Operational Risk Assessment Methodology for the Portuguese Transmission System

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1. INTRODUCTION

The increasing competitiveness of the power systems' environment has created new challenges to the power system security assessment, demanding the development of new methodologies. The unbundling of generation, transmission and distribution, caused by regulatory changes, the increased environmental concerns, making it more difficult to build new assets, and the strong incentives to the generation from renewable energy sources have created more vulnerable networks and a more complex security assessment in operations environment. The electricity market also presents more unpredictable power flows and a less controllable market-driven generation pattern. Therefore, control room operators are frequently faced with difficult situations caused by stressed system operating conditions while their permanent goal is to keep the system secure, fulfilling all the established security criteria.

The use of methodologies that take advantage of the actual real-time conditions in combination with past knowledge, using probabilistic methods, is extremely interesting in the system operation environment, because it gives a more accurate overview to the control room operators. The deterministic security assessment has been widely used by Transmission System Operators (TSOs) to guarantee a high level of security in system operations, being known as N-1 criterion [1]. It tends to provide a conservative security zone for protecting the system against severe disturbances. However, the deterministic approach only addresses the severity of contingencies, in terms of thermal loading, voltage violations and loss of load, considering that events are equally likely and therefore it cannot address increased or decreased uncertainty in the operating conditions. Facing an adverse weather situation, such as lightning occurrence or a high risk of forest fires, there are TSOs that also include specific N-k events, with k>1, in their "must-run" contingencies list, but their likelihood is still the same. The deterministic security assessment does not consider the effect of longer overhead lines (OHLs), which are more exposed to the action of external factors due to their dispersion over a wide area than the shorter ones; neither the inherent characteristics of the geographical area where they are deployed nor the actual presence of the fault's cause, which increases significantly its probability. The probabilistic assessment versus deterministic assessment is a broadly discussed topic, which appears in several references, such as [2]-[4]. Reference [2] gives a very good insight on the operational risk assessment and discusses the external influencing factors and the concept of short-term failure rate developed in this work.

The risk methodology proposed in this paper takes into account probability and severity, providing control room operators with risk-based indices and allowing them to react in advance and to be aware of inherent risks, preventing harmful situations. Single and common cause double contingencies were considered in the risk analysis. The probabilistic part, described for overhead lines (OHLs) in [5], takes into account the effect of frequency of faults, local conditions, such as physical network, environmental, geographical and geological characteristics, and current conditions, such as adverse weather, e.g. lightning occurrence, and risk of active forest fires, or their forecasts. It considers the fault historical data from 2001 until the end of 2009. A concept of short-term failure rate was implemented. Statistical analysis for the estimation of the probability of events and mathematical modelling for the inclusion of all influencing factors that introduce realism in the methodology were made. The areas that are more exposed to risk were identified per type of risk. To evaluate severity, a steady-state analysis was performed. The severity evaluation is composed of several functions, aiming to reflect the consequences of each contingency in terms of thermal overload, voltage limit violations, voltage instability, loss of load, loss of generation and cascading sequences. The severity functions per type of impact are defined in such a way that their outcome is a normalized value, which is used in the calculation of a global severity index.

The methodology was applied to the Portuguese Transmission System in the second half of 2009 and results per hour were obtained.

2. RISK ASSESSMENT METHODOLOGY

The probabilistic nature of power system security has been well recognized since the early days of modern power system operation and control. By combining severity and probability it is possible to evaluate the risk of contingencies, as in (1).

$$Risk_i = probability_i \times severity_i \qquad (1)$$

where i represents the ith contingency under analysis.

Operational risk can be mainly evaluated in two time frames: a longer one in operations planning (e.g. for the day ahead D-1) and a shorter one online in the control room (for the hour ahead H-1). The uncertainty of the analysis will diminish with the proximity of the period under analysis, because more information is available (such as lightning occurrence, active forest fire information and generation pattern) and also the used forecasts, such as risk of forest fires or wind generation, are more accurate. For this work, the analysis of the risk of contingencies per hour was performed.

The flowchart of the integral risk assessment methodology is shown in Fig. 1.

