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Monitoring and control of the performance indexes in electrical power system by business intelligence

Control y monitoreo de los indicadores de desempeño en sistemas eléctricos de potencia mediante el sistema de inteligencia de negocios

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ABSTRACT

The following article refers to the monitoring and control of power systems with integration of individual and systemic indexes that measure the true performance of the system because of their complementarity from the point of view of the evaluation of performance, this online monitoring through business intelligence to improve decision making with better support information.

Keywords: Performance, systemic indexes, individual indexes, business intelligence.

RESUMEN

El siguiente artículo hace referencia al monitoreo y control de sistemas eléctricos de potencia con la integración de indicadores individuales y sistémicos que miden el verdadero comportamiento del sistema debido a su complementariedad desde el punto de vista de la evaluación del performance, este monitoreo en línea a través del sistema de inteligencia de negocios mejora la toma de decisiones con un mejor soporte de información.

Palabras clave: Desempeño, indicadores sistémicos, indicadores individuales, sistema de inteligencia de negocios.

Introduction

In general, regulatory agencies are focused on the aspects of continuity of electric service, wave quality and customer service; Table 1 shows the benchmarking in countries based on the electrical power system quality (Abbad, 2007).

Table 1. Benchmarking of regulatory aspects about electricity quality service

Country	Aspects of regulatory quality	Incentives/ penalties	Quality indexes	Control of quality
Argentina	Continuity, quality of customer and wave	Penalties: Reduced rates to customers affected	System and individual indexes	Selective measurements contingency databases
Chile	Continuity, quality of customer and wave	Penalties	System and individual index	Specific customer surveys
England and Wales	Customer care	Penalties, compensation to affected customers	Individual guaranteed	Surveys, reports distributors
Norway	Voltage, frequency	Penalties	Individual indexes for continuity	Surveys, reports distributors

Since October 1997, the electrical power system quality has been based in the standard: *Norma técnica de calidad de los servicios eléctricos* (NTCSE, 1997) .The peruvian laws set by Osinergmin the obligation to monitoring and supervise the accomplishment with safety and quality standards of electrical companies. Fig.1 shows the historical and predictive calculations (Abbad, 2007) of the electrical power system quality indexes in Peru considering the NTCSE and Osinergmin process.

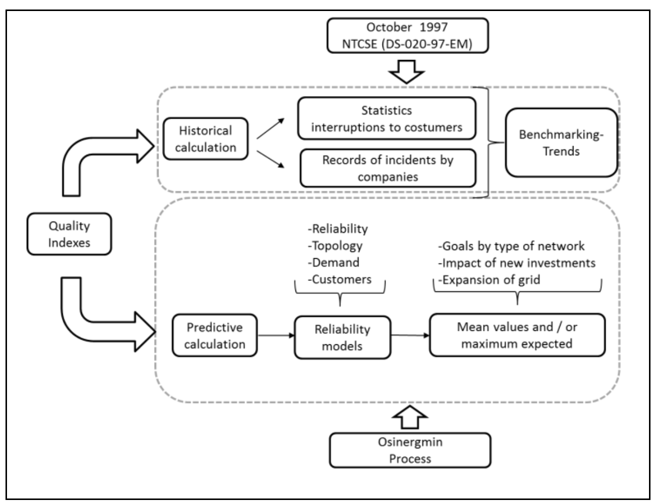

Figure 1. Historical and predictive calculations of the electrical power system quality indexes

The *Gerencia de Fiscallización Eléctrica (GFE)* in 2012 through a process of transforming data to information, it has been used techniques for support to make strategic decisions: Business Intelligence (BI).

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Electrical Power System Quality

Perceived electrical power system quality

It is related to the occurrence of interruptions in the electrical system, both duration and times. Fig.2 shows a diagram of the perception of the electrical power system quality in the customers also shows in average percent of interruptions in the distributions system.

