INFLUENCE OF DIFFERENT PROBABILITY DISTRIBUTIONS OF RELIABILITY PARAMETERS ON SHORT-TERM INVESTMENT PRIORITIZATION IN DISTRIBUTION NETWORKS

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ABSTRACT

One fundamental part of the system performance evaluation, when utilities have to choose among different investment alternatives, is the reliability assessment. The reliability assessment provides an effective manner to balance the economical and technical concerns. There are two general methods for assessing the distribution network reliability, which are the analytical and simulation methods. The analytical methods generally provide mean or expected values of the assessed indexes in a relatively short computing time. On the other hand, the simulation methods are able to provide probability distributions of the reliability indexes. Therefore, it is possible to carry out a risk assessment. Uncertainty in the planning parameters is considered using fuzzy numbers. Thus, a fuzzy performance and economic evaluation of each investment alternative is obtained. Then, an investment hierarchy according to a confidence level is achieved using a method for ranking fuzzy numbers. The results portray in different manners that the position ranking of the investment alternatives is modified since the risk assessment is incorporated within the prioritization process. Furthermore, the corresponding comparison between several distribution probability cases suggests that it is important to characterize the probability distribution of the reliability parameters. Depending on the type of the used probability distribution, the ranking position may vary.

INTRODUCTION

The opening of the electricity markets has produced modifications in the distribution planning strategies. Thus, distribution utilities ***(DU)*** are submerged in deep changes such as those in their regulatory frameworks (traditional regulation based on service cost is being replaced by regulation based on system performance) [6, 12]. Within these new regulatory schemes, the budgetary restrictions compel utilities to limit the investment list over their networks. Therefore, utilities truly need to have a tool for prioritizing the possible investment alternatives [9].

Since ***DUs*** have to choose among different investment alternatives, they must assess the performance system of each alternative. One fundamental part of the system performance evaluation is the reliability assessment ***(RA)*** which in distribution networks ***(DisNs)*** has received less attention than in generation and transmission systems [3]. The major reason for this is that the investment in the latter systems is very capital-intensive; moreover, their inadequacy may have widespread consequences. However, the distribution activity has become more business-oriented since new regulatory frameworks are being implemented. Therefore the ***RA*** in ***DisNs*** is reaching higher importance within the decision-making process.

Broadly speaking, the ***RA*** of ***DisNs*** can be accomplished using two methods, which are analytical and simulation methods [2, 3, and 4]. The analytical methods generally provide mean or expected values of the reliability indexes in a relatively short computing time, while the simulation methods estimate the reliability indexes by simulating the real process and random behaviour of the system.

This paper aims to evaluate the influence of different probability distributions of the reliability parameters of the network components on the prioritization of short-term investments in ***DisNs*** by means of adopting a simulation method in order to assess the risk level of violating the regulatory reliability standards. The probability distributions to be considered in the ***RA*** are: exponential, weibull, and lognormal.

The paper is organized as follows: a description of the ***RA*** in distribution networks is presented in the second section. In the third section the way that the results, given by the ***RA*** are used, is presented. That refers to, the information about the risk of exceeding the limit requirements imposed by regulations. Then, the next section describes a method for prioritizing short-term investments considering uncertainties. Finally, in the last sections a numerical example is given to illustrate and analyse the results.

DISTRIBUTION SYSTEM RELIABILITY ASSESSMENT

It is well known that the ***DisN*** behavior is stochastic in nature, and therefore it is logical to consider that its assessment should be based on methods that respond to this behavior, i.e. probabilistic methods. Namely, the distribution network reliability assessment can be accomplished using a variety of methods. Nevertheless, there are two main classifications, which are analytical and simulation methods. The analytical methods represent the network by a mathematical model and evaluate the reliability indexes from this model using direct numerical solutions. Meanwhile, the simulation methods estimate the reliability indexes by simulating the real process and random behavior of the system [2, 3, 4, and 11].

Unlike the majority of analytical methods, the simulation methods have taken a minor role in specialized applications because they generally call for long periods of computing time, and moreover analytical methods have provided planners and designers with the enough results needed to make objective decisions. Nonetheless, the simulation methods have some advantages over the analytical ones, such as: (a) they provide the possibility to obtain probability distributions of the reliability indexes. (b) They make it possible to take into account many inherent aspects in the planning, design, and operation of the ***DisNs*** as well as the chronological aspects of the load behavior. (c) The simulation methods are capable of accomplishing the reliability assessment regardless of the probability distribution type of the reliability parameters of the ***DisNs*** components. (d) Simulation methods can indicate the likelihood of various target levels being either fulfilled or violated.

