IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 16, Issue 5 Ser. II (Sep. – Oct. 2021), PP 15-20
www.iosrjournals.org

Calculation of Continuity Indicators in the Design Stage

Gheorghe Hazi[1], Aneta Hazi[1]
[1]*Department of Power Engineering, Faculty of Engineering, Vasile Alecsandri University of Bacău, Romania*

Abstract:
The paper presents a methodology for determining the continuity indicators of the electricity supply of consumers, in the design stage. In operation, these indicators are determined by recording the number and duration of power outages affecting consumers in the analyzed network.
The first part of the paper presents the continuity indicators provided in the performance standards, indicators required by some distribution operators in the design phase.
The calculation of the reliability indicators is done using the continuous time Markov chain method, which assumes that the equipment is either in a failure process with intensity λ, or in a repair process with intensity μ.
The last part of the paper presents a calculation example for a 20 / 0.4 kV network in Bacau County, Romania.
***Key Word**: Continuity indicators; Reliability indicators; Distribution network; Design stage.*

Date of Submission: 15-10-2021 Date of Acceptance: 30-10-2021

I. Introduction

The determination of continuity indicators is usually done in the operation of electrical networks. Their determination is required by mandatory regulations for the distribution operators [1]. The indicators are:

- the number of long interruptions of the electricity supply or evacuation path;
- SAIFI (System Average Interruption Frequency Index)
- SAIDI (System Average Interruption Duration Index)
- ENS (Energy Not Supplied)
- AIT (Average Interruption Time).

Distribution operators are required to record all long-term outages as well as short-term outages of the electricity supply / evacuation path for the places of consumption and / or production connected to the electricity distribution network (RED), regardless of their voltage.

Some distribution operators have requested the determination of these indicators at the design stage. As, at this stage, we have no records, these indicators need to be assessed through reliability calculations. These calculations can determine the number and duration of interruptions removed through repair, the number of interruptions removed through manual maneuvers, the number of interruptions removed through automatic maneuvers. As for the duration of the interruptions removed through manual maneuvers, this can be established on a statistical basis according to the average distances traveled and according to the personnel available to carry them out.

Methods for determining continuity indicators based on measurements are analyzed in the literature [2]. This version is not usable at the design stage. The paper [3] presents a method for evaluating continuity indicators for a distribution line. The presented method is not applicable for a larger power system.

Other works, [4], [5], [6], [8] present procedures for optimizing the reliability of distribution networks by optimally locating switching equipment, optimal reconfiguration or by establishing optimal intervals for maintenance activities.

The paper [7] proposes a method to reduce the SAIFI indicator by optimizing the design of installations for protection against atmospheric surges.

In this paper we propose a method for determining the continuity indicators for distribution networks, at the design stage, by evaluating the reliability indicators: average annual number and duration of interruptions removed through repairs and average annual number of interruptions removed through maneuvers. The other necessary information, such as the average duration of a maneuver, the number of consumers fed per area or the power required per network area, is obtained from distribution operators.

II. Determination of reliability indicators by consumption areas

The analysis is performed for a medium voltage distribution network. The points where the reliability indicators are determined are the low voltage (JT) bars (0.4 kV) of the transformer substations. As their number is large, they are grouped by consumption areas. The distances between the transformer substations are small, they are located in the same locality or in close localities. To better understand this, we present an example in Figure 1.

The determination of the reliability indicators at the JT bars of the transformer substations, by consumption areas, is done in the following steps:

I. Taking over the equivalent reliability indicators on the medium voltage (MT) bar of the supply station: λ1, μ1, λm1.

λ1 - equivalent failure rate (faults removed through repair) on the supply bar of the distribution network

μ1 - equivalent repair rate on the supply bar of the distribution network

λm1 - equivalent failure rate (faults removed through maneuver) on the supply bar of the distribution network

These indicators are determined using programs to calculate the reliability of complex networks.

II. Establishing the reliability block scheme for the calculated area.

III. Calculation of the equivalent indicators λe, μe, λme for the reliability block diagram of the calculated area. The reduction is done by serial groups, parallel groups or by using a calculation program.

