# Analysis Of The Methodology Adopted By The Italian Regulatory Authority For Identifying Major Event Days

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***Abstract*— The Italian regulatory mechanism for quality of service in electricity distribution links the tariff to the SAIDI indicator, net of contributions from exceptional events. In the year 2004 a two-step statistical methodology was introduced to identify *major event days* (MEDs). This statistical criterion defines a *potential MED* as a day with a daily CAIDI greater than the mean plus one standard deviation of the annual distribution of daily CAIDI for the relevant spatial unit, the territorial district; within this subset, a MED is a day with a daily SAIDI greater than the mean plus three standard deviations of the daily SAIDI distribution. A one year experience with this approach confirms its validity and suggests an alternative definition of the first step. The suggested definition is still based on a model-free statistical approach, but refers instead to percentiles. This modification would enhance the robustness of the method and enable to drop a currently necessary *ex-post* adjustment of the regulatory procedure.**

***Index Terms*— Continuity of service, electricity distribution, major event days, performance-based regulation, statistical methodology.**

## I. Introduction

Continuity of supply regulation in electricity distribution has received significant attention in recent years, following a widespread adoption of performance-based regulation in the form of a price cap. It is known that price cap regulation, while providing strong incentives to reduce costs, always results in quality levels that are sub optimal [1]. Regulators, thus, usually design incentive mechanisms specifically targeted at continuity of supply, assuming the form of financial penalties and rewards for the distribution company. A common problem encountered in implementing these incentive mechanisms is the treatment of major events, and first of all, their definition.

The Italian Regulatory Authority (Autorità per l'energia elettrica e il gas, AEEG) applies penalties and incentives to continuity indicators net of exceptional events. For this reason, the AEEG needs a criterion for identifying such events and for handling the relative continuity data separately from the set of normal operation data. When, in 1999, a continuity of supply regulation was introduced for the first time, the AEEG chose to identify exceptional events on the basis of *Force Majeure*. This criterion, however, resulted difficult to implement and not sufficiently unambiguous. Hence, along with other European and US institutions, the AEGG adopted, in 2004, a statistical methodology for identifying *major event days* (MEDs) [2], [3], [4]. This methodology, although similar in concept to the one proposed in the IEEE Standards 1366-2003 [2], is specifically designed to suit the overall regulatory framework of the country [5].

This paper describes the current statistical methodology for identifying MEDs in Italy and presents empirical as well as numerical analyses of continuity data for the years 2003 and 2004. First of all, the study shows that statistical methodologies in general are quite sensitive with respect to the transformation of MEDs into 'minutes lost', used in the calculation of incentives and penalties. Secondly, the analysis finds that the statistical approach adopted by the AEEG is, in most cases, robust; however, it also presents a weakness in the identification of *potential* MEDs, generating a small, but significant number of incorrect classifications. Hence, this paper suggests the adoption of a different statistical definition for the first step, based on percentiles, that is shown to be better suited for the purpose. This modification, without changing the overall design of the methodology, would enhance the reliability of the procedure, give a better description of the status of the distribution system, and enable to drop the regulatory refinement.

The paper is organized as follows: Section II briefly introduces the Italian regulation of continuity of supply; Section III describes the evolution of the criteria for the identification of exceptional events; Section IV gives a formal description of the proposed adjustment to the current methodology; Section V presents a comparative numerical analysis of the current and the proposed method; Section VI concludes.

## II. Regulation Of Continuity Of Supply In Italy

The Italian Regulatory Authority introduced, in the year 2000, a quality targeted incentive mechanism linking the electricity distribution tariff to a unique indicator of quality of supply: the cumulative duration of long, unplanned interruptions, expressed in minutes per consumer per year (System Average Interruption Duration Index, *SAIDI*), net of interruptions due to third parties damages or attributable to *Force Majeure*. This indicator, together with *SAIFI* (System Average Interruption

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Frequency Index), is measured separately in more than 300 territorial *districts*, covering the entire national territory, and homogeneous in population density. Accordingly, districts are classified in three different groups: high, medium and low density. A district is, in most cases, a small part of a utility and very rarely coincides with it: the largest utility, Enel, counting almost 30 million customers, is divided in 275 districts, with an average of 105.000 customers each (the number of customers, however, ranges from a dozen of thousand to a half a million). The choice of the district as the territorial unit enables the Italian regulator to account for exogenous (mainly geographical and technical) factors that influence company performances, as well as to closely monitor the continuity levels of different regions. This is consistent with one of the main objectives of the regulation: filling the gaps in continuity levels among regions with analogous territorial structure but, sometimes, extremely different reliability.

