeling (issue specific details).

Current Process Simulation Phase: The tasks' length, the logic gates' likelihood and the times related to the events, are identified in this phase. Finally, a simulation is set up in order to identify the issue dynamic.

Feasibility Stage

The main purpose is to study the feasibility of automating some of the identified sub-processes within the modeling stage.

It is recommended to identify different assessment criteria to carry out such feasibility study (along with the expert personnel on the issue) and afterwards, to assess each sub-process.

Engineering Stage

The engineering studies required are made to automate the sub-processes selected in the feasibility stage, in addition, the software engineering models related to the automation are developed.

As a result of this stage, the technical specifications are brought out in order to execute the automation plan or, at worst, to reject the automation.

Development Stage

The network automation plan is executed. Such plan includes two main activities: field equipment installation and the software platform development.

Study Case

The dynamic model of the operational information flow presented herein, was implemented at CODENSA Company in order to improve the current restoration process within the electric power distribution system.

Modeling Stage Results

Six macro-processes were identified regarding the information setting-up stage: failure detecting, failure locating, failure isolating, searching for temporary supplies, failure repairing, and network resetting Fig. 2.
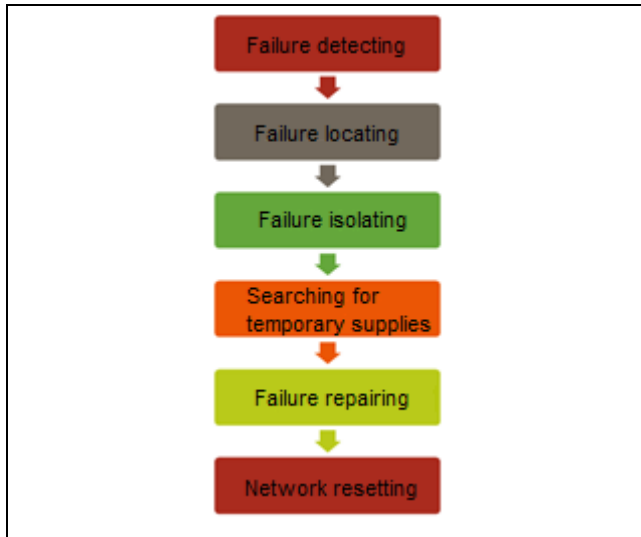

Figure 2. Macro-processes related to the restoration.

The modeling of each macro-process within the current process modeling stage was made through the tool Oracle BPM suite. The activities, logic gates and events existing in each macro-process as well as those described by the CODENSA personnel, were bore in mind within such modeling. Refer to figure 3 to see the detail model of the "Search Substitutions" macro-process.
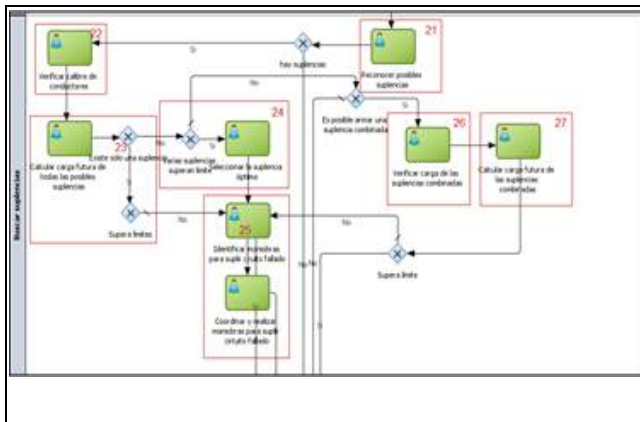

Figure 3. Detailed modeling of the "Failure detecting" macro-process.

The length of the tasks, the logic gates likelihood and the time related to the events were set up for the simulation. It should be pointed out that the information used for the simulation set-up was obtained from the control center personnel interviews so as from the monthly reports from the Average Handle Time (AHT).

After the simulation set-up was performed, different tests were executed by altering the times (1 month, 3 months and 12

months) as well as altering the set-up parameters related to the tasks, gates and events.

The simulations showed up the damage level of each sub-process within the general process of restoration (refer Fig. 4)

Figure 4. Damage level of each sub-process.