Reliability Assessment Applying Simulation Methods

It generally assumes that the reliability parameters of the components, i.e. the failure rates, failure durations, switching times, etc, are exponentially distributed. But, what can be done if these distributions are different from the exponential distribution? One practical way of overcoming this situation is to adopt a simulation approach to realize the reliability assessment. There are several types of simulation methods, although, they are all frequently and loosely referred to as Monte Carlo Simulation. The term Monte Carlo Simulation is used consistently in the bibliography regarding power systems referring to the assessment of the reliability power system applying simulation methods [1, 5]. Briefly, the Monte Carlo simulation can follow one of two basic approaches in order to evaluate the distribution network reliability [2, 3]: non-sequential or sequential simulation methods.

The non-sequential simulation methods sample the states of all components and a non-chronological system state is obtained. Meanwhile, the sequential simulation method simulates the up and down cycles of all components and then a system operation cycle is obtained by combining all the component cycles. These techniques permit that chronological aspects be considered and distributions of the reliability indices be calculated [2, 4].

RISK OF EXCEEDING THE LIMIT REQUIREMENTS

Since ***DUs*** must consider the reliability requirements imposed by the Performance-Based Regulation (***PBR***) in their decision-making process, it is extremely important for the ***DUs*** to count on a tool for assessing the risk of exceeding the limit of these requirements. In many cases, a decision regarding the investment alternatives can be easily made if the expected values of the reliability indexes are known but in other cases these expected values are not enough to make judicious decisions.

In order to accomplish the corresponding risk assessment, the ***RA*** in ***DisNs*** is accomplished by a sequential simulation method which gives the appropriate framework for achieving this sort of analysis.

Particularly in this paper, the ***SAIDI*** and ***SAIFI*** indexes have been considered as the reliability requirements that the ***DU*** must fulfill. Therefore, the risk level of exceeding the reliability requirements is defined as "***the probability of exceeding either the SAIDI or SAIFI or both indexes***". Similarly, this risk represents the ***DU*** risk of paying penalization. The required ***SAIDI*** and ***SAIFI*** were assumed as 1.50 hr/yr and 0.30 1/yr respectively.

PRIORITIZING SHORT-TERM INVESTMENTS

In this paper, the network performance and economic evaluation of a given list of investment alternatives is assessed accounting for data uncertainty in the planning parameters using fuzzy numbers. Fuzzy Arithmetic ***(FA)*** is an effective tool used to solve engineering problems with uncertain parameters reflecting the influence of the assumed uncertainties on the overall solution of the problem [7, 10]. Thus, in this paper a fuzzy performance and economic evaluation of each investment alternative is obtained by means of ***FA***. In this way the parameters considered with uncertainties are: basic reliability parameters of the network components (failure rates ***(λ)***, interruption durations ***(tD)*** and fault location duration ***(tD')***), energy price ***(pE)***, discount rate, investment costs ***(CI)***, revenues and the demand with its respective demand growth rate ***(dgr)***. [9] presents a detailed method for prioritizing short-term investments considering uncertainties, in which the reliability assessment was carried out using the analytical method. Following, the major features of the method are presented.

Energy not supplied ***(ENS)***, energy losses ***(L)***, and voltage drops ***(tol_k)*** to determine the energy supplied with low quality ***(ESLQ)*** were selected as the network performance indicators. The normal network operation (branch currents and node voltage drops in each load level) is determined using the forward-backwards sweep process [9, 8]. The reliability indexes consisted in the expected values of the ***ENS***, the System Average Interruption Frequency Index ***(SAIFI)*** and the System Average Interruption Duration Index ***(SAIDI)***. The economic evaluation considered the following attributes: revenues, investment cost, loss cost, ***ENS Cost***, and ***ESLQ Cost***. The losses are valorized to the ***pE*** and the ***ESLQ*** is valorized to the penalty for supplying low-quality energy **Pen[a, b]**.