At the beginning of each four-year regulatory period, the regulator fixes, for each territorial district, yearly improvement targets in *SAIDI*, differentiated according to population density and initial level of continuity. The baseline, or, yearly required improvement per district, is designed so that higher improvements are required in districts having an initial quality level that is worse. Quality related company performances are measured annually, as the difference (positive or negative) between the baseline and a two year rolling average of the measured *SAIDI* per each territorial district. Financial incentives are calculated on an annual basis, as a function of a monetary incentive (or penalty) rate, the energy delivered in a given district at Medium Voltage (MV) and Low Voltage (LV) customers, and the difference between *target-SAIDI* and *actual-SAIDI*.

The unique national distribution tariff, $p_t$, in the year $t$ varies according to a modified price cap formula, of the type:

$$p_{t+1} = p_t(1 + RPI - X \pm Q) \tag{1}$$

where $RPI$ is the retail price index, $X$ is the efficiency gain fixed by the regulator for the four year tariff period, and $Q$ is a quality parameter. Yearly values of the parameter $Q$ are calculated, *ex post*, on the basis of net company performances and relative financial incentives[6].

This regulatory framework has been quite successful in reaching of the targets set by the AEEG in the period 2000-2003: average duration and number of interruptions had been significantly reduced, especially in those regions were the initial situation was worse. The framework was thus applied to the period 2004-2007 with few modifications. Among them, the criterion for the identification of exceptional events.

## III. Exceptional Events

In the first regulatory period, the regulation required companies to classify interruptions according to three categories: i) due to *Force Majeure*, ii) due to external causes, iii) due to utility responsibility. *Force Majeure* included public authority (police, firemen) interventions, exceptional natural events leading to either a natural calamity declaration or to climatic conditions beyond the technical design parameters of the grid, and strikes. External causes included third party responsibilities and interruptions originated on the transmission grid (or on other interconnected systems). The financial incentives scheme was applied only to the *SAIDI* of long, unplanned interruptions net of the first two categories.

It is important to note that the Italian regulatory authority allowed companies to classify an event as due to *Force Majeure* only if the exceptional nature of the event could be proven by technical or administrative evidence. For instance, a formal declaration of calamity made by the government, measures of wind speed made by an independent weather center, and so on. In practical terms, this procedure turned out to be rather burdensome both for the companies, that were collecting the data, and for the regulatory authority, who was controlling the documentation provided. In addition, a few controversial cases, where the exceptional nature of the event was claimed by the companies, but could not be formally proven, generated a large amount of conflicts.

Toward the end of the first regulatory period, the AEEG began to study a different procedure, that would identify exceptional events on the basis of the nature of the interruption they caused, compared to the characteristics of the interruptions caused by normal events. The literature indicated that by looking at the distribution of daily continuity indicators MEDs could be identified [2], [3]. Empirical evidence provided the idea that the daily *CAIDI* (Customer Average Interruption Duration Index) was a good indicator of difficult operational conditions. In addition, a statistical approach seemed to offer significant advantages over the existing system: it did not require documentation and it was going to be unambiguous in its implementation. All these considerations induced the AEEG to introduce a method based on the idea that MEDs are characterized by a longer-than-average restoration time (calculated as *CAIDI* on a daily basis).

According to this idea, the AEEG now considers as a *potential* MED a day with a *CAIDI* greater than the mean plus one standard deviation of the annual per district sample distribution of daily *CAIDIs*. Days with *CAIDI* greater than this threshold are then observed with respect to their *SAIDI*: the mean and the standard deviation of their distribution is computed and those with *SAIDI* greater than the mean plus three standard deviations are defined as MEDs. The new methodology is thus consistent with the general continuity of supply regulation, in particular with its territorial and temporal units: respectively, the district and the year. The process that lead to the definition of this Two Step method, is throughly illustrated in [5]. The same work compares the Italian method with other definition of MEDs, in particular with the definition given in the IEEE Standards 1366-2003 [2].

