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Distribution System Reliability Indices

Case Study Albanian Distribution System

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***Abstract*— The power supply reliability directly affects the consumers' service. During the last decades, following the economical and political reforms the structure of electricity consumption, losses, peak load, balance of exchanged energy, electricity production, profile of the voltage and having the number of consumers completely changed has brought about a completely different profile in this market. Consumers may consider a utility system reliable only if it supplies them with the quantity and quality of electricity they desire at the time they desire it. This paper is based on analytical methods, well known probabilistic tools and different reliability evaluation criteria, which are calculated with key parameters such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI). Utilization of reliability indices at the operating district levels has allowed us to more accurately pinpoint trouble areas and take specific corrective actions to enhance reliability. Unsupplied energy and the respective costs aim to evaluate to define the priority of investments in the distribution network.**

Keywords— Reliability indices; electricity markets; regulatory strategies; power system.

I. INTRODUCTION

Asset Management is the combination of management, financial, economic and engineering applied to physical assets of power system with the objective of providing the required level of service in the most cost effective manner. Asset management time frames are divided as follow:

Long-term Asset management (yearly and beyond). In such a case strategic planning, decide which assets need to be replaced (using which technologies) and grid expansion.

Mid-term Asset management (from monthly to yearly): In such a case maintenance management: optimal maintenance strategy and optimal outage plan.

Short-term Asset management (from real-time to months/year): In such a case operational management: secure and reliable operation of the system, system monitoring and control, fault restoration.

Today, it is common practice in the electric utility industry to use the standard IEEE reliability indices (CAIDI, SAIFI, SAIDI) to track and benchmark reliability performance.

The function of an electrical power system is to meet the needs of its customers while maintaining acceptable levels of quality and continuity of supply [1]. Pressures are increasing upon utilities world-wide to provide a high level of service quality at minimum cost, which requires a well founded AMS to ensure network assets remain in a satisfactory condition.

The main goal of power system reliability assessment is to provide qualitative analysis and indices in power supply reliability for the operation and planning system. It is also necessary to ensure a reasonable balance in the reliability of three constituent parts (generation, transmission and distribution) [3]. The electric utility has developed several measures (indices) of reliability to measure power system performance. These reliability indices include measures of outage duration, frequency outages, system availability and response time.

Reliability is a responsibility of the system agents, imposed by the market regulator in the form of targets that have to be satisfied or otherwise they will incur in monetary penalties. This fact combined with the increased the amount of distributed generation with intermittent sources, makes it more difficult to solve any reliability related problem and HL III (hierarchic level of distribution) studies are now growing in importance. Distribution utilities are now focused on improving their performance and achieving greater customer satisfaction while ensuring that costs of operating the network are kept under control [5].

The electric power transmission and distribution networks has to evaluate and know the technical condition and performance characteristics of all inventoried assets to define asset management strategies.

The maintenance procedures or strategies to maintain different kinds of equipment are: preventive maintenance, condition based preventive maintenance and reliability centered maintenance (RCM). Asset Management theories recommend the reliability centered maintenance (RCM). RCM is a preventive maintenance strategy that is being increasingly used by many utilities. In this method, condition based measurements data are used to determine the various components that require maintenance. Maintenance projects then are ranked based on a criterion that reflects equipment condition and its importance. Optimization of one or more reliability indices is generally chosen as the criterion and projects are carried out to achieve desired target levels.

II. THE ALBANIAN POWER SYSTEM

Over the last decades, the power demands in Albania are increased rapidly (Fig.1) while the investments in power system are rather slow. The transmission system in Albania has a longitude profile from the North to the South causing a shading profile of the voltage level. The main generating units are located in the north part of the country, while the main consumption centers are located in the central and southern part. Nowadays, many factors, including the rapid increase of power demand which tend to overload the already stressed distribution network has resulted in a necessary to analyze the network in terms of its ability to serve reliability to its customers.

