Analysis and identification of short circuit faults in the complex's electrical distribution system SIDER El-Hadjar

Analyse et identification des défauts de court-circuit du Système de distribution électrique du complexe SIDER-El-Hadjar

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Abstract

The difficulty in calculating the short-circuit currents lies essentially in the determination of the value of the impedance of the fault, the traditional calculation method consists in locating the fault of maximum short-circuit current at the starting head in the networks distribution. The objective is to determine the maximum currents by each departure, then to verify the dimensioning and the thermal resistance of the various equipment's of the network and the future needs at the bar games 225kv, 63kv and 15kv. A new calculation of the short-circuit current must be calculated following the change of the topology of the distribution network to verify the reliability of the existing protection system. The calculation of short-circuit currents is a key step in qualifying the equipment to withstand the thermal and electromagnetic effects. The numerical method for calculating short-circuits currents requires modeling and simulations of the network studied with Cyme, a reference software for electrical distribution networks.

Résumé

La difficulté du calcul des courants de court-circuit réside essentiellement dans la détermination de la valeur de l'impédance du défaut. La méthode de calcul traditionnelle consiste à situer le défaut de courant de court-circuit maximum en tête de départ dans les réseaux de distribution. L'objectif poursuivi dans cet article, est de déterminer les courants maximaux par chaque départ, puis vérifier le dimensionnement et la tenue thermique des différents équipements du réseau et les besoins futur au niveau jeux de barre 225kv, 63kv et 15kv. Un nouveau calcul du courant de court-circuit doit être entrepris suite au changement de la topologie du réseau de distribution pour vérifier la fiabilité du système de protection existant. Le calcul des courants de court-circuit est une étape principale pour la qualification de l'équipement à résister aux effets thermique et électromagnétique. La méthode numérique de calcul des courants de court-circuit nécessite la modélisation et des simulations du réseau étudié avec Cyme, un logiciel de référence des réseaux de distribution électrique.

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1. INTRODUCTION

Power systems and distribution networks play an important role in the distribution of electrical energy. The growth of distribution networks and the penetration of distributed generations [1, 2], rapidly increase the level of current. Short-circuit faults can disrupt the safety and stability of the distribution networks. Therefore, calculating short-circuit currents is one of the most important tasks when planning power systems [3]. Short circuit faults can be reduced in the system through good planning, careful design, good maintenance and thorough system operation. They cannot be totally avoided due to the presence of external factors that can influence the system [4]. Some measures should be taken to limit the fault currents [5], [6]. To achieve the desired objective of limiting fault currents, the adoption of protective devices must make accurate judgments, ie ie that it should operate during the fault birth time to limit the impact of fault currents. The speed and accuracy of detection of short-circuit faults are crucial clues in the performance of protective devices [7].

Proper adjustment and selection of protection devices requires accurate calculation of short-circuit currents. As with all studies, accuracy in this kind of calculation is difficult to obtain given the unpredictability of the effects of each defect, so the fault impedance can fluctuate widely and include nonlinear and stochastic phenomena. Short-circuit currents therefore have an important influence on the design and operation of equipment and power supply systems. Currents flowing through the earth can induce inadmissible voltages in neighbours such as communication and power circuits. Generator group oscillations that will also lead to active and reactive power oscillations, which will lead to power transfer stability problems that can finally lead to a blackout. Therefore, the short circuit depends on different parameters such as the voltage level, the impedance at the fault point, the temperature of the equipment influencing the resistance [4], [8].

The actual situations of the distribution networks are much more complicated, the reliability of the calculation algorithm in various abnormal situations are studied. A software, cyme is used to build a simulation system of distribution networks and simulate the different types of short-circuit current and to check the thermal behaviour of the bus bars of transformer stations.