Modeling Stage Results

As a result of the modeling stage, 5 sub-processes affecting to a greater extent the restoration process were identified (refer table 1).

Table 1. Damage per sub-process

Sub-process	Level	General description
Failure locating	28%	Sub-process allowing to identify the circuit area where the failure is located and, therefore, to where the mobile must be directed.
Mobile's redirecting	13%	Sub-process allowing to execute field maneuvers whether to identify the failure exact location, isolating the failure, repairing the failure or restoring the circuit. Such maneuvers are coordinated by the control center personnel.
Failure solve detecting and proof	13%	Sub-process allowing to identify the event occurrence from the SCADA alarms as well as to proof if the failure was solved by the field equipment (e.g. reconnectors).
Failure isolating	11%	Sub-process allowing to isolate the failure location to go ahead with the repairing. If the failure repairing requires long times, it is necessary to resort to temporary supplies in the circuit.
Remote download of records	9%	Sub-process allowing to manage the monitoring and safe equipment information. This information is used within the failure locating sub-process, as well as to search for temporary supplies and to proof the circuit general status.

4 feasibility criteria were analyzed for each sub-process: current automation level, if field maneuvers are required, if there are existing equipment in the market allowing to automate the sub-process, and if there are existing software in the market allowing to automate the sub-process.

The feasibility criteria results for each sub-process are presented in table 2.

Table 2. Feasibility criteria assessment

Sub-process	Current auto-mation level	Requires field equipment ma-neuvers.	There are equipment in the market.	There are software in the market
Failure locating	Low	No	Yes	Yes
Mobile's redirecting	Low	Yes	No	No
Failure solve detecting and proof	High	No	Yes	Yes
Failure isolating	Low	Yes	No	Yes
Remote download of records	Medium	No	Yes	Yes

The following statements can be concluded from the feasibility criteria assessment:

The automation of the "mobile's redirecting" and "failure isolating" sub-processes is discarded due to the fact that both processes require field interventions that must be performed on-site.

The automation of the "failure solve detecting and proof" sub-process is discarded due to the fact that nowadays this sub-process is automated in a greater extent.

It is possible to carry out the automation of the "failure locating" and "remote download of records" sub-processes.

Automating the "failure locating" sub-process would represent a restoration time improvement of 28% higher than automating the "remote download of records" sub-process representing a 9% improvement.

According to the previous statements, it was decided to automate the "failure locating" sub-process.

Software Engineering and Modeling Stage Results

The engineering study to automate the failure locating was made in 4 phases: criteria definition to the equipment integration on a failure locating system, equipment selection according to the specified criteria, selection and characterization of the circuit to intervene, and equipment location within the circuit.

The failure locating platform modeling is accomplished after the engineering studies.

Criteria Definition Phase Results: the main goal of this phase is to identify the criteria required for any equipment intended to be integrated to a failure locating system. The criteria were classified into design criteria (refer table 3) technical criteria (refer table 4), communication criteria (refer table 5) and operation criteria (refer table 6).

Table 3. Design criteria.

Design Criteria
4 hours minimum autonomy (battery)
Outdoor working equipment.
Modular design of its components
Portable equipment
Easy installation

Table 4. Technical criteria

Technical Criteria
The equipment must allow ground connection
Lightning resistance
Failure current measurement and detection
Setting-up option of shutdown limits

Table 5. Communication criteria

Communication Criteria
Current communications' infrastructure compatibility
ENDESA profile, protocol 104
GPRS communication
Equipment status reporting
Integration likelihood to the SCADA

Table 6. Operation Criteria

Operation Criteria
Reading times < 5 ms
Data releasing times < 10 s

Equipment Selection Phase Results: The search of equipment fulfilling such criteria is accomplished after the criteria definition to the equipment integration on the failure locating system. From this equipment search 2 technologies were identify.