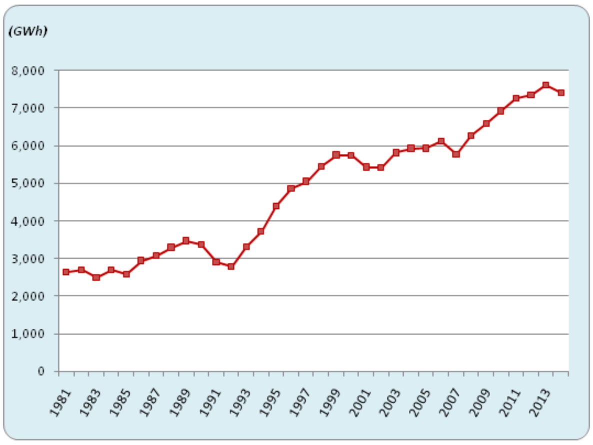

Fig. 1. *The power demand in Albania*

Following the economical and political reforms the structure of electricity consumption, losses, peak load, balance of exchanged energy, electricity production, profile of the voltage and having the number of consumers completely changed has brought about a completely different profile in the market. A reform was undertaken for the system decentralization however less attention has been paid to the reliability aspects in the power system. The distribution system in Albania after an unsuccessful privatization process has now become a public company 100% owned by the state.

The unbundling process of Public Utility-KESH (that operated like a vertically integrated monopoly) started in 2004 and was focused on: 1) Functional unbundling - the three core activities: generation, transmission and distribution and retail supply; 2) Accounting unbundling - identification of costs for each service/function; 3) Legal unbundling (corporatization) – the Transmission System Operator (TSO) was registered first as a joint stock company in 2004 and in 2005, the Transmission System Operator was legally unbundled; in 2008, the Distribution System Operator (performing the retail service as well) was legally unbundled; and 4) The privatization of the Distribution System Operator (DSO) started in 2008 and was finalized in mid-2009.

More attention has been positioned on improving the reliability of the generation and transmission capacities in Albania power system. The distribution systems have considerably less concentration.

The liberalization of the generation sector started in 2002. The small hydro power plants (SHPPs), up to 15MW, were given by concession or privatized. The public utility was authorized to purchase the energy generated by SHPPs at regulated prices.

The total installed capacity of all power plants in Albania is around 1,878 MW. The total installed capacity of private producers is around 347 MW. The country's power sector relies heavily on hydropower. Low rainfall over the recent years has led to frequent energy shortages forcing the country to import much of its electricity. Hydro provides about 1700 MW of the total power plant capacity. The average annual generation by hydro plants is now about 5370 GWh/year. Installed generation capacity that is owned by a public company, KESH Generation (Drin cascade), represents 81.5% of total installed generation capacity in Albania and accounts for 1,450 MW (hydro generation capacity is 1,350 MW and 98 MW is by thermo power plants-TPP). Production of electricity, in Albania in 2013, was realized 100% by hydroelectric power plants (HPP).

The transmission system is operated by the Transmission System Operator (TSO) and includes all electric overhead lines, substations and other installations (compensation, etc.), with voltage from 110 KV to 400 KV, used for transmission of electricity and international connection. The main electrical network consists on transmission lines with voltage 220 KV connecting the main sources of electricity (originating in Drin River cascade in the north of the country) with the main centers of consumption (mainly in the central part of the country).

The transmission lines with voltage 110 KV lines, are extended in all urban areas of the country and supplies substations 110/TM KV (medium voltage TM), belonging to the distribution system voltage. The 400kV network has been developed recently, particularly through the interconnection lines with neighboring countries. The Albanian TSO has under its administration 14 substations with total installed power of 3756 MW.

The transmission system of 220kV and 110kV is between 30-60 years old. As a result of long service time, the lack of investments, the difficult terrains in which those lines cross and working on them in conditions of heavy electrical loads, has caused amortization of metallic poles, wires and all other accessories.

III. ALBANIAN DISTRIBUTION SYSTEM

Albanian distribution network, due to the significant lack of investments, the presence of very high non-technical losses, lower billing collections levels and a failed privatization process is under an entire restructuring process. It is focused, as well, on management and administration policies.

It was thought that the private company CEZ Distribution JSC that privatized the distribution system operator in 2009 would have reduced the electricity losses from the level of 32% at time of privatization to 15%, at the end of the first three regulatory periods (in 2013), would have increased the levels of the paid bills, through implementation of new technologies and service standards.

The situation of the private company of distribution was quite different (Distribution System Operator and Retail Public Supplier) after 3-4 years. Collective outages, high level of network losses, lower levels of paid bills, lack of payments to public operators KESH Generation, TSO and to dealers, as well as unjustified expenditure growth to the detriment of the financial situation of CEZ Distribution JSC were the main findings referring to the monitoring that the Albanian Power Regulatory Entity (ERE) has conducted at this company.

