MATLAB APPLICATION DEDICATED TO THE AUTOMATIC CIRCUIT BREAKER SELECTION CORRESPONDING TO THE NETWORK TECHNICAL PARAMETERS

Maria BROJBOIU, Virginia IVANOV, Cristina POPESCU*

*University of Craiova, Faculty for Electrical Engineering, *CEZ Craiova*
mbrojboiu@elth.ucv.ro, vivanov@elth.ucv.ro

Abstract **– In this work a Matlab application dedicated to the automatic selection of the high voltage circuit breaker based on the its computed technical parameters depending on the network or installation parameters is presented. The ambient conditions allow the adjustment of the circuit breaker parameters. The insulation type and the manufacturing company are also the selection criteria. The technical parameters of the circuit breakers manufactured by the different companies (ABB, Siemens) are entered in a data base which allows the circuit breaker selection.**

***Keywords*:** *circuit breaker, high power network, data base selection.*

1. INTRODUCTION

The circuit breaker selection is based on the computation of its technical data depending on the input data which characterizes the network, imposed by the beneficiary. These parameters are: the primary circuit type (LEA or LEC), number of phases, rated voltage U_n , maximum operating voltage $U_{\max}$, rated frequency, rated current of the primary circuit, maximum of long standing current I_{md}, the over load regime having the limited duration, the total time of the base protection, the total time of the back up protection, the needed parameters to compute the rated short-circuit breaking/making capacity, the rated short-time withstand current, the rated peak withstand current, the characteristics corresponding to the certain operating and testing conditions, concerning the line surge impedance. It is also needful the testing the behaviour of the circuit breaker to the breaking or making of the no-load line or the circuit breaker behaviour to the breaking of the small inductive or capacitive current. Are also important the data concerning to the geographical area, altitude, the ambient conditions and the pollution level. The further restrictions for the circuit breaker selection is the necessity of the auto-reclosing (three or single phase), required conditions by the protection designer.

2. COMPUTATION OF THE CIRCUIT BREAKER TECHNICAL PARAMETERS

The rated voltage of the circuit breaker is equal to the maximum voltage of the network in the installation place. Depending on the rated voltage level, the standards in force establish the rated insulation level. *The rated circuit breaker current* I_n must subject to the relation: $I_n \geq I_{md}$.

The value of the symmetrical short-circuit current (RMS value) corresponding to the instant of the contacts opening, can be computed with the relation:

$$I_{pr} = a/2/\sqrt{2}\,, \qquad (1)$$

where a is the measured value on the short-circuit current envelope.

The rated short-circuit breaking current I_{prn} is assimilated to the maximum of the symmetrical short-circuit current values. The total asymmetrical breaking current (RMS value) in the instant of the contacts opening is computed with relation:

$$I_r = \sqrt{I_{pr}^2 + I_{cc}^2} = \sqrt{\left(\frac{a}{2\sqrt{2}}\right)^2 + b^2}\,, \qquad (2)$$

where b is the DC component of the short-circuit in the instant of the contacts opening. The maximum value of the total asymmetrical breaking current value represents *the rated asymmetrical current value of the circuit breaker*. The ratio α between the I_{pr} and I_r values depends on the time duration between the moment of the short-circuit coming out and the contacts opening instant. The ratio α value is variable under the assumptions: the dumping of the DC component of the current is 80% in 0.01s and the value of the symmetrical component is constant:

$$\alpha = \left(\frac{I_{pr}}{I_r}\right) = \sqrt{1 + 2\beta^2} \text{ ,where } \beta = 2b/a\,. \qquad (3)$$

