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Contribution in Increasing the Design Quality in Automation Project

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Abstract

The effectiveness in the execution of an automation project is linked to correct planning of the objectives and scope, execution period, and expense budget and it is where more errors are made, which brings costly deviations, motivated by the absence of a methodology Despite the many existing ones, that complying with all the current Standards is applied during the life cycle of the Project. Therefore, the problem to be solved is the elimination of the frequent technical and organizational errors that cause rectifications and modifications due to the lack of precision in the management of project information. An analysis of different known methods of planning and execution of projects is carried out, taking their experiences and successes to propose a Methodology and develop its documentation to facilitate the planning of the different stages. A vast business experience is included in real automation projects that enrich the proposed methodology. To validate its effectiveness, a comparative analysis of two projects executed in the CUBANIQUEL business group is carried out, one without applying the Methodology and the other applying it, where the advantages obtained are demonstrated.

Keywords: Automation design, automation project, management of project information

1. Introduction

The automation of industrial plants is an aspect of great importance in the development of companies since they bring therefore an increase in efficiency and productivity, this is achieved by rationalizing raw materials and supplies, reducing operating costs and energy consumption, increasing the safety of the processes, optimizing the human resources of the company, and improving the process of diagnosis, supervision, and quality control of production [1].

In the branch of automation, the engineer or the staff that projects or requests the automation services for a processor entity, finds it difficult to not have a guide or methodology, despite; the many that exist, to face the task from the beginning: the stages through which the project that faces must go, how to do the requirements survey, the areas that must be prioritized in the automation process, the inputs and outputs of the System automation, the equipment and instrumentation to be used, the recommended suppliers and thus a set of aspects to take into account so that the Automation project is carried out efficiently and the expected results are obtained without having to make undesirable rectifications and modifications during its execution by unforeseen situations, resulting in extra expenses that were not planned [2-4].

"Project management is a discipline that since the rise of humanity has refined its management, today becoming a benchmark for international bodies of knowledge which compile good practices in project management and allow with a greater degree of possibility the success in achieving the objectives of a given project in the different interdisciplinary areas to which this knowledge can be applied, improving the economic results and the satisfaction of the interested parties" [5].

To ensure the success of any project, it is necessary to identify the critical factors that, according to the literature, distinguish it to reduce the impact on the triple restriction of projects (cost, time, and scope) and therefore on the company that develops it and the company requesting the service [5].

Based on the advances made in this field on an international scale [3-7] and the experiences acquired during many years of work in the execution and coordination of automation projects in different branches of industry, a methodology is proposed to the elimination of frequent technical and organizational problems that cause rectifications and modifications that can be avoided with implications that negatively impact the project budget and the execution schedule due to the lack of systematicity and precision in the management project information.

This work proposes the development of a methodology that complies with ISO 21500: 2013 [5] and allows the integration in a project of the necessary knowledge from other branches of Information and Communication Technologies (ICT) and from science to increase the efficiency of the projection process. In addition, a Manual of Automation Projects is provided for its application in the companies of the Business Group and the rest of Cuba and the possibility of integration to projects of other branches.

The first section contains the review made in the bibliography on the different methods of planning and execution of projects in general and specifically in the branch of Automation, as well as the requirements of ISO 21500: 2013 that must be met in the project development [5]. The second section describes the proposed methodology to

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achieve greater efficiency in the projection based on national and international experience, the application of good practices, and compliance with the requirements of the Standard. As a validation of the Methodology, the analysis of the execution of two Projects by the Automation Division of the SERCONI Company, of the CUBANIQUEL Business Group, Cuba; in one of them the proposed methodology is applied and the other is not, which demonstrates the advantages of the proposal presented in this scientific investigation.

2. Materials and Methods

The methodology of a project is understood to be the process that is followed to manage the project activities through requirements and steps, to find optimized work routes. It is understood that a project is a single unit of work, in which the management of available resources is carried out to achieve the specific objective of the project, all this in an adequate period and established in the planning, hence, to design the methodology of a project, it is necessary to take into account certain elements such as the resources, the objectives set, the execution time, the planning of the tasks and activities, among others [8-9].