In [9] the ***ENS Cost*** was determined valorizing the ***ENS*** to the value of the Energy-Not-Supplied Penalty ***(pENS)***. Whereas in this paper, the ***ENS*** will be valorized using the additional information given by the risk assessment. Thus, the risk of exceeding the limit of the regulatory reliability standards will be used to split the ***ENS*** in two parts. The first split part embraces the ***ENS*** that should pay penalties for violating the regulatory reliability standards (***SAIFI*** and

SAIDI). This part will be determined multiplying the expected ***ENS*** by the assessed risk and valuated at ***pENS***. The second split part refers to the opportunity cost of the energy not sold due to the failures in the network. This part will be the difference between the total expected ***ENS*** and the first split part of the valued ***ENS***, and accordingly, it is valorized to the tariff value. The aforementioned is proposed in order to measure and consider in monetary terms the associated risk of fulfilling or not the regulatory reliability standards. Finally, an investment hierarchy according to a confidence level is achieved using a method for ranking fuzzy numbers. This ranking method gives the confidence level ***(CL)*** for which the analyzed investment alternative has the largest profit.

NUMERICAL EXAMPLE AND RESULTS

To illustrate the influence of different probability distributions of reliability parameters on investment prioritization, the test feeder shown in Fig. 1 was used. The data used are presented in the following paragraphs and tables.

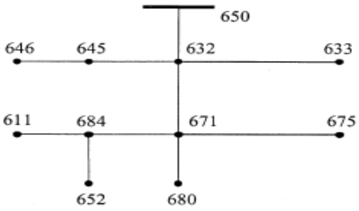

FIGURE 1. ONE LINE DIAGRAM OF THE USED NODE TEST FEEDER

The test feeder is a 4.16 KV feeder. It is assumed that the network is balanced, and has three load levels in the load duration curve, with each level duration of Tmax = 1000 h, Tmed = 6760 h, Tmin = 1000 h. Table 1 presents the test feeder data and economic parameters where *gk* refers to the amount of served customer in every node.

The input fuzzy variables have three scalar parameters (*a*, *b*, and *c*) which are the vertices of triangular fuzzy numbers. The time horizon for this analysis is five years. The load currents for the first year, failures rates, interruption durations and impedances (without investments) are presented in table 2. Analyzing the data obtained in the performance evaluation of the distribution network in the first year, fifteen investment alternatives were proposed by means of expert knowledge.

These alternatives are related to maintenance and reconductoring; therefore they principally affect the reliability parameters considered in the reliability and risk assessment.

Using the simulation method, the distribution network reliability and the risk assessment were achieved considering three different probability distributions to model the failure rates and the interruption durations.

Namely, the probability distributions used were exponential, lognormal and weibull distributions.