The adoption of the statistical Two Step method in the regulatory framework for the period 2004-2007 required two refinements, one dictated by technical reasons, and one resulting from the regulatory process. As for the first refinement, it is important to note that interruptions recorded in a given day originate most frequently on the MV network, but they can occur at LV level, or at both levels. Because its very unlikely that an event that produces no interruption at MV level is a major event, days without MV interruption have been excluded by the application of the methodology. Secondly, the methodology has been complemented by the provision that, in case the set of MEDs identified by the Two Step method is an empty set, the day with the maximum *SAIDI* among the days that pass the first step test is identified as MED. This second refinement has been introduced in order to take into account the request of distribution companies to classify as MEDs a given number of days per year[1].

In the following sections actual values for the years 2003 and 2004 are analysed. The analysis shows that the methodology could be improved by the introduction of a different definition for the first threshold. Such revision does not modify the structure of the methodology that is found otherwise robust.

## IV. Data Analysis And A Proposal

It is important to remember here that [5] showed that the assumption of a log-normal distribution for daily *SAIDIs* of the Italian data set was not verified. For this reason, the IEEE Standard 1366-2003 methodology was not adopted, and a preference was given to a model- free, non-parametric, approach aimed at identifying an extreme region in the *SAIFI-SAIDI* plane where MEDs belong to. For the sake of simplicity, the regions boundaries were defined using thresholds defined by functions of the mean and of the standard deviation. These parameters were deemed easier to implement and to understand by parties involved in quality regulation (regulator, distribution companies and consumer associations).

The current Two Step method can be formalised as follows: let us fix a territorial district $A$ and a year $t$; let us number the days of the year from 1 to 365 and indicate as *SAIDI(i)* (respectively *CAIDI(i)*) the value of the *SAIDI* index (*CAIDI* index) of day $i$, in district $A$ for year $t$. Let $P_t$ be the subset of the set {1,...,365} of days with positive *SAIDI* and at least one interruption at MV level, in district $A$ for year $t$.

I. First step

Let $M_t$ be the subset of $P_t$ such that day $j$ belongs to $M_t$ if and only if

$$\begin{aligned} CAIDI(j) &> CAIDI_{th} = \\ &= \mu(\{CAIDI(i)\}_{i\in P_t}) + \sigma(\{CAIDI(i)\}_{i\in P_t}) \end{aligned} \quad (2)$$

where $\mu$ stands for the mean and $\sigma$ for the standard deviation. Note that when $P_t$ is empty the district has not experienced any interruption at MV level during the year. Obviously no MEDs can be found in this case.

II. Second step

A day $k$ in $M_t$ is a MED if

$$\begin{aligned} SAIDI(k) &> SAIDI_{th} = \\ &= \mu(\{SAIDI(i)\}_{i\in M_t}) + 3\sigma(\{SAIDI(i)\}_{i\in M_t}) \end{aligned} \quad (3)$$

MEDs identified at this level are called *computed MEDs*.

III. Additional step:

In case no computed MEDs are found for district $A$ in year $t$, district $A$ is assigned

- zero MEDs if no days move to the second step ($M_t = \emptyset$);
- one MED if some days move to the second step ($M_t \neq \emptyset$). In this case, the *assigned MED* is the day in $M_t$ with the largest *SAIDI* value.

The purpose of the first step is to identify normal operation days and to exclude them from the subsequent analysis. Days that are below the first threshold, $CAIDI_{th}$, are assumed to be definitely not exceptional; days above it (set $M_t$) are considered *potential MEDs*. The purpose of the second step is to identify days, in set $M_t$, that are characterized by exceptionally high values of daily *SAIDI*. Note that the method proposed in the IEEE Standard 1366-2003 identifies MEDs in a rather similar manner: days on the tail of the daily *SAIDI* distribution[2] are identified as MEDs; however, in this case all daily *SAIDIs* of a five year data set are included in the analysis.

The Two Step method was applied for the first time in the year 2004 and appeared to accurately meet the above mentioned objectives in the large majority of cases. For a small number of districts, however, it was unable to identify some events that the companies would have classified as exceptional, on the basis of their knowledge and experience. A closer inspection of the data showed that these events were labelled by the methodology as normal operation days. In other words, they did not pass the first of the two thresholds. The adequacy of the first threshold to extract all the *potential MEDs* was thus studied in more details.