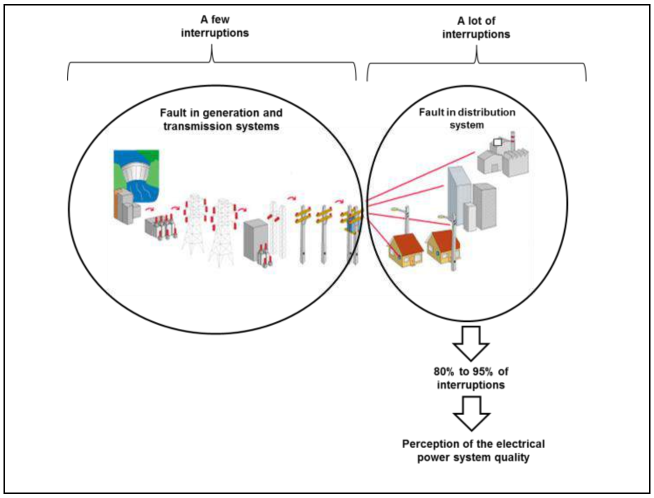

Figure 2. Perception of the electrical power system quality

Indicators of electrical power system quality

An important aspect of the electrical power system quality, how should it is measured and indexes are used. Fig. 3 shows the scopes of the systematic indexes refer to Osinergmin process in transmission and distribution system (RS-OS N° 074).

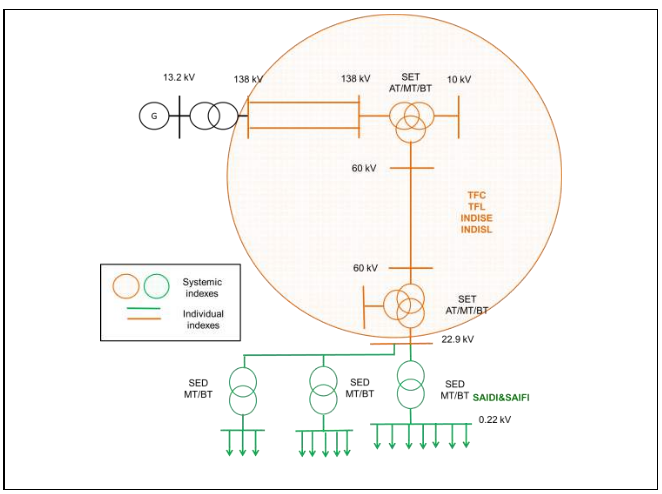

Figure 3. Evaluation of individual and systemic indexes of electrical power system quality.

Individual indexes: They reflect the level of electrical power system quality experienced by particular customer to service provided by the electric company. The NTCSE measures the individual electrical power system quality provided by the electric company to customers and sets limits for voltage level, indexes of interruptions per customer number (N) and total duration (D) of interruptions per customer (NTCSE,1997).

Systemic or global indexes: Show the average behavior or percentages of service electrical power system quality in the system, defined as: grid, service area, region, etc; where electric power is supplied. Also they are classified into client indexes: SAIFI (Interruptions / year), SAIDI (hours / year), TIEB (min / year), IIS (%) CAIFI (interruptions / year) and CAIDI (hours / year); potential indexes: NIEPI (hours), TIEPI (hours), ISS (ratio), TIEPED (minutes), energy indexes: ENS (kWh), ASCI (kWh / customers) ACCI (kWh / customers), indexes for predictability analysis: IKR (int /100 km) (Abbad, 2007).

Advantages and disadvantages of the system and individuals electrical power system quality indexes.

Continuity indexes attempt to measure the reliability of electricity supply, the number of times that interrupted the electricity supply and duration of interruption. Fig. 4 shows the approach to the electrical power system quality, the scope is: interruptions, power connected and customers supplied and effected. (Abbad, 2007)

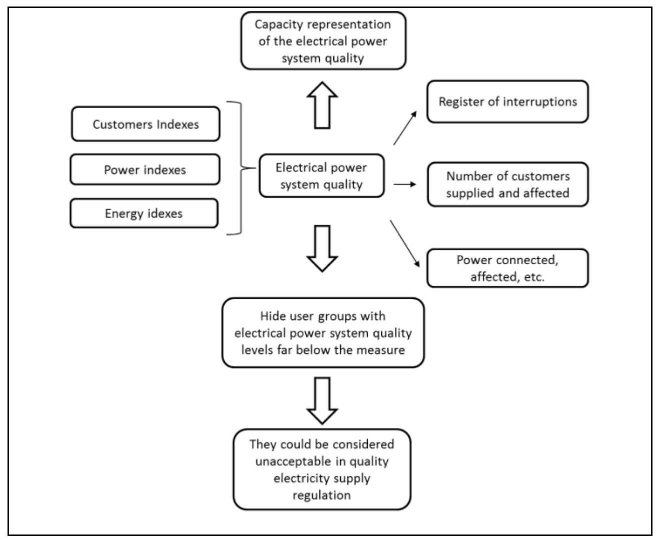

Figure 4. Electrical power system quality (systemic approach)

Fig. 5 shows the advantage of systemic index, evaluates behavior supplier in general and as this influence in the overall electrical power system quality, the disadvantage is that users who are inside are considered average, and those outside the average will not be taken into consideration.