Unit to automate the failure indicator communication: this unit allows to automate the communication of the failure indicators currently installed at CODENSA (refer Fig. 5)

DISCOS equipment: the DISCOS System has been mainly designed to provide current and voltage measures within the medium-tension and low-tension electric power networks whether during usual functioning conditions or failures (refer Fig. 6).
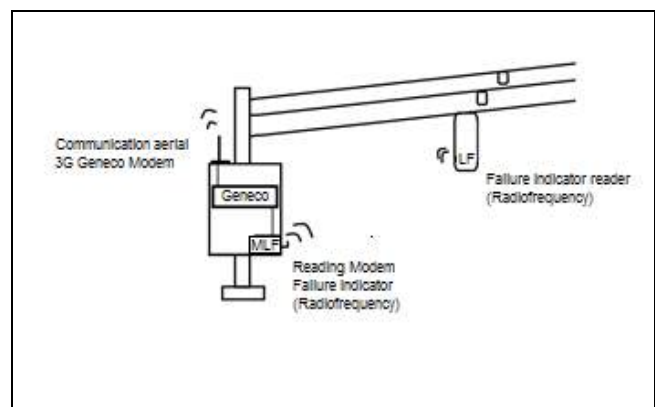

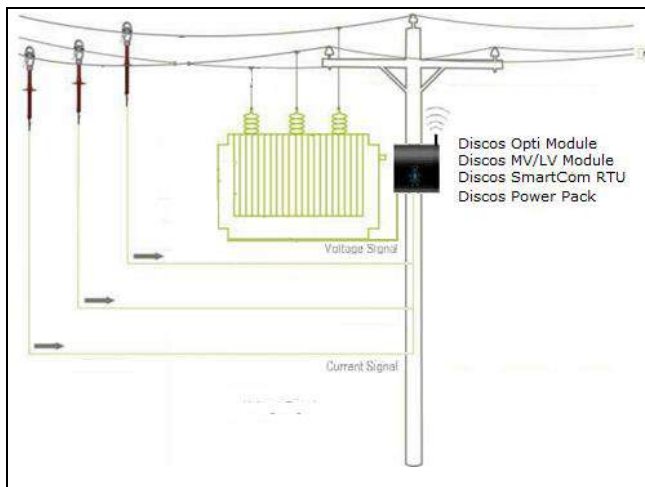Figure 5. Unit to automate the failure indicator communication.

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Figure 6. DISCOS system set-up on an electric power network.

Results from the phase of Selection and Characterization of the Circuits to intervene: after an analysis of different selection criteria was made, 13 potential circuits were identified to carry out the automation (refer table 7)

Table 7. Potential circuits to carry out the automation.

Circuit	Ind. Cal.	C1	Topology	C2	Dist. (km)	C3	CT	#
Minero	4,5	0,20	7,0	0,37	80	0,14	0,71	5
Tibacuy	3,5	0,16	5,5	0,29	87	0,13	0,57	10
Yacopi	3,5	0,16	5,5	0,29	150	0,00	0,45	13
Cabrera	3,5	0,16	5,5	0,29	95	0,11	0,56	11
Hacienda	3,5	0,16	6,0	0,32	134	0,03	0,50	12
Espigas	3,5	0,16	6,5	0,34	63	0,17	0,67	7
El_pomar	3,5	0,16	6,0	0,32	39	0,22	0,69	6
Urbiza	3,5	0,16	8,0	0,42	11	0,28	0,85	2
Plastihoga	3,5	0,16	8,0	0,42	23	0,25	0,83	3
Urbanizac	3,5	0,16	8,0	0,42	23	0,25	0,83	3
Malterias	3,5	0,16	5,0	0,26	47	0,21	0,62	8
Termales	**3,5**	**0,16**	**9,5**	**0,50**	**45**	**0,21**	**0,87**	**1**
Naranjal	4,0	0,18	6,0	0,32	91	0,12	0,61	9

The **Termales** circuit from the **Tabio** substation was chosen according to the results in table 7.