ERE (Albanian power regulatory entity) reports that in 2012, CEZ Distribution JSC has not liquidated the financial obligations related to Wholesale Public Supply (KESH Generation) and traders. During 2013 the trend of energy efficiency continued to be low compared with the previous periods in reference of high level of electricity losses in distribution system and the low level of paid bills

Total losses reported by the company CEZ Distribution JSC for 2013, were around of 45.04% compared with the target contractual value of about 15%. On January 2013 ERE decided to revoke the CEZ Distribution JSC license in the activity of distribution and retail public power supplies. Based on Law, Statue Nr. 9072, dated 05/22/2003 "On Power Sector", amended, CEZ Distribution JSC moved into temporary administration, a status which changed at the end of 2014 when the distribution company moved again from private to government administration, known as "Distribution Network Operator" (OSHEE).

Distribution Network Operator (OSHEE) is organized in 10 distribution zones and 40 agencies. Tirana distribution network occupies the majority of the Power Consumption Specific Weight, respectively 34.59%. [7]

The distribution network of Tirana city that presents now the major consumption center in Albania suffered rapid changes which depended on the socio-economic and demographic developments during the years of political transition. Thus, during the last decades the structure of electricity consumption, losses, peak load, balance of exchanged energy, electricity production and profile of the voltage and the number of consumers have completely changed because of economical and political reform consequences. The rapid changes mentioned above were faced with slower changes to the necessary developments of electric network in Tirana between 1996 -2001.

The rapid growth of demand conditioned both; increasing of the substation numbers and increasing installed capacities in existing substations. When the electrical distribution grids acquired new investments that were associated with rising demands in some instances were shifted to a new level of voltage 20 KV. However, this rise in voltage level of the new electrical grids failed to replace the existing voltage level of 6 and 10 KV grids due to the unsuspected higher demand and Distribution System Operator were forced to use both grids of the new and old.

During the years 2001 to 2005 demands for electricity to consumers were not met and hourly limits were applied to electricity supply, regardless of the consequences that were brought to the country's economy. During two years; from 2007 and 2008 the Albanian government was forced to subsidize 370 million Euros for electricity purchases from abroad so as to manage the distribution system to ensure uninterrupted supply to consumers accepting that economic losses from loss of load were greater.

From 2009 to 2013 when the distribution system was privatized, in the substations, in the primary distribution system and in the secondary distribution system, there were no new investments made to meet the increased demand for electricity. Of course this state of the distribution system in Albania will be reflected in the distribution system reliability indices overall and in the Tirana region.

The lifetime of distribution network elements such as lines and transformers under the provision of regular periodical maintenance and normal operation condition is estimated between 35 to 50 years. In distribution lines the average rate of amortization is about 2.1% per year. The high degree of the deterioration of distribution assets is mainly due to their ages, (between 35 to 50 years), lack of investment in the past, lack of periodic maintenance (such as lines insulators damaged or ruined, aging of transformer oil with loss of dielectric parameters and missing of periodic treatment of transformer oil). [4].

IV. Distribution System Reliability Indices

System reliability pertains to sustained interruptions and momentary interruptions. Power quality involves voltage fluctuations, abnormal waveforms, and harmonic distortions. An interruption of greater than five minutes is generally considered a reliability issue, and interruptions of less than five minutes are a power quality concern.

Institute of Electrical and Electronic Engineers (IEEE) defines the generally accepted reliability indices in its' standard number P1366, "Guide for Electric Distribution Reliability Indices". IEEE-P1366 lists several important definitions for reliability including what are momentary interruptions, momentary interruption events, and sustained interruptions quality.

An interruption is loss of power supply to the customer [2], but the affects of an interruption is variable. It depends on the type of customer interrupted. To a domestic user, an interruption may mean resetting of clocks or having to go without air-conditioning on a summer day. To an industrial or a commercial establishment this would mean crashing computers to lost production worth millions. Interruptions are classified based on the duration as:

- *Temporary/momentary interruption-* An interruption that lasts for durations less than five minutes is considered as a temporary interruption [2]

- *Permanent/sustained interruption-* An interruption that is greater than or equal to five minutes is termed as a permanent interruption. These are faults are not self-clearing and require the crew to get to the location of the fault to repair and restore the system.

