Optimization of LV Electrical Installation Design Introducing Novel Software: ElecDesigner®

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***Abstract*—In this article we introduce new version of software for designing building's electrical installation. The aim of this software is to provide optimal solutions in the field of electrical installations buildings especially in low voltage networks. Designed application will have the ability to create DXF file containing riser and single line diagram according to designed installation. It also provides a Microsoft Word document of performed calculations. Proposed software is a major step forward in the implementation of national regulations and following electrical engineers rules in Engineering Organizations. In addition it improves the quality of electrical installation implementation in buildings and immunes reworking.**

***Keywords*—electrical installation;national building regulation; building; software**

I. Introduction

Traditional manual methods in electrical installation are time-consuming and they might contain computational errors. In addition generating auto-cad maps are tedious without any useful tools to work with. In the presented software, the designers are able to use different low voltage elements in design platform in order to compute necessary parameters. The software optimized executive and designed costs; in addition it minimized computational errors. National standards have also been included in the software. Saving electrical energy and systematic buildings are some of the greatest side-effects of this software.

The following parts contain the software introduction including main elements in the designed low voltage network. Section III reviews the important calculation formulas which are used to computes required information. Section IV describes implemented algorithms and section V illustrates the obtained results of the software.

II. Software Introduction

This paper presents the third version of Parham electrical installation software which has been registered in 2009[1]. There are some improvement in different areas such as accuracy and level of calculations and great design platform by using rich graphical user interface. Automatic generating computational book according to user design and auto-cad map report are other advantages of the current version.

The software includes different sections such as low voltage network, lighting calculations by Lumen method, lightning by NFC standards, elevator motor power calculation, fire alarm system, generator and earthling system. The low voltage network is the most complete section of the software and it will be described in details in the following.

A. Main elements of low voltage network

There is a toolbox containing all necessary elements for designing single line diagram of a low voltage network in the left side of the software window. This toolbox contains transformer with upstream network, input feeder in the case of using common transformer in distribution network, bus bar, input feeder with meter panel, loads (motor, consumers and luminary). Each element has a properties window in the right side of the software which allows the user to customize the parameters values in order to meet the project specifications.

III. Low Voltage Equations and Calculations

A. Estimation of simultaneity factor

Simultaneity factor affects the calculation of maximum installation demand and main entrance current rating. Additional information like environment and usage parameters change the values of simultaneity factor. In the third subsection of 13th Iran national building regulations, two methods are introduced to set the main branch specification. One is to use simultaneity factor for loads according to available tables and the other is to use experienced local rules. In this software we recommend simultaneity factors it is described in Schneider Electric Handbook [2].

B. Utilization Coefficient (Ku)

In normal operating conditions the load power consumption is sometimes less than its nominal power rating. This factor must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load. Ku is also used in the software as a part of demand calculations.

C. Cable Calculations

Cable calculations in building are generally according to current and voltage drop. The proposed software also considers the impact of harmonics and short circuit calculations according to ABB handbook. Table 1 demonstrates the way of calculating correction factors to affect the third harmonic component [2]. Also to calculate cable with stood against short circuit, the minimum short circuit is computed, as illustrated in equation 1.

$$I^2 t \leq K^2 S^2 \quad (1)$$

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Table 1: correction factors for third harmonic component, $I_N = \frac{I_b}{k_{tot}} * 3 * k_{III}$

The impact of third harmonic component	Reduction factor			
%	CS_Current	Maximum $I_b^{'}$	CS_Neutral Current	Maximum $I_b^{'}$
0 ÷ 15	1	$I_b^{'} = \frac{I_b}{k_{tot}}$	-	-
15 ÷ 33	0.86	$I_b^{'} = \frac{I_b}{k_{tot} * 0.86}$	-	-
33 ÷ 45	-	-	0.86	$I_b^{'} = \frac{I_N}{0.86}$
> 45	-	-	1	$I_b^{'} = I_N$

Table 2: maximum withstood energy for cables, $\mathbf{K^2S^2}$

Cable		k	Cross section [mm²] 1.5	2.5	4	6	10	16	25	35
PVC	Cu	115	$2.98 \cdot 10^{-2}$	$8.27 \cdot 10^{-2}$	$2.12 \cdot 10^{-1}$	$4.76 \cdot 10^{-1}$	1.32	3.39	8.27	$1.62 \cdot 10^{1}$
	Al	76	$1.30 \cdot 10^{-2}$	$3.61 \cdot 10^{-2}$	$9.24 \cdot 10^{-2}$	$2.08 \cdot 10^{-1}$	$5.78 \cdot 10^{-1}$	1.48	3.61	7.08
EPR/XLPE	Cu	143	$4.60 \cdot 10^{-2}$	$1.28 \cdot 10^{-1}$	$3.27 \cdot 10^{-1}$	$7.36 \cdot 10^{-1}$	2.04	5.23	$1.28 \cdot 10^{1}$	$2.51 \cdot 10^{1}$
	Al	94	$1.99 \cdot 10^{-2}$	$5.52 \cdot 10^{-2}$	$1.41 \cdot 10^{-1}$	$3.18 \cdot 10^{-1}$	$8.84 \cdot 10^{-1}$	2.26	5.52	$1.08 \cdot 10^{1}$
Rubber	Cu	141	$4.47 \cdot 10^{-2}$	$1.24 \cdot 10^{-1}$	$3.18 \cdot 10^{-1}$	$7.16 \cdot 10^{-1}$	1.99	5.09	$1.24 \cdot 10^{1}$	$2.44 \cdot 10^{1}$
	Al	93	$1.95 \cdot 10^{-2}$	$5.41 \cdot 10^{-2}$	$1.38 \cdot 10^{-1}$	$3.11 \cdot 10^{-1}$	$8.65 \cdot 10^{-1}$	2.21	5.41	$1.06 \cdot 10^{1}$

