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Performance analysis of protection devices in electrical power distribution system: Eko Electricity Distribution Company as a case study

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ABSTRACT

One of the major challenges hindering the effective operation of the electricity distribution system is the malfunctioning of the protection scheme. Therefore, in this study, the performance of an interrupter (oil circuit breaker (OCB)) on the Eko Electricity Distribution Company (EKEDC) network was assessed. Five-year outage data (2014 to 2018) regarding tripping of the interrupter on fault and health conditions were collected from the EKEDC Agbara/Badagry Business Unit. The tripping frequency was compared. Inspection of selected OCBs within the considered network was conducted over the study period. A breakdown voltage (BDV) test was carried out on six oil samples each for 11 and 33 kV OCB using Megger OTS60PB. The highest tripping frequency of 75 and 10 were observed in 2014 and 2018 respectively when the interrupter tripped on fault and healthy conditions. The lowest tripping frequency was, however, observed in 2018 with values of 46 and 7 respectively when the interrupter tripped on fault and healthy conditions. The inspection conducted revealed carbonized OCB contacts. The BDV test showed that two oil samples each violated the standard value of 40 kV for 11 and 33 kV OCBs respectively. This study indicated that the defective oil samples required filtration or complete replacement.

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1. INTRODUCTION

Protection schemes in power systems play a very impactful role in maintaining the stable and secure operation of the various interconnected devices for quality and reliable service delivery from the overall system. A protection scheme is an automatic system that monitors and protects electrical equipment under its supervision to ensure that a larger section of the power system network remains functional during fault occurrence. Malfunctions or inconsistencies in the correct operating sequence of these schemes can cause wrong-tripping which could have a devastating effect on the system thereby leading to service interruption to the customers [1]–[4].

The main goal of any protection scheme is to clearly discriminate between healthy and unhealthy sections of the power system so that faulty elements in the unhealthy part can be promptly detected and isolated without any threat or danger to the overall system stability and security [5]. The function of interrupters during the operation of a power system is typically rendered through the combined efforts of relays and circuit breakers [6], [7]. The protective relay senses any unhealthy system operating condition and passes such information to the circuit breaker for further processing whereas the circuit breaker which is an electromechanical device disengages the faulty section of the circuit before the impending danger associated with the fault spreads to the healthy part, hence, limiting the fault chain from multiplying.

Circuit breakers can either trip due to a fault which allows other parts of the system to healthy or open for maintenance purposes for the safety of the personnel. A situation where a circuit breaker trips aside from the two principles mentioned, it is called malfunctioning of operation which is very dangerous to personnel and equipment. On no account should a circuit breaker trip while the system is healthy, if it does, apart from the effect on the equipment and personnel, thousands of customers would have been affected which in turn jeopardized the business of many.

In a power system, any failure that causes supply interruptions either on a temporary or permanent basis can be termed a fault [6], [8], [9]. According to Quiroga *et al*. [10], while temporary fault allows the faulty circuit to be re-energized after a fault-clearing operation, permanent fault involves complete repair or replacement of the damaged elements in the faulty section of the circuit. These faults when occurring do not only negatively affect the efficiency of the power supply system but also, the quality of electrical energy delivered is impaired [8], [9]. Hence, to ensure a fully functional power system where only the faulty parts are isolated while the healthy parts are left uninterrupted during operation, optimum analysis of the performance of the protection scheme is necessary.

Power system protection is classified into two major categories, namely, primary and backup protection [6], [7], [11], [12]. Primary protection which is the main defense line usually provided for every part of power system installation allows prompt and selective fault clearing within the zone of the circuit it protects. Backup protection on the other hand is the second defense line called into play whenever the primary protection is slow in its responsibility. More so, since this form of protection is only triggered into action when the main protection fails, it is usually designed to be less selective and slow in operation for effective coordination [13].

Fundamentally, the act of protection in the power system is crucial for the smooth and effective running of the system [14]. The protection scheme must swiftly respond to avert any danger or damage that may arise as a result of fault occurrence in any part of the system. It is therefore required that the scheme possesses certain unique qualities to be efficient in performing its responsibility. These qualities among others include simplicity, selectivity, reliability, sensitivity, and cost-effectiveness [5], [10]–[12], [15].