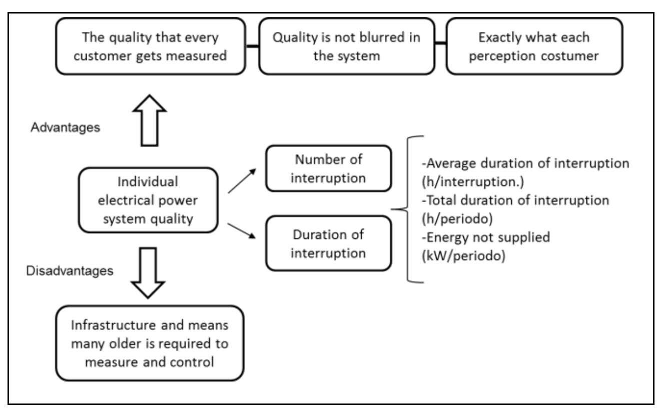

Figure 5. Electrical power system quality (particular approach)

The advantage of the individual index, it evaluate individual behavior of each client in the grid, the disadvantage is that users are not a measure of overall electricity quality and requires additional means to control and monitoring (Abbad, 2007).

In any case the pay for systematic and individual indexes is considered in both cases. In the case of Perú first there are evaluations referred to individual indexes then systemic indexes (SAIDI and SAIFI).

Complementarity of systemic and individual indexes

The quality electricity indexes approach allows the system to adjust the remuneration of distribution investments, controlling the electrical power system quality of system offered by encouraging distributor companies to invest until the optimum level of electrical power system quality; the electrical power system quality indexes approach allows a minimum level of electrical power system quality for all customers and be compensated customers who do not get the level of electrical power system quality. A better understanding of the complementarity viewed from the standpoint that the electrical power system quality provided to each customer is a stochastic phenomenon defined by a probability distribution. Because the individual indexes refer a particular customer and a compensation when the indexes is exceed the tolerance, the systemic indexes refer an average in the system and a penalty when the indexes is up the tolerance, both measure the true performance of the system because of their complementarity from the point of view of the evaluation of performance (Abbad, 2007). Fig. 6 shows the complementarity about indexes through probability distribution.

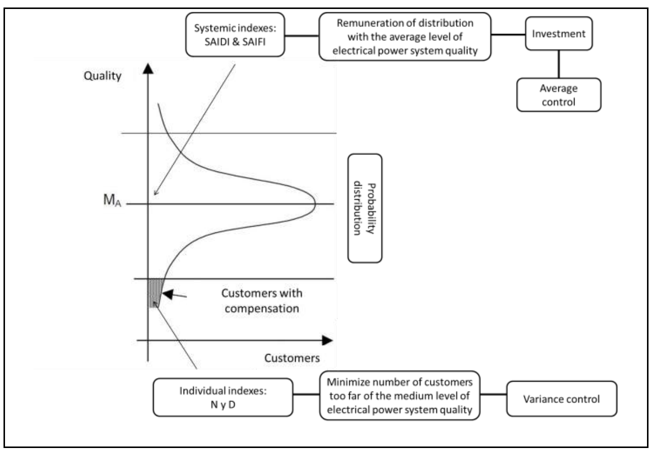

Figure 6. Complementarity of systemic and individual indexes

Optimal level of electrical power system quality

Any regulation should concern the minimization of the Net Social Cost (NSC) associated with the presentation of the electricity service, it is referred to the incurred cost by society in the presentation of considerate electricity service, is necessary to know the cost of supply the product or service, and its utility function for recipients of the product or service. Fig. 7 shows the lack of the knowledge about the cost of investments to improve de electrical power system quality, in other hand the actual customer cost when there are interruptions, so the NSC must focus to quality improvement for example through installation of signaling switching, alternative connections, etc (Abbad, 2007).

