Reliability of power electric systems in Pemex Refining: experiences and realities

Luis Iván Ruiz Flores y Francisco Cuauhtémoc Poujol Galván


En este artículo, se presenta la experiencia de 10 años de colaboración entre el Instituto de Investigaciones Eléctricas y Pemex Refinación para modernizar los sistemas eléctricos de potencia del Sistema Nacional de Refinación (SNR) en México, la colaboración en conjunto para diseñar un sistema eléctrico de distribución de energía que pueda operar de manera confiable ante el incremento de la cantidad y calidad de los productos petrolíferos con la integración de nuevas plantas de proceso. Se presentan las realidades de sinergia entre el personal involucrado y en contraste la planeación no ejecutada para implementar las soluciones encontradas. También, se presentan las realidades y contrastes en una década para dejar en condiciones los sistemas eléctricos para los próximos años y poder concretar la confiabilidad del Sistema Nacional de Refinación para la demanda energética de gasolinas; sus factores y retos a mediano y largo plazo, para obtener como resultado una confiabilidad operacional acorde a una empresa de Clase Mundial.
Abstract

In this paper, we present the experience of 10 years of collaboration between the Electric Research Institute and Pemex Refining to modernize the power electric systems of the National Refining System in Mexico, collaborating together to design an electrical energy system for distribution that can operate reliably at the increase in the quantity and quality of oil products with the integration of new processing plants. We present the extensive cooperation between the personnel involved and in contrast unexecuted planning to implement the solutions. Also, after a decade of collaboration, we present the different scenarios, factors and challenges in the medium and long term that will assure that the electrical systems are in healthier conditions to operate for the next years and will achieve the required reliability of the national refining system for gasoline demand, to result in an operational reliability conferring to a World Class utility practice.

Keywords: assets, clean fuels, conceptual design, economic planning, electric grid, electric systems, energy, interruption capacity, load flow, maintenance, oil, petroleum, refining, refining security, reliability, short circuit, synchronization bus.

Introduction

For the past ten years, the National Refining Industry manages to plan projects that improve the operating conditions of production in fuel demand [1]. There is a programed budget set of over 200 million USD in projects that have a direct benefit, with schemes in place to allow an operating condition for future electrical distribution systems and their implementation in optimal conditions.

In contrast, the current system of refineries has an energy deficit of the order of 20 MW, each refinery average of integrating more energy services, air, water and steam [2]. This deficit, required carry out engineering projects since late 2002 for: a) the development of conceptual engineering for electrical systems, b) the technical and economic feasibility studies [3], c) electrical equipment specifications, d) user requirements indicating operating conditions and descriptive data design, e) biddings f) the analysis of electrical power systems to implement specific solutions to electrical, mechanical and control equipment [4].

Efforts are scheduled for this investment focused on the reliability of the national refining system. However, the frequency of unscheduled shutdowns at refineries exceeds international standards [5]. This implies a reduction in the processing of crude oil and imports increased during the contingencies that occur with the faults in the power system.
Energy demand for gasoline in Mexico is served by the six refineries “Pemex Refining” offering a combined processing capacity of 1.54 million barrels a day (b/d), for example, the production in the following refineries is Salina Cruz (330,000 b/d), Tula (315,000 b/d), Cadereyta (275,000 b/d), Salamanca (245,000 b/d), Minatitlan (185,000 b/d) and Madero (190,000 b/d). However, the reality is that the operational capacity is limited by bottlenecks and only process about 1.35 million barrels a day.

On the other hand, this energy demand is supplied by Pemex itself to its own self-generated energy to process their fuels, from extraction to refining. Their self-generation has reached in recent years on the order of 7000 GWh as shown in Figure 1 [6].

Therefore it is necessary to mention that on one hand you have a current energy demand in Mexico, and on the other there is an energy deficit for processing at each refinery. There is also the need to modernize the electrical systems with adequate financial planning and budgeting, and on the other hand, there are unplanned outages that depend on various current factors and criteria for the operation of existing power systems [7].

In this paper, we present the experiences and realities that for ten years has sought to provide reliability to the National Refining System (NRS), with the participation of the Electrical Research Institute (IIE) in engineering and development of individual solutions for each refinery and the collaboration between specialists from different disciplines of Pemex Refining and project realities not yet executed and implemented in full for this period.