A. General concepts about automation projects

The methodology of a project has always been a key element for managing work. Project management dates to ancient times when it was necessary to plan and organize resources to get to build pyramids, design an airplane or build the Great Wall of China [10-11]. However, it was not until the twentieth century when the different contemporary techniques and methodologies began to be theorized and defined, to apply the most appropriate ones. Many theorists place the beginning of Project Management in the publication of the Gantt Chart, still used today with innovative variations [12-13]. Already in the middle of the last century, the United States Navy developed the Program Evaluation and Review Technique (PERT) and the Critical Path or Critical Path Method (CPM) to apply predictive techniques in their Projects [15].

Regardless of the methodology used for Project Management, the following steps must be followed in all of them [16]:

• Define the objective and the need that leads us to carry out a project.

• Identify the information and resources that we have and those that we require. For this, it is important to define well the basic requirements, define with those involved, both clients and executors, the desired results, and the necessary resources to achieve it, both material and human.

• Research and plan. More details and requirements are added, the tasks to be carried out and the estimated times are defined, the material resources that each one requires, and the sequence of execution of said tasks is defined.

• Review and carry out continuous monitoring. The revision and continuous control are carried out, making the necessary modifications iteratively and the corresponding improvements in all aspects of the Project. This allows you to minimize risks or last-minute setbacks.

These steps are inscribed or performed with different methods and techniques. In Cuba, where most companies have their Quality Management Systems certified by ISO 9001: 2015 [5]. For any company, it is of utmost importance for its productivity how to manage its projects, which is not only solved with high-performance software, but also with a detailed analysis of the well-established work procedure [17], [18]. For this, the best practices must be unified and reflected considering the five essential processes of project management during its life cycle, that is, the initiation, planning, execution, monitoring, supervision, and control processes, and finally, the project closure process [19].

The development of a general methodology that exhaustively defines the steps to be followed, that complies with international and national standards and regulations and that applies the most innovative methods in the field of automation project management [20] is part of the objectives of this job.

B. Evolution of automation project methods

There are many studies carried out on methods, techniques, guides for Project Management [21-25], given their importance in the productivity and quality of projects in any branch of knowledge. The search for the dates from the first decades of the 20th century and can be summarized in the milestones related to work [5], [10-11].

Among the most used project management methodologies are the Gantt Chart, PERT / CPM, and the Critical Chain Method [12-14], [26]. Each of them has its advantages and disadvantages, but all of them are a great help when planning and managing resources in the best way and about controlling the evolution of the project.

Since its introduction, Gantt charts have become a basic tool in project management. It has been in use for nearly seven decades and is one of the most famous methodologies for project management [12-13]. The simplicity of its structure and the manageability of its approach make it the ideal tool both for those who are starting in Project Management and for those who already have extensive experience in Project Management. The Gantt Chart as a methodology for project management is made up of two axes where the tasks and activities that make up a project are collected and associated with a schedule, reflecting their duration, start time, and expected delivery period. In this coordinate axis, there is also space to mark the different phases that make up the project and to highlight the events or events that represent a notable milestone for the participants in it. The main difficulties of the Gantt Chart are derived from the establishment of priorities and the detection of dependencies between activities [27]. It provides a clear and realistic view of the situation but requires continuous updating to ensure its validity. Its application is not recommended for projects subject to many changes.

In [28] the Gantt chart is applied together with a UML design for the planning of development tasks of a reconfigurable distributed controller. Figure 1 presents the Gantt chart and time chart of controller tasks in an application process.

The origin of the Critical Path Method (CPM) is located between December 1956 and February 1959, being used by the DuPont company in its commercial computers UNIVAC1 to expand 300 factories [29-30], which could not be approached with the Gantt Method that was the best known. The CPM shows the optimal trajectory of a project and its activities. Finding this route simplifies project management, however, relying only on this tool is risky since it does not consider uncertainty. Knowing the activities that make up the project, its priorities, and its dependencies can be associated with a specific term. In this way, it is possible to establish the necessary resources in each case and distribute the workloads. With this data, the critical path can be visualized, which will be calculated based on the successive activities whose slack is equal to zero. In its application, it must be considered that

there may be more than one critical path and that updating is essential [31].