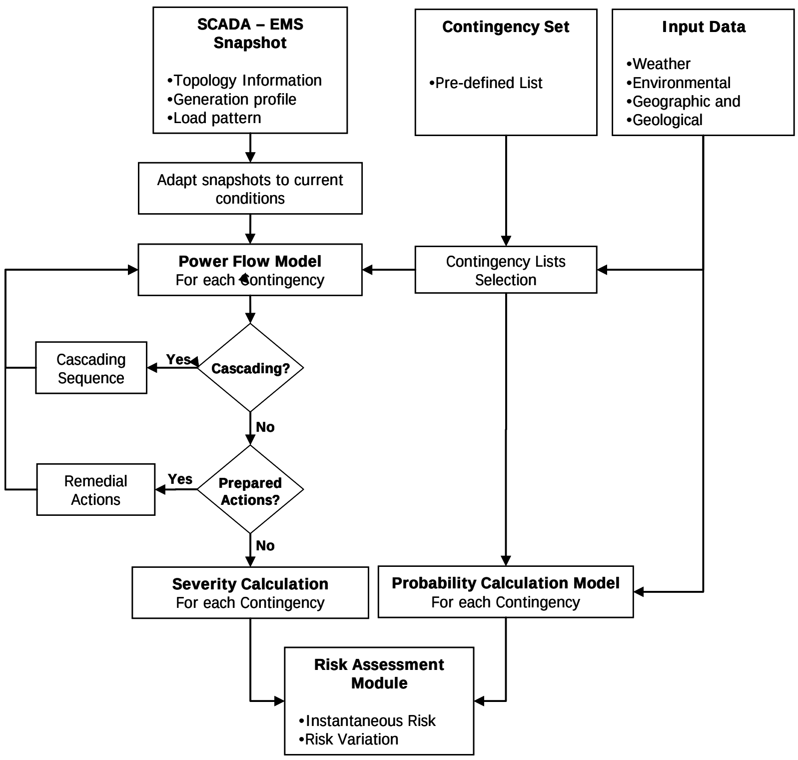

Fig. 1. Risk Assessment Flowchart

2.1. INFORMATION

In order to incorporate the intrinsic characteristics of Portugal that influence the occurrence of faults and the actual risk, based on current conditions, information gathering and knowledge is crucial. The available information used for the calculation of the fault probability is shown in Fig. 2.

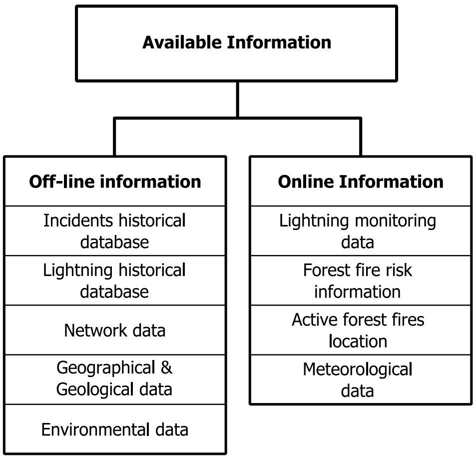

Fig. 2. Information Categories

Near future information must be integrated in the model, such as lightning real-time data, forest fire risk and meteorological information. It will prevent that the simple use of the historical average failure rate for operational risk assessment will overestimate the risk during periods of normal weather and strongly underestimate the risk during periods of adverse weather.

2.2. PROBABILISTIC PART

The probability of fault occurrence on a line can be modelled using the Poisson distribution with a constant fault rate. The average failure rate is replaced by the frequency of fault occurrence, obtained from historical data, since the duration of a fault is always extremely short [6].

Every power system has its own intrinsic characteristics, such as topology, type of generation available, geography, geology, weather, environment, among others. Many of the characteristics may change depending on the current conditions, time of day, month, and season. The current conditions and the intrinsic characteristics of the network must be included in the calculation, in order to assess short-term risk, identifying when and which are the areas more exposed to failures, and consequently which OHLs. An accurate characterization of the incident’s main causes, an analysis of their occurrence and of the intrinsic characteristics of the Portuguese territory is presented in reference [7], including all the mentioned input data, which are crucial for the risk assessment methodology.