The maximum value of the short-circuit current DC component depends on the β values:

$$\beta = I_{cc} / \left(\sqrt{2 \cdot I_{pr}}\right). \quad (4)$$

The rated transient recovery voltage is the voltage for which the rated short-circuit breaking current is guaranteed. The parameters of this voltage are: U_m the peak value at the rated frequency 50 Hz, $f^{'}$ the transient recovery voltage frequency, t_m the instant of the transient recovery voltage peak value, δ is the transient recovery voltage dumping coefficient:

$$u_r = U_m \left(1 - e^{-\delta \cdot t} \cos 2\pi f\,'\right). \quad (5)$$

The standards in force gives the $f^{'}$ values depending on the rated symmetrical breaking current I_{prn} or $0.6 I_{prn}$, corresponding to the voltage factor $k = 1.5$. For the other I_{pr} values, the references in the field give the following computation relation for the transient recovery voltage frequency [1]:

$$f_x^{'} = f_1^{'} + \left(f_{0.6}^{'} - f_1^{'}\right) \cdot \left(\frac{1.5}{x} - 1.5\right). \quad (6)$$

For the smaller breaking current values than $0.6 I_{prn}$ the $f^{'}$ value is taken equal to $f_{0.6}^{'}$.

The rated short circuit making current I_{in} is correlated with the peak value of the closing current I_i. The last one value depends on the network configuration, the fault type and its location, as well as the voltage value. The computation of the I_i value is made depending on the I_{po} value and the ratio R/X value where *R* and *X* are the components of the complex impedance: $I_i = \chi \sqrt{2} I_{po}$, where I_{po} is the initial effective value of the short-circuit current symmetrical component and χ is the peak coefficient of the short-circuit current.

The rated short circuit making current will be $I_{in} = 1.8 \chi I_{prn}$.

The rated short time withstand current (RMS value), is the maximum current which the circuit breaker shall be able to carry in closed position during a specified short time. Usually it is equal to the rated short- circuit breaking current. The rated short time withstand current gives a measure of the circuit breaker thermal stability and depends on the fault place where the thermal stresses are maximum. The average thermal equivalent current I_m having the same thermal effects during 1s time, is computed:

$$I_m = I_{po} \sqrt{(m+n) \cdot t}, \quad (7)$$

where *m* is the coefficient which takes into account the DC current component contribution and *n* is the coefficient which takes into account the variation with time of the RMS value of the short-circuit current, $m = f(t, \chi)$, $n = f(t, I_{po}/I_\infty)$, where I_∞ is the RMS value of the steady state three phase short-circuit current. The total opening time depends on the base protection type.

The rated peak withstand current of the circuit breaker I_d gives a measure of the electro-dynamical stability circuit breaker. Usually, the rated peak withstand current value is taken equal to the rated short-circuit making current and the following condition must be fulfilled:

$$\chi \sqrt{2} \cdot I_{po} \le I_d. \quad (8)$$

Regarding to *the ambient conditions*, the circuit breaker keeps its assured parameters by the manufacturer only within the ratings covering the range of the operation temperature, relative humidity and air pressure. The circuit breaker performances are also assured for the maximum 1000 m design altitude. For the higher altitude than this one, the correction of the parameters is required. Thus, the allowable over-temperature values are decreased with 1% for each 300m exceeding of the design altitude. The insulation distances in air are also reduced with 3% for each 300m exceeding. The air relative humidity has the influence on the flashover voltage value, $U_c = U_{co} \cdot (\delta / k_u)$, where U_{co} is the flashover voltage value in the normalized operating condition and δ is the relative air density.

The rain, the wet fog, the dew and the snow lead also to the decreasing flashover voltage value:

$$U_{cp} = U_{co} \cdot k_p, \quad (9)$$

where $k_p = 0.5 \cdot (1 + p/760)$.

Taking into consideration of the climatic factors is very important because the National Energetic System from Romania meets annually undesired events (incidents, damages) due to the wind and the ice deposition, the acts which are amplifying because of the intense climatic changes. Consequently, SEN divides the national territory in several meteorological areas in accordance with the wind speed and the coating thickness of the hard rime layer [2].

The wind load over the electrical equipment can be computed using the relation: $p = 0.7 \cdot v_{max}^2 / 10 \ [N/m^2]$, where $v_{max} [m/s]$ is the maximum wind speed value.

With respect to the circuit breaker operating sequence this depends on the three or single phase auto-reclosing requirement, imposed by the installation designer.