### Background information

**Pemex Refining**

Pemex Refining, is in the 13th global position for its processing capacity of gasoline, as shown in Table 1, has a capacity of approximately 1.703 gross thousands of b/d, just beneath Petroleo Brasilerio SA (Petrobras), which ranks number 12th on the list. [8].

Pemex Refining, aims to provide with quality, timeliness and efficiently the petroleum products from the National Refining Industry (NRI) in Mexico, consisting of six refineries: Cadereyta, Nuevo Leon (HRLS), Ciudad Madero, Tamaulipas (FIM), Tula, Hidalgo (MHI), Salamanca, Guanajuato (AMA); Minatitlan, Veracruz (LC) and Salina Cruz, Oaxaca (ADJ).

**Electrical Research Institute (IIE)**

The Electrical Research Institute (IIE: Instituto de Investigaciones Eléctricas) is a public agency created for research and technological development of the country. Since 2002 it collaborated with the National Refineries for: a) the development of conceptual engineering, b) economic feasibility studies, c) specifications of electrical and control equipment, d) user requirements indicating operating conditions, e) bidding, f) electrical systems analysis, and g) particular solutions implementation through technical assistance during construction, supply and commissioning of the new equipment.

The IIE was requested by Pemex Refining to define the specifications to be met by electrical distribution systems, control and instrumentation.
systems of the future, considering optimization criteria.

**Joint collaboration: IIE & Pemex Refining**

The IIE, in conjunction with Pemex Refining has helped define the most suitable electrical schemes based on the experience of the specialists of both institutions; being substantiated the implementation of the projects as indicated in reference [9]. Decision making by Pemex is backed by a large number of specialists involved, such as: Investment Analysis Management and Operating Expenses (GAIGO), Corporate Management and Project Engineering (DCIDP), the Directorate Corporate Operations (DCO), the Process Engineering Management (IPM) and local users of each refinery in the country or what is called the NRI.

Consequently, Pemex and IIE have sought during this decade, the statement of the National Development Plan 2007-2012, which states: “To ensure a reliable supply, high quality, at a competitive price, of energy inputs that consumers demand.”

In contrast, there have been factors influencing not achieving the reliability of electrical systems in the NRS, such as lack of investment resources, high operating costs, and low implementation capacity, as well as the autonomy and independence to design business strategies and improve the gasoline distribution chain.

The following challenges are placed for the medium and long term that prevent a reliable electric system, and terms that must be clearly understood, such as: a) A interpretation of reliability in power systems of national oil industry; b) Risks of oil shortage; c) Corollary of the current power system analysis; d) PtD: Prevention through Design; e) Operational reliability; f) RCAM (Reliability Centered Active Maintenance); g) Reliability Analysis and h) Staff Training.

<table>
<thead>
<tr>
<th>Position by capacity</th>
<th>Company</th>
<th>Gross capacity, thousands of barrels per calendar day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Exxon Mobil Corporation</td>
<td>5,783</td>
</tr>
<tr>
<td>2.</td>
<td>Royal Dutch / Shell (Países Bajos)</td>
<td>4,509</td>
</tr>
<tr>
<td>3.</td>
<td>Sinopec (China)</td>
<td>3,971</td>
</tr>
<tr>
<td>4.</td>
<td>BP (Reino Unido)</td>
<td>3,325</td>
</tr>
<tr>
<td>5.</td>
<td>ConocoPhillips</td>
<td>2,778</td>
</tr>
<tr>
<td>6.</td>
<td>Chevron Corp.</td>
<td>2,756</td>
</tr>
<tr>
<td>7.</td>
<td>Petróleos de Venezuela.SA (Venezuela)</td>
<td>2,678</td>
</tr>
<tr>
<td>8.</td>
<td>Valero Energy Corporation</td>
<td>2,616</td>
</tr>
<tr>
<td>9.</td>
<td>China National Petroleum Company (China)</td>
<td>2,615</td>
</tr>
<tr>
<td>10.</td>
<td>Total (Francia)</td>
<td>2,451</td>
</tr>
<tr>
<td>11.</td>
<td>Saudi Arabian Oil Company (Arabia Saudita)</td>
<td>2,433</td>
</tr>
<tr>
<td>12.</td>
<td>Petroleo Brasilerio SA (Brasil)</td>
<td>1,997</td>
</tr>
<tr>
<td>13.</td>
<td>Petróleos Mexicanos (México)</td>
<td>1,703</td>
</tr>
<tr>
<td>14.</td>
<td>Flint Hills Resources</td>
<td>816</td>
</tr>
</tbody>
</table>