In [32] the CPM method is applied with the D-CPM variant as a dynamic process planning model that combines the project management tool with the product design tool. Figure 2 shows an example of the application of the developed method.

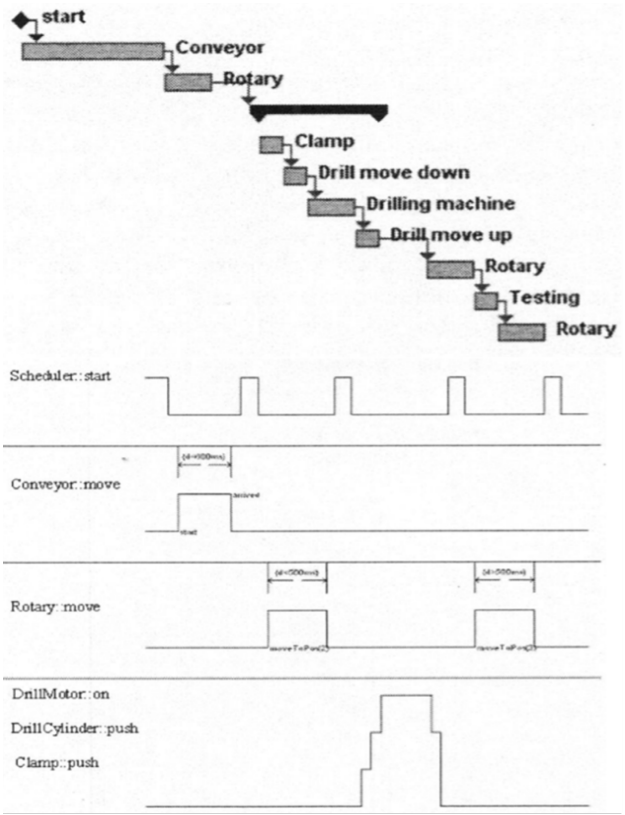


Fig. 1. Gantt chart and time chart of controller tasks in an application process [28].

PERT is one of the most widely used project management methodologies, especially since it often acts as a complement to CPM and the Gantt Chart. This technique consists of determining the activities in which the project is broken down, their dependencies, and their duration to apply a probabilistic function that helps to calculate the total execution time based on an optimistic, pessimistic, or normal perspective that, when combined, allows determining the time Estimated for each activity. With the data obtained, a mesh composed of nodes can be designed that allows determining the critical path and its standard deviation, as well as the variance for each activity. This methodology is very practical when the project combines activities that are executed in sequence and parallel [33].

In [34] the PERT method is applied to the planning and control of a projection process and a random simulation method is added to find the best variant of the project. Figure 3 represents the application of the PERT method in this article.

Having a general idea of the traditional methods, a comparative assessment of the existing methods, and an analysis of the company's experience in project management is carried out, which allows characterizing the object and field of action of this research.

Currently, there are many techniques with general or specific applications for project management, including Agile, Scrum, PRINCE2, Adaptive Project Framework, Extreme programming (XP), Kanban, and many others that are used in certain sectors, among them for the execution of Software Projects, such as Agile and XP [35], [36]. Tab. 1 contains a comparison of the main methods that exist for project management.

		A	*B*	*C*	*D*	*F*	*M*	*N*	*L*
Technical design	**A**	A							
place an order		1	B						
B									
baiting	**C**	1		C					
Tolling 1	**D**	1			D				
mechanical processing 1	**F**			1		F			
Integrated activity		1			1		M		
M									
Integrated activity					1			N	
N									
Assembling and testing	**L**		1			1	1	1	L