Fig. 8 shows the calculation of optimum electrical power system quality, the behavior of electrical companies (when the quality and cost increases) and customers (when the quality increases and the cost decreases)

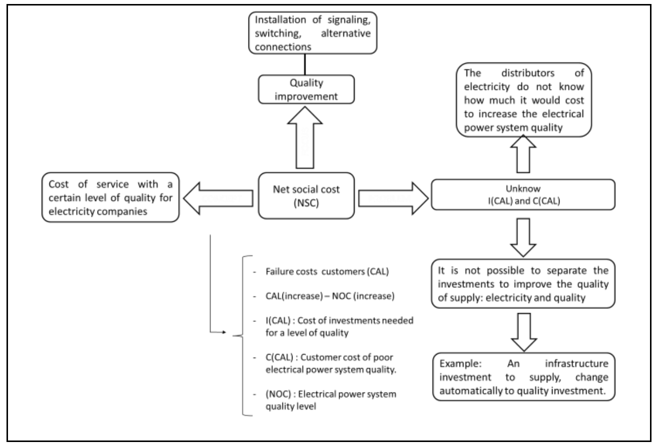

Figure 7.Approach of net social cost (NSC)

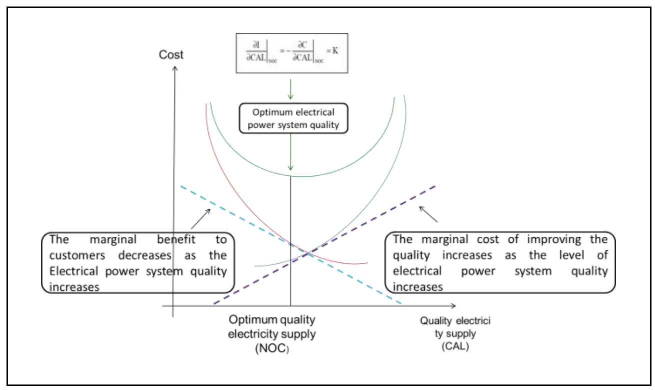

Figure 8.Diagram of optimum electrical power system quality

Economic function valuation of continuity

Fig. 9 shows each quality aspect is associated with a cost, so that different rates costs can add through economic function valuation of continuity (VEC) function (Abbad, 2007).

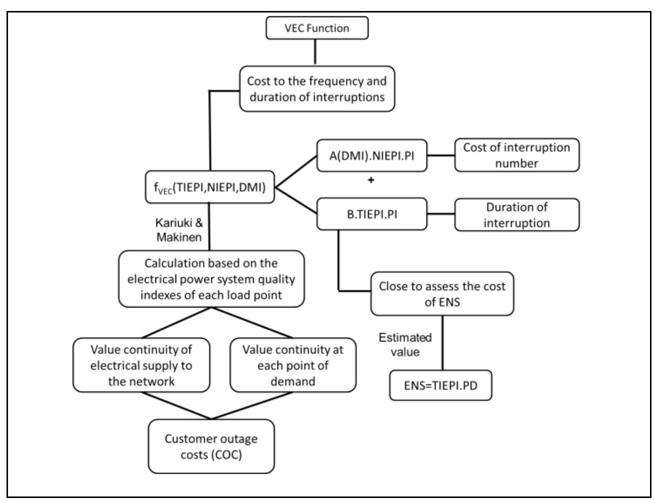

Figure 9. VEC Function

Incentives/Penalties

Through a mechanism of incentives/penalties based in system and individual indexes, to check that the remuneration of the distributor company is adequate considering the electrical power system quality offered by individual indexes to ensure the minimum level of electrical power system quality to all customers. Fig. 10 shows the regulatory aspect through incentives/penalties and the relation with individual and system electrical power system quality indexes.

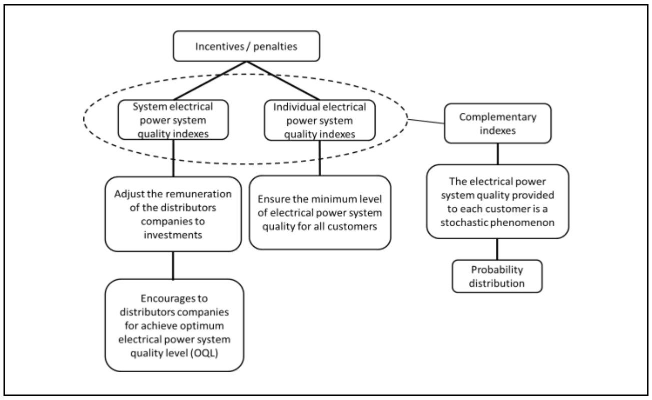

Figure 10.Approach of incentives/penalties

Global indexes that measure the performance of the system

Performance indexes for the operation of electrical distribution systems

The performance of the electrical systems of distribution is monitoring by Osinergmin through indexes showed in Table 2, SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) (IEEE 1366-2012), tolerances are reference and set depending on the voltage level, sectors called: "Typical Distribution Sectors". (RS-OS N° 074)