Table 1. Gross capacity of the largest refineries in the world [8].
Experiences and realities

Interpretation of Reliability in Power Systems Pemex in the 70’s = Redundant Power System

Within the framework of a technical definition, the concept of reliability of a system or equipment is related to the idea that the probability that the equipment or system is in operation for a number of hours (years) without failure. In some of the literature, it’s defined as the probability that a device performs a required function under certain conditions, over a period of time [10]. For example, if we were to define the basic concept of reliability, would be with the formula 1.

\[ R(t) = P(X > t) = 1 - P(X \leq t) \]  

(1)

In Pemex Refining, the processing of raw materials as a series system, as well as a parallel system, will influence the reliability in both systems that the outcome will be the continuous production for a certain period defined in hours. While for a series system is defined by the formula 2 and the parallel system defined by the formula 3, the expected value obtained will reflect the operation of the power system, using an exponential distribution defined by the formulas 4 and 5.

\[ P(T < t) = P1(T < t) * P2(T > t) + P1(T > t) * P2(T < t) + P1(T < t) * P2(T < t) \]  

(2)

\[ P(T < t) = P1(T < t) * P2(T < t) \]  

(3)

\[ V = \lambda e^{-\lambda t} \]  

(4)

\[ P = \lambda e^{-\lambda t} \]  

(5)

Therefore, the design of electrical power systems of the seventies by Pemex Refining was focused on having a redundant or parallel electrical system that could offer the advantage of providing continuity of production. This was for the designers, “the reliability of process plants” = zero shutdowns and 100% energy production. Today, redundant design that is not enough, because in parallel systems require a redesign and a new electrical reconfiguration.

To demonstrate this, we define the typical example, serial system in the terms referred to as “interlocks” describing protections coordination feeder upstream of the source, such as a switchgear where the relay that has an element as marked in Figure 2, and that opening such power switch “IJ1A” accordingly should automatically open power switch “ITR-1” as part of protective interlocks. This means that the joint probability that the switch “IJ1A” fails before “t”, or switch “ITR-1” fails before “t”, and that both elements fail before “t”, is directly related to an interlock, which will directly leave the refinery disconnected from the National Electricity System (NES). Having said that, the failure that occurs in this path will take less time for the “continuity of production”, than in the comparative case of a parallel system.

A “parallel system” therefore is what is known in Pemex Refining as “redundant” or also known as a “secondary selective”, which is a design of a power system with two feeders connected to two switchgear defined as SB1 and SB2 as shown in Figure 2. In this figure is seen as a technical advantage and as an alternative to maintain production of gasoline processing for longer than the series system.

Therefore, Pemex Refining current power systems have an advantage that provides more reliability in redundant power conditions electrical substations around the NRS. However, the conditions of reliability power system depends not only on the type of serial or parallel systems, but the factor that influences the condition of the installed equipment that make up the electrical current electrical system operation.

Risks of oil shortage

The supply of petroleum products in the country depends on having
modern infrastructure, top-level process plant, and the implementation of projects of electrical reconfiguration of refineries as indicated in “Prospective Oil in Mexico” [11].

The NRS in a short time increased distillate production, although it has been necessary to resort to imports to meet demand. This situation was exacerbated by permitting the coming into effect of the new specification for low sulfur fuels, since as a result, has reached that more than 90% of the consumption of ultra-low sulfur diesel and 70% gasoline Premium are import [12].

In the NRI, there is an average load of about 70 to 100 MW per refinery, which is supplied with three and up to six steam turbo generators depending on the refinery. There is a backup power supply from the NES to connect between 115 or 230 kV. The above to ensure the electrical foresight production plants according to demand analysis presented in Figure 3.