The values of the first thresholds, $CAIDI_{th}$ for all districts in the year 2004 are shown, in gray, in Fig. 1. Data are grouped by territorial density (high, medium, and low) and ordered per increasing values of the threshold.

It is clear that for all three territorial densities the curves present a steep rising tail: the first threshold assumes significantly large values in a few number of cases. More precisely, a number of districts presents a first threshold that is above 100 minutes. Considering that the mean value of daily *CAIDIs* is approximately 40 minutes with a standard deviation of 36 minutes, in some districts the first threshold is two standard deviations greater than the mean value.

These extremely large thresholds mask potential MEDs, making the methodology less reliable. In addition, they make the methodology less equitable across different districts: the requirement for a *potential MED* is more stringent in some cases. Finally, limiting the number of days that move to the second step, large thresholds create a prerequisite for increasing the number of districts where no MEDs are found. As a consequence, a larger number of districts is administratively assigned one MED per year (Additional step).

The mentioned drawbacks motivate the proposal for a minor change in the methodology that has good potential to introduce improvements without modifying the structure of the regulatory provision. If the purpose of the first step is to distinguish normal operation days from days that are potentially

[1]This provision does not modify the quality improvement targets of the companies: the baseline for each district for the period 2004-2007 is, in fact, calculated excluding MEDs or, in case no MEDs are found, excluding the day with the maximum *SAIDI* among the days that pass the first step test.

[2]In this approach, daily *SAIDIs* are measured per distribution companies, not per districts.

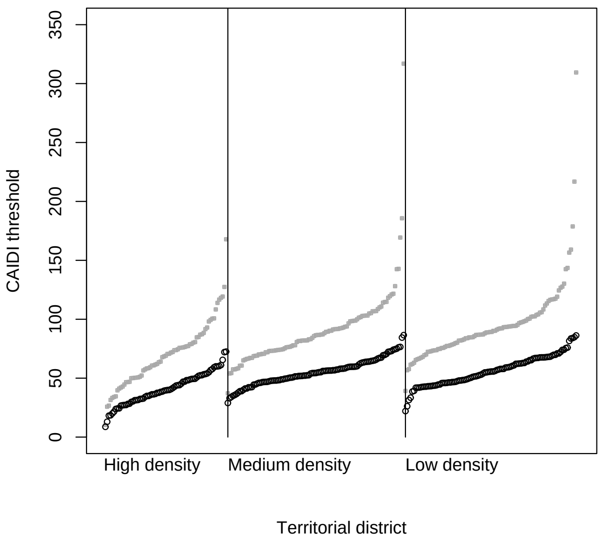


Fig. 1. First step: current (in gray) and proposed (in black) thresholds (year 2004)

exceptional, a good approach is to define the threshold using percentiles. In this manner, a preference is still given to a model- free, non-parametric, statistical approach; on the other hand, percentiles are not influenced by extreme values as the mean and the standard deviation are. For this reason, they are a more suitable tool for the purpose. As detailed in Section V, the available data were analysed using as a threshold value the 75th percentile of the distribution of daily *CAIDIs* [7]. The objective of the analysis is to show the advantages of the proposed approach, not yet to indicate a specific percentile as an alternative threshold. Fig. 1 shows, in black, the values of the first thresholds calculated using the 75th precentile. It is clear that these values are all below 100 minutes.

The second step of the current method, having the purpose to detect extreme values (in set $M_t$ of daily *SAIDIs*) needs no modifications: an analysis based on the mean and standard deviation correctly describes this information already. Note that a criterion based on percentiles would fix the percentage of MEDs passing the second threshold. On the contrary the current criterion gives a better description of the volatility of the phenomenon and finds extreme values, if they exist.

Finally, as illustrated in Section V, the adjustment in the first step eliminates the need for the Additional step in the methodology.

Before entering the details of the numerical analysis of the current as well as the proposed methodology, let us formally define the Reviewed Two Step method. As before, let $P_t$ be the subset of the set {1,...,365} of days with positive *SAIDI* and at least one interruption at MV level, in district $A$ for year $t$.