2. MATHEMATICAL EQUATIONS

2.1. ANALYTICAL METHOD

The impedance method is used to determine the value of the short-circuit current at any point in the network, by summing the resistances and reactance's of the faulty loop from the source to the fault point and calculating the equivalent impedance. The values of the short-circuit currents were calculated by using the following equations:

$$\mathrm{Icc3} = \frac{U}{\sqrt{3} * \mathrm{Zcc}} \qquad (1)$$

$$\mathrm{Icc2} = \frac{\sqrt{3}}{2}\mathrm{Icc3} \qquad (2)$$

$$\mathrm{Icc1} = \frac{V}{\mathrm{Zcc}+\mathrm{Zc}} \qquad (3)$$

Where:

U : Voltage between phases at fault point
V : Simple voltage at the point of default
Zcc : Short circuit impedance
$Icc3$: Three-phase short-circuit current
$Icc2$: Two-phase short-circuit current
$Icc1$: Single-phase short-circuit current

The fault which were giving the maximum short-circuit current is assumed to be three-phase and generally located at the start of the fault [9].

2.2. NUMERICAL METHOD

The numerical methods were based on the iterative calculation of non-linear systems of the steady state of the electrical network by reducing it to a linear system. The behaviour of an electrical network during a short circuit can be modelled by an equivalent network composed of a voltage source before the fault and impedance Z_{Ki} for the sequence of the direct system, reverse and homopolar at the fault point, the symmetric components are only connected at the fault location [10].
The following equations were related to this type of defect:

- Three-phase fault :

$$Ik_1'' = \frac{Uk}{Zk_1''} \quad (4)$$

$$Ik_2''=0 \quad (5)$$

$$Ik_0'' = 0 \quad (6)$$

- Two-phase fault :

$$Ik_1'' = \frac{Uk}{Zk_1+Zk_2} \quad (7)$$

$$Ik_2''=-Ik_1'' \quad (8)$$

$$Ik_0'' =0 \quad (9)$$

U_k: Voltage before fault at node k

Z_{ki}: Impedance of the network to the faulty node of the direct, inverse and homopolar system.

2.3. CALCULATION ALGORITHM

After modeling the network studied, the calculation of the parameters is done in four stages:

- Calculation of the voltage equivalent to the fault point.
- Determination and summation of the direct, inverse and homopolar equivalent impedances at the point of failure.
- Calculations of the initial short-circuit current using the symmetrical components.
- Determination of other quantities characteristic:
    - i_p: The peak value of the short-circuit current.
    - i_b: The effective value of the cut-off symmetrical short-circuit current
    - i_{cc} : The aperiodic component
    - i_{th} : The thermal equivalent short-circuits current.

2.3.1 CALCULATION METHOD FOR MAXIMUM SHORT- CIRCUIT CURRENTS

The calculation of maximal short-circuit current is the main design for the rating of equipment to withstand the effects of short-circuit currents (thermal and electromagnetic effects). We used the IEC60909 2001 standard. This standard applies to all radial and meshed networks up to 550KV [11]. The calculation method is based on THEVENIN theorem, which consists in calculating a voltage source equivalent to then to determine the current at that same point. All power supplies are replaced by their direct, inverse and zero-sequence impedances by neglecting all the admittances and capacities of the lines. The voltage equivalent to the point of failure is equal to

$C*\frac{Un}{\sqrt{3}}$ with C, is a voltage factor whose introduction into the calculation is necessary to take into account:
(i) Voltage variations in space and time.
(ii) Possible change of transformer outlet.

2.3.2 CALCULATION METHOD OF THE THERMAL RESISTANCE

Short-circuit currents that are flowing in the system create thermal effects due to heating on equipment and conductors. The joule integral is a measure of the energy generated in the system by the short-circuit current. It is measured by the value [11], [12].

$$Ith = Icc3 * \sqrt{m+n} \quad (10)$$

m : the time-dependent heat effect of the d.c. component of the short-circuit current.
n : the time-dependent heat effect of the AC component of the short-circuit current.