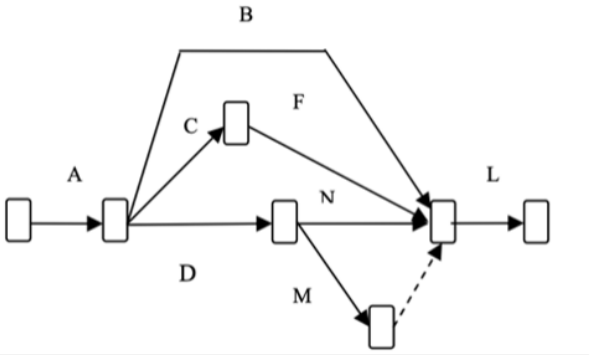
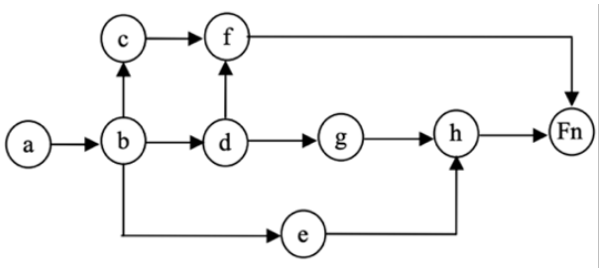


Fig. 2. Application example of the D-CPM Method [32]



activity	preceding activity	a	m	b	$D_{i,j}$	σ_{ij}^2
a	-	8	10	16	10.67	1.78
b	a	11	12	14	12.17	0.25
c	b	7	12	19	12.33	4.00
d	b	6	6	6	6.00	0.00
e	b	10	14	20	14.33	2.78
f	c,d	6	10	10	9.33	0.44
g	d	5	10	17	10.33	4.00
h	e,g	4	8	11	7.83	1.36

Fig. 3. Application of the PERT method to the planning and control of a projection process [34].

As can be seen in Tab. 1, none of the existing methods meets 100% of the requirements of ISO 21500, but the automation project methodology proposed in this research does. In this way, from the beginning of the project, a survey

of requirements and definition of the scope of the project is achieved that allows efficient planning that includes resources, time, costs, risk, and quality; only in this way can good project management be achieved.

The detailed study of all these methods allows us to ensure that it is mandatory to establish stages in a process as complex as the projection of automation systems and that these stages coincide with the Plan-Do-Verify-Act (PDCA) proposal adapted to the particularities of the design of an automation system [37]. In addition, each of these stages must have well-planned execution times according to the conditions and risks of the application. The required resources, their suppliers, their cost, the personnel prepared for their use, everything that allows avoiding risks and unforeseen events that affect the planning and the result of the project [38], [39] should also be studied.

Table 1. Comparison of existing methods with the proposed one

Method	Require-ments	Means	Time	Cost	Risk	Quality	Rule ISO 21500
Gantt diagram	No	Yes	Yes	Yes	No	No	50 %
Pert method	No	No	Yes	No	No	No	17 %
CPM method	No	No	Yes	Yes	No	No	34 %
Critical Chain Method	No	No	Yes	No	No	No	17 %
Agile	Yes	No	Yes	No	No	Yes	50 %
Extreme programming (XP)	Yes	No	Yes	Yes	No	Yes	67 %
Kanban	Yes	Yes	No	No	No	Yes	50 %
Automation Projects Methodology	Yes	Yes	Yes	Yes	Yes	Yes	100 %

3. Proposed methodology for automation projects

The proposal is made according to [5] and incorporates the life cycle of the Project with the Plan-Do-Verify-Act (PDVA) stages. For this reason, the Plan stage as Conceptual Stage, the Do Stage as the Definition, and Implementation Stage, the Verify stage as the Operation Stage, and the Act Stage as the Deactivation and Service Stage can be identified in the flowchart shown.

Starting from this conception, the Project is developed according to the general project flow chart shown in Figures 4 and 5, depending on the magnitude of the project and the strategy to be followed.

Next, the stages are briefly explained according to the general flowchart, however, in the proposed methodology each stage has its detailed flowchart and a series of templates and formats of the documentation to be used.

A. Description of the stages in the proposed methodology

Conceptual Stage: The Conceptual Stage marks the beginning of a project. In it, a set of studies are carried out to decide through the feasibility analysis whether the project proceeds or not. The elements to consider for said analysis include the project objectives, the identification of the interested parties, the analysis of technical and economic feasibility, the identification of needs, the obtaining of environmental data (socio-cultural aspects, environmental considerations), and the approval or rejection of the Project.