IV. Calculation of reliability indicators for the fed area [9]:

Yearly mean number of failures eliminated through repairs:

$$N_r = \frac{\mu_e \cdot \lambda_e}{\lambda_e + \mu_e} \cdot T \quad \text{[interr/year]} \tag{1}$$

Yearly mean number of failures eliminated through manual maneuvers:

$$N_m = \frac{\mu_e \cdot \lambda_{me}}{\lambda_e + \mu_e} \cdot T \quad \text{[interr /year]} \tag{2}$$

Mean duration of failures removed through repairs:

$$T_r = \frac{1}{\mu_e} \quad \text{[h/ interr]} \tag{3}$$

Annual duration of non-supply due to faults eliminated through repairs:

$$T_{ran} = N_r \cdot T_r \quad \text{[h/year]} \tag{4}$$

Annual duration of non-supply due to faults eliminated through manual maneuvers:

$$T_{man} = N_m \cdot T_m \quad \text{[h/year]} \tag{5}$$

where Tm represents the mean duration of a maneuver eliminated through maneuver determined on a statistical basis according to the intervention distances and the available operating personnel.

III. Calculation of continuity indicators

We calculate the indicators specified in point I of the paper, with the relationships given in [1], adapted to the indicators calculated in point II.

For the calculation of these indicators, information is required such as the number of consumers connected to each transformer substation and the mean interrupted power in the event of an accident. This information is obtained from the network database and from the analysis of accidental event reports.