The main causes for faults in the Portuguese Transmission System (PTS) are lightning, forest fires, storks and fog in combination with pollution [7]. These causes are dependent on length and on the characteristics of the Portuguese territory; therefore they affect mainly the circuit part of an OHL. Most of the geographical information associated with each cause is available per municipality. This is also the data structure adopted by this work. The exact borders of each municipality were obtained from the Portuguese Geographical Institute [8]. In addition to these causes, OHL faults also occur due to OHL equipment failure or a small group classified in this work as others, which includes trees, other animals, and proximity with external objects (like cranes). In the case of transformers, as well as faults caused by the transformer components, e.g. trip caused by Buchholz relay, also the intrinsic characteristics of the location where they are installed and the current conditions influence their performance, such as local fauna. Regarding busbars, the main causes of faults are fog associated with pollution within an identified area and internal origin, like equipment, human errors and protection or control system anomalies, which are causes that affect equally the bays associated with other grid elements. The different fault causes are assumed to be statistically independent events, which makes it possible to calculate the probability of an OHL circuit-part, transformer, busbar or circuit-end, considering all causes.

2.2.1. GRID ELEMENTS

The methodology evaluates the probability of occurrence of contingencies for three types of grid elements, namely: OHLs, transformers and busbars. Figures 3, 4 and 5 show the probability calculation scheme for OHLs, transformers and busbars respectively.

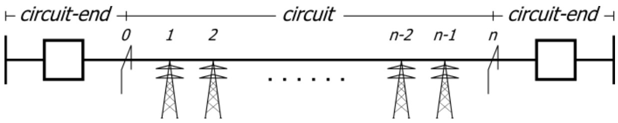

Fig. 3. Overhead line scheme for probability calculation

Fig. 4. Transformer scheme for probability calculation

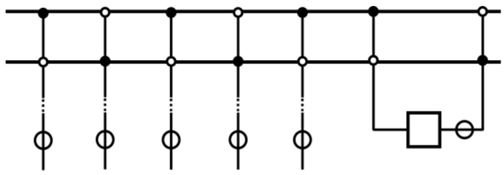
Fig. 5. Busbar scheme for probability calculation

OHLs and transformers have normally three different and independent parts, namely the circuit/transformer part and two circuit-ends. The OHL scheme for probability calculation is explained in detail in [9], although it is worth to emphasize that each segment is affected by its intrinsic characteristics of the region where it is located, such as environmental and geological, and also by current conditions, such as adverse weather and forest fires.

2.2.2. PROBABILISTIC METHOD FOR OHL CIRCUIT-PART

For each cause dependent on length, namely storks, lightning, forest fires, fog combined with pollution, OHL equipment and others, the probability of fault is calculated taking into account the average failure rates, the geographical, geological, environmental and meteorological influence, and using weighting factors based on location which will affect the considered length at risk and the current conditions, as described in [5] and in [9]. The total probability of faults in an OHL circuit-part is determined by the probability of occurrence of each individual cause, where the probability of cause_i per OHL_k is equal to (2):

$$\text{prob}_{\text{cause}_i,\,\text{OHL}_k} = \left\lfloor \lambda_{cause_i}(m,\text{p},\text{u}) \times LR_{\text{cause}_i,\,\text{OHL}_k} \right\rfloor \cdot t \qquad (2)$$

where m is the month, p is the day period, u is the voltage level and t is the analysis duration (for on-line assessment this is typically 1 hour); $\lambda_{cause_i}(m,p,u)$ is the average failure rate and LR is the length at risk of OHL_k, per cause.

In case of OHL, the failure rates are calculated yearly in order to compensate the significant changes in length of the Portuguese transmission network in the last years. The historical number of faults per km is calculated per cause, month, day period and voltage level for each year. The average failure rate based on historical data was calculated dividing the faults in four day periods of 6 hours each per month, after performing the full characterization of all incidents regarding all causes, location, time and season of occurrence. The analysis also included the actions taken to improve performance for each cause, when controllable [7]. The calculation of independent failure rates per cause prevents the ones that are not dependent on length to be considered in the circuit-part analysis; they are integrated in the circuit-end probability. The seasonal and time characteristics are directly incorporated in the failure rates, but the remaining information is included in the “length at risk” value [9]. The considered “length at risk” (LR), in km, associated to each fault depends on the cause and on the location. It is calculated for every OHL per cause per municipality, as in (3) and subjected to result being smaller or equal to the OHL total length. Due to this fact, for storks, forest fires and fog combined with pollution, different weighting factors (α) were defined for each of the n municipalities. These weighting factors per cause are presented in [9] and they take into account current conditions regarding forest fires.

