PREDICTIVE ASSESSMENT OF POWER CONTINUITY INDICATORS

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ABSTRACT

The subject addressed in the paper is the predictive assessment of power continuity (PC) indicators (TIEPI, SAIDI, SAIFI) having as goal the estimation of investment needed to accomplish the intervals established by the Regulator to the DSO.

The focus is on understanding the behaviour of power continuity indicators, breaking apart their drivers and using them to forecast future evolution. In the paper is analyzed the indicator TIEPI.

The question is addressed creating a model based on historical data, where distribution network natural aging, past investment and weather influence are taken into account.

Following this analysis two important outcomes are brought to consideration. The first is that creating a forecast PC model the DSO could improve its knowledge about the impact of each driver in their results and even verify in some points how a management strategic option (technology, reallocation of human resources, …) affected them. The second is that being the historical data vital to such a model reveal what real matter, is critical a culture of formal events registration where the wasted time characterizing an event is understood also as an investment that will enable proper future investment decisions.

INTRODUCTION

Gone are the days where a power interruption was received with some passivity and tolerance. From the time where only the big industries depended on the transmission loop network, to the world where every little service connected to the far end of LV radial network depends on a computer, more and more people feel despair when an interruption occurs.

To react to the increasing level of continuity request the DSOs have been concerned in investing in a more reliable network, topology and equipment speaking, in sensoring systems that flow more and more information to their dispatch centres and in remote control equipment, to reconfigure the network based on the information received.

With a more and more reliable network and teams empowered by real time information and reconfiguration capacity, the DSOs succeeded to anticipate future expected levels of continuity service. But lower continuity levels also mean additional responsibility and extra difficulty: responsibility in maintain the level and difficulty in bring them down.

To face this responsibility and difficulty the DSOs should to be capable to understand the behaviour of power continuity indicators (PCI), breaking apart their drivers and using them to forecast future evolution.

This can be accomplished creating a model based on historical data, where distribution network natural aging, past investment and weather influence are taken into account.

CONSIDERATIONS

Drivers

Taking into consideration that the PCI variation from a moment *n-1* to a moment *n* depends on the (1) investment with impact in the PC made in *n-1*, (2) network natural aging during *n* and (3) weather conditions during *n*, results in Eq. 1.

$$\Delta PCI = PCI_{n-1} - PCI_n = \\ = PCI_{inv\ n-1} - (PCI_{aging\ n} + PCI_{weather\ n}) \quad \textbf{Eq. 1}$$

In Fig. 1 a possible outcome of the three drivers is schematically represented.

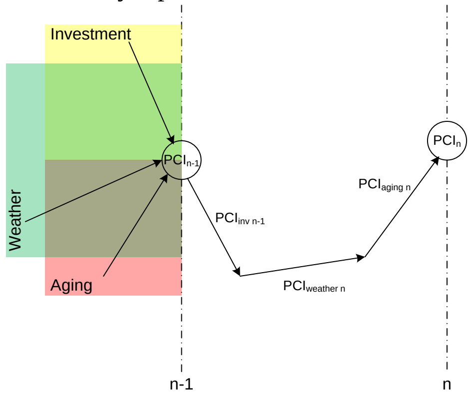

Fig. 1

Diary aggregation

The analysis of the PCI based in the breakdown of the individual contribution of each interruption does not give a general vision about PCI behaviour and how it is affected by the drivers. This is accomplished by a diary incidents aggregation, taking in consideration that in a day period the drivers will affect equally each individual interruption.

WEATHER DRIVER

The PCI diary evolution shows years where significant diary jumps are notice (2006, 2009 e 2010), while other years where such jumps do not have that magnitude

(2007, 2008 e 2011), Fig. 2.

Considering the diary results as a variable observations a box plot can be draw, Fig. 3, pointing out the extreme outliers.

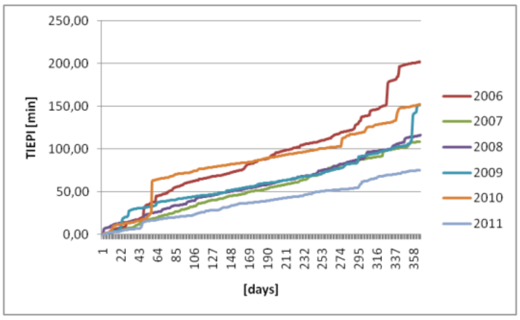

Fig. 2

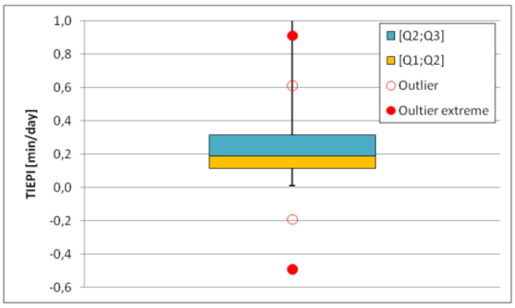

Fig. 3

Taking into consideration that to an extreme diary value correspond extreme weather conditions then, replacing the PCI extreme outliers by an average without such values, we obtain the PCI evolution corrected from the weather driver, being the Fig. 2 replaced by the Fig. 4. In Fig. 5 the annual totals are assess.