TABLE 1. TEST FEEDER DATA AND ECONOMIC PARAMETERS

<table>
<tr><th colspan="4">Lengths of feeder branches</th><th colspan="2">Customers number</th><th rowspan="2">Year</th><th colspan="3">REVENUE (US $ x 50)</th></tr>
<tr><th>Node A</th><th>Node B</th><th>Branch</th><th>Length (ft)</th><th>Node</th><th>g_k</th><th>a</th><th>b</th><th>c</th></tr>
<tr><td>650</td><td>632</td><td>1</td><td>2000</td><td>632</td><td>0</td><td>1</td><td>1236</td><td>1328</td><td>1391</td></tr>
<tr><td>632</td><td>633</td><td>2</td><td>500</td><td>633</td><td>40</td><td>2</td><td>1347</td><td>1449</td><td>1518</td></tr>
<tr><td>632</td><td>645</td><td>3</td><td>500</td><td>645</td><td>50</td><td>3</td><td>1493</td><td>1605</td><td>1682</td></tr>
<tr><td>645</td><td>646</td><td>4</td><td>300</td><td>646</td><td>50</td><td>4</td><td>1619</td><td>1742</td><td>1826</td></tr>
<tr><td>632</td><td>671</td><td>5</td><td>2000</td><td>671</td><td>60</td><td>5</td><td>1797</td><td>1932</td><td>2024</td></tr>
<tr><td>671</td><td>675</td><td>6</td><td>500</td><td>675</td><td>50</td><td colspan="4">pE (US$/kWh)</td></tr>
<tr><td>671</td><td>684</td><td>7</td><td>300</td><td>684</td><td>40</td><td colspan="2">a</td><td>b</td><td>c</td></tr>
<tr><td>684</td><td>611</td><td>8</td><td>300</td><td>611</td><td>70</td><td colspan="2">0.03</td><td>0.05</td><td>0.07</td></tr>
<tr><td>684</td><td>652</td><td>9</td><td>800</td><td>652</td><td>80</td><td colspan="4">discount rate (%)</td></tr>
<tr><td>671</td><td>680</td><td>10</td><td>1000</td><td>680</td><td>60</td><td colspan="2">11</td><td>12</td><td>13</td></tr>
<tr><td colspan="6">Penalties for ESLQ</td><td colspan="4">dgr (%)</td></tr>
<tr><td>if</td><td colspan="2">$a<tol_k \leq b$</td><td>then</td><td colspan="2">$Pen_{[a,b]}$ (US$/MWh)</td><td colspan="2">a</td><td>b</td><td>c</td></tr>
<tr><td>if</td><td colspan="2">$0,08<tol_k \leq 0,10$</td><td>then</td><td colspan="2">$Pen_{[0,08,0,09]}=0,15$</td><td colspan="2">8</td><td>10</td><td>12</td></tr>
<tr><td>if</td><td colspan="2">$0,10<tol_k \leq 0,12$</td><td>then</td><td colspan="2">$Pen_{[0,09,0,10]}=0,50$</td><td colspan="4">pENS(US$/kWh)</td></tr>
<tr><td>if</td><td colspan="2">$0,12<tol_k \leq 0,14$</td><td>then</td><td colspan="2">$Pen_{[0,10,0,11]}=1,00$</td><td colspan="4">2.27</td></tr>
<tr><td>if</td><td colspan="2">$0,14<tol_k \leq 0,16$</td><td>then</td><td colspan="2">$Pen_{[0,11,0,12]}=1,20$</td><td colspan="4">tD’ (h)</td></tr>
<tr><td>if</td><td colspan="2">$0,16<tol_k \leq 0,18$</td><td>then</td><td colspan="2">$Pen_{[0,11,0,12]}=1,60$</td><td colspan="2">a</td><td>b</td><td>c</td></tr>
<tr><td>if</td><td colspan="2">$tol_k>0,18$</td><td>then</td><td colspan="2">$Pen_{[0,18,-]}=2,000$</td><td colspan="2">0.3</td><td>0.6</td><td>0.8</td></tr>
</table>

In the cases of lognormal and weibull distributions, three different standard deviations (10%, 50% and 90% concerning the mean values of the respective interruption durations) were used. It was assumed that the failure rates have exponential distributions in all the assessed cases.

For simplicity, the notation weibull/lognormal XX% means that the weibull/lognormal distributions have $\sigma = \mu \times XX\%$.

The expected value of ***ENS*** calculated with the simulation method, in the case that all the reliability parameters was modeled with exponential distributions, was compared with the analytical method presented in [9].

Table 3 shows the relative error in the expected value of the ***ENS*** and ***SAIDI*** between the results given by the analytical method and the results obtained by a particular execution of the simulation method. These relative errors were determined for each investment alternative.

The different values of the relative error, in ***ENS*** and ***SAIDI***, are due to the randomness inherent to the simulation methods. Thus, this error will be different if other execution of the simulation method is conducted.

The risk of exceeding the limit of the reliability standards, i. e. the penalty risk level, was determined for the different probability distributions. Fig. 2 shows the case of lognormal distribution using a standard deviation of 50% of the mean value of all the interruption duration.

The profit of each investment alternative for the different probability distributions was assessed. Fig 3 shows the case of weibull distribution using a standard deviation of 10% of the mean value of all the interruption duration.

The same sort of results was achieved for each considered probability distribution.

Table 4 shows the prioritization for the different cases. The analytical cases correspond to the prioritization achieved when the ***RA*** was accomplished with the analytical method.