$$OHL_k\ \mathrm{LR}_{cause_i,\ municip_j} = length_{municip_j,\ OHL_k} \cdot \alpha_{cause_i,\ municip_j} \tag{3}$$

For the other causes, except for lightning, α is equal to one, since they affect the total length of the OHL. No special current conditions are considered, because they can happen unexpectedly anywhere and at any moment. For lightning, a completely different approach was adopted. The backflash rate per OHL is calculated based on the probabilistic method for lightning performance of an overhead line developed by CIGRE [10]. The method uses a large amount of information, such as tower geometry, the tower footing resistance, the insulation level, the conductor diameter, geographical and geological information, lightning monitoring system data and faults’ historical data. The critical current, minimum current that causes flashover, is calculated per tower, due to the fact that each tower within an OHL has different characteristics. Afterwards, also per tower, the probability of a flashover is determined through CIGRE reference cumulative distribution for negative lightning current amplitudes, first stroke. The average of the probability of all the towers is calculated per OHL, as in (4).

$$P_{av}\left[I_C, OHL_k\right] = \frac{1}{n} \cdot \sum_{i=1}^{n} P\left(I_{C,i}\right)_{OHL_k} \tag{4}$$

where n is the number of towers that compose the k^{th} OHL, $I_{C,i}$ is the i^{th} tower critical current and $P\left(I_{C,i}\right)_{OHL_k}$ the probability of flashover of the i^{th} tower. The backflash rate (BFR) is the multiplication of this probability by the number of flashes, NL, that terminate on the ground wire per OHL. In order to apply the method to the Portuguese TSO, a scaling factor (SF) per voltage level is introduced, fitting the calculated values to the actual historical fault data, which consists of the ratio between the total number of faults per voltage level and the sum of $NL_{OHL_k} \cdot P_{av}\left[I_C, OHL_k\right]$ for all the OHLs of each voltage level. Thus, the BFR per OHL is calculated as in (5).

$$B\mathrm{FR}_{\mathrm{OHL_k}} = SF \cdot NL_{OHL_k} \cdot \mathrm{P_{av}}\left[\mathrm{I_C}, OHL_k\right] \tag{5}$$

where BFR_{OHL_k} is expressed in number of faults per year.

There is only risk of faults caused by lightning when there is actually lightning activity. Therefore, the on-line conditions based on the lightning monitoring system and the meteorological institute forecast must be considered. It is also not reasonable to consider the BFR per OHL per year simply divided by the number of hours within 1 year, because this would underestimate the risk when it is actually present. Due to this fact, the estimation of how often the observation “lightning occurs” within a specific period and location is made, calculating N/P where N is the number of periods that have lightning and P the total number of periods within a specific area. For that reason, the expected number of faults caused by lightning, per OHL, for the next t is determined as in (6).

$$probability_{OHL_k} = BFR_{OHL_k} \cdot \frac{t}{8760} \cdot \delta_j \tag{6}$$

The duration and location of the analysis and the on-line conditions are taken into account with δ_i, as in (7). After analyzing the lightning historical data, it was concluded that often the lightning activity would only affect the north or the south of Portugal, thus the division North/South of the country by using the accurate borders of the centre districts. If a path of an OHL is located both in North and South, the proportion of the length will be calculated in case of lightning activity in only one region. The $\left(N/P\right)^{-1}$ value depends on the duration of the analysis.

$$\begin{cases} \delta_j = 0, \text{ without lightning activity or forecast} \\ \delta_j = 0.5 \cdot \left(\dfrac{N}{P}\right)^{-1}, \text{ with only lightning forecast} \\ \qquad \text{or LMS unavailability} \\ \delta_j = 1 \cdot \left(\dfrac{N}{P}\right)^{-1}, \text{ with actual lightning activity} \end{cases} \quad (7)$$

where j represents the North or South part of the country.