Once the execution of the project is approved, the initial criteria are established to prepare the project, form the contract, and perform the cost estimate, the functions, or priorities to be taken into account during the development of the project are considered through risk analysis, Choose the project manager and propose team members. To start the development of the project, a record of the Execution Order is issued, passing to the second stage.

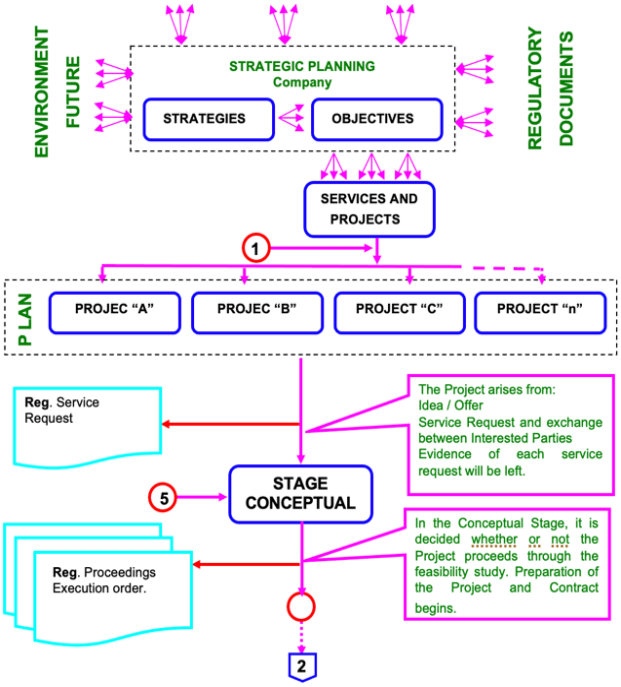


Fig. 4. Initial part of the general flowchart of automation projects.

Definition and Implementation Stage: The Definition stage is the one that corresponds to the detailed design of the project and in it must be established the scope of the project and how the work is going to be developed. Furthermore, customer participation is very important at this stage. Implementation is the execution of the project using all the established rules and procedures. These two stages at a certain moment coexist and are carried out simultaneously, which is why they have been proposed as a joint stage.

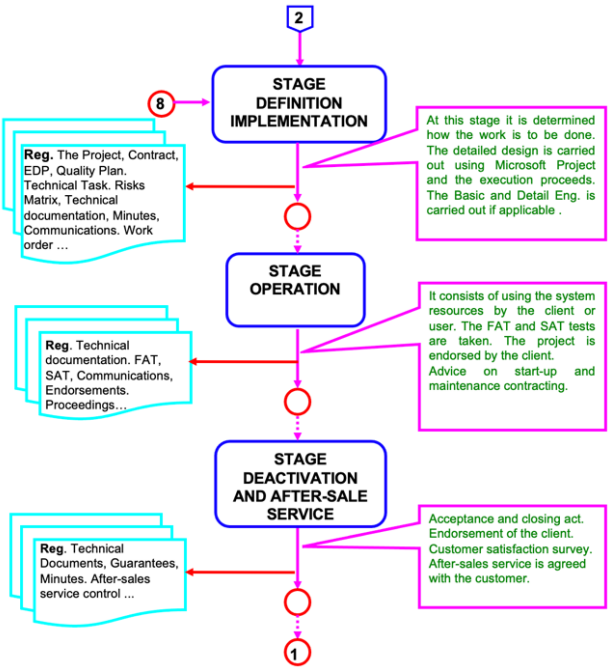


Fig. 5. Final part of the general flowchart of automation projects.

The tasks to be executed are:
• Create the project team.
• Identify, prepare, and review the documentation required to implement the project, such as standards, policies, strategies, procedures, instructions, description of tasks, among others. The declaration of the processes serves as a support for the execution of this stage, the Processes that are not identified, must be established during the Project Definition stage.
• Prepare the registry The Project.
• Determine material resources required.
• Start the hiring process.
• Prepare the detailed work plan, that is, the Project Disaggregation Structure with the list of activities. Structuring their dependence, assigning resources to each of the activities. These resources include personnel, financial resources, and other items. It is recommended to use Microsoft Project.
• Plan the budget or Cost Sheet.
• Prepare the Quality Assurance and Control Plan. The project manager is obliged to review the work plans, determine the status of the project, and adjust so that the main objectives are met (Proactive Management). Any changes to the schedule, acceptance criteria, and objectives must be resolved, and the Change Order template will be used. Changes can be agreed upon through Supplements to the contract, that is, changes in the budget, term, scope and therefore it is not required to apply the Change Order template.
• Prepare the risk matrix.