Therefore, Mexico is at risk of suffering what seemed impossible in many decades, the shortage of petroleum products. On the one hand there is experience and working knowledge of the Technical Group NRS specialists who knows the conditions necessary to optimize electrical systems, and on the other, the Congress Legislature repeatedly has determined to continue to be responsible for Pemex, which to that effect, have signed new supply contracts to service stations and wholesale which for ten years have not been fully implemented.

![Figure 2. Typical electric system in refineries.](image1)

![Figure 3. Descriptive scheme of supply and demand of energy in a typical refinery in Mexico NRI. Their analysis is proposed in 3 phases of increasing energy.](image2)

**Corollary of the analysis of existing power systems**

**Technical assistance of IIE to the NRS in electrical systems analysis**

Currently, in Mexico the NRI is in the process of reconfiguration of the electrical system to supply the production of its oil products in at least three of the six refineries, and the rest of the refineries have specialized analysis projects to progressively reconfigure them.

Normally each refinery is interconnected to the National Electricity System (NES), ensuring continuity of electricity in contingency conditions. However, the cost of acquiring energy and paying bills to NES, in some refineries ascends to around USD $ 800,000 monthly.
The existing electrical systems have similar characteristics to implement the reconfiguration source indicated in the technical literature. The reconfiguration or modernization of the electrical system of each refinery must comply with current regulations and technical requirements, by updating its technology, substantially improvement in efficiency, meet the demand, increased production and operational reliability.

During the last decade the NRI sought to preserve operational and integral security of the process plants through its electrical system which it’s top priority, and provide solutions to current problems of power electric systems. For example, the reconfiguration of electrical power systems is due to:

- A lack of modernization of obsolete equipment.
- The lack of spare parts of some equipment.
- The equipment operates with technological disadvantage against up-to-date equipment.
- There are aging mechanisms and insulation.
- There are voltage drops over the limits permitted by international standards [13].
- There is a short circuit interrupting capacity over the safety factor limits recommended in international standards [14].
- There is exposure to internal and atmospheric overvoltages in the connection with the NES.
- There is a lack of power supply.
- There is a limited capacity at the voltage levels in the power distribution.

The analysis in each refinery in the last ten years have considered and proposed new schemes of action in the requirements for the electric system reconfiguration, such as migrating your energy level distribution of 13.8 kV to 34.5 kV and in others cases to 115 kV. Also, the integration of new power equipment, and generation units have been considered, which allow self-supply of electrical power to reach an average of 120 MW for a 34.5 kV level and 320 MW for a 115 level kV as a distribution medium.

Corollary of the literature of ten years of IIE technical assistance to NRS Pemex

Within the literature on the subject, Pemex and IIE specialists’ synergy has focused on the reasons to migrate from one energy level distribution of 13.8 kV, such as: the three-phase short circuit current that the distribution buses have does not take into account the safety factor of 20% of the design capacity, the voltage drops exceed ± 5%, there is a limited capacity of the voltage level of 13.8 kV among the engineering conceptualizations leading to modernization of the electrical power systems.

Also, the NRS requires integrate new processing plants to reduce sulfur content in products such as gasoline and diesel and the integration of new generation units to the current power system which leads to upgrading electrical power systems.

During these joint participations improve flexibility, reliability, continuity of service, and capacity on present electrical systems to refineries was sought, concluding, in the financial side, that a substantial investment to fix it is required.

Conceptual designs were developed according to the impact within the existing electrical power systems, such as minimum impact, medium impact and high impact. Also, alternatives were considered, medium effects in some cases, and the most impact on others. For each implementation of a new synchronization bus in the power electric system in the NRI, it should consider the scope and issues such as:

1. To migrate the voltage level of the synchronization bus.
2. Comply with the guidelines of international standards for the issue of the safety factor in interrupting capacity of existing boards.
3. Gradually migrate to the technologies mentioned as gas-insulated substations or hybrid systems [15,16].
4. Optimize the power flow between the NRS and public grid which belongs to NES.
5. Adapt single bar devices to double or triple bar.
6. In some cases replace instrument transformers to have adaptive protection coordination.
7. Implement new technological developments and new technologies such as those mentioned in [17, 18].
8. Provide the opportunity that new loads and new generation modules can be connected in a future available cell of the new synchronization bus, for example.
9. Monitor and supervise with cutting edge technology facilities such as those mentioned in [19].