The most common indices are System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI):

- *System Average Interruption Frequency Index* **(SAIFI)**

$$SAIFI = \frac{\text{Total Number of Customer Interruptions}}{\text{Total Number of Customers Served}} \quad (1)$$

The index represents the average number of sustained interruptions seen by a customer in a unit time (generally 1 year). The definition of area is flexible in the sense that the no. of customers and the interruptions seen by them changes with the definition of the enclosed area. For instance, a feeder SAIFI indicates the average number of interruptions a customer serviced by the particular feeder would see in a year. Similarly SAIFI reported for a substation or a distribution system encloses the total customers in the service area.

- *System Average Interruption Duration Index* **(SAIDI)**

$$SAIDI = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customers Served}} \quad (2)$$

The index indicates the average time a customer has an interruption during a time cycle (1 year). It is usually specified in customer minutes or customer hours of interruption/year. SAIDI can be improved by reducing the number of interruptions or the duration of the interruptions.

- *Customer Average Interruption Duration Index* **(CAIDI)**

$$CAIDI = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customers Interruptions}} \quad (3)$$

The index is the ratio of SAIDI to SAIFI. It represents the average time taken to restore service to the customers when a sustained interruption occurs. CAIDI can be improved by reducing the length of interruptions by faster crew response time and repair times. The value of CAIDI for a given area:

$$\text{CAIDI} = \frac{\sum r_i N_i}{\sum N_i} = \frac{\text{SAIDI}}{\text{SAIFI}} \quad (4)$$

Where:

- N_i is the number of interrupted customers for each interruption event during the reporting period and

- r_i is restoration time for each interruption event.

Reliability Centered Asset Management (RCAM) combines the results of the Condition Assessment with the importance of each asset in the system in order to help define AMS. Fig.2 shows a typical RCAM diagram in which the relation between condition and importance is analyzed in order to select asset management strategies. The condition index is calculated in a scale between 0 and 1 (where “0” means the best condition and “1” means the worst condition). The importance index is also calculated in a scale between 0 and 1 (where “0” means least importance and “1” means maximum importance).

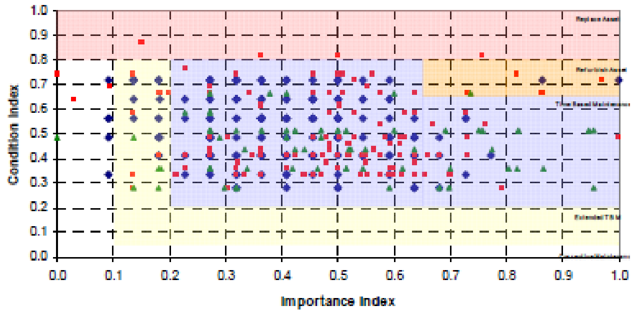

Fig. 2. *RCAM Diagram [8]*

In the next section we will analyze the system indices.

V. Analyses Of Some Distribution Reliability Indices In Albania

In Albania there is not any organization (for example like the American Public Power Association – APPA) that reports and records reliability indices for its members but there is "Distribution Network Operator" (OSHEE) that determines reliability indices that can be used to assess past system performance.

In distinction from others, OSHEE calculates the reliability indices, referring the sustained interruption that is greater than or equal to ten minutes. This indicates that "Distribution Network Operator" OSHEE determines the reliability indices and reports them to ERE (Albanian power regulatory entity) in a way that these indices appear smaller and are not comparable with others. Some reliability indices are used to compare the performance of the electricity systems of various utilities or countries in so-called ‘benchmarking’ surveys.

In practice, the indices are difficult to compare because they refer to networks with different customer densities, constructed using different technologies, and/or in regions exposed to different intensities of the conditions causing the faults.[6] It is known that reliability indices of an electric distribution system are functions of factors such as component failures, ageing, restoration times etc. which are random by nature and comparisons between reliability indices of different electrical distribution systems are not so determinant. The comparison in the same system of reliability indices in year after year or its values between months of the same year becomes quite different matter. In our distribution system now there is an increased awareness of the need to evaluate parameters which give information regarding the variation of the indices around their mean value. Even if our distribution system does not participate in a comparative survey, it can use the indices to identify the trends in reliability.