Ia. Reviewed first step

Let $M_t$ be the subset of $P_t$ such that day $j$ belongs to $M_t$

TABLE I

TWO STEP METHOD

| | | 2003 | 2004 |
|---|---|---|---|
| N. of MEDs | computed | 95 | 86 |
| | assigned | 183 | 189 |
| | **Total** | **278** | **275** |
| $SAIDI_e$[min] | computed | 5.35 | 8.50 |
| | assigned | 2.20 | 7.50 |
| | **Total** | **7.55** | **16** |
| N. of districts with | | | |
| computed | 0 MED | 0 | 1 |
| computed | 1 MED | 89 | 84 |
| computed | 2 MEDs | 3 | 1 |
| computed | 3 MEDs | 0 | 0 |
| assigned | 1 MED | 183 | 189 |

if and only if

$$\begin{aligned} CAIDI(j) &> CAIDI_{th} = \\ &= Q_{0.75}(\{CAIDI(i)\}_{i \in P_t}) \end{aligned} \quad (4)$$

where $Q_{0.75}$ is the 75th percentile of the distribution of daily CAIDIs.

IIa. Reviewed second step: as second step in current method.

IIIa. Reviewed additional step: removed.

## V. COMPARISON OF THE METHODOLOGIES

The current and reviewed methodologies are compared in terms of three figures: the number of MEDs, the corresponding minutes ascribed to exceptional events, the number of districts with a given number of MEDs. The available data set includes daily *CAIDIs* and *SAIDIs* for all territorial districts in the years 2003 and 2004.

Table I is computed using the current methodology, Table II using the reviewed one. Figures are given for:

- the total number of MEDs;
- the total number of minutes ascribed to exceptional events ($SAIDI_e$);
- the number of districts having respectively 0, 1, 2, and 3 MEDs.

All figures are detailed with respect to computed and assigned days and minutes. The number of minutes ascribed to exceptional events for a territorial district, *d*, is the sum of daily *SAIDIs* of all days identified as MEDs (computed and assigned). Indicating this figure as the *per-district exceptional SAIDI* ($SAIDI_{e,d}$), the values given in Tables I and II are the sum of *per-district exceptional SAIDIs*, weighted on the number of consumers served in the corresponding district ($N_d$):

$$SAIDI_e = \frac{\sum_{d=1}^{275} N_d SAIDI_{e,d}}{\sum_{d=1}^{275} N_d} \quad (5)$$

where the sum extends to all districts ($d = 1, ..., 275$).

A first observation regards the use of statistical methodologies for the identification of MEDs in general. Numerical values highlight a sensitivity of these approaches when MEDs are translated into minutes ascribed to exceptional events. In

TABLE II

REVIEWED TWO STEP METHOD

| | | 2003 | 2004 |
|---|---|---|---|
| N. of MEDs | computed | 192 | 201 |
| | assigned | / | / |
| | **Total** | **192** | **201** |
| $SAIDI_e$[min] | computed | 10.48 | 18.66 |
| | assigned | / | / |
| | **Total** | **10.48** | **18.66** |
| N. of districts with | | | |
| computed | 0 MED | 115 | 105 |
| computed | 1 MED | 129 | 144 |
| computed | 2 MEDs | 30 | 21 |
| computed | 3 MEDs | 1 | 5 |
| assigned | 1 MED | / | / |

2004[3] the number of days in $P_t$ (those having at least one interruption at MV level) is 27432. Days classified as MEDs are 275 (current method), or roughly 1% of the days in $P_t$. In terms of minutes, days in $P_t$ have a weighted *SAIDI* of just above 90 minutes and the minutes ascribed to exceptional events are 16 (current method), or approximately 20%. Hence, it is clear that a small error in the identification of MEDs has potentially a much larger impact on the minutes ascribed to exceptional events. For this reason, statistical methods need a great accuracy in the definition of thresholds.

Secondly, in 2004[4] the current methodology (Additional step included) finds a relatively larger number of MEDs (275) then found by the reviewed one (201). On the contrary, in terms of minutes the current method finds a smaller figure (16 minutes) than the reviewed one (18.66 minutes)[5].