Table 2. Performance indexes for the operation of electrical distribution system

Description	**Index**
System Average Interruption Frequency Index	$\mathbf{SAIFI}=\frac{\sum_{i=1}^{n} ui}{N}$
System Average Interruption Duration Index	$\mathbf{SAIDI}=\frac{\sum_{i=1}^{n} ti \times ui}{N}$

Where:
ui: Number of customers affected by each interruption
ti: Duration of each interruption (hours)
n: Number of interruptions in a time period
N: Number of customers in the grid ending the period

Critical electrical systems: The Osinergmin is monitoring the electrical systems that are being affected by sustained power interruption, which exceeded twice the tolerance or more; these systems are called "critical electrical systems", in which perceived discomfort to customers claims the authorities and representatives of customers. Through the 074 process, monitoring of interruptions by measuring the results of the calculation of certain indexes based on reports from electricity companies across an online system (Extranet), as in the case of major interruptions that are reported by the of electricity companies to Osinergmin within the next twelve (12) hours of the event occurred. Fig. 11 shows the schematic form of supervision in transmission, electric systems and critical electric system, the proactive approaches like a: monitoring transformer overload, isolated generation reserve margin and other monitoring reports.

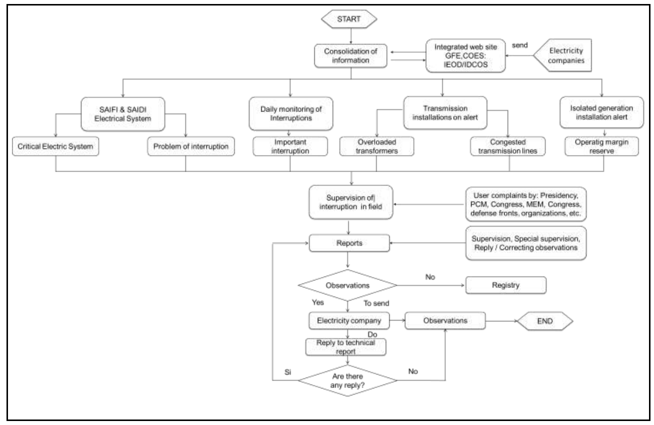

Figure 11. Monitoring scheme through process and performance indexes.

Performance indexes for the operation of electric transmission systems

The frequency and duration of disconnections that alter the electrical power system quality by the process N° 091-2006-OS / CD Osinergmin, regulating tolerances to international standards, resulting in operators concern for reducing disruptions through investments to rehabilitate the systems operating with deficiencies or overload. Table 3 shows the indexes about the process (RS-OS N° 091).

Table 3. Performance indexes for the operation of electrical transmission system

Description	**Index**
Failure rate of substation equipment	**TFC = N° Failure**
Failure rate of each transmission line	$\mathbf{TFL}=\frac{\mathbf{N°Failure}}{\mathbf{Ext.\ LT}}\ \mathbf{X100}$
Unavailability of substation equipment	**INDISE = ∑HIND**
Unavailability of equipment each transmission line	**INDISL = ∑HIND**

Electrical performance indexes of isolated generation systems

The performance of power systems with isolated generation is monitoring by Osinergmin (RS-OS N° 220). Table 4 shows the indexes in the process to evaluate isolated electrical system according GART.

Table 4. Performance indexes of isolated generation system

Description	**Index**
Operating reserve margin generating	**MR=(PE/MD)-1**
Rate of forced outputs	**TSF=NSF/TES**
Forced unavailability index	**IIF=HIF/TES**

Control and monitoring of indexes through business intelligence

Business Intelligence

The business intelligence (BI) includes a web environment for display indexes of monitoring procedures of GFE, also has a georeferenced map. Fig. 12 shows a view of BI to monitoring with de Osinergmin process in electric system, using BI is most easily to take decisions.