The documentation is delivered to the client for review and approval, a copy of the documents is attached to the project folder.

Operation Stage: It consists of the use of the resources of the system installed by the client or user, for this the SAT tests (Site Acceptance Testing / Acceptance Test in operation site) are carried out and it is verified that the equipment and the system comply with the design parameters specified by the manufacturer or contractor.

During the planning of this stage, it must be specified who defines the start-up program, who carries out the start-up, how the documentary verification of the result will be carried out (minutes, who writes it, when, and who signs it).

Deactivation Stage: It is the closure of the Project and among the tasks to be executed in this stage are the preparation of the technical documentation of the Project; the technical and quality review of the documentation; the delivery to the client of the documentation in the Project Folder; the execution of training actions; the preparation of the acceptance and closing act; obtaining customer compliance guarantees and studying for the analysis and improvement of the service processes carried out.

B. Presentation of the Project with the proposed methodology

A successful project, in addition to the results of its execution, must be accompanied by well-prepared and properly organized documentation in folders stored in any medium, but well identified and easy to consult. To achieve this, it is proposed that it have the sections corresponding to the Cover page or identification sheet; a descriptive memory; the technical task to be executed; the study of risk management; the integrated management of quality, human capital, safety and health at work and the environment; expense budget management and impact analysis.

Each of these documents is detailed in the proposed methodology and application examples are used oriented to the type of projects that interest us, that is, automation.

Following the proposed Methodology, an Automation Projects Manual is prepared to facilitate both their documentation and their development from the initial stages of the Project, Conceptual Stage, and Planning.

4. Results and Discussion

It is intended to carry out a discussion of cases of different Projects executed by our company, this we analyze two important Automation Projects due to their scope and cost within the CUBANIQUEL Business Group.
• Project for the Automation of the Ammonia Base of the Puerto Moa Company (EPM).
• Project for the replacement of the automatic of the Reduction Furnaces Plant at the Ernesto Che Guevara Company (ECG).

The details of the management of automation projects in each one allows us to validate the proposed methodology and shows how the experience of our company allows us to perfect the proposal presented in this work.

A. A project without applying the proposed methodology

The Ammonia Base Automation Project of the Puerto Moa company was conceived with the general objective of automating the technological process of the Ammonia Base with the scope of installing and configuring the instrumentation with Fieldbus Foundation technology for the measurement of the variables operating an area comprising an ammonia tank or bullet, installing and configuring the EROS SCADA with the defined control loops, setting up an Operations Panel, preparing the hardware and software documentation for the automatic system, training the operations personnel and maintenance in the use of the automatic system.

As a result of not having made a good survey of requirements as stated in the Standard and therefore the proposed Methodology, the scope of the project and its objectives were not well defined, which resulted in the

redefinition of the scope of the Project being necessary to recalculate the budget and supplement the Contract agreed with the Puerto Moa Company to modify the scope, the total cost of the Project and the execution schedule. Initially, it was conceived with a duration of one year and later the time was increased to 2 years.

By increasing the scope, it was necessary to expand the request for supplies and the execution of works with third parties. The Import Contracts for the supply of materials and tools, as well as the Contract for training in the facilities of SMAR Technology Company [40], in Brazil, suffered considerable unforeseen delays that affected the second version of the execution schedule. Something similar happened with the contracting of third parties for civil works such as the installation of the prefabricated operation panel and the grounding.

Although the results of the Base Automation were good, Figure 6, both from the point of view of the operating facilities and environmental safety during the unloading of the ships, which allowed obtaining the Client's Acceptance Certificate without Non-conformities, the project was affected by the organizational point of view due to the two major modifications made during the execution of the Project.