As already noted above, the first step thresholds fixed by current methodology, being defined in terms of mean and standard deviation, are influenced by extreme values in the distribution of daily *CAIDIs*. As Fig. 1 shows, these thresholds are always higher than those defined by the reviewed method (and a number of extremely large thresholds are also found). The number of days moving to the second step is thus relatively lower and among these days, it is possible that no extreme values are found. Hence, the number of computed MEDs is definitely lower for the current method (86) with respect to the reviewed one (201).

In terms of MEDs per district, the current method finds a small number of districts with at least one computed MED (85) and thus requires to administratively assign a high number of them (189). On the contrary, a first step threshold set at the 75th percentile finds 170 districts with at least one computed MED (144+21+5).

Nevertheless, as noted above, more minutes are ascribed to exceptional events with the reviewed method than with the current one. The contribution of (mostly) *assigned* MEDs to the $SAIDI_e$ indicator in the current method is evidently smaller than the contribution given by *computed* (only) MEDs in the reviewed one. In other words, a number of the days identified as MEDs by the current method are suspected to be not exceptional (their *SAIDI* contribution is rather small). This is possible, given that they are found among the days passing a first threshold that was shown to be not completely stable. On the other hand, this difference in terms of minutes strengthens the idea that the reviewed method is better suited to correctly identify days that are truly exceptional (their *SAIDI* contribution is significant). In this sense, the proposed method improves on the current one and eliminates the need for an ex-post adjustment.

Finally, the reviewed method seems to give a more realistic description of events registered in the various territorial districts. As illustrated in Table II, the method finds a distribution of different situations: a significant number of districts without MEDs (105), a good number with one MED only (144) and some with 2 or 3 (respectively 21 and 5). For this reason also the reviewed method seems preferable[6].

## VI. CONCLUSIONS

Statistical methodologies for identifying MEDs represent a significant improvement over non statistical ones as they greatly simplify the procedure and make it more equitable. These methods, however, are intrinsically sensitive to the choice of days that are identified as MEDs: a small error in the choice of the days significantly affects the results of the regulatory procedure in terms of minutes ascribed to exceptional events. Hence, they have a non trivial effect on the calculation of incentives and penalties in continuity of supply regulations. This difficulty requires regulatory authorities to monitor closely the implementation of the chosen procedure and to eventually introduce adjustments. In addition, it suggests that each country should adopt a methodology that fits well in their overall regulatory framework.

This paper describes the current statistical methodology for identifying MEDs in Italy. The Two Step methodology substituted an approach based on the definition of Force Majeure. Implemented for the first time in 2004, the statistical method enabled interested parties (companies and the regulatory authority) to avoid most of the difficulties encountered with the previous system. Nevertheless, from empirical observation as well as numerical analysis emerges that a small modification of the methodology could improve the implementation process without significantly modifying its overall structure.

In particular, the proposal regards the redefinition of the first threshold. A definition based on percentiles of the distribution of daily *CAIDIs* per territorial district was found more adequate than one based on the mean and standard deviation of the same distribution. Percentiles were shown to avoid incorrect exclusions of potential MEDs from the subset of days that move to the second step and to give a more realistic representation of status of the system. The analysis needs to be carried further in order to indicate the most adequate percentile to

[3]Similar results are found for the year 2003.

[4]Again, similar results are found for the year 2003.

[5]Of course, a different choice of the percentile for the first threshold would result in a different number of minutes. In particular, the choice of a higher percentile results in a lower number of minutes. For this reason, further analyses are needed before fixing the value of the percentile.

[6]Note that the current method, Table I finds only one district with 0 MEDs: the only district in 2004 having registered no interruptions at MV level ($P_t = \emptyset$). The number of districts with 0 MEDs is 105 with the reviewed method, Table II: mostly, the districts in 2004 with no extreme *SAIDI* values among those passing the first threshold ($M_t = \emptyset$).

use in the regulation. The second step, defined in terms of the mean and standard deviation of the distribution of daily *SAIDIs* was found satisfactory. This approach is, in fact, adequate for identifying extreme values. Finally, the reviewed method has the advantage of not requiring an additional, ex-post refinement of the calculation of the number of MEDs. For all these reasons the authors plan to test the proposed modification on data for the coming years and to discuss the reviewed approach with all interested parties in the consultation process that will precede the next regulatory period.

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