2.4. ALGORITHME GAUSS -SEIDEL

The following algorithm starts from the voltage equation for (k+1) iteration for the ith node.

$$U_i^{(k+1)} = \frac{1}{Yii}\left(\sum_{\substack{k=1 \\ j\neq i}}^{i-1} Y_{ij} * U_j^{(k+1)} + \sum_{j=i+1}^{n} Yij * U_j^k - \frac{S}{\hat{U}_i^k} + Y_{i0} * U_0\right) \quad (11)$$

U_0 : Basic voltage
S : predefined apparent power
The solution of this equation start with $U_1^{(0)} = U_2^{(0)} = U_3^{(0)} = U_4^{(0)} = \cdots U_n^{(0)} = U_0 = U_N$ as the value of the first approximation and continues until the convergence criteria is reached:

$$\left|U^{k+1} - U_i^k\right| < \varepsilon \quad (12)$$

3. NETWORK MODELLING STUDIED

Figure1 represents the single-line diagram of the SIDER -El-Hadjar distribution network, comprises three (03) modes of exploitation. The evaluation of the calculation of short-circuits currents mainly concerns operating mode 1 [13], [14], [15]:

- operating mode N ° 1: supply network 225kv + supply network 63kv
- operating mode N ° 2: power supply network 225kv only
- operating mode N ° 3: single thermal power station.