PtD: Prevention through Design

The design of power systems and electrical power equipment impact the electrical construction and mortality rates.

Power systems today are complex. Also, to modernize them, it is necessary to use the specialist’s experience of NRS. Similarly safety procedures and operation are equally complex and require safe practices and procedures as applied in the NRI, especially in regard to the topics listed in [21] for safety regulations in the workplace, such as:

- Electrical hazards,
- Replacement of electrical equipment and accessories
- Engineering Controls
- Personal Protective Equipment
- Warning signs and other media

In contrast to this design using “PtD” requires an integral implementation which reconfiguring projects are executed under a heading without having to exceed a 5-year financial budget as authorized by the Secretary of Finance and Public Credit (SHyCP). This means that the alternatives proposed in this decade have been partially implemented for various reasons: lack of budget, attention to electric system contingencies which invests part of the annual budget of each refinery, clear definition of investing in a solution for the power electric system, internal separate group efforts to run PEMEX projects, among others.

At present, such is the case of an integrated project to sustain reliability and to migrate electrical distribution system from 13.8 kV to 34.5 kV at the FIM Refinery, in the electrical subsystems defined as Thermo I and Thermo II; it was migrated only on the Thermo II during 2008. The terms for these electrical systems to receive new generation units, the TG-7 for Thermo I, and TG-8 for Thermo II, both required for integral modernization. However, efforts were divided into groups, one technical group installing the TG-7 and other group letting the integration of TG-8 on “stand-by”.

On the other hand, the experience of the electrical power system in the FIM Refinery, is that there were some failures in the past twelve months due to needy conditions of the equipment leaving weak operational reliability.
In similar cases were found MHI and HRLS Refineries, where projects that already have a “proposed solution” and properly justified in this last decade, to migrate the electrical power system to a Synchronization Bus in 115 kV and to a 34.5 kV bus respectively, Although not materialize yet, while both refineries have presented power failures over the past 5 years that go from ionization that generates a trip in the protections coordination system, to a copper bar electro-erosion at the main boards in the absence of a robust electrical power system with suitable grounding systems.

In the above cases, have had to continually stop producing gasoline, generating great loses that in consequence could have been mitigated with the implementation of each project in an inclusive manner, fulfilling what 4 years ago decided to implement with the methodology Reliability Centered Maintenance (RCM) in the NRS. This methodology is intended to implement since 2008 in what is known as RCA, FMECA and FMEA that are definitions for its acronym in English: “Root Cause Analysis (RCA)”, “Failure mode, effects and criticality analysis (FMECA) and “Failure modes and effects analysis (FMEA)”.

So in recent years, Pemex sought awareness and planning by staff to apply different philosophies that at worldwide level are being used such as “PtD” and that in time results in a chief focus that are electrical equipment and power electric systems, as shown in Figure 4.

**Operational Reliability**

Nowadays in Pemex, there is a technical guide that allows administrators to generate a commitment to operational reliability through the application of consistent practices throughout time, so that it is integrated as one of the fundamental values of the culture of Pemex. The scope of the guide is based on having an interaction between commitment and leadership, as well as continuous improvement practices to the solid commitment of the elements that conform the operational reliability marked in Table 2.

Operational reliability is based on the life cycle of the assets, their designs and the applicable regulations, is the unification of human reliabilities objectives, of process, equipment and design, aimed at maximizing the profitability of the company.

The operational reliability model is composed of 14 best practices, same as those that interact and create value throughout the organization, representing the conceptual and normative framework, the latter containing an axis of meeting at least five documents relating to operational reliability in PEMEX and which is shown in Table 3.

In contrast, the reality is that the systems in a process plant in the NRS, typically are composed of a number of subsystems and equipment (electrical, mechanical, instrumentation and structures), that when fault an equipment or subsystem generate loss of function of the process plant.