TABLE 2. LOAD CURRENTS (FIRST YEAR), FAILURE RATES, INTERRUPTION DURATIONS AND IMPEDANCES

Node	J_{maxR} (A)			J_{maxI} (A)			J_{medR} (A)			J_{medI} (A)			J_{minR} (A)			J_{minI} (A)			Branch	λ (fl./mile-year)			t_D (h)			$z=r+jx$ (Ω/mile)
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c		a	b	c	a	b	c	
632	20.12	21.51	22.9	8.327	10.41	11.52	16.93	17.9	19.01	7.356	9.16	9.993	16.52	17.63	18.46	7.772	9.16	10.55	1	0.09	0.12	0.15	10	12	14	0,75+j1,19
633	18.74	22.9	25.68	8.744	10.41	11.38	15.54	19.29	21.51	7.633	9.16	9.993	15.68	18.32	20.54	8.05	8.466	9.715	2	0.13	0.16	0.2	7	9	11	1,32+j1,34
645	23.59	25.68	28.45	10.96	11.8	13.18	19.85	21.37	23.45	9.576	10.13	11.24	17.63	20.12	21.51	8.882	9.993	10.83	3	0.13	0.16	0.2	7	9	11	1,32+j1,34
646	27.06	29.84	31.37	12.91	14.71	16.24	23.04	24.7	25.95	11.24	12.63	13.74	21.65	23.04	24.84	10.55	11.8	13.05	4	0.13	0.16	0.2	7	9	11	1,32+j1,34
671	49.96	53.43	55.38	26.51	27.76	29.84	40.25	43.72	45.11	22.07	23.04	24.7	36.08	38.17	38.86	18.04	20.12	21.51	5	0.09	0.12	0.15	10	12	14	0,75+j1,19
675	45.24	48.02	49.27	19.43	21.65	22.9	37.06	39.28	40.25	16.38	18.04	19.15	32.06	34.14	35.39	15.27	16.65	18.04	6	0.13	0.16	0.2	7	9	11	1,32+j1,34
684	34.7	36.5	38.17	15.13	16.52	17.49	27.76	29.56	31.37	11.8	13.18	14.71	27.76	29.15	30.53	10.41	11.8	13.18	7	0.13	0.16	0.2	7	9	11	1,32+j1,34
611	25.4	27.06	28.45	9.021	10.41	11.8	21.23	22.48	23.59	8.05	9.16	10.27	17.35	19.29	20.96	8.327	9.715	11.1	8	0.13	0.16	0.2	7	9	11	1,32+j1,34
652	17.49	20.12	21.51	9.715	11.1	13.05	14.85	17.21	18.04	8.605	9.715	11.24	13.05	16.65	17.35	7.356	8.744	9.715	9	0.13	0.16	0.2	7	9	11	1,32+j1,34
680	17.07	18.87	20.4	5.551	7.772	8.327	14.57	15.96	17.07	5.274	7.078	7.494	13.18	15.54	16.79	5.551	6.939	8.327	10	0.13	0.16	0.2	7	9	11	1,32+j1,34

TABLE 3. RELATIVE ERROR BETWEEN ANALYTICAL AND SIMULATION RESULTS

Investment alternative	error in ENS (%)			error in SAIDI (%)		
	Alpha-Cut a	Alpha-Cut b	Alpha-Cut c	Alpha-Cut a	Alpha-Cut b	Alpha-Cut c
Inv01	9.03	6.12	8.64	6.6197	8.6233	3.4997
Inv02	9.38	6.92	9.38	9.375	8.046	9.3028
Inv03	2.19	1.00	3.84	0.9553	1.2762	5.0927
Inv04	9.61	0.87	6.11	6.6146	0.9216	8.7086
Inv05	6.48	10.24	3.21	8.8282	1.3136	5.5098
Inv06	3.69	7.46	3.40	6.6359	3.6897	6.0855
Inv07	9.51	10.09	6.79	4.6681	7.0156	8.5719
Inv08	1.28	1.57	4.42	3.3378	6.3718	6.5157
Inv09	2.59	2.51	12.84	5.0191	5.3047	8.569
Inv10	7.78	6.19	9.52	4.2594	8.5448	7.1966
Inv11	8.78	7.98	8.87	9.083	8.3297	6.5112
Inv12	6.35	5.63	8.39	6.2695	7.6756	9.3741
Inv13	4.63	1.07	6.70	9.8016	1.6741	9.3328
Inv14	5.25	10.97	4.39	3.6675	5.4291	6.2695
Inv15	8.83	10.31	0.24	3.3579	10.771	5.9746