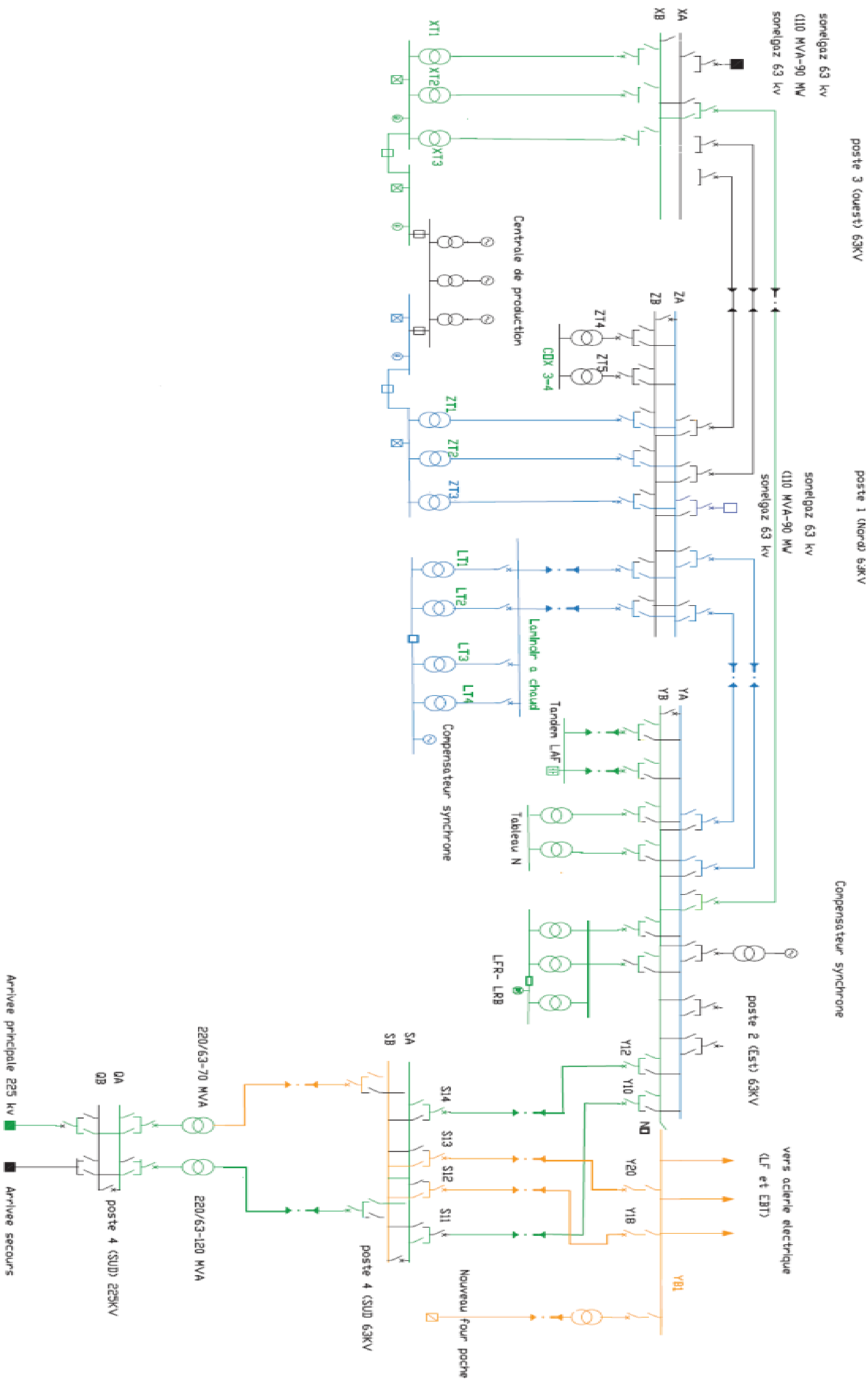

Figure 1 .Single line diagram of the SIDER El-Hadjar distribution network

4. REPRESENTATION OF THE SIMULATION DIAGRAM OF CYME SOFTWARE

The diagram in figure 2 shows the current operating mode of the sider El-Hadjar distribution network; has four (04) transformer stations powered by two independent arrivals, the 225kv supply feeds two transformers HTB / HTA TR1 of power 120MVA and TR2 of power 70MVA, the arrival 63kv feeds three transformers HTB / HTA TR6, TR7 and TR8 22.5MVA power each, the station 3 is powered from the 225kv arrival via the station 4 following the saturation of the arrival SONELGAZ 63kv with increase of the load of the station 4 by change of the transformer 70MVA by transformer120MVA.

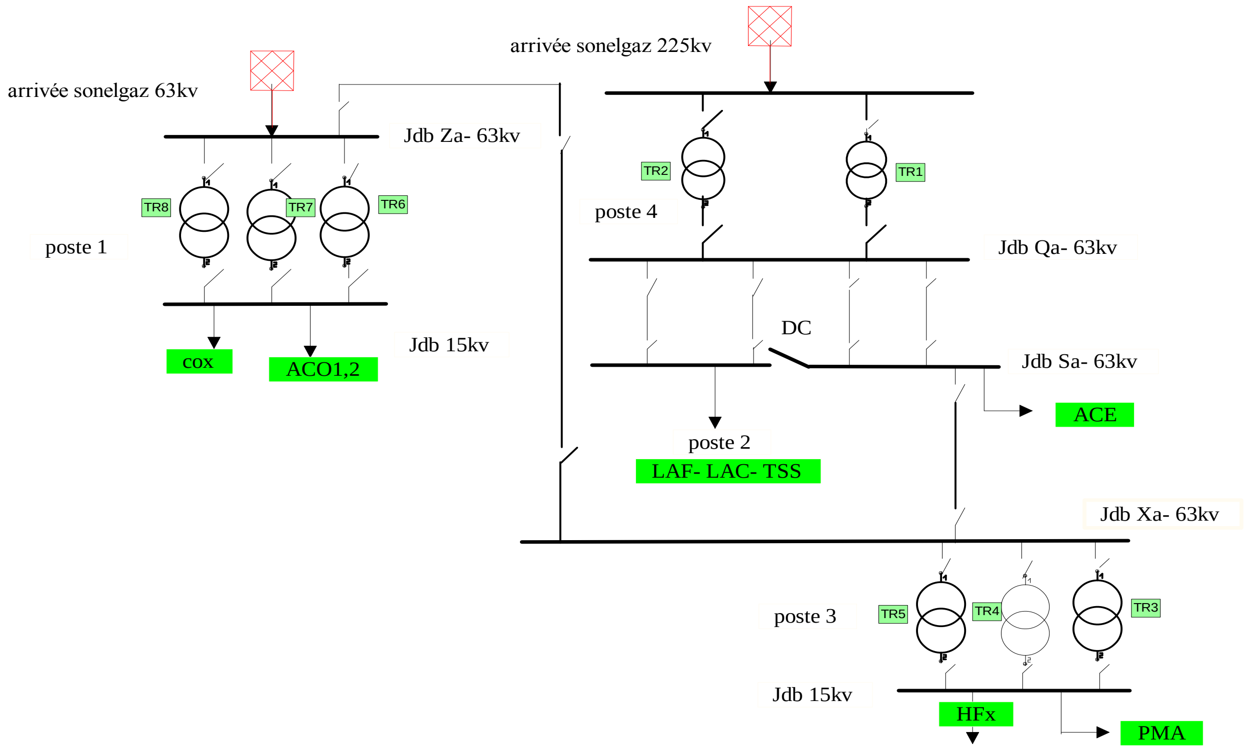

Figure 2. Simulation diagram of the SIDER El-Hadjar distribution network

Under normal operating conditions, the two transformers TR1 and TR2 operate in parallel, therefore in degraded mode, the two transformers TR1 and TR2 operate separately. The results of the simulations are shown below.