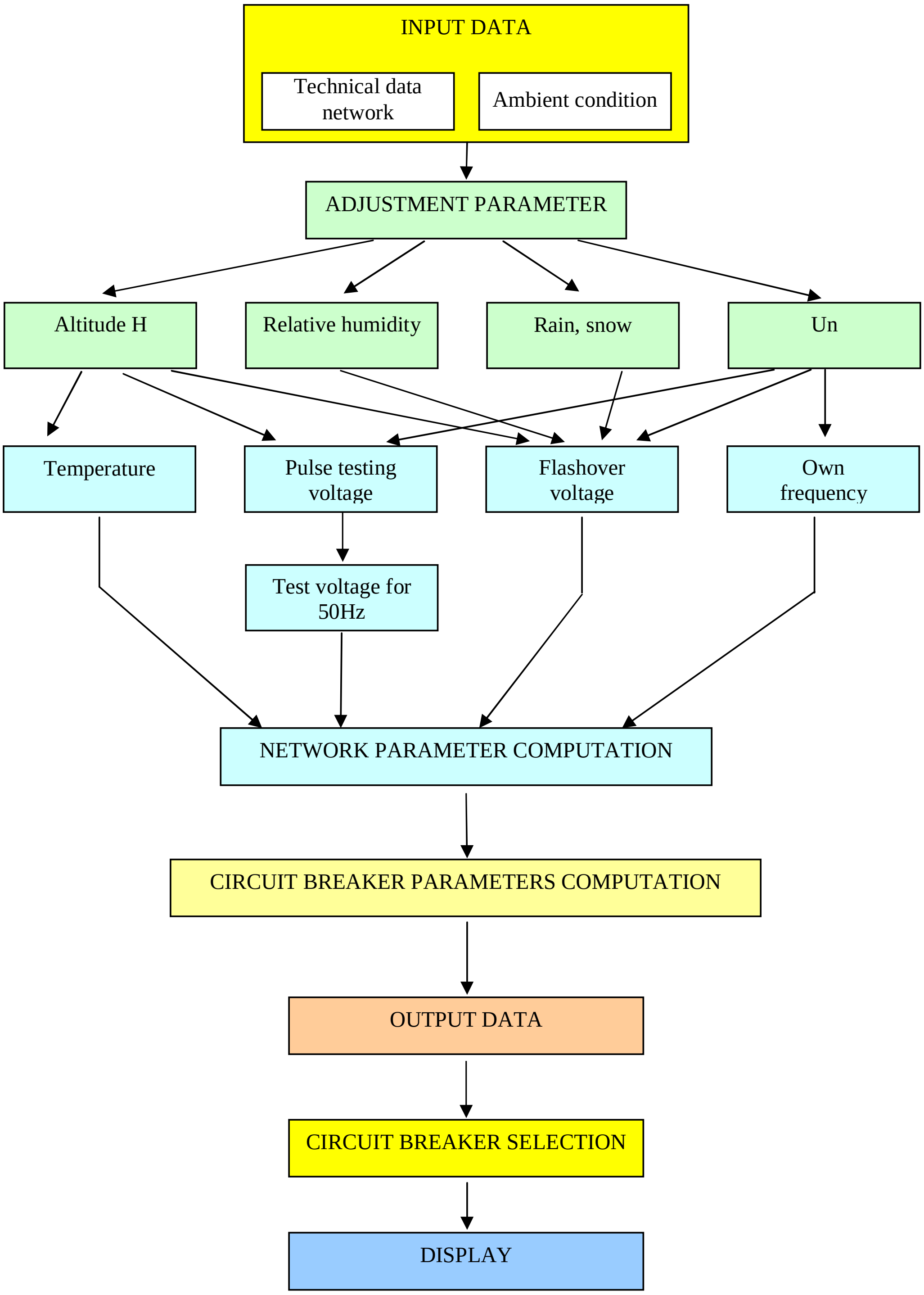

Figure 1: The flow chart of the Matlab application.