Figure 12. BI Portal home

Datawarehouse: The BI has developed a database in Oracle, SQIL Server, Access and Excel files of users for ad-hoc reports, all this makes it possible to conduct consultations "on line", through the Office cognos go producing automatic reports of indexes, alert reports via email and analyzing information which are displayed via LCD screens and mobile devices, the reports of the concession made by affidavit verified by Osinergmin up the database referred. The advantages are: Minimize the time of issuance of reports, generate automatic reports, avoid printing physical reports, connection with Georeferenced GIS systems, and improved control through indexes automatic alert and making more objective decisions optimizing resources audit. Fig. 13 shows the datawerhouse's components with analysis models to analyze reports, alerts and the interaction with boss, coordinators and users.

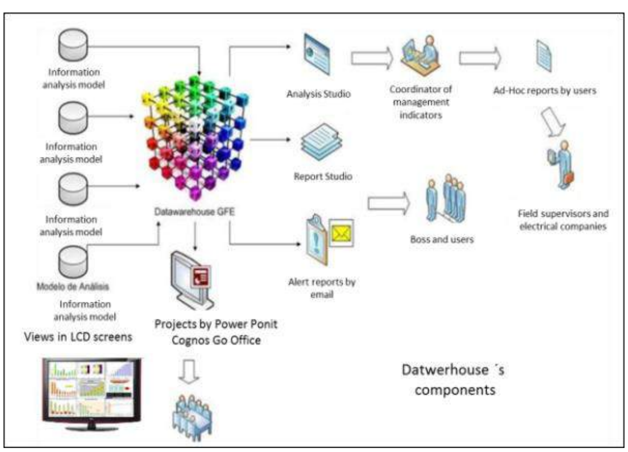

Figure 13.Integration through BI report

Results

General results

Monitoring compliance with the compensation for poor electrical power system quality (interruptions) was achieved in the period from 2004 to the First Half of 2015*, ten companies managed by FONAFE, returned to its users, through receipts, amounting to 115 million. Fig. 14 shows total compensation for poor power quality by electricity company since 2004 – 2015. The companies with the highest compensations are: Electro Oriente S.A. and Hidrandina S.A.

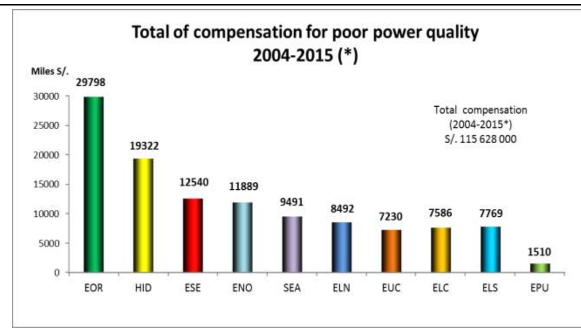

Figure 14. Total compensation 2004 - 2015

Results at the institutional level

- Control interruptions through the extranet system with information from the companies.
- Identification of electric critical systems.
- Reduced time of the monitoring process.
- Determination of systemic indexes.
- Almost immediate effectuation of disciplinary procedures.
- Automatic issuance of reports and statistical tables.

Results per process

Results of the performance monitoring of the operation of medium voltage electrical systems: This control has consolidated a safe, efficient and reliable supply, by recording specific information that is accurate and truthful provided by the actors themselves, and it is used to develop strategies for supervision and monitoring as well as to identify the location (source) and the causes of interruptions, so restore the electricity supply in reasonable time. Fig. 15 shows the monitoring of SADI in the last three years, in general the index is decreasing, the mayor percent of interruptions was in distributions system.

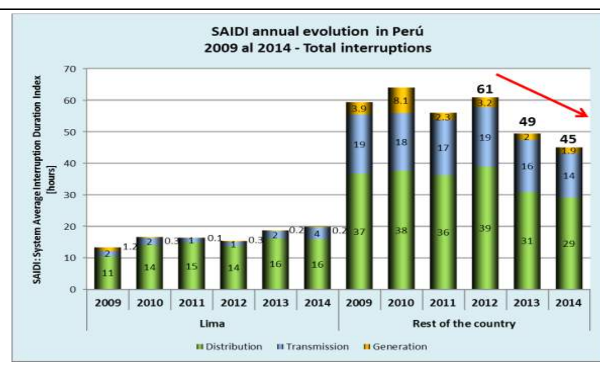

Figure 15. Monitoring of SAIDI during 2009-2014

Fig. 16 shows the monitoring of SAIDI y SAIFI in distribution system, in 2013 Electro Norte S.A. was the highest SAIDI and Electro Nor Oeste S.A. was the highest SAIFI.