Generally, frequent fault occurrences in power systems are not permissible. This is a result of the system being a huge capital-based project coupled with the fact that customers' service interruption is not a welcome idea [16]. Fault occurrences will not only damage the various essential components such as transformers, generators, transmission and distribution lines, cables, static, and dynamic loads among others making up the power system but also will hike the cost of maintaining and replacing these components when damaged. It has been discovered that failures in protection schemes are responsible for virtually all accidents and service interruptions. Therefore, protection schemes offer the most potent link to prevent power supply interruptions, damage to electrical equipment as well as injury to personnel. Hence, for a stable, secure, and reliable operation of this system, a good quality protection scheme must be put in place. Given this fact, the present study is geared toward performance analysis of protection schemes in electrical power distribution systems with a major emphasis on interrupters, particularly, and oil circuit breakers (OCBs).

2. REVIEW OF RELATED LITERATURE

De-escalating the spread of negative impacts of faults occurrence in power system networks is one of the basic functions of the protection scheme [16], [17]. Experiences have shown that failures of interrupters are responsible for virtually all accidents and service interruptions in distribution networks. It is, therefore, imperative to plan and maintain stable and reliable power system protection because failure in their operations can lead to power outages and catastrophic effects which will subsequently have severe economic effects on the utility and its customers. In line with this view, several investigations have been conducted to analyze the performance of protection schemes in electric power systems around the world including Nigeria.

Adejumobi [18] examined the effect of ionization and carbonization on OCB. The work focused on the ionization and carbonization of the insulating oil around the breaker's contacts which usually results in its failure. Constant reconditioning and preventive maintenance were reported to reduce the failure experienced on the circuit breaker. Arya *et al*. [19] conducted an oil dielectric strength test on a 13.8 kV OCB aged between 29 to 43 years using six oil samples. Findings from the study declared the oil as failed because the breakdown voltage (BDV) obtained was below the threshold value of 27 kV. Vedachalam *et al*. [20]

investigated the ambient hydrostatic pressure impact on the operation of pressure-compensated electromagnetically actuated OCB. Evidence from the work revealed that the duration of circuit breaking, and energy of the generated arc reduced fivefold and threefold respectively at 150 bar pressures in comparison to performance at 1 bar condition. However, at a pressure above 200 bar, the duration of circuit breaking rises with an increase in insulating oil viscosity which was accompanied by a corresponding rise in the energy of the generated arc and production of larger carbon conglomerations as a result of the breakdown of the insulating oil. Peng *et al*. [21] carried out a static calculation at a key moment during the oil buffering operation of an OCB to determine the fatigue life of an insulating oil. Results obtained showed that during the process of the circuit breaker operation, points of maximum stress and strain generally appeared close to the edge of the oil discharge orifice and the cycle life of the insulating oil was still within the recommended standard. Parthasarathy and Heising [22] worked on an OCB predictive maintenance program. Through the analysis of the insulating oil samples used, gas, and particle contents as well as the fluid quality were determined as measures of the conditions of contacts, interrupters, and other load path components internal to the circuit breaker. Liu *et al*. [23] analyzed the insulating oil of power transformer and OCB. The study identified some of the issues affecting the long-time insulating oil preparation including the oil bottle's high cleanliness requirement and incorrect sealing. Xiao *et al*. [24] examined the dielectric recovery capability of a vacuum interrupter subject to interruption of varying rated current magnitudes. Findings from the work revealed that with a small rated current of 2 kA, there was an insignificant difference in the interrupter’s recovery strength with axial magnetic field and butt contacts. However, with a higher rated current of 10 kA, the recovery strength of the interrupter with butt contacts reduced drastically when compared with the axial magnetic field contacts. Hence, the interrupter displayed a very poor dielectric recovery capability with butt contacts under a high-rated current. Goeritno and Rasiman [25] evaluated the performance of bulk OCB. Findings from the work revealed that the BDV of the insulating oil being within the recommended standard still qualifies it as an insulating and cooling medium for the considered OCB.

A critical assessment of the reviewed literature revealed that several good attempts have been analyze the dielectric strength and quality of insulating oil for OCBs. However, more research efforts are still very much required in this regard taking into cognizance the importance of distribution systems which are one of the key areas where these devices are employed. Distribution networks being the closest links in the power system to the consumers, interruption of these networks as a result of malfunctioning protection devices such as circuit breakers is not a welcomed development. Hence, the essence of the present study.