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4.1. SIMULATION OF THE LOAD

The table 1 below shows the real and simulated power exchanges between the different network elements, to compare the real charge consumed with the simulated charge.

Table 1. Comparison between real and simulated consumption

Name of substation	Real consumption			Simulated consumption			Deviation (%)	
	P(MW)	Q(MVR)	cosα	P(MW)	Q(MVR)	cosα	P (MW)	Q (MVAR)
P4	214	164	0.793	213.610	164.617	0.792	0.39	0.617
P1	47	10	0.978	44.708	9.105	0.977	0.371	0.096
P3	45	9	0.9806	44.708	9.105	0.98	0.292	0.105

ANALYSIS

The power factor at the connection points P1 and P3 with the network 63 kv is greater than 0.8 ; except the P4 station where it is less than 0.8, because there is a significant overload. In addition, it would be interesting to

distribute the charge more evenly over the three arrivals or to add a transformer 225/63kv at the south substation (P4) in order to avoid overloading.
In our simulation all the charges operate at the same time, which explains why, in the event of a loss of one of the two 63KV arrivals, the 120 MVA transformer at the P4 substation would not be able to take over the work. In this case, the power of the 225KV substation would have to be increased.

4.2 SIMULATED DEFECTS

The defects considered as major are simulated:
Three-phase, two-phase and single-phase short circuit close to the 225kv, 63kv and 15kv bar sets of the P1, P3 and P4 processing stations to be compared with the thermal resistance of the bar sets , fault calculation will be carried out according to IEC 60909-2001 norm.

Table 2. Short-circuit currents with separate operation

Name of substation	Name of JdB	Voltage (KV)	I_{cc3} (KA)	I_{cc2} (KA)	I_{cc1} (KA)	I_{th} (KA)	Result of the holding
P4	Jdb-Q_a	225	12.1	12.3	11.18	20	yes
	Jdb-S_a	63	10.6	11.4	11.81	14	yes
P1	Jdb-Z_a	63	15.5	14.7	13.37	14	NO
	Jdb-15	15	21.9	19	0.54	19	NO
P3	Jdb-X_a	63	14.2	14.1	14.02	14	NO
	Jdb-15	15	21.9	19	0.54	19	NO

Figure 3. Thermal resistance compared with maximum short circuit with separate operation

Table 3. Short-circuit currents with parallel operation

Name of substation	Name of JdB	Voltage (KV)	I_{cc3} (KA)	I_{cc2} (KA)	I_{cc1} (KA)	I_{th} (KA)	Result of the holding
P4	Jdb-Q_a	225	11.6	11.6	10.77	20	yes
	Jdb-S_a	63	15.3	17	17.63	14	NO
P1	Jdb-Z_a	63	17.7	16.9	14.79	14	NO
	Jdb-15	15	23.3	19.4	0.54	19	NO
P3	Jdb-X_a	63	17.6	16.8	14.7	14	NO
	Jdb-15	15	22.3	19.4	0.54	19	NO

Figure 4. Thermal resistance compared with maximum short circuit with parallel operation

ANALYSIS

The tables above show the thermal resistance of the different bus bars to be compared with the three-phase short-circuit current. By analyzing the tables 2 and 3, it is noted that the actual maximum short-circuit current is greater than that obtained. The maximum short-circuit current value is 15.3 KA for the network in its normal operating state, and 10,6KA in separate operating mode, we notice that the 225kv bus bars have a good thermal resistance in the face of the maximum short-circuit current, the thermal resistance of certain 63kv and 15kv bus bars to the short-circuit current is exceeded this is mainly due to asynchronous motors of medium and high power which supply a current during the short circuit. The diagrams in figures 3 and 4 give a clearer view of the thermal resistance of the bus bars with respect to the maximum short-circuit currents. These results show that the analytical calculation of the short-circuit currents is only valid for industrial networks. Those only have some transformer and loads are also mastered. As for distribution grids, the digital method is essential. In this case the authors used the Cyme software to obtain concrete and exploitable results.