The data taken from "Distribution Network Operator" OSHEE has been used to evaluate yearly variation of reliability indices SAIFI, SAIDI and CAIDI for the period from 2012 to 2014. In the Fig.3 it is shown that the trend of reliability indices lines from 2012 to 2014 don`t have the obvious improvements. This was expected and it is clearly acceptable. These trends of reliability indices lines have reflected the weaknesses in the financial and technical conditions in the distribution system during the transition cycle from a private company to a public company. Lack of investments to improve the substations and a primary and secondary distribution system network that were associated with using a reactive maintenance from Distribution System Operator cannot reduce the reliability indices to desired levels.

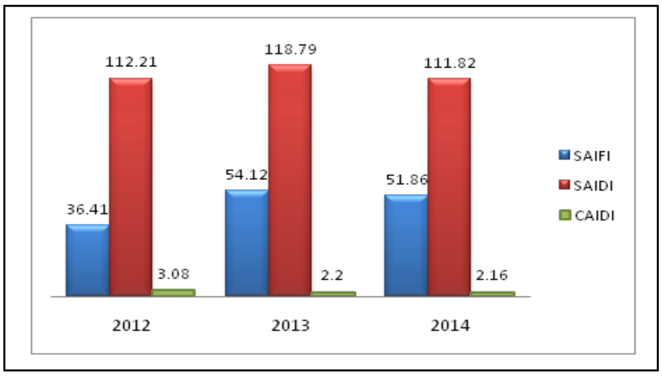

Fig. 3. *The trend of reliability indices lines during 2012-2014 years*

At the same time, the data taken from "Distribution Network Operator" OSHEE, has been used for monthly evaluation of variation of reliability indices SAIFI, SAIDI and CAIDI during the year 2014 (Fig.4.).

On the Fig.4 it is clearly shown that SAIFI receives high value in April, September and December corresponding mainly with the deterioration of weather conditions in Albania.

Weather is an important factor that influences the useful life of equipment and increases the chances of failure. Ageing, the load, weather and human factors or increased activity in case of protective equipment like reclosers influence together in maintenance cycles of network and its equipment.

Also, on the Fig.4 it is shown that SAIDI receives high value in April, September and December, but the graphic line of SAIDI is smoother than the line of SAIFI. This means that the electricity interruptions are frequent but they are associated with feedback in the short term by maintenance crew.

The SAIDI index, that gives the average time a customer has had in an interruption during a time cycle of one year, has reached in a level of 112 hours/ interruption per customer in one year.

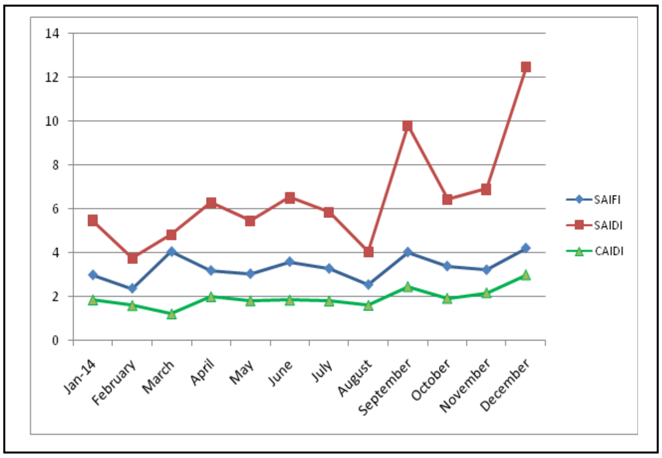

Fig. 4. *The trend of reliability indices lines during 2014 year (SAIDI-interruption hours/year, CAIDI-interruption hours/consumer in a year).*

They can be accompanied with interruptions and thus will be reflected in the distribution reliability indices. SAIFI in December 2014 reached very high values which show except others that electrical network and its maintenance was not responded to consumer demands, family and business alike, for electricity. In the Fig.5 are shown reliability indices in the distribution network of the Tirana region.