3. RESEARCH METHOD

3.1. Performance evaluation of the interrupter

The monthly five years data on the tripping frequency of the selected OCBs used as the preliminary information on which the performance of the interrupter in this work was evaluated were collected from Eko Electricity Distribution Company (EKEDC) [26]. These outage data were specifically obtained from the fault logbook of the Agbara/Badagry Business Unit of EKEDC from 2014 to 2018. From the obtained data, the percent total tripping frequency of the OCBs when the system was faulty and healthy was observed and this was used as the basis for further analysis on the OCB.

3.2. Inspection of the interrupter

Inspection of the contacts of the selected OCBs was physically done to check any possibility of carbon deposits. Carbon deposits are characteristically weak conductors that allow the passage of electric current during the operation of OCBs. The contacts of OCBs are usually immersed in an insulating oil for the quenching or extinction of arcs generated during the opening of the contacts. These arcs are characterized by high temperature and the extreme heat produced during the process of arcing results in the ionization or vaporization of the insulating circuit breaker oil, causing the accumulation or deposition of carbon particles on the contacts. The output of the physical inspection was deployed for further analysis on the OCB.

3.3. Testing of the interrupter insulating oil

The main contents of the insulating oil used in OCBs are naphtha, paraffin, and aromatic [27]. The proportion of these contents varies for different sources of oil and decides its aging properties [27]. In this study, the dielectric strength test was carried out on twelve samples of the OCB insulating oil (six samples each for 11 and 33 kV OCBs considered) using the Megger OTS60PB oil tester to determine the BDV of the samples.

Dielectric or BDV strength of an insulating material is the threshold potential gradient above which electric failure or breakdown results subject to the prescribed operating conditions. It is an important factor in measuring the capability of an insulating material to withstand potential stress without failure. It can also serve as a measure to indicate the presence of polluting agents such as dirt, conducting particles, and water in an insulating material like oil [27]. The presence of these pollutants in an insulating material is usually confirmed by low BDV strength during the test where any of the polluting agents may be present singly or concurrently with other agents. According to Pabla [27], a high dielectric or BDV strength, however, does not necessarily signify the absence of all pollutants.

4. RESULTS AND DISCUSSION

4.1. Results of performance evaluation

The collected monthly five-year data detailing the tripping frequency of the OCBs considered in this work from 2014 to 2018 are presented in Table 1. Analysis of the results in Table 1 revealed that for the period of study, the considered OCBs tripped more during the faulty system conditions than when the system was healthy or free from fault. The highest and lowest tripping frequencies recorded when the system was faulty were 75 and 46 in 2014 and 2018 respectively. Similarly, the highest and lowest tripping frequency of 12 and 7 were obtained in 2015 and 2018 respectively when the system was free from fault. A more detailed observation of the results in Table 1 indicated the tripping frequency of the OCBs when the system was healthy which were 12, 14, 10, 12, and 13% for 2014 to 2018 respectively were higher than expected.

This observation is in sharp contrast with the main objective of power system protection that protective devices such as circuit breakers are expected to open only during an abnormal condition or for maintenance purposes on the power system. A situation where the breakers open when the system is free from fault results from incorrect tripping and this raise concerns over the reliable and efficient functionality of the breakers. The false tripping makes the electrical distribution system unstable thereby creating problems in urban cities and production centers [18] and this necessitated physical inspection of the OCBs considered for the period of study.

Table 1. Number of outages on OCB when the considered electric power distribution network is faulty and healthy

Months	Number of times OCB operates when the system is faulty and when the system is healthy									
	2014		2015		2016		2017		2018	
	X	Y	X	Y	X	Y	X	Y	X	Y
January	9	1	5	0	7	1	9	1	6	2
February	6	2	8	1	5	0	4	0	8	1
March	8	0	6	2	6	1	6	0	5	0
April	6	0	9	0	9	1	8	2	1	1
May	4	1	7	0	7	1	5	0	0	0
June	9	0	3	0	3	2	7	2	5	1
July	7	1	9	2	0	0	3	1	2	0
August	5	0	4	3	4	0	5	0	2	1
September	10	0	2	0	6	0	8	1	6	0
October	2	2	6	1	9	1	3	0	0	0
November	4	1	7	1	7	1	5	1	4	1
December	5	2	6	2	8	0	4	1	2	0
Total	75	10	72	12	71	8	67	9	46	7
% Tripping	88	12	86	14	90	10	88	12	87	13

Keys: X-When the system is faulty and Y-When the system is healthy.