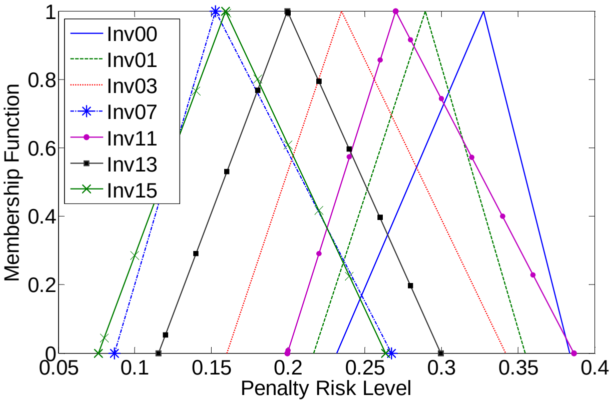

FIGURE 2. PENALTY RISK LEVEL OF EACH INVESTMENT ALTERNATIVE FOR LOGNORMAL DISTRIBUTION. CASES σ = µx50%

Under this approach, it was not possible to know the risk of exceeding the imposed reliability standards.

Finally, Table 5 shows the prioritization for the lognormal 50% case in several simulations in order to reflect the influence of the inherent randomness in the simulation methods on the ranking process.

RESULT ANALYSIS AND CONCLUSIONS

In table 4 the shaded columns show the changes in the ranking process. In the exponential case, the changes are given by the comparison of the results with the analytical ones. In the rest of the cases, the changes are given by the comparison of the results with the exponential ones.

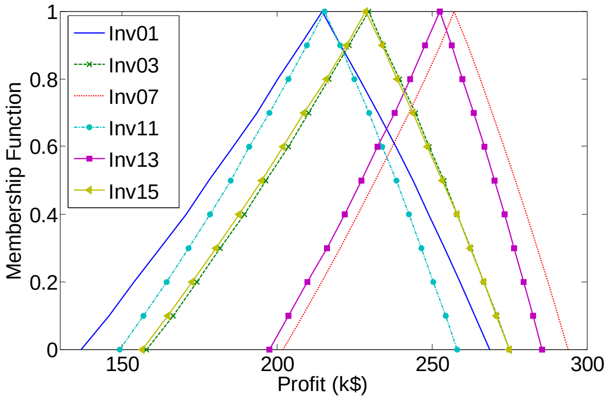

FIGURE 3. PROFITS OF EACH INVESTMENT ALTERNATIVE FOR WEIBULL DISTRIBUTION. CASES σ = µx10%

There are significant modifications in the obtained ranking position in comparison with the analytical and exponential result. Thus, only three alternatives are in the same ranking position. That is attributed to the fact that in the analytical approach the risk of exceeding the limit of the imposed reliability standards has not been contemplated. Furthermore, the whole ***ENS*** is valorized to ***pENS***. On the other hand, in the simulation approach one part of the ***ENS*** is valorized to ***pENS*** and the other part is valorized to the tariff value (it was assumed a value of 0.05 US$/kWh).

The most considerable modifications in the ranking position were in alternatives 11 and 7. Alternative 11 changed from the 6th position to the last one and alternative 7 changed from the 7th position to the second one. This is because alternatives 11 and 7 have high and low risk levels respectively (Figure 2). The information granted by the simulation methods, namely by the reliability and risk assessment, gives correct signals to the investment prioritization process, i.e., the smaller the risk, the better the rank of the alternative.

On the other hand, the biggest modification of the remaining investment alternatives was three positions.

TABLE 4. PRIORITIZATION FOR THE DIFFERENT CONSIDERED CASES

ANALYTIC		EXPONENTIAL		LOG-NORMAL (10 %)		LOG-NORMAL (50 %)		LOG-NORMAL (90 %)		WEIBULL (10 %)		WEIBULL (50 %)		WEIBULL (90 %)	
RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL
14	0.744	14	0.705	14	0.710	14	0.706	14	0.709	14	0.710	12	0.700	14	0.711
13	0.684	7	0.660	7	0.658	7	0.664	7	0.660	7	0.666	7	0.660	7	0.664
12	0.637	12	0.640	12	0.649	12	0.644	12	0.652	12	0.649	14	0.632	12	0.644
9	0.616	13	0.625	6	0.622	6	0.624	13	0.618	6	0.621	6	0.630	13	0.617
8	0.571	6	0.623	13	0.612	13	0.602	6	0.608	13	0.613	13	0.630	6	0.616
11	0.554	5	0.583	5	0.578	5	0.579	5	0.586	5	0.581	5	0.580	9	0.586
7	0.531	9	0.571	9	0.555	9	0.565	9	0.570	9	0.559	9	0.576	5	0.575
6	0.527	8	0.488	8	0.485	8	0.478	8	0.482	4	0.475	8	0.472	8	0.492
5	0.523	4	0.452	4	0.459	4	0.463	4	0.466	8	0.470	4	0.454	4	0.453
10	0.496	15	0.407	3	0.425	3	0.420	3	0.420	3	0.414	3	0.416	3	0.419
4	0.331	3	0.406	15	0.407	15	0.418	15	0.411	15	0.409	15	0.407	15	0.408
3	0.327	2	0.377	2	0.383	2	0.366	2	0.378	2	0.376	2	0.370	2	0.374
2	0.323	10	0.326	1	0.331	1	0.337	1	0.319	1	0.326	11	0.331	1	0.330
1	0.319	1	0.322	11	0.325	11	0.325	11	0.317	10	0.316	1	0.327	10	0.307
15	0.319	11	0.315	10	0.299	10	0.308	10	0.304	11	0.315	10	0.314	11	0.303