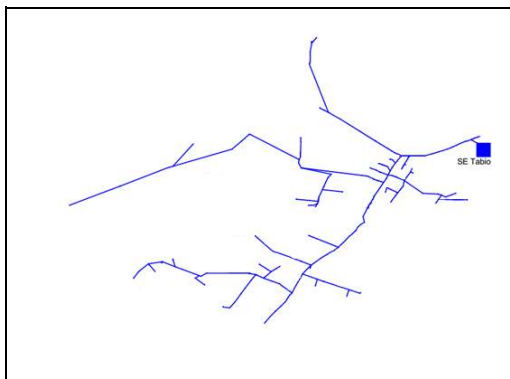A scale representation of the **Termales** circuit from the **Tabio** Substation is presented in figure 7.

Figure 7. Termales circuit from Tabio

Equipment Locating Phase Results: 8 are the available failure indicators sets which are distributed along the circuit according to installed load criteria, cut and maneuver elements proximity (switches) and accessibility to the installation location.

Firstly, each equipment set is intended to be placed near a cut and maneuver element in order to section the circuit during a failure event. In addition, it was attempted to evenly distribute the installed load on the circuit for each of the sections. Finally, the access routes to the installation location were bore in mind to have an accessibility picture.

The figure 8 shows the final location proposal for the failure indicators and the figure 9 presents each of the sections the circuit was divided into.
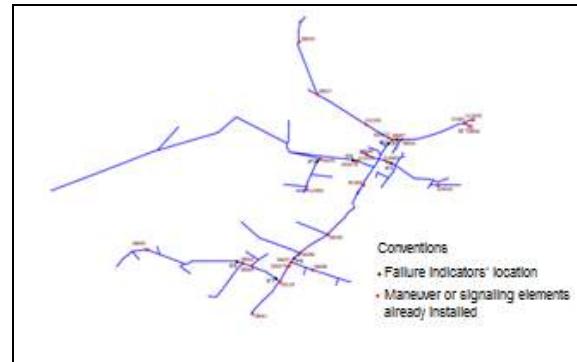

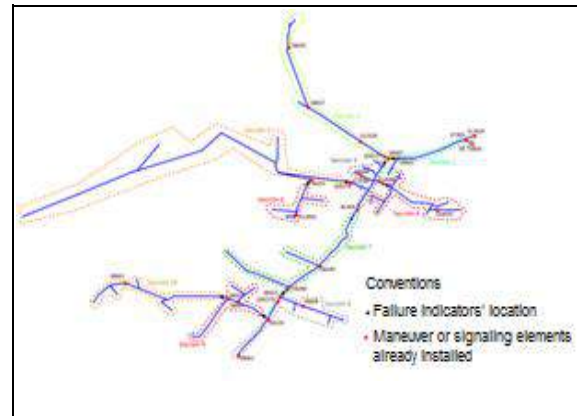Figure 8. Location of the 8 failure indicators sets.

Figure 9. Circuit sectioning regarding the failure indicators' location.

Software modeling: such model is mainly compound by field equipment, failure locating system and user interface.

Field Equipment: refers to the failure indicators, DISCOS equipment and safe equipment. These equipment are in charge of broadcasting the circuit information at all times (steady status or failure status).

Failure Locating System: application in charge of processing the information in order to locate the failures.

User Interface: web application used to visualize the information provided by the failure locating system.

Users: anyone wanting to watch the failures within the Termales circuit from Tabio (must have required permissions)

All the integrated elements of the failure locating system can be observed in figure 10.
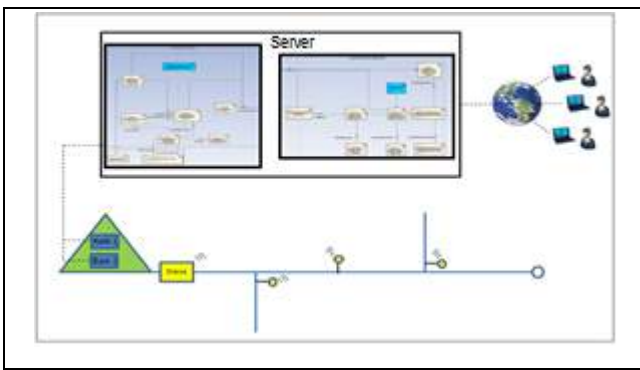
Figure 10. Integrated elements of the failure locating system.

Development Stage Results

The network automation plan is executed in this stage. Such plan includes 2 main activities: on-field equipment installation and software platform development.