4.2. Results of physical inspection of the oil circuit breakers

The results of the physical inspection conducted on the considered OCBs are presented in Figure 1. From Figure 1, the accumulation of carbon deposits on the male and female contacts of the OCB as a result of arc production was discovered. These contacts being immersed in an insulating oil, there is a higher chance that the accumulated carbon deposits would have mixed with the oil and polluted it. The aftermath effects of such pollution are decreasing BDV of the oil, reduced lifespan, and frequent tripping. This, therefore, necessitated a dielectric strength test on the OCBs.

4.3. Results of breakdown voltage test on the insulating oil samples of the oil circuit breakers

According to Pabla [27], the standard BDV for any equipment below 72.5 kV should be ≥40 kV. The results of the BDV test conducted on twelve oil samples from six 33 kV OCBs and six 11 kV OCBs from the EKEDC network are presented in Tables 2 and 3. The BDV test results in Table 2 revealed that four oil samples (samples 1, 2, 4, and 6) from the 33 kV OCBs considered were in good condition. From the test results in Tables 2 and 3, it was shown that some of the circuit breakers' oil was in good condition since all the BDV values obtained from five different tests on each of the six samples were greater than or equal to the standard value of 40 kV [27] specified for the breaker. The oil samples 3 and 5 from 33 kV OCBs, however, failed the test since at least one of BDV values obtained from the five different tests was below the standard value of 40kV [27].

Similarly, from the BDV test results in Table 3, four oil samples (samples 1, 2, 5, and 6) the 11 kV OCBs considered were discovered to be in good condition; with all the BDV values obtained during the five tests conducted greater than or equal to the standard value of 40 kV [27] specified for the breakers. However, for oil samples 3 and 4 from 11 kV OCBs, at least one of the BDV values recorded during the five different tests on the samples fell below the standard value of 40 kV [27] and therefore, failed the BDV test.

The results of the BDV test obtained in this study are indications that four (two each for 11 and 33 kV OCBs) of the twelve samples of insulating oil of OCBs considered within the network of EKEDC being controlled by Agbara/Badagry Business Unit in Lagos State needed prompt maintenance actions in the form of filtration or total replacement to avoid explosion or fire outbreak.

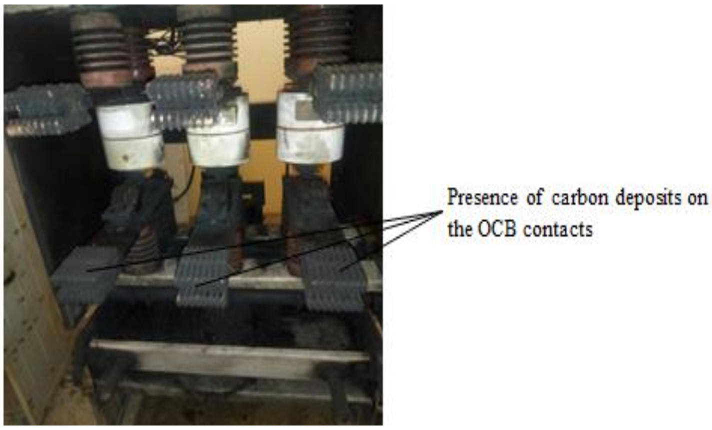

Figure 1. Carbonized OCB contacts during physical inspection

Table 2. BDV test results from six oil samples from 33 kV OCBs

Rating of OCBs (kV)	Oil samples	Test 1 (kV)	Test 2 (kV)	Test 3 (kV)	Test 4 (kV)	Test 5 (kV)	International standard ≥40 kV
33	1	54	61	58	55	64	Good
33	2	60	48	54	62	57	Good
33	3	36	39	33	37	39	Bad
33	4	52	47	50	49	50	Good
33	5	25	38	40	36	40	Bad
33	6	54	61	58	55	64	Good