TABLE 5. PRIORITIZATION FOR SEVERAL SIMULATIONS IN THE LOGNORMAL 50% CASE

SIMULATION																					
0		1		2		3		4		5		6		7		8		9		10	
Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL	Rank	CL
14	0.706	14	0.704	14	0.709	14	0.710	13	0.703	14	0.699	14	0.711	14	0.707	14	0.709	14	0.706	14	0.699
7	0.664	7	0.663	7	0.666	7	0.655	14	0.689	7	0.670	7	0.664	7	0.660	7	0.669	7	0.660	7	0.666
12	0.644	12	0.651	12	0.643	12	0.650	7	0.652	12	0.649	12	0.650	12	0.651	12	0.654	12	0.652	12	0.653
6	0.624	6	0.618	6	0.624	6	0.614	12	0.639	6	0.628	6	0.630	6	0.625	6	0.619	6	0.632	6	0.625
13	0.602	13	0.606	13	0.613	13	0.605	6	0.616	13	0.606	13	0.602	13	0.614	13	0.605	13	0.605	13	0.606
5	0.579	5	0.594	5	0.588	5	0.601	5	0.575	5	0.575	5	0.581	5	0.581	5	0.583	5	0.579	5	0.576
9	0.565	9	0.579	9	0.557	9	0.564	9	0.555	9	0.573	9	0.562	9	0.556	9	0.570	9	0.572	9	0.570
8	0.478	8	0.505	8	0.483	8	0.483	8	0.484	8	0.497	8	0.483	8	0.487	8	0.476	8	0.471	8	0.490
4	0.463	4	0.463	4	0.470	4	0.468	4	0.453	4	0.462	4	0.473	4	0.463	4	0.469	4	0.465	4	0.459
3	0.420	3	0.409	3	0.428	3	0.417	3	0.422	3	0.420	3	0.417	3	0.423	3	0.423	3	0.417	3	0.426
15	0.418	15	0.400	15	0.407	15	0.409	15	0.401	15	0.411	15	0.405	15	0.400	15	0.404	15	0.401	15	0.404
2	0.366	2	0.371	2	0.372	2	0.374	2	0.381	2	0.359	2	0.371	2	0.364	2	0.376	2	0.368	2	0.372
1	0.337	11	0.314	11	0.318	10	0.319	1	0.320	1	0.327	10	0.323	1	0.328	1	0.319	11	0.334	11	0.327
11	0.325	1	0.312	1	0.315	11	0.318	11	0.308	11	0.320	1	0.318	11	0.327	11	0.317	1	0.325	1	0.316
10	0.308	10	0.311	10	0.306	1	0.314	10	0.302	10	0.306	11	0.309	10	0.313	10	0.308	10	0.311	10	0.309

The three first alternatives remain in the same ranking position in all the cases evaluated with the simulation method (although not in the same ranking position in weibull 50%). Moreover, the ranking position of seven investment alternatives changed in the lognormal 10% and a lognormal 50% cases in comparison with the exponential case (third column, Table 4), nevertheless the biggest modification was two positions.

The results of the three cases of the lognormal distributions are almost identical (only two alternatives changed in lognormal 90 %, 6 and 13), which suggest that different values of standard deviation of the interruption durations hardly influence on the prioritization investment process and what is more the results are quite comparable.

In contrast, the ranking of eight investment alternatives changed in the weibull 10% and weibull 50% cases, and seven in the case of weibull 90%.