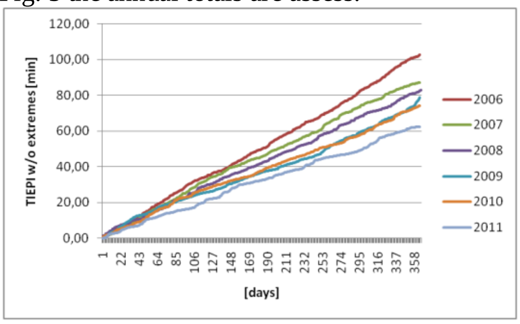

Fig. 4

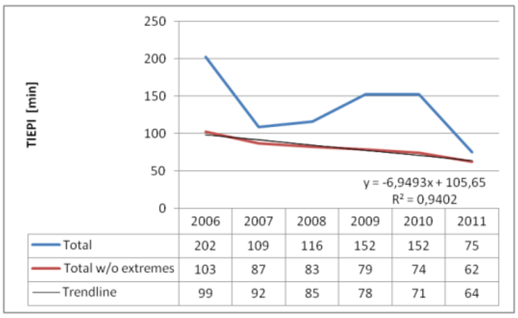

Fig. 5

Given that the risk of extreme diary values must be considered, the probability of their occurrence should be calculated. By drawing extractions of the diary observations, each with 365 random draws, summing up their extreme outliers values results in a distribution of yearly extreme weather contribution, Fig. 6.

Based in Fig. 6 distribution we can determine for a desired confidence level the extreme weather contribution, Tab. 1.

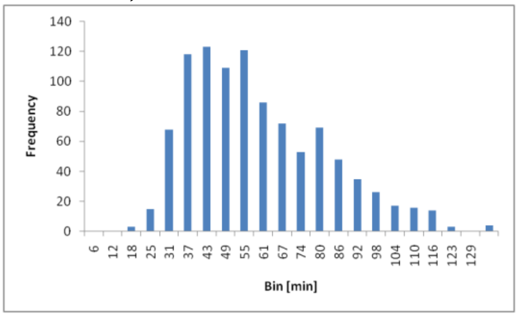

Fig. 6

Tab. 1

Confidence level	0%	5%	15%	50%	85%	95%	100%
TIE extreme [min]	0	28	34	52	81	100	142

Adding the confidence level values, Tab. 1, with the values without extremes, Fig. 5, we get their relationship with the actual values, Fig. 7.

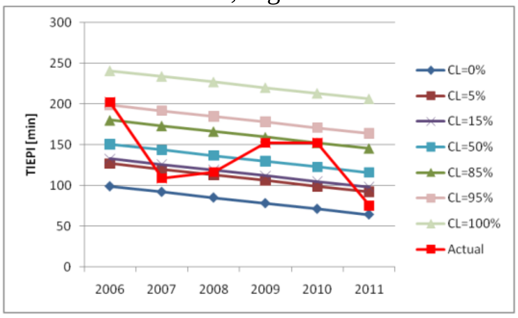

Fig. 7

NETWORK NATURAL AGING AND PAST INVESTMENT DRIVERS

Regarded the weather driver as isolated, then the Eq. 1 PCI variation can be simplified to Eq. 2.

$$\Delta PCI_{\text{without extreme weather}} = \\ = PCI_{\text{inv } n-1} - PCI_{\text{aging } n} \qquad \textbf{Eq. 2}$$

Graphically we can represent the network natural aging effect as the PCI natural path and the investment effect as the imposed path, Fig. 8.

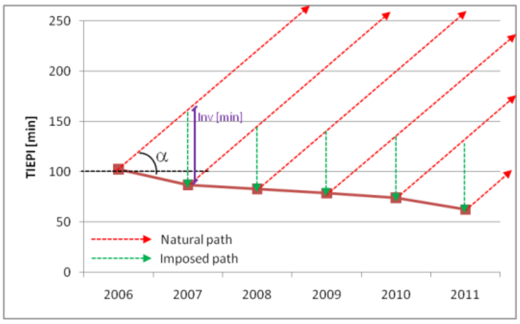

Fig. 8

Intending to determine the Eq. 2 variables values we can assess each individually:

- Variation: From the weather driver analysis we get this variable from Fig. 5, Tab. 2.

Tab. 2					
Year n	2007	2008	2009	2010	2011
$\Delta TIE_{sem\ clima\ ext}$	15,3 min	4,4 min	4,2 min	4,3 min	11,8 min

- Investment: Although the DSO invests a monetary unit expecting an estimated return in PCI units, the known values are those in monetary values, Tab. 3. The PCI units return is only known, knowing the network natural aging effect.

Tab. 3					
Year n-1	2006	2007	2008	2009	2010
$Inv_{inv\ n-1}$	50,0 M€	42,6 M€	46,9 M€	40,5 M€	42,5 M€

- Network natural aging: This component intends to translate the effect of network natural aging in the PCI, bearing in mind that the relation between the network natural aging and its effect in the PCI can change (e.g. change in investment or operational strategy).