Table 3. BDV test results from six oil samples from 11 kV OCBs

Rating of OCBs (kV)	Oil samples	Test 1 (kV)	Test 2 (kV)	Test 3 (kV)	Test 4 (kV)	Test 5 (kV)	International standard ≥40 kV
11	1	40	48	45	47	48	Good
11	2	48	45	46	45	46	Good
11	3	34	30	33	38	37	Bad
11	4	38	38	36	33	39	Bad
11	5	45	47	47	49	46	Good
11	6	40	48	45	47	48	Good

5. CONCLUSION

This study analyzed the performance of interrupters OCBs in an electric power distribution using the EKEDC network controlled by the Agbara/Badagry Business Unit in Lagos State as a case study. Findings from the work revealed that the considered OCBs tripped more when the system was faulty than when it was healthy for the study period and that the frequency of tripping observed from OCBs when the system was healthy was relatively higher than expected, considering that protective devices such as circuit breakers are expected to open only during an abnormal condition or maintenance. This, therefore, raises concerns about false tripping on the network. Physical inspection of the considered OCBs within the EKEDC network indicated the presence of carbon deposits at the contacts of breakers; with the great potential of contaminating the oil, reducing its dielectric strength and age. The BDV test carried out on twelve insulating oil samples from six each of 11 and 33 kV OCBs considered showed that eight of the samples (four each for 11 and 33 kV OCBs) were in good condition while four of the samples (two each for 11 and 33 kV OCBs) had deteriorated since they failed the BDV test and required urgent maintenance or replacement; otherwise, the OCBs would malfunction and the result of such malfunctions could be frequent tripping as observed in the study. It can also lead to an explosion or fire outbreak, damage not only the faulty equipment but also other components, and fatal accidents to the personnel.

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REFERENCES

[1] M. M. Ghalesefidi and N. Ghaffarzadeh, "A new phaselet-based method for detecting the power swing in order to prevent the malfunction of distance relays in transmission lines," *Energy Systems*, vol. 12, no. 2, pp. 491–515, May 2021, doi: 10.1007/s12667-019-00366-8.

[2] C. Li, P. Rakhra, P. J. Norman, G. M. Burt, and P. Clarkson, "Multi-sample differential protection scheme in DC microgrids," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 9, no. 3, pp. 2560–2573, Jun. 2021, doi: 10.1109/JESTPE.2020.3005588.

[3] A. Gholami and A. K. Srivastava, "Data-driven failure diagnosis in transmission protection system with multiple events and data anomalies," *Journal of Modern Power Systems and Clean Energy*, vol. 7, no. 4, pp. 767–778, Jul. 2019, doi: 10.1007/s40565-019-0541-6.

[4] A. P. Vaidya and P. A. Venikar, "ANN based distance protection of long transmission lines by considering the effect of fault resistance," in *IEEE-International Conference on Advances in Engineering, Science and Management, ICAESM-2012*, 2012, pp. 590–594.

[5] D. Karlsson, L. Broski, and S. Ganesan, "Maximizing power system stability through wide area protection," in *57th Annual Conference for Protective Relay Engineers*, 2004, pp. 403–418, doi: 10.1109/CPRE.2004.238557.

[6] P. V. Gupta, M. L. Soni, U. S. Bhatnagar, and A. Chakrabarti, *A textbook on power system engineering*. New Delhi: Dhanpat Bai and Company Limited, 2017.

[7] J. B. Gupta, *A course in power system*. New Delhi: S.K. Katari and Sons Publisher, 2011.

[8] A. S. 2011 Filomena, A. D., Resener, M., Salim, R. H. and Bretas, "Distribution system fault analysis considering fault resistance estimation," *Electrical Power and Energy System*, vol. 33, pp. 1326–1335, 2011.

[9] M. Mirzaei, M. Z. A. Ab Kadir, E. Moazami, and H. Hizam, "Review of fault location methods for distribution power system," *Australian Journal of Basic and Applied Sciences*, vol. 3, no. 3, pp. 2670–2676, 2009.