5. CONCLUSION

The various simulation tests allow the following conclusions to be drawn:

- In our article, IEC60909-0 is used to calculate different types of short-circuit current in a power system. Our power system is divided into several different voltage levels, or calculations are made for short circuit on the levels of 15 kV, 63 kV and 225 kV.

- 225kV bus bars have good thermal resistance to maximum short-circuit currents.
- Some bus bars of the current installation, 63kV and 15kV in this configuration, does not hold up to maximum short-circuit currents. This is due to the fact that several medium voltage motors are connected to some panels, and operate in parallel.

6. RECOMMENDATION AND FUTURE WORK

In order to reduce the short-circuit currents on the bus bars where the thermal resistance is exceeded, we recommend the self-limiting installation at the 1 & 3 (63kV) substations.

REFERENCES

[1] Bagheri A, Monsef H, Lesani H., 2015. Integrated distribution network expansion planningincorporating distributed generation considering uncertainties, reliability, and operational conditions. Int J Electr Power Energy Syst; 73:56–70.

[2] Kaddah SS, El-Saadawi MM, El-Hassanin DM., 2015. Influence of distributed generation on distribution networks during faults. Electr Power Compon Syst ; 43(16):1781–92.

[3] Nedic, Dusko, Bathurst, Graeme & Heath J., 2007.Comparison of Short Circuit Calculation Methods and Guidelines for Distribution Networks, CIRED2007session3, paper No. 0562. 19th International Conference on Electricity Distribution; 21-24 May 2007; Vienna.

[4] Schlabbach, Jürgen., 2005. Short-Circuit Currents. London, United Kingdom: Institution of Engineeringand Technology (IET), ISBN: 0-86341-514-8 & 978-0-86341-514-2.

[5] Ghanbari T., Farjah E., Tashakor N., 2016. Thyristor based bridge-type fault current limiter for fault current limiting capability enhancement. IET Gener Transm Distrib , 10(9),2202-15.

[6] Radmanesh H., Fathi S., Gharehpetian G., 2016. Thyristor-controlled AC reactor based fault current limiter for current limiter for distribution network stability enhancement. J Electr Eng Technol,11(5),1070–6.

[7] Yang S, Wu S, Dai C., 2013. A method to fast recognize short-circuit fault based on curvature of line current waveform. Power Syst. Technol.; 37(2):551–6.

[8] Guo M, You L, Wei X, et al., 2017. A flexible current limiting method of distribution network short circuit fault based on the voltage feedback control [J]. Trans. China Electrotechn. Soc.; 32(11):48–56.

[9] International Standard IEC 60909. , 2001. "Short-Circuit current in three phases. AC. systems".

[10] Goswani S.K., Basau S.K., 1992. ''A new algorithm for the configuration of distribution feeders for los minimization", IEEE, Transaction on Power Delivery, vol. 7, no. 3? PP 1484-1491

[11] Scheif.ele, J., Waider, G., 2001. Maximal short-circuitcurrents through linear optimisation (maximale Kurzschlussströme durch lineare Optimierung). *etzArchiv* 10 (1998), pp. 275–280 current in three phases. AC. systems".

[12] International Electrotechnical Commion,IEC (2001). Ilnternational Standard-IEC 60909-0:2001

[13] Tleis, Nasser D., 2008. Power Systems Modelling and Fault Analysis: Theory and Practice. Oxford: Elsevier Ltd. ISBN-13: 9780750680745.

[14] Zhu J.Z. & Chang C.S., 2002. ''Optimal reconfiguration of electrical distribution network using the refinedgenetic algorithm'', Elect. Power Syst. Res, vol. 62, pp 37-42.

[15] Alves H., Fonseca RNB., 2014. An algorithm based on discrete wavelet transform for fault detection and evaluation of the performance of over current protection in radial distribution systems. IEEE Lat Am Trans , 1 12(4),