There are two alternatives: a) O–3min-CO-3min-CO for the circuit breakers not intended for rapid auto-reclosing or O-0.3s-CO-3min-CO for the circuit breakers intended for rapid auto-reclosing; b) CO-15sec-CO for circuit breakers not intended for auto-reclosing.

Another selection criterion such as *the operating mechanism type* or the type of arc extinguishing are also taken into consideration. The circuit breaker behaviour face to the special disconnecting regimes such as the short line fault disconnecting, no load line disconnecting, and small inductive or capacitive current disconnecting there is also an important criterion circuit breaker selection. Therefore if the circuit breaker disconnects an earth fault not far from the circuit breaker, travelling waves generate a very step initial recovery voltage. This initial recovery voltage is depending on the short circuit current and the surge impedance. The surge impedance has been standardized to a value of 450Ω. Other parameters for the short line fault are the peak factor and the rate of rise of recovery voltage (RRRV) factor which have the following standardized values: peak factor 1.6 and RRRV factor: 0.2kV/µs for 50Hz. Thus the circuit breaker is able to disconnect the short line fault only if its rated transient recovery voltage is in any time beyond the transient recovery voltage. The values of the peak voltage u_m and the RRRV factor depending on the ratio $k = I_{pr} / I_{prn}$ can be computed using the relation from the Table 1 [3]:

Characteristic	$k = I_{pr} / I_{prn}$		
	0.9	0.75	0.6
$u_m = 2\frac{\sqrt{2}}{\sqrt{3}} U_n (1-k)$ [kV]	$0.16U_n$	$0.4U_n$	$0.65U_n$
RRRV [kV/µs] $U_n \le 220kV$	$0.2I_{prn}$	$0.165I_{prn}$	$0.13I_{prn}$
RRRV [kV/µs] $U_n = 380kV$	$0.16I_{prn}$	$0.135I_{prn}$	$0.11I_{prn}$

Table 1: Parameters and theirs values.

Between the distances to the fault location, which leads to the different values of the *k* ratio there are the relations $L_{0.75} = 3L_{0.9}$ and $L_{0.6} = 6L_{0.9}$, where the indices correspond to the *k* values.

3. THE MATLAB APPLICATION DESCRIPTION

The Matlab application is dedicated to the computation of the circuit breaker parameters having as input data the network technical data imposed by the beneficiary or the program user.

The computed data allow the circuit breaker selection from the data base which comprises the circuit breaker parameters produced by the companies in the field such as ABB, Siemens, Electroputere Holding. The flow chart of the Matlab application is presented in Figure 1.

The input data are: a) concerning the network or installation, b) concerning the environment. The input data can be entered from the keyboard or from the data files made actual when is needed concerning the beneficiary requirements. The program allows the automatic choosing of the correction factors: k_u depending on the relative humidity value and the altitude value, k_p depending on the air pressure, choosing of the specific creepage distance depending on the pollution level, choosing of the χ coefficient depending on the R/X ratio, the choosing of the *m* and *n* coefficients. All these data are introduced in a vectorial or matriceal form corresponding to presentation form from the references in the field. Corresponding to the output data the circuit breaker parameters are presented in vectorial form or in the text files. The program comprises a data base corresponding to the circuit breakers types produced by the companies, selected after the insulation type and the manufacturing companies. The circuit breaker selection in accordance with the beneficiary requirements or the network technical data is made by the comparison of the computed data vector components with the vector components from data base.

4. CONCLUSIONS

In this paper a Matlab application dedicated to the automatic selection of the high voltage circuit breaker based on the its computed technical parameters depending on the network or installation parameters is presented.

References

[1] D. Cristescu, L. Pantelimon , S. Darie, *Centrale şi reţele electrice*, Editura Didactică şi Pedagogică, Bucureşti, 1982.

[2] **** , *Întreruptoare de înaltă tensiune*, Îndrumar de proiectare centrale şi statii, volumul IV, Institutul de studii şi proiectări energetice, Bucureşti, 1966.

[3] *** - http://library.abb.com.