The equipment installations were accomplished in 4 days. The first day, the DISCOS equipment was installed. The second day, 4 indicators' sets were installed. The third day, the ground connections were installed as well as 4 indicators' sets. The fourth day, equipment tests were performed.

Two pictures corresponding to the installation on the circuit can be seen in figures 11 and 12.
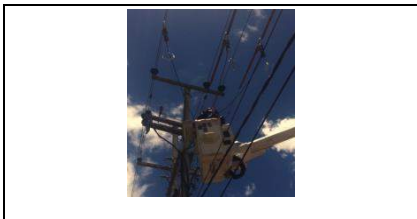

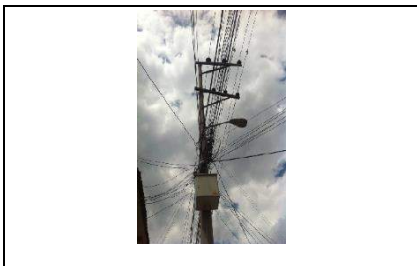Figure 11. DISCOS equipment installation.

Figure 12. Indicators' set installed.

The software platform was developed as a web system allowing to have remote access to the failure locating system.

The main system interface can be seen in figure 13. It is compound of four units:

Global Positioning Unit (1): through this unit, both the unit and its equipment's geographic location can be seen. In addition, it presents the failing section according to the results provided by the failure locating system by indicators as well as from the results provided by the failure locating system by simulation. It should be pointed out, that this unit admits graphic information from supports so as from the substation.

Identified Failures by Indicators Unit (2): this unit presents a historical summary of the circuit failures as well as if such failures have been identified by the user.

Circuit Status and Failure Locating by Simulation Unit (3): this unit presents the current information that the DISCOS equipment identifies at the circuit's head as so if its current values report whether a usual or a failure status. In addition, it simulates the simulated failure location based on the current datum identified by the DISCOS equipment.

Historical Information Unit (4): through this unit the circuit historical information can be checked, either the punctual value of the failure indicators or the failure current values identified by the DISCOS equipment.
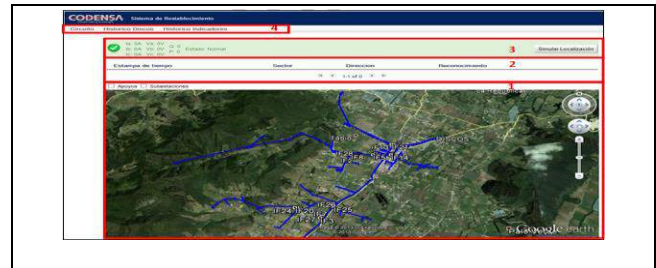

Figure 13. Developed software platform.

Conclusions

A dynamic model of operational information flow was presented. This model allows to guide the decision making related to the operational process automation.

The model application of the operational information flow was presented as a study case in order to improve the current restoration process on the electric power distribution system of CODENSA

As a future work, it is expected to have the proposed model formalized to be applied on different automation processes within CODENSA or any other company.

Acknowledgments

References

[Loshin, 2003] Loshin, David. Business Models and Information flow. En: Business Intelligence: The Savvy Manager's Guide, Getting Onboard with Emerging IT. San Francisco: ElSevier Science, 2003, p. 66.

[Aldin, 2009] Aldin, Laden and DE CESARE, Sergio. A comparative analysis of business process modeling techniques. OxfordShire: U.K. Academy for Information Systems (UKAIS), 2009, 17p.

[Pressman, 2002] Pressman S., Roger. Modelado del análisis. En: Ingeniería del Software – Un enfoque práctico. Quinta edición. Nueva York: McGraw-Hill, 2002, p. 199-218.

[Jiménez, 2003] Emilio Jiménez. Técnicas de automatización avanzadas en procesos industriales / Advanced Automation Techniques on Industrial Process. Universidad de La Rioja, ISBN: 84-689-0360-4.

[Turan Gönen, 2014] Turan Gönen. Electric Power Distribution Engineering. Third Edition. ISBN 9781482207002.