Now, while that for the implementation of RCM in the NRS results that 70% of faults can be removed by running the method and the other 30% can be removed by an implementation of continuous improvement, both concepts lead to make countless activities through responsible for
operating activities at the NRS, i.e. the need to converge continuous improvement efforts and implementing a preventive task list (predictive, procedures, among others) marked in Figure 5, and execute plans in an efficient and flowing tactic that allow to have power electric system available and consequently continuous production reducing causes of failure modes.

The reality of the implementation of the methodology is that: its necessary upgrading the power electric systems and associated devices, i.e. while already conducted since 2003 efforts to strengthen the power systems of the NRI with electric reconfigurations, in subsequent years comes the need to raise awareness in all staff axes for continuous improvement and application of the RCM method.

The indicators of unscheduled shutdowns, the percentage of emergency corrective maintenance, and the number of faults unforeseen in the last two years made an urgent need to implement what some call Transformative Leadership, seeking harmony within an organization, and achieving cultural change to the processes, and the commitment of the organization staff for a first class operational reliability.

RCAM: Reliability Centered Asset Maintenance

The issue of RCAM defines the implementation of Reliability Centered Asset Maintenance Method. The literature proposes that the RCAM be executed in 10 steps ranging from substantial reliability analysis, modeling a reliable component, to system reliability and cost-benefit analysis [23, 24].

<table>
<thead>
<tr>
<th>Elements</th>
<th>To maintain compliance with applicable standards</th>
<th>Competition Establish process reliability</th>
<th>Promote the involvement of staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishing Reliability fundamental value</td>
<td>Ensure consistent implementation of standards system</td>
<td>Set goals</td>
<td>Ensure consistent implementation</td>
</tr>
<tr>
<td>Provide strong leadership</td>
<td>Identify when required compliance standards</td>
<td>Define responsible</td>
<td>Involve relevant staff</td>
</tr>
<tr>
<td>Establish and reinforce high standards of performance</td>
<td>Involve relevant staff</td>
<td>Identify benefits</td>
<td></td>
</tr>
<tr>
<td>Documenting Culture of Reliability</td>
<td>Practices to ensure that compliance standards are effective</td>
<td></td>
<td>Promoting organizational learning</td>
</tr>
</tbody>
</table>

Table 2. Practices that are intended to allow staff interaction to a strong commitment and leadership in Operational Reliability [22].

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE JA-1011-1999</td>
<td>Evaluation criteria for processes Reliability Centered Maintenance</td>
</tr>
<tr>
<td>SAE JA-1012-2002</td>
<td>Standard Guide for Reliability Centered Maintenance</td>
</tr>
<tr>
<td>ISO-14224:1997</td>
<td>Industries Oil and natural gas - Collection and exchange of reliability and maintenance data for equipment</td>
</tr>
<tr>
<td>800/16000/DCO/GT/017/07</td>
<td>Technical Guide for mechanical integrity</td>
</tr>
<tr>
<td>800/16000/DCO/MA/001/07</td>
<td>Management System Manual Pemex SSPA</td>
</tr>
</tbody>
</table>

Table 3. Normative reference documents to meet Operational Reliability.

In Pemex, there is a tendency to implement this method for electrical power systems, including interrelated approaches to security management the processes (preventive maintenance and predictive maintenance).

So on the one hand, it seeks to raise awareness that the assets are the essential foundation of the processes of production, maximizing the effectiveness of their life cycle, increase utilization and reduce the risk associated with their operation, promotes the creation of value and profitability of the company. And on the other, the reality of implementation of the methodology to achieve maximum utilization of Productive Capacity and Various Processes of the NRS, is still in the training process. In that sense it is reflecting since 2008 the performance of scheduled repairs,
The fact is that the NRI currently holds parameters which are indicators to generate a self-diagnostic as shown in Figure 6. However, the reality in the future of the application of the methodologies RCM, RCAM points to perform a “reliability analysis” of electrical power systems that unlike the “Contingency Analysis” evaluates quantitatively and probabilistically, and develops strategies to improve the reliability of supply or to reduce costs, in addition to requiring more data and time to analyze all possible contingencies, and does considered automation.