[10] O. A. Quiroga, J. Meléndez, and S. Herraiz, "Fault causes analysis in feeders of power distribution networks," *Renewable Energy and Power Quality Journal*, vol. 1, no. 9, pp. 1269–1272, May 2011, doi: 10.24084/repqj09.619.

[11] R. Mason, *The art and science of protective relaying*. 2007.

[12] W. A. Elmore, *Protective relaying theory and application*. Abingdon: Dekker, 2003.

[13] A. G. Phadke, P. Wall, L. Ding, and V. Terzija, "Improving the performance of power system protection using wide area monitoring systems," *Journal of Modern Power Systems and Clean Energy*, vol. 4, no. 3, pp. 319–331, Jul. 2016, doi: 10.1007/s40565-016-0211-x.

[14] M. A. Aftab, S. M. S. Hussain, I. Ali, and T. S. Ustun, "Dynamic protection of power systems with high penetration of renewables: a review of the traveling wave based fault location techniques," *International Journal of Electrical Power and Energy Systems*, vol. 114, Jan. 2020, doi: 10.1016/j.ijepes.2019.105410.

[15] D. P. Kothari and I. J. Nagrath, *Power system engineering*, 2nd ed. New Delhi: Tata McGraw Hill, 2007.

[16] H. H. Goh *et al.*, "Fault location techniques in electrical power system-a review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 8, no. 1, pp. 206-212, Oct. 2017, doi: 10.11591/ijeecs.v8.i1.pp206-212.

[17] M. Jeevan, "A review on power system faults and protection," *International Journal of Engineering Research and Technology (IJERT)*, vol. 11, no. 4, pp. 395–398, 2022, doi: 10.17577/IJERTV11IS040201.

[18] I. A. Adejumobi, "Effects of ionization and carbonization on oil circuit breaker contacts," *International Journal of Biological and Physical Sciences*, vol. 9, pp. 37–41, 2004.

[19] E. H. Arya, B. Maharmi, and M. Lutfi, "Analysis of oil dielectric strength insulation on oil circuit breakers based on service life and operating frequency," *Journal of Ocean, Mechanical and Aerospace -science and engineering- (JOMAse)*, vol. 66, no. 2, pp. 50–56, Jul. 2022, doi: 10.36842/jomase.v66i2.300.

[20] N. Vedachalam, A. Umapathy, S. M. Babu, K. Venketesan, N. K. S. Kumar, and M. A. Atmanand, "Performance of electromagnetic oil circuit breakers under hyperbaric conditions," *Marine Technology Society Journal*, vol. 53, no. 1, pp. 74–82, Jan. 2019, doi: 10.4031/MTSJ.53.1.8.

[21] Y. Peng, J. Wang, L. Wang, J. Qin, X. Zhou, and H. Dong, "Fatigue life analysis of oil buffer used in circuit breaker operating mechanism in action process," in *2nd International Symposium on Mechanical Systems and Electronic Engineering, ISMSEE 2022*, 2022, pp. 90–94.

[22] A. Parthasarathy and C. D. Heising, "To develop a set of profiles for a family of Alliant Energy's oil circuit breakers," in *2004 International Conference on Probabilistic Methods Applied to Power Systems*, 2004, pp. 1014–1019.

[23] C. Liu, S. Wang, J. Li, H. Zhang, Q. Zhao, and S. Tao, "Shorten the time of insulating oil analysis test," in *2022 IEEE 5th International Conference on Automation, Electronics and Electrical Engineering (AUTEEE)*, Nov. 2022, pp. 851–855, doi: 10.1109/AUTEEE56487.2022.9994502.

[24] Y. Xiao *et al.*, "Study on dielectric recovery characteristic of vacuum interrupter after high frequency interruption," in *2019 5th International Conference on Electric Power Equipment - Switching Technology (ICEPE-ST)*, Oct. 2019, pp. 197–200, doi: 10.1109/ICEPE-ST.2019.8928914.

[25] A. Goeritno and S. Rasiman, "Performance of bulk oil circuit breaker (BOCB) influenced by its parameters (Case study at the substation of Bogor Baru)," 2017, doi: 10.1063/1.4985446.
[26] Eko Electricity Distribution Company, "Monthly fault reports (Jan. 2014 to Dec. 2018)," 2018.
[27] A. S. Pabla, *Electric power distribution*. Mcgraw Hill, 2010.

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