2.2.3. PROBABILISTIC METHOD FOR TRANSFORMERS

The probability of fault occurrence for transformers and autotransformers is based on the fault failure rate, for each cause, per voltage level and per transformer. Both transformers and autotransformers are added when considering the total number of units. The historical number of faults per transformer is calculated per cause and voltage level for each year. For each cause, equation (8) represents the yearly average failure rate, with T the number of hours per year of the considered period, e.g. if the failure rate is expressed in faults per transformer, per voltage level and per hour, where T is equal to 8760 hours.

$$\lambda_{cause_i,\,TR}(u) = \frac{1}{nT} \cdot \sum_{k}^{n} \left(\frac{n^\circ\ faults_{k,cause_i}(u)}{n^\circ\ transformers_k(u)} \right) \quad (8)$$

where k is the year, n the number of years, u is the voltage level and i represents the i^{th} cause.

The three main causes that affect transformers in the PTS are the transformer itself, its own components and protections (installed in the machine), lightning and a set of other less significant causes. Although the probability in case of transformers is based on historical failure rates, for lightning current conditions are considered, because as previously mentioned without lightning there is no risk of faults caused by it. Therefore, the δ applied for OHLs, as in (7) is also applied for transformers. The probability of fault occurrence is then calculated as in (9) for lightning and as in (10) for the other causes.

$$prob_{lightning,\,TR}(u) = \lambda_{lightning,TR}(u) \cdot \delta_j \cdot t \quad (9)$$

$$prob_{cause_i,\,TR}(u) = \lambda_{cause_i,TR}(u) \cdot t \quad (10)$$

where t is the analysis duration (for on-line assessment this is typically 1 hour).

2.2.4. PROBABILISTIC METHOD FOR CIRCUIT-ENDS AND BUSBARS

The probability of fault occurrence for circuit-ends and busbars is also based on the fault failure rate, for each cause, per voltage level and in this case either per bay or per busbar. The historical number of faults per circuit-end and per busbar is calculated per cause and voltage level for each year. The yearly average failure rate per voltage level is also calculated as in (8), being the denominators respectively the number of bays and busbars per voltage level instead of the number of transformers.

Some of the factors that may cause busbars faults, generally lie at circuit-end level, namely substation equipment, human errors and protection and control systems, which implies that part of the faults caused by them is associated to busbars and the other part to circuit-ends. These causes do not affect OHL circuit-part or transformers and beyond them busbars are also affected by fog combined with pollution and other environmental causes. For human errors, it is also considered whether the fault happened during working hours, because it is when the vast majority of these faults occur. Therefore, two failure rates are used: one for faults during working hours, which are much more likely, and another one for faults outside working hours, which are rare.

To the circuit-end, the considered fault causes are end-equipment, protection and control systems and human errors, which did not cause a busbar fault. The probability of fault in the circuit-end caused by the i^th cause is given by (11).

$$prob_{cause_i,\, end}(u) = \left(\frac{TNF_{cause_i}(u) - BNF_{cause_i}(u)}{TNF_{cause_i}(u)} \right) \times \lambda_{cause_i,end}(u) \cdot t \tag{11}$$

where $TNF_{cause_i}(u)$ is the total number of faults with the i^th cause in the voltage level u and $BNF_{cause_i}(u)$ is the number of faults in busbars with the i^th cause in the voltage level u.

For busbars, concerning the causes that are common with the circuit-end part, the probability of fault caused by the i^th cause is given by (12), where the variables are the same used in (11).

$$prob_{cause_i,\, bus}(u) = \left(\frac{BNF_{cause_i}(u)}{TNF_{cause_i}(u)} \right) \cdot \lambda_{cause_i,end}(u) \cdot t \tag{12}$$

Regarding the other causes that affect busbars, the probability of fault is calculated as in (13). Fog combined with pollution is a seasonal cause and all the busbar faults caused by it only happened in July, therefore this cause will only be considered in summer.

$$prob_{cause_i,\, bus}(u) = \lambda_{cause_i,bus}(u) \cdot t \tag{13}$$

2.2.5. FINAL PROBABILITY CALCULATION

After calculating the fault probability in all components, separately, it is time to join the parts and calculate the probability of fault occurrence per OHL and transformers, including the two circuit-ends, as shown in Fig. 3 and 4. With $prob_{end}(u)$ the failure probability of circuit-ends, $prob_{OHL_k}$ the failure probability of the kth OHL and $prob_{TR_k}$ the failure probability of the k^th transformer or autotransformer, including all causes, the final fault occurrence probability will be calculated as in (14), using $prob_{OHL_k}$ for OHLs or $prob_{TR_k}$, respectively.