Consequently the meaning of “Reliability Analysis” is defined by evaluating the probability of service interruption to the client for a given configuration of the electrical power system. For example, the NRI has experience and a reference for implementation of the RCM, and in that sense is a priority action for continuous improvement of electrical power systems, as indicated in paragraph 3.5, i.e. what refineries required is to make a “reliability analysis” that allows prediction of the system behavior for different scenarios. Figure 7 shows the comparative statistical analysis of failures and reliability analysis of the behavior of the future envisions.

While the analysis of power electric systems give us a “present condition” of the NRI, such as the analysis of: load flow, short circuit, protection coordination, transient stability of electric arc now, these have been developed only in some refineries in the country, and it’s necessary to determine the present condition of all electrical system as indicated in [25].

Figure 5. Implementation of RCM for Pemex and its interrelation for continuous improvement.

as an area of significant opportunity in terms of their planning and implementation of the RCAM.

Reliability Analysis

During those years, PEMEX, like any other company seeks to be competitive and meet the needs of a market that demands their products. Feasible and sustainable strategy searching in the last four years reflects a profit in the company, its members and their customers.

This strategy is based on self-diagnosis capable of determining what the present situation and thus establish its growth plan whose objective is increasing the productivity of the company, with the support of tools and information systems which at the present account on.

In this regard it is considered that for self-diagnosis there has been performed a statistical analysis of component failures which the most appropriate term of the literature called “contingency analysis” that evaluates qualitative and probabilistic conditions in the NRI. Such analysis develops strategies to reduce or limit violation to address the problems of contingencies, requires less data and less time for a manner of speaking.
Now, the reality is that while the analysis of electrical power systems of the NRI have partially been made, it is necessary to perform “Reliability Analysis” of electrical power systems. Such “analysis” allows comparisons among different variants of planning and different grid configurations and topologies for the same substations, allows comparison investment costs against interruption costs per user.

The “Reliability Analysis” allows simulations with analytical methods such as the Markov, which can give accurate results and reflects the constant failure types that may occur. So the recommendation to have a prediction of the behavior of electrical systems and their components in the future is to initiate with the “reliability analysis” in the NRI.

Staff Training

The Human Reliability is the cornerstones in the Operational Reliability; this concept is focusing from senior management to trusted personnel and unionized workers. Probably since 2008, Pemex instills that the RCM deployment planning focuses on achieving the “staff committed” to strengthen operational discipline.

The reality today is that the NRS requires trained personnel not only in the technologies that are entering the market, but also in existing technologies allowing it to obtain the goal of sustaining a continuous production in NRI. For example, it requires focus their efforts on emerging techniques for applying adaptive relay protection, contingency simulating emergent conditions in electrical substations, which are on average more than 70 in each refinery. Today these simulations would enable to determine the operating conditions for more than 10 brands that exist in the market and its facilities with equipment dating from the 50s. This, to lessen the high costs involved in making contracts to modify or calibrate equipment installed relays of transnational corporations.

Another need that today comes in PEMEX, is to have a testing laboratory of electrical equipment that allows the assessment and enforcement of international standards in commissioning tests, while in Federal Electricity Commission has a Laboratory Test as LAPEM, Pemex has yet to make an investment of this magnitude. Staff training in the NRS against the technological challenges and emerging conditions, is an investment that enables a high-level Collegiate Group who acts contingency operating conditions, building on the experience of staff year after year pension retires conditions.
Currently, the implementation of electrical reconfiguration projects develops gradually by installing synchronization buses 34.5 kV and 115 kV in the “MHI” and “HRLS” refineries respectively. On the other hand, by 2017 it has to be implemented in NRI a variety of projects, such as migrating synchronization bus 34.5 kV of the “ADJ Refinery”. There are six refineries in the NRI, and enough technical capacity of Pemex Refining specialists for the implementation of projects. In addition, work is being carried out in conjunction with the IIE, so that PEMEX can tackle and substantially improve their performance and thus comply with SENER (Ministry of Energy) proposed in the National Development Plan (PND 2007-2012), see Table 4. The collaboration and technical support by the IIE to Pemex has an increase tendency for the future, henceforth the NRS can guarantee operational reliability which is one of the most important traits in the oil industry.