Nevertheless, the biggest change in the ranking position was two positions. Additionally, considering the information given in table 5, it can be said that there are no significant changes in the ranking position among the ten different sampled simulations. The biggest modification in the ranking was two positions, without considering the fourth simulation. Only the fourth simulation gave a considerable change in alternative 13. That is because in this simulation the level risk of exceeding the imposed reliability standards decreased in comparison to the others alternatives. Thus, the ranking for alternative 13 has improved significantly. Furthermore, this change is ascribable to the inherent randomness of the simulation method that has been applied to carry out the reliability and risk assessment.

Table 6 shows a comparison of the ranking changes in the prioritization considering only the weibull cases. The changes in the prioritization are shaded.

The results of the three cases of the weibull distributions are not equal, which suggest that if the standard deviation of the probability distributions of the interruption durations changes, the ranking process will be affected.

Therefore, obtaining the correct value of the standard deviations takes higher importance in contrast to what happens in the lognormal distribution cases.

In table 7 the changes between lognormal 10% case and weibull cases are compared and the changes shaded. There are changes in each case (the position ranking of four investment alternatives was changed in the weibull 10% and weibull 50% cases, and six in the case of weibull 90%), which suggest that it is important to determine the correct probability distribution to model the interruption durations.

One of the recurring problems when a ***DU*** wants to decide on its investments is the lack of historical data of the duration and frequency interruptions of its elements. Then what probability distributions should the ***DU*** use or what will be the influence or impact of using an erroneous one?

TABLE 6. PRIORITIZATION FOR PROBABILITY DISTRIBUTION WEIBULL CASES

WEIBULL (10 %)		WEIBULL (50 %)		WEIBULL (90 %)	
RANKING	CL	RANKING	CL	RANKING	CL
14	0.710	12	0.700	14	0.711
7	0.666	7	0.660	7	0.664
12	0.649	14	0.632	12	0.644
6	0.621	6	0.630	13	0.617
13	0.613	13	0.630	6	0.616
5	0.581	5	0.580	9	0.586
9	0.559	9	0.576	5	0.575
4	0.475	8	0.472	8	0.492
8	0.470	4	0.454	4	0.453
3	0.414	3	0.416	3	0.419
15	0.409	15	0.407	15	0.408
2	0.376	2	0.370	2	0.374
1	0.326	11	0.331	1	0.330
10	0.316	1	0.327	10	0.307
11	0.315	10	0.314	11	0.303

TABLE 7. COMPARISON BETWEEN PROBABILITY DISTRIBUTION LOGNORMAL $\sigma = \mu x 10\%$ AND WEIBULL CASES

LOG-NORMAL (10 %)		WEIBULL (10 %)		WEIBULL (50 %)		WEIBULL (90 %)	
RANKING	CL	RANKING	CL	RANKING	CL	RANKING	CL
14	0.710	14	0.710	12	0.700	14	0.711
7	0.658	7	0.666	7	0.660	7	0.664
12	0.649	12	0.649	14	0.632	12	0.644
6	0.622	6	0.621	6	0.630	13	0.617
13	0.612	13	0.613	13	0.630	6	0.616
5	0.578	5	0.581	5	0.580	9	0.586
9	0.555	9	0.559	9	0.576	5	0.575
8	0.485	4	0.475	8	0.472	8	0.492
4	0.459	8	0.470	4	0.454	4	0.453
3	0.425	3	0.414	3	0.416	3	0.419
15	0.407	15	0.409	15	0.407	15	0.408
2	0.383	2	0.376	2	0.370	2	0.374
1	0.331	1	0.326	11	0.331	1	0.330
11	0.325	10	0.316	1	0.327	10	0.307
10	0.299	11	0.315	10	0.314	11	0.303

In order to gain insight into this problem, this paper has evaluated the influence of three different probability distributions of the reliability parameters of the ***DisNs*** components on the prioritization of the short-term investments in ***DisNs*** by means of adopting a simulation method in order to assess the risk level of violating the regulatory reliability standards. The simulation methods provided the appropriate framework for accomplishing the risk assessment and incorporating the appropriate result within the prioritization process.

Finally, an original combination of two completely different approaches for modeling the uncertainty, probability and fuzzy theory, has been presented. A framework where both probability and fuzzy theory interact harmoniously with each other has been introduced. And furthermore, an innovative investment prioritization methodology has been proved.

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