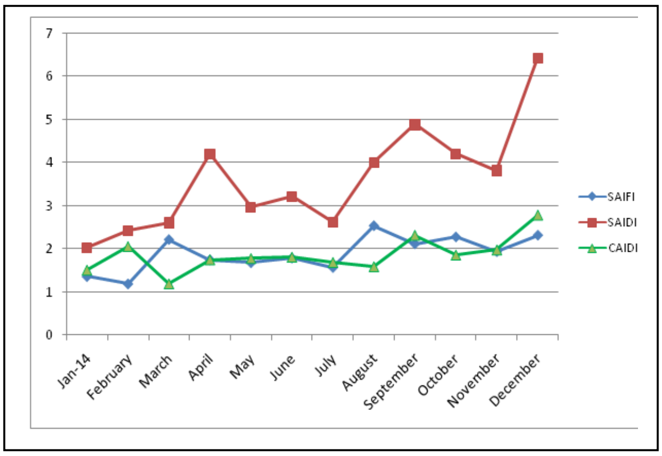

Fig. 5. *The trend of reliability indices lines during 2014 year (SAIDI-interruption hours/year, CAIDI-interruption hours/consumer in a* year) in distribution network of Tirana region.

In the Fig.6, a,b,c are compare the reliability indices of the distribution network of the Tirana region with total distribution network of Albania.

From Fig.6 we can see that the reliability indices SAIFI and SAIDI of the distribution system between the regions of the country with the region of Tirana, has a ratio of changes 2-3 times. This is a reflection of the electrical network topology of Tirana that has shorter feeders, greater load, better maintenance and shorter response time.

On the other hand the reliability indices CAIDI are almost the same.

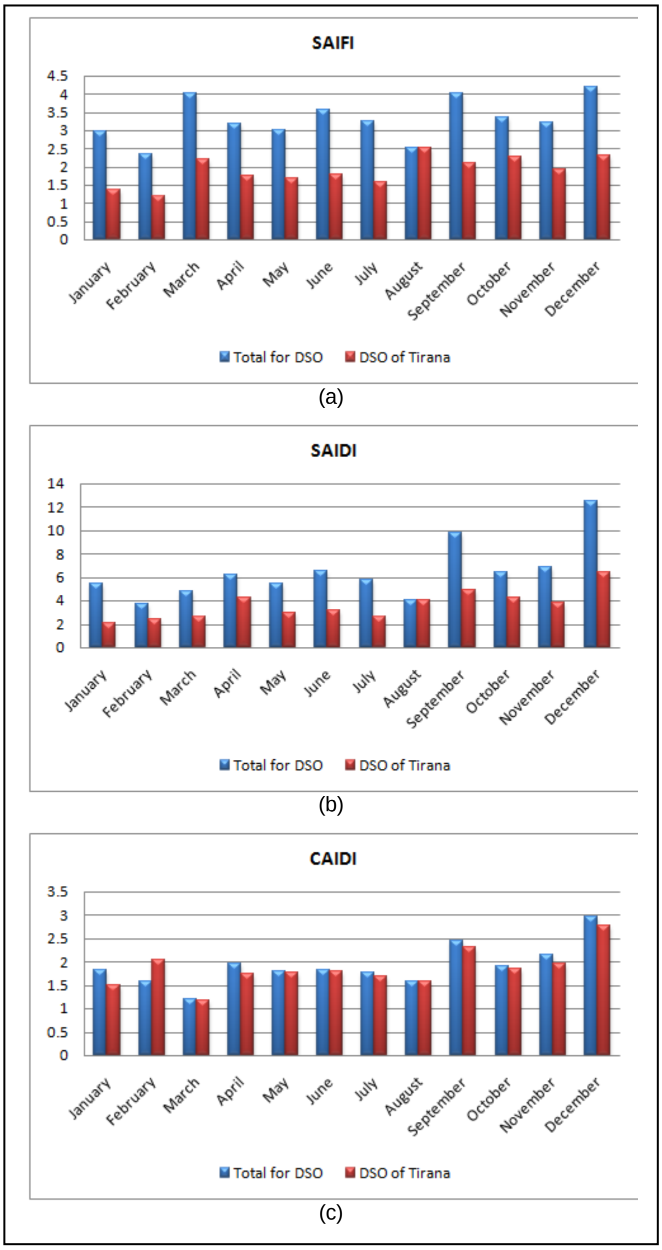

Fig. 6. *The reliability indices of the distribution network of the Tirana region with total distribution network of Albania.*

The method to improve on the SAIFI levels of a distribution system is by reducing the number of sustained interruptions that occur. This can be achieved through a proper maintenance cycle for each of the component in the system and through the use of automation and improved protective equipment that sense faults and attempt to clear the same before it turns into a permanent outage. [5]