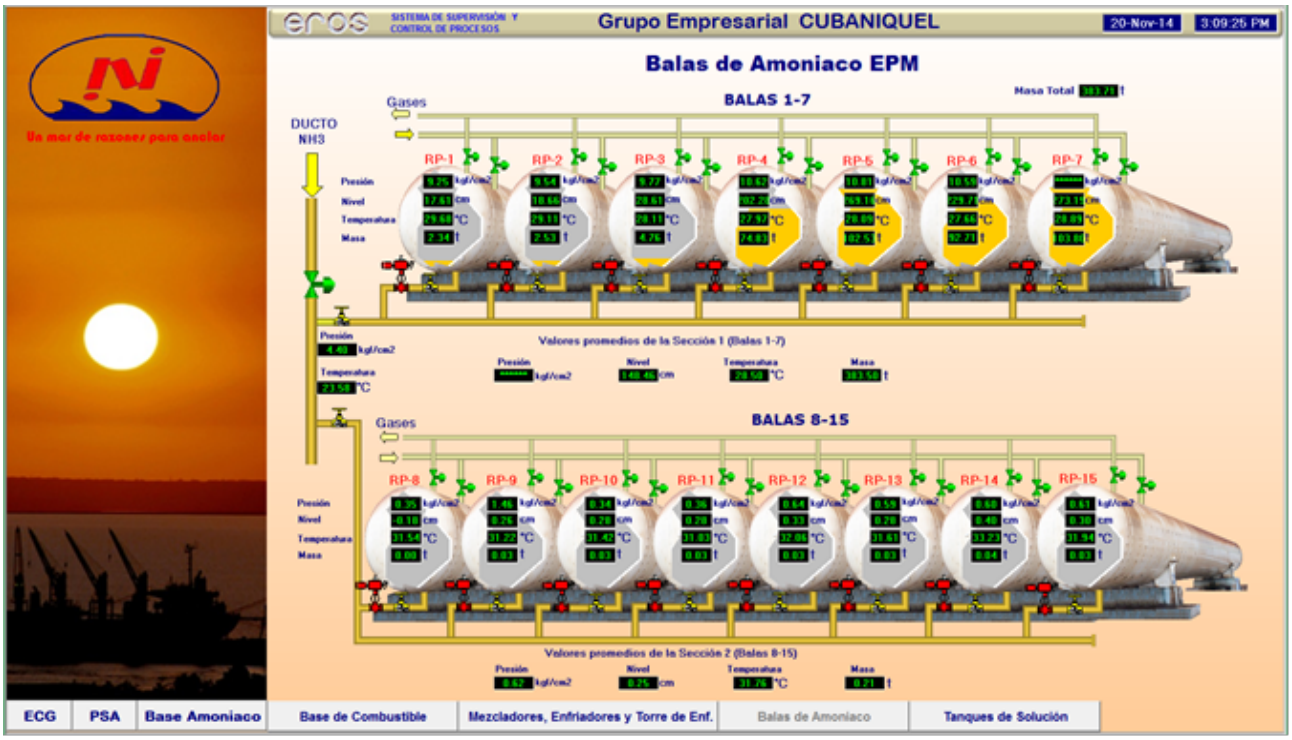


Fig. 6. Screen with representation in the EROS SCADA of the tanks in the Ammonia Base.

From the automation of the Base with SMAR Field Bus Technology, whose quality is recognized internationally, operations were made safer, avoiding the environmental hazards that an ammonia leak can cause during unloading maneuvers. In this way, the delays in the Project increased the time of exposure to a higher level of risk, both for the personnel of the port and the population close to it.

B. Project with the application of the proposed methodology

The general objective of the second project was to carry out the assembly, adjustment, and start-up of the weighing system and the equipment for the replacement of the automatic control system in Slab III of the ECG Reduction Furnaces plant.

This Project from its inception was planned to follow the designed Methodology, complying with the ISO 21500: 2013 Standard, with its well-defined stages, the initial Project Documentation was presented to the Client together with the corresponding Contract. An example of the results is presented in Figure 7.