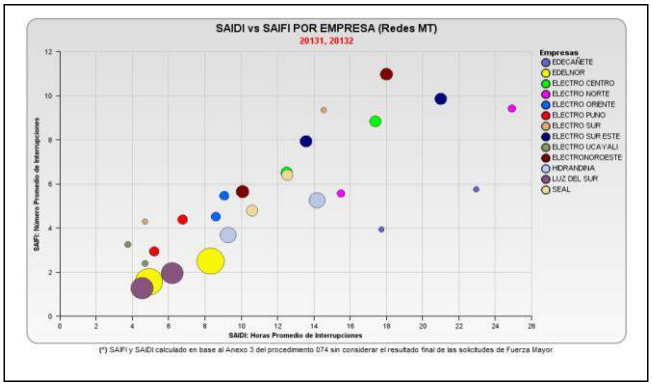

Figure 16. Monitoring of SAIDI & SAIFI during 2013

Results of Monitoring performance transmission system: This control has identified overloaded transformers and congested transmission lines to engage members of the transmission system to improve the electrical power system quality, improving facilities and / or replacing equipment and implementing contingency plans. Fig.17 shows monitoring transmission lines during 2013-2014

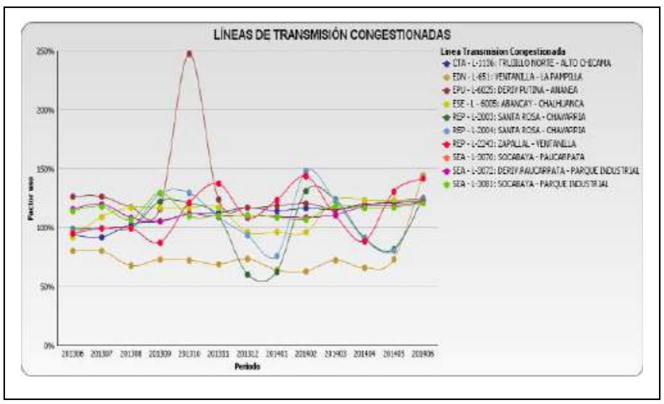

Figure 17. Monitoring of congested transmission 2013–2014

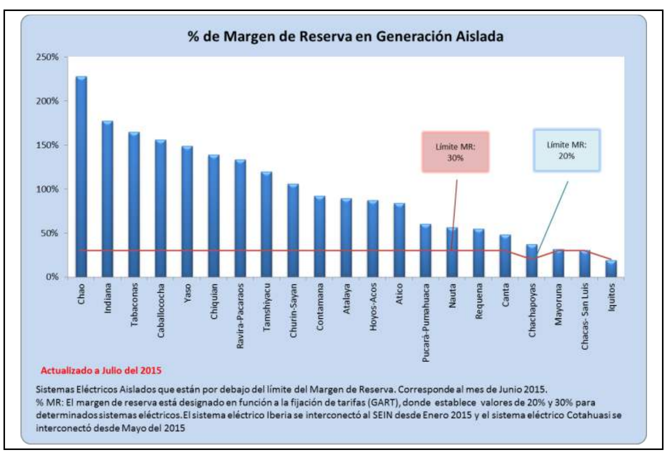

Figure 18. Isolated generation reserve margin during 2015 (July)

Results Performance Monitoring electrical systems with isolated generation: This control has identified the isolated electrical systems that violate the operating margin reserve according GART. Fig.18 shows monitoring of reserve margin during 2015(April), some electric systems like: Moyoruna and Chacas-San Luis do not have necessary reserve margin.

Conclusions

Osinergmin monitoring generation, transmission and distribution system by performance indexes.

Osinergmin use the individual (N&D) and global (SAIDI&SAIFI) indexes to monitoring the Electrical Power System Quality because they are complementary.

The monitoring process is improved by generating reports on line by BI.

The generation, transmission and distribution companies report information across the Extranet is used to generate a reliable and consistent basis for the functioning of BI.

In general, companies have improved the quality indexes of service to their customers.

Control and monitoring of performance indicators of electrical systems, has been replicated by electricity companies in Peru and other regulatory institutions like: OSIPTEL and SUNASS.

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