Not knowing exactly the weight of this driver in the PCI, but starting the analysis by taking in consideration that it is constant, we can determine for a given weight (in PCI units) the effect in past cost results, Eq. 3.

$$Inv_{inv\ n-1}/\left(\Delta PCI_{without\ extreme\ weather}+PCI_{aging\ n}\right) = C_{inv\ n-1}[M€/min] \quad \textbf{Eq. 3}$$

Plotting the Eq. 3 results, Fig. 9, show an increasing cost until 2009, decreasing after.

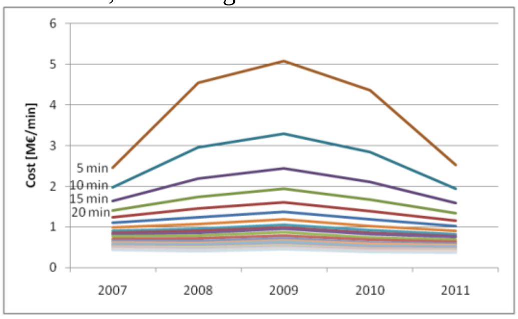

Fig. 9

Since it is expected that as the PCI gets down, the cost gets higher, the inversion signs the effect of a change in investment or operational strategy. In this case study it was concluded that the inversion in 2010 was due to a change in operational strategy (shows the discontinuity in 2010 between PCI and rainfall precipitation), and that the inversion in 2011 was due to a change in investment strategy (reinforcement of network reconfiguration remote devices).

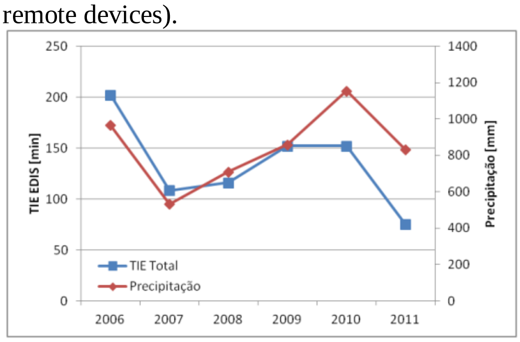

Fig. 10

A judiciously Fig. 9 curve choose could be made by comparing those curves with DSO equivalent investment plans in the beginning and end of the period in analysis. In this case study 2007 and 2013 investment plans estimated PCI costs were compared, resulting in an estimated difference of 1,56 M€/min. Considering that without strategic changes from 2007 to 2013 it would occur a linear growth of 1,56 M€/min we choose the weight of network aging for which the curve and the linear growth best fits, Fig. 11, that in this case is 20 minutes.

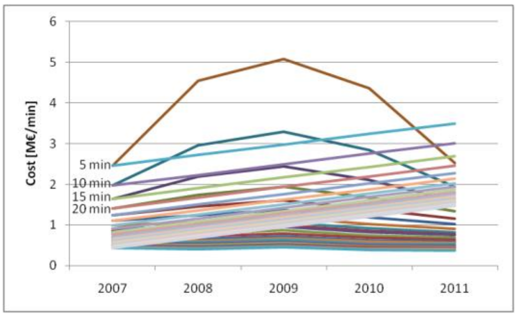

Fig. 11

Correcting the network natural aging weight, considering the strategy changes, and based in Fig. 11 results, we are now able to forecast the expected cost values, Tab. 4.

Tab. 4				
Year n	2012	2013	2014	2015
$C_{inv\ n-1}$(linear)	1,87 M€/min	2,41 M€/min	2,95 M€/min	3,49 M€/min

PREDICT THE INVESTMENT RESULT

Having determined the probabilistic weights for weather driver, the weight of network aging and forecast expected cost values, the DSO can determine the investment level to achieve its objectives and conclude about the Regulator intervals default risk, like shown in Fig. 12.

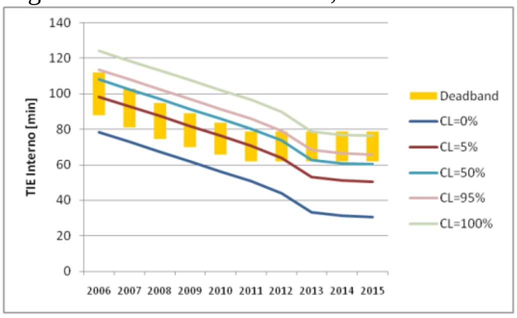

Fig. 12

CONCLUSIONS

Through a case study it is shown that a statistical model can be made to explain and predict a PCI evolution, breaking it down in weather, network aging and investment drivers.

The first outcome of creating such a model is that the DSO could improve its knowledge about the impact of each driver in their results and even verify in some points how a management strategic option affected them. The second is that being the historical data vital to such a model reveal what real matter, is critical a culture of formal events registration where the wasted time characterizing an event is understood also as an investment that will enable proper future investment decisions.