In the Project documentation, all the elements proposed in the Methodology were included, the descriptive report with the description of the technical solution in which the weighing system is included, which is its development and whose manufacture required hiring a foreign company for the preparation and assembly of printed circuit boards. The project defined the general objective and scope, the interested parties with their specific roles in the project, the execution stages, the disaggregation structure with the corresponding Gantt Chart, the identification of risks, the budget, and the curriculum vitae of the Project manager.

The application of the Methodology allowed the development of several stages of the Project in a synchronized manner, the manufacture in China of the electronic cards that make up the weighing system, their assembly in Cuba, the hardware and firmware tests, as well as the programming of the application for Slab III of the Furnace Plant with the internal assembly of the control cabinets, their FAT tests, their installation in the Plant, the assembly and wiring of the signals and the configuration of the SCADA EROS. The last stage was carried out by another work team, also foreseen in the project, and which carried out the fiber optic communications cabling and the installation of the telephony. All the previous organizations resulted in that the SAT tests were carried out optimally and without setbacks, that is, as planned from the beginning of the project so that the start-up of the System in the first Furnace was done quickly and safely.

This project, despite being complex due to the many different tasks to be executed, only faced problems in the start-up of the last three Kilns, since to incorporate them into

the distributed weighing system, their capital repair was necessary, which was being carried out. executing for another company and faced difficulties with the supply of materials to complete the repair. The ovens were delivered partially, complying with the scheduled time until the first delivery, as agreed with the Client.

The environmental contamination existing in the Che Guevara Company Furnace Plant was high, one of its causes being the inefficient operation of the obsolete weighing systems, together with the problems of the mechanical parts of the funnels, hoppers, and other attachments allowed the mineral to be spread in the form of a very fine powder on the upper floors of the Plant, making the work environment very difficult for the operators and maintenance personnel. With the execution of the new Project, which included as a fundamental element the replacement of the weighing systems with new distributed weighing systems, the level of contamination was significantly reduced, which leads to improvements in the work environment of the Plant personnel and the nearby town.

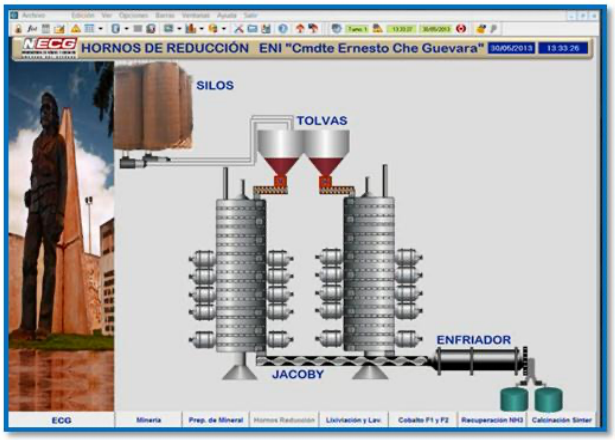


Fig. 7. Representation in EROS SCADA of a Section of the Reduction Furnace Plant.

5. Conclusions

The work carried out manages to develop a Methodology considering compliance with international standards for the processes that make up an Automation Project, guaranteeing greater efficiency of the projection process. In the development of the research, the search and study of different existing methodologies were carried out, assessing the common aspects to be included in the Methodology.

The proposed methodology was applied to several Projects, validating the results of its application, comparing it with the execution of Projects where it was not applied, managing to identify the deficiencies and their causes that allowed enriching the proposal.

Following the Methodology, a Manual of Automation Projects is prepared to facilitate both their documentation and the search for important information for the initial stages of the Project, Conceptual Stage, and Planning.

The Methodology is applicable for the execution of Projects of other branches, like the Manual, with the only chance of the information collection templates.

In addition to applying the current Norms for the execution of Projects, the Norms of Quality Management Systems, Guidelines for the Quality Management of Projects, Environmental Management Systems, Health, and Safety Management Systems were also applied in the Job.

With the application of the Methodology in several Projects, it was possible to verify that the results are better in three fundamental aspects, in the Organization and documentation, in the fulfillment of the Execution Schedule, and the fulfillment of the Project Budget. However, most of them stand out as a deficiency in the delays in the process of importing equipment and materials, which introduces delays in the execution deadlines that are difficult to foresee due to multiple factors influencing them.

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