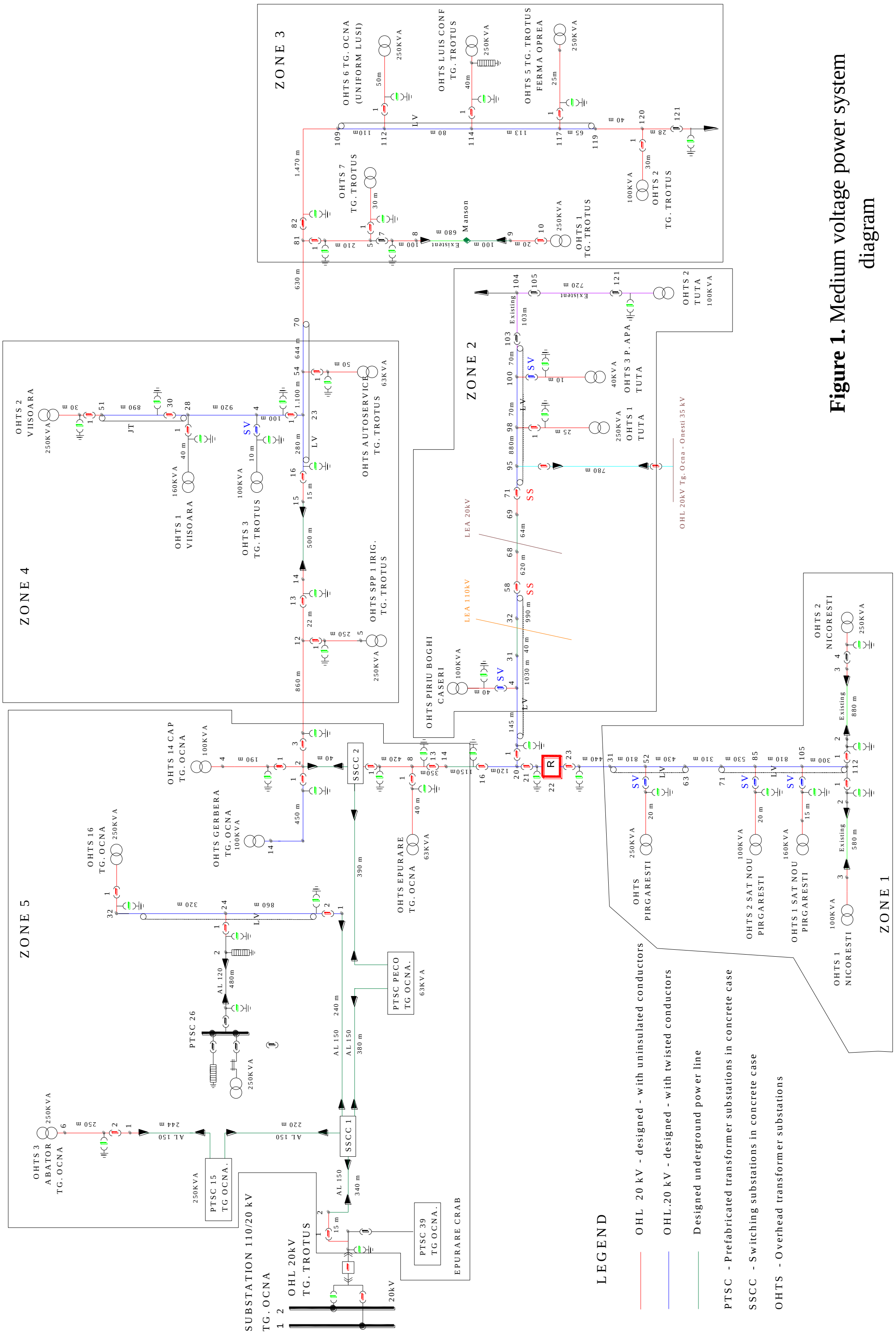

Figure 1. Medium voltage power system diagram

The calculation of the continuity indicators per area is done with the relations:

$$SAIFI = \frac{\sum_{i=1}^{Nz} N_{ri} \cdot N_{ci} + \sum_{i=1}^{Nz} N_{mi} \cdot N_{ci}}{\sum_{i=1}^{Nz} N_{ci}} \text{ [interr/customer.year]} \quad (6)$$

$$SAIDI = \frac{\sum_{i=1}^{Nz} N_{ri} \cdot N_{ci} \cdot T_{ri} + \sum_{i=1}^{Nz} N_{mi} \cdot N_{ci} \cdot T_{mi}}{\sum_{i=1}^{Nz} N_{ci}} \text{ [hours/customer.year]} \quad (7)$$

$$ENS = \sum_{i=1}^{Nz} P_i \cdot N_{ri} \cdot T_{ri} + \sum_{i=1}^{Nz} P_i \cdot N_{mi} \cdot T_{mi} \text{ [kWh/year]} \quad (8)$$

$$AIT = 8760 \cdot 60 \cdot \frac{ENS}{AD} \text{ [minutes/year]} \quad (9)$$

where Nz represents the number of zones in the network, Pi the power interrupted on zone i, given in table 2, and AD (Annual Demand) the annual electricity consumption in the network.

IV. Simulation Results

Table 1 shows reliability indicators by areas, for the example in figure 1.

Table no 1: Reliability indicators by areas, for the example in figure 1

Area	λ_e x10^{-5} h^{-1}	μ_e h^{-1}	λ_e x10^{-5} h^{-1}	N_r interr /year	T_r h/ interr	N_m interr /year	T_m h/man	T_{ran} h/year	T_{man} h/year
1	4.50	0.073	29.16	0.394	13.77	2.55	0.5	5.43	1.28
2	4.62	0.071	26.58	0.404	14.09	2.33	0.5	5.70	1.16
3	4.95	0.078	44.09	0.433	12.80	3.86	0.5	5.54	1.93
4	4.60	0.076	27.60	0.403	13.21	2.42	0.5	5.32	1.21
5	3.05	0.081	28.61	0.267	12.31	2.51	0.5	3.29	1.25

Table 2 shows the list of the number of consumers per transformer substation, as well as the mean interrupted power at an accidental event, by area, for the example in Figure 1.

Table no 2: Number of consumers per transformer substation and area

Area	Name	Transformer power [kVA]	Number of consumers N_c	Mean interrupted power, P [kW]
1	OHTS Pirgaresti	250	331	105
	OHTS 1 Sat Nou Pirgaresti	160	296	
	OHTS 2 Sat Nou Pirgaresti	100	336	
	OHTS 1 Nicoresti	100	110	
	OHTS 2 Nicoresti	250	119	
	TOTAL area:	**1192**		
2	OHTS Piriu Boghi Caseri	100	224	82
	OHTS 1 Tuta	250	501	
	OHTS 2 Tuta	100	193	
	OHTS 3P. apa Tuta	40	1	
	TOTAL area:	**919**		
3	OHTS 1 Tg. Trotus	250	361	91
	OHTS 2 Tg. Trotus	100	100	
	OHTS 7 Tg. Trotus	63	55	
	OHTS 6 Tg. Ocna	250	1	
	OHTS Luis Conf Tg. Trotus	250	1	
	OHTS 5 Tg. Trotus ferma Oprea	250	2	
	TOTAL area:	**520**		
4	OHTS 1 Viisoara	160	169	149
	OHTS 2 Viisoara	250	310	
	OHTS 3Tg. Trotus	100	143	
	OHTS Autoservice	63	104	