The method to improve on the SAIDI levels of a distribution system is by reducing the time taken to restore service to the customers when a sustained interruption occurs. The time taken to restore service to the customers consists in the time that spends the maintenance crew to go near to the fault, the time to locate it and repair time of the fault. For rural areas and long distance feeders, the time taken to reach the outage spot is comparatively larger than the actual time of repair. The time required to identify and repair a fault in the system is important in determining the outage customers would face when a failure of the particular component occurs. [5]

VI. Some Recommendations To Improve Reliability

To estimate reliability and compute its indices is only one side of the issue but to analyze the reliability indices and to look behind the numbers to find the causes and then to realize corrective actions to improve the reliability of distribution system is the other side of the issue. Here below, we are giving some recommendations on improving the reliability of the distribution system in Albania, neglecting the difficulties arising from the process of calculation of the reliability indices, to the decision-making process.

In all types of distribution systems and in all countries, the fundamental critical question is: how much money should be spent to have a certain level of reliability in a system.

Even in a public distribution system operator, the real value for the general manager trying to meet reliability expectations while being pressure to reduce costs is the data behind the distribution reliability indices.

Benefits obtained by various measures like maintenance and upgrading the circuit can be evaluated to choose the best alternative.

A. *Inspection and Maintenance*

Distribution systems are comprised of tens of thousands of components that tend to fail and require maintenance. Inspection and maintenance of equipment form a critical part of utility expenditure. Utilities spend huge portions for their budgetary and crew resources to assess and improve the conditions of the system.

It is known that equipment failures cause the most interruptions. Increased inspection and monitoring of the equipment provides adequate information about what might go wrong and what action is necessary to prevent failure. Equipment condition information obtained for e.g.: Dissolved gas tests for the insulating oil in transformers, counter measurements of reclosers etc. give an idea of the activity the equipment is under and predict with reasonable accuracy its failure probability and when and what maintenance must be done to reduce the same.

Load management is another important method to improve the performance of equipment. Ensuring that the system operates within its prescribed limits helps reduce losses and improve the efficiency of equipment.

Maintenance of equipment reduces their failure rate and thereby the frequency and duration of interruptions experienced by its customers.

Utilities follow different maintenance procedures or strategies to maintain different kinds of equipment. At least during the past 20 years the distribution system operator in Albania has used reactive maintenance procedure. This is one of the most commonly used maintenance methods and simple to implement. The maintenance crew waits until an equipment failure occurs and then runs to fix it.

B. Upgrading of Substations, Primary and Secondary Distribution System Networks at the Same Time.

The Albanian distribution system now, needs to function harmoniously in the three of its components; substation, primary network and secondary network.

Distribution System Operator has made investments in its networks during the last 20 years in new substations or in increasing transformers capacity in substations and the addition of its feeders but when that was not associated with other investments such as the improving of the secondary network, it made a load management that has not brought the improvement of the distribution system reliability indices al all.

Other way is smartening the grid. The monitoring and communication tools will improve also the Operational management, Reliability evaluation, Security assessment, etc.

REFERENCES

[1] L. Goel, and R. Billinton, "Determination of reliability worth for distribution system planning," IEEE Trans. Power Delivery, vol. 9, no.3, July 1994.

[2] IEEE Guide for Electric Power Distribution Reliability Indices, IEEE Standard 1366, 2003 Edition

[3] R. N. Allan and M.G. Da Siva, "Evaluation of Reliability Indices and Outage costs in distribution system," EEE Trans. Power Systems, vol. 10, no. 1. pp. 413-419, Feb. 1995.

[4] ERE reports; 2007, 2008. 2009, 2010, 2011, 2012, 2013.

[5] Module 1, -Fundamentals of Distribution Reliability Analysis, Module 2- Reliability Analysis in Distribution Systems Primary Author: Sree Rama Kumar Yeddanapudi, http://www.learningace.com/doc/2590369/8212aefed5fb6f81d89d606ebd60a596/distributionreliabilityfundamentals

[6] R. Herman, C. T. Gaunt and L. Tait "On the adequacy of electricity reliability indices in South Africa" http://www.erc.uct.ac.za/Research/ publications/15-Herman-etal-Adequacy_reliability_indices.pdf

[7] Distribution Network Operator (OSHEE), Database of Outage Management Systems (OMS) 2012, 2013, 2014.

[8] J. Ledezma, C. Dortolina, H. Hakelberg, K. Furuno, "Condition assessment and asset management in electric power T&D networks", CIRED Workshop, Lyon, France, June 7-8, 2010.