$$fault\ probability_{OHL_k} = 1 - \left[(1 - prob_{end}(u)) \times (1 - prob_{OHL_k}) \times (1 - prob_{end}(u)) \right] \tag{14}$$

2.2.6. PROBABILITY RESULTS

Every influencing factor takes part in the probability calculation [9]. Storks and fog combined with pollution affect in the same way a whole period of 6 hours, because they are based on failure rates, where the different seasons and times are well defined. Forest fires and lightning can affect each hour in a different way, because they are based not only on failure rates, but also on current conditions, which are assessed on-line. Fig. 6 presents the probability of fault occurrence results, from the beginning of June to the end of December 2009. It refers to an OHL located in the south of Portugal, which is affected by several different causes.

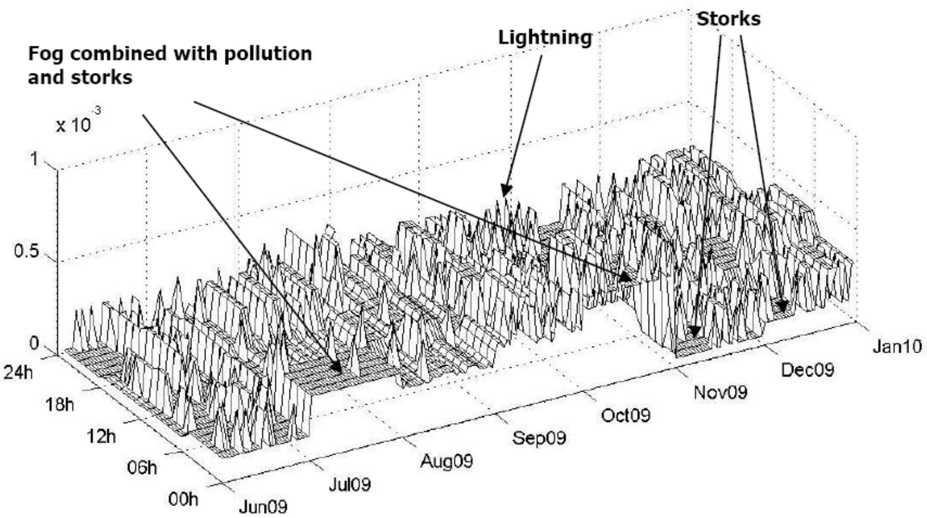

Fig.6. Probability of fault occurrence for a 150kV OHL

Reference [5] presents the probability of fault in a 400kV OHL and also the probability of a common cause fault in a 220kV corridor, affecting simultaneously two OHLs. The integration of common cause faults in the analysis is presented in [11]. In the case of transformers, the probability of faults is based on yearly average failure rates and they are rarely affected by lightning and not at all by forest fire. Therefore, the results are much more constant and stable within the year and time periods. The probability of faults in case of busbars is much smaller; it has an order of magnitude of 10^{-6} or 10^{-7}, in case they are affected or not by fog combined with pollution, respectively.

2.3. SEVERITY PART

The severity of contingencies is assessed in terms of thermal loading, voltage violations, voltage instability (non-convergence index), loss of generation and loss of load, considering the pre-defined contingency lists for analysis. A cascading algorithm based on the protection systems installed in the PTS was introduced in the analysis to evaluate the chances of cascading with severe overloads. In this work, N-1 and N-2 common cause contingencies were evaluated. The analysis for the next hour is performed using State Estimator (SE) snapshots that are created automatically every 15 minutes and contain system information for the period under analysis, including the expected changes in the topology, wind generation forecast, load forecast, programmed outages and expected generation pattern (which is market driven). Most of the information is available on an hourly basis. Severity functions are adopted to quantify the impact of each contingency, based on the post-contingency results of the analysed SE snapshot.