	Tg. Trotus			
	OHTS SPP1 Irig Tg. Trotus	250	1	
	TOTAL area:	**727**		
5	PTSC 39 Tg. Ocna	2 x 400	1	292
	PTSC PECO Tg. Ocna	63	27	
	PTSC 15 Tg. Ocna	250	157	
	OHTS 3 Abator Tg. Ocna	250	5	
	PTSC 26 Tg. Ocna	250	73	
	OHTS 16 Tg. Ocna	250	298	
	OHTS Gherbera Tg. Ocna	100	1	
	OHTS 14CAP Tg. Ocna	100	11	
	OHTS EPURARE Tg. Ocna	63	1	
	TOTAL area:	**574**		

For the analyzed network we get the values given in table 3.

Table no 3: Calculated continuity indicators

No.	Indicator	U.M.	Value
1	SAIFI	interr/customer.year	3.025
2	SAIDI	hours/customer.year	6.495
3	END	kWh/year	4246.215
4	AD	kWh/year	7735000
5	AIT	minutes/year	288.534

V. Conclusions

The following conclusions can be drawn from the calculations presented:

- Continuity indicators can be determined in the design phase by determining the number of failures removed through repairs and maneuvers using reliability calculations.
- The number of failures eliminated through automatic maneuvers can also be assessed by reliability calculations. A relation of form (2) can be used. These influence the MAIFI indicator.
- The grouping by zones is justified by the results presented in table 1. In the table we observe that the reliability indicators at the JT bars of the transformer substations, from different areas, have close values. These results will be closer for transformer substations in the same area.
- The higher the number of zones, the greater the accuracy for calculating the reliability indicators. The calculation volume also increases accordingly.

References

[1]. ANRE Romania, Performance Standard for the electricity distribution service, approved by Order no. 46/2021.
[2]. Mirosław Kornatka, Anna Gawlak, and Grzegorz Dudek, Determination of reliability indices of the distribution network based on data from AMI, E3S Web of Conferences, Volume 84, 2019, https://www.e3s- conferences.org/articles/e3sconf/abs/
a. 2019/10/e3sconf_pe2019_02004.
[3]. Ivan Bandurin, Alexey Khaimin, SAIFI reliability calculation for the distribution line, E3S Web of Conferences 58, 02010 (2018), https://www.https://www.e3s-conferences.org/articles/e3sconf/abs/2018/33/e3sconf_rses2018_02010.
[4]. Degarege Anteneh, Baseem Khan, Om Prakash Mahela, Hassan Haes Alhelou, Josep M. Guerrero, Distribution network reliability enhancement and power loss reduction by optimal network reconfiguration, Computers and Electrical Engineering 96, 2021.
[5]. L.D. Arya, S.C. Choube, Rajesh Arya, Differential evolution applied for reliability optimization of radial distribution systems, Electrical Power and Energy Systems 33,2011, pp. 271–277.
[6]. H. Zhenga, Y. Chenga, B. Goub, D. Frankc, A. Bernc, W.E. Mustonc, Impact of automatic switches on power distribution system reliability, Electric Power SystemsResearch 83, 2012, pp. 51– 57.
[7]. Roberto José Cabral, Roberto Chouhy Leborgne, Arturo Suman Bretasc,Gustavo Dorneles Ferreira, John Armando Morales, Lightning protection system design for distribution networks based on System Average Interruption Frequency minimization, Electric Power Systems Research 160, 2018, pp. 1–12.
[8]. Abdollah Kavousi-Fard, Mohammad-Reza Akbari-Zadeh, Reliability enhancement using optimal distribution feeder reconfiguration, Neurocomputing 106, 2013, pp.1–11.
[9]. R. Billintonand R. Allan, Reliability Evaluation of Power Systems, 2nd ed., New York: Plenum Press, 1996.

Gheorghe Hazi, et. al. “Calculation of Continuity Indicators in the Design Stage.” *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 16(5), (2021): pp. 15-20.