**Conclusions**

One of the results in this decade of working together between Pemex Refining and the IIE, has been a substantial improvement in operational security - the "master orchestrator" of the operations of the NRI today. In a world where global fuel demand is almost equal to the overall capacity, each time a plant is out of operation is a problem. So reliability is the most important feature in the oil industry.

It is important to note for new projects partners in the upgrading the NRS, the following: 1) the estimated cost is presented according to the domestic market and may increase when performing tenders package due to the volumes with the most accurate measurements, 2) may suffer increased cost for updates on the following factors according to the Law on Public Works and Related Services with the same (LOPSRM); 3) Pemex factors - National Industry Chamber, 4) inflation rate reported by the Bank of Mexico, 5) market study area, 6) increase in cost for additional work not covered in the volumes, 7) increase in time and cost restatement in case the tender is declared void public of the work; 8) increased cost and time for rescission of the contract for public works to the winning company and 9) increased time for delays attributable to weather and environmental conditions (rainfall).

The risks, commonly affecting the implementation of the modernization of the NRS considered in the last ten years. However, these risks also influence the construction of a new oil refinery, i.e. Mexico energy demand of crude oil in the next 20 years, along the horizon, should be considered in economic amounts, and in the changes that happen every day in technological developments.

Although the issue of the NRS reliability related to power electric systems is gradually materializing in partially executed objectives it is required to accelerate the implementation of short-term projects as outlined in the terms of

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Table 4. Collaboration results between NRS and the IIE in relation to the new electrical power system designs.
an approved financial planning by SHyCP that is valid for five years.

In contrast, we must remember that in Mexico there has not been built a refinery since 1979, and for the next years it is required to have a upgrade electrical power systems that provides reliability operations and petroleum products that meet the National Standard NOM-086-SEMARNA-SENER-SCFI-2005[26].

The ideal conditions for reliable operation in electrical power systems require different actions:

• Having a RCM application of short-term.

• Apply the RCAM as philosophy in electrical power systems.

• Invest in a own test laboratory for indirectly allowing PEMEX taking evidence from their own equipment and equipment that will be installed in the future.

• Follow up on continuous improvement projects that after a decade still have undefined execution date.

• Designing future systems in NRI using PtD.

• Comply with the recommendations of international standards applicable to electrical power systems analysis.

• Initiate and formulate a plan of action for “Reliability Analysis in each refinery of the NRI”.

• Knowledge transfer of staff with extensive experience to new generations that operate electrical power systems in the next 30 years.

• Ongoing training of new generations of staff.

Finally, it is necessary to transform Pemex and Pemex Refining in autonomous bodies to enable them to execute their projects with greater agility. The joint efforts of the Technical Groups should take a conjoint path for the benefit of the State and those who make energy development.

References


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Ingeniero Eléctrico por el Instituto Tecnológico de Orizaba en 1999. Ingresó al Instituto de Investigaciones Eléctricas en el año 2000. a la División de Sistemas Eléctricos, donde ha colaborado en proyectos relacionados con el análisis y diseño de sistemas eléctricos de potencia industriales, y sistemas informáticos de diseño de especificaciones técnicas de equipos eléctricos y sistemas de energía eléctrica para las empresas estatales. Es autor o coautor de más de 48 artículos en publicaciones internacionales. Ha sido conferencista en más de 170 ocasiones en congresos internacionales. Ha entrenado a más de 1,700 ingenieros en más de 10 países en el tema relacionado a "análisis de sistemas eléctricos con software. A la fecha cuenta con 13 derechos de autor en las categorías de software y el trabajo literario. Recibió la distinción "Achievement Award 2011" del IEEE MGA por su contribución para promover el conocimiento de los países de América Latina y también recibió el premio como “Ingeniero Distinguido 2013” por el IEEE Sección Bolivia, por su contribución a la promoción de la investigación y el desarrollo tecnológico en el país durante cinco años. Actualmente es Presidente del Capítulo de Aplicaciones Industriales del IEEE Sección Morelos y Fundador de PCIC México, el evento más importante técnicamente a nivel mundial en la industria petroquímica.

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