Impact	Severity per violation	Total Severity
Overload	$sev_{overload_i} = \begin{cases} \dfrac{S_i - S_{\max_i}}{S_{\max_i}}, & S_i > S_{\max_i} \\ 0, & S_i \le S_{\max_i} \end{cases}$	$S_{overload} = \sum_i^n \left(sev_{overload_i} \cdot 100\right)^2$
Voltage	$sev_{voltage_j} = \begin{cases} \dfrac{v_{\min} - v_j}{v_{\min}}, & v_j < v_{\min} \\ 0, & v_{\min} \le v_j \le v_{\max} \\ \dfrac{v_j - v_{\max}}{v_{\max}}, & v_j > v_{\max} \end{cases}$	$S_{voltage} = \sum_j^n \left(sev_{voltage_j} \cdot 100\right)^2$
Loss of Load	$\sum_j^n LL_j$	$S_{LL} = \dfrac{\sum_j^n LL_j}{Total \text{ Load}} \times 100$

Table 1. Severity functions – three examples

Table 1 presents three examples of the severity functions used, where for all the severity functions, i represents the ith branch,j the jth busbar and n the number of branches or busbars. The input results are the same ones that are calculated in the deterministic approach, and therefore they are easily understandable by control room operators. To evaluate severity, several normalized functions, one per type of impact, are calculated from the results of the power flow simulation, using the same operating limits as in the deterministic criteria. Normalized functions enable the calculation of a global severity index. The analysis was made from July until December 2009, based on 4416 recorded SE snapshots.

2.4. RISK RESULTS

Risk management inside a control room is not only about the probability of faults, their consequences also assume a preponderant role and they are affected by many inputs, such as the generation pattern, the quality of the forecasts and the current conditions. The latter must influence the contingency list that is assessed, because of e.g. lightning or forest fire occurrence. The selection of the contingency lists is applicable in the H-1 analysis that evaluates the security for the next hour, after evaluating the current conditions.

For each type of impact, an individual risk index $Risk_{type}^{k}$ can be calculated by multiplying the probability of the kth contingency by the result of the severity function for each type S_{type}^{k}, expressing the consequences of the kth contingency which is being evaluated, as in equation (15).

$$Risk_{type}^{k} = probability_k \times S_{type}^{k} \qquad (15)$$

Nevertheless, also a global severity function per contingency is calculated as in equation (16).

$$Severity_k = \sum_{type} \left(\omega_{type} \cdot S_{type}^{k} \right) \qquad (16)$$

where ω_{type} is the weighting factor to value the importance of each type of severity. The weighting factors were determined based on the comparison of the numerical results of each individual type of severity and also on an engineering judgement of how important each type of severity is.

In order to evaluate the developed methodology, the risk was calculated from July until the end of December 2009, aiming to perform the H-1 analysis based on recorded conditions as if it was performed online in the control room. With probability and severity results, risk is evaluated. Fig. 7 shows the total risk per hour of a 400kV OHL contingency. In the entire period of 6 months, there was only one cascading situation, which corresponds to the highest value of severity. The high risk in this contingency corresponds to a high severity and results from the fact that this OHL was essential in the supply to Lisbon, due to the fact that only 2 OHLs were connected from the 6 OHLs that compose the north corridor. The outage of the other OHLs in that corridor was caused by damage due to extreme wind conditions on the 23rd December 2009.

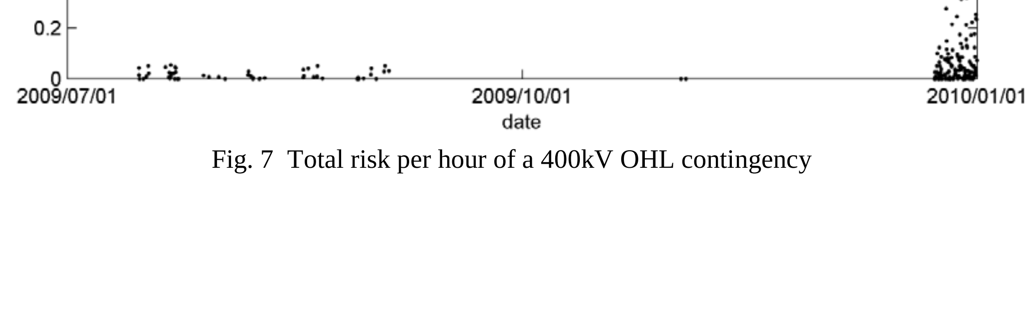

Fig. 7 Total risk per hour of a 400kV OHL contingency

Fig. 8 shows the probability versus severity of each contingency, in which is possible to observe that some of the contingencies have a high risk. On the right side, a zoomed image of the area of the represented rectangle is presented to give an exemplification of a level of risk, and the iso-risk curve that is drawn represents the median of the total risk per hour. The definition of the acceptable level of risk is a management decision that has to be taken by the TSO and is beyond the scope of this work.

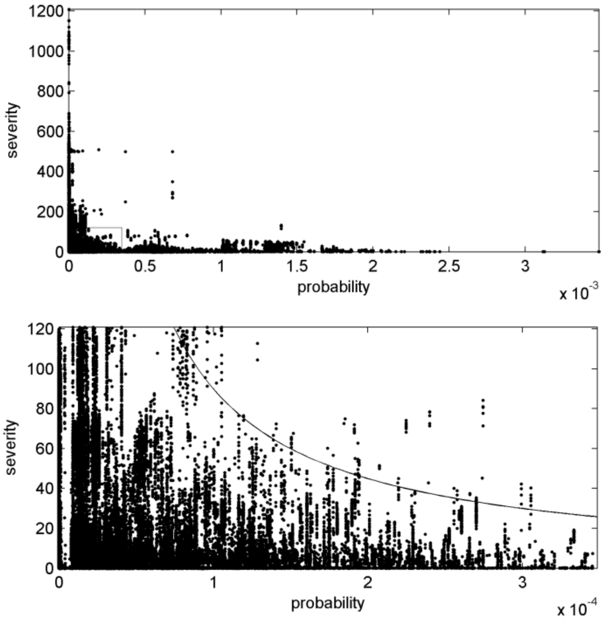

Fig. 8 Probability vs. severity graph of the period under analysis

3. CONCLUSIONS

A methodology to evaluate operational risk for a short-period of time was developed, taking into account the probabilistic nature of contingencies and their severity under specific operating conditions. This methodology uses several types of information to calculate risk indices, including current conditions. The risk indices provide an insight to control room operators of the network state and of the constraints that operators face. They have to be simple and fully understood by who operates the system. In the beginning they should be as close as possible to the deterministic results to which operators are used. Both methods, deterministic and probabilistic, should run in parallel and the transition between approaches should happen progressively. The new methodology has to be accepted by control room operators, therefore sufficient time is required to interpret, test and better understand its outcomes with several operating states. It aims to provide control room operators with risk-based security indices for the following period (such as 1 hour), allowing them to react in advance, to be aware of inherent risks and to prevent harmful situations. To be used on-line as a decision support tool for security evaluation, it is fast and thus compatible with real-time operations environment.

For risk calculation, the probability and the severity of each contingency are calculated. In the probabilistic part, this methodology includes all the influencing factors that are considered significant in terms of OHL performance, such as: number and location of stork nests, identified polluted areas, composite insulators location, risk level of forest fire occurrence per municipality, active forest fires information, lightning density, number of ground wires per OHL, soil resistivity and footing resistance per tower, among others. The data organization is made by municipality, aiming to influence the length of OHLs and substations exposed to risks. For the other causes yearly average failure rates are used, because no other influencing factors were identified, except working schedule for human error that uses different failure rates according to the period under analysis. Additionally and because we are developing work for system operations environment, current conditions are also included, aiming to assess short-term risk in a realistic way. Here the concept of short-term failure rates is implemented, valuing the current risks that are actually present in each evaluation. The severity evaluation is composed of several functions, aiming to reflect the consequences of each contingency in terms of thermal overload, voltage limit violations, voltage instability, loss of load, loss of generation and cascading sequences. The severity functions per type of impact are defined in such a way that their outcome is a normalized value, which is used in the calculation of a global severity index.

Information organization represents a big challenge and an extremely time-consuming task for a TSO and it allows the development of methodologies that will improve the system performance. There is no such thing as perfect information, but for this work data collection and organization becomes crucial to obtain better results. This forces the TSO to maintain an updated asset database with all the required information. The need of field input data makes this methodology only possible within a TSO structure, where the asset owner and the system operator are the same entity, and joins together, in a unique way, two different realities: systems operation and field information, increasing veracity in the results.

There is no such thing as no risk, also in the deterministic approach there is risk, but it is just not assessed. Low and high risk are treated in the same way. With so many uncertainties, the probabilistic approach is adequate to evaluate power systems' behaviour and performance.

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