Cable		k	Cross section [mm²] 50	70	95	120	150	185	240	300
PVC	Cu	115	$3.31 \cdot 10^{1}$	$6.48 \cdot 10^{1}$	$1.19 \cdot 10^{1}$	$1.90 \cdot 10^{2}$	$2.98 \cdot 10^{2}$	$4.53 \cdot 10^{2}$	$7.62 \cdot 10^{2}$	$1.19 \cdot 10^{3}$
	Al	76	$1.44 \cdot 10^{1}$	$2.83 \cdot 10^{1}$	$5.21 \cdot 10^{1}$	$8.32 \cdot 10^{1}$	$1.30 \cdot 10^{2}$	$1.98 \cdot 10^{2}$	$3.33 \cdot 10^{2}$	$5.20 \cdot 10^{2}$
EPR/XLPE	Cu	143	$5.11 \cdot 10^{1}$	$1.00 \cdot 10^{1}$	$1.85 \cdot 10^{1}$	$2.94 \cdot 10^{2}$	$4.60 \cdot 10^{2}$	$7.00 \cdot 10^{2}$	$1.18 \cdot 10^{3}$	$1.84 \cdot 10^{3}$
	Al	94	$2.21 \cdot 10^{1}$	$4.33 \cdot 10^{1}$	$7.97 \cdot 10^{1}$	$1.27 \cdot 10^{2}$	$1.99 \cdot 10^{2}$	$3.02 \cdot 10^{2}$	$5.09 \cdot 10^{2}$	$7.95 \cdot 10^{2}$
G2	Cu	141	$4.97 \cdot 10^{1}$	$9.74 \cdot 10^{1}$	$1.79 \cdot 10^{1}$	$2.86 \cdot 10^{2}$	$4.47 \cdot 10^{2}$	$6.80 \cdot 10^{2}$	$1.15 \cdot 10^{3}$	$1.79 \cdot 10^{3}$
	Al	93	$2.16 \cdot 10^{1}$	$4.24 \cdot 10^{1}$	$7.81 \cdot 10^{1}$	$1.25 \cdot 10^{2}$	$1.95 \cdot 10^{2}$	$2.96 \cdot 10^{2}$	$4.98 \cdot 10^{2}$	$7.78 \cdot 10^{2}$

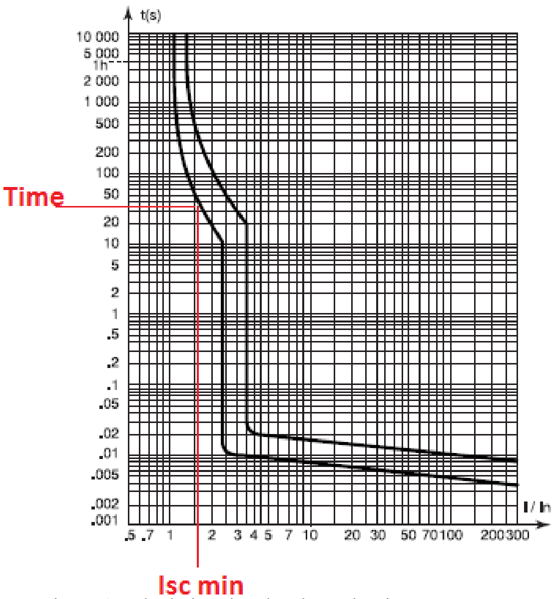


Figure 1: calculating time by short-circuit current

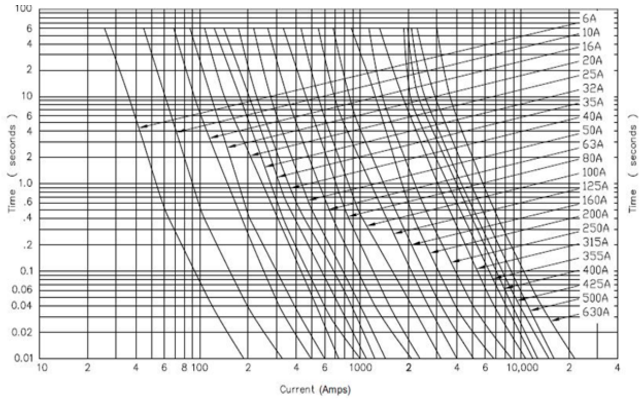


Figure 2: Time-current relation for fuse

Figure 2 demonstrates how to calculateI^2t. After calculating short-circuit current, cut-off time is computed and equation 1will be considered. Table 2 shows maximum withstood energy for cables (K^2S^2) [4]. Another factor to be considered in cable calculations is starting current which is calculated through the equation 2 [2].

$$I_b^{'}=I_b + \frac{I_{starting}}{3} \quad (2)$$

For Example the initial values for direct starting currents are as follows,

$$Dol \begin{cases} 1\ phase = 7 - 20 \\ 3\ phase = 4 - 7 \end{cases}$$

D. Short-Circuit Calculations

Another issue which is not commonly used in designing low voltage network is short-circuiting calculations. According to ABB Handbook, approximate methods for computing short circuits are sufficient [4]. Further information is available in [4].

$$I_k = \frac{S_k}{\sqrt{3}.U_r} \quad \text{Three phases short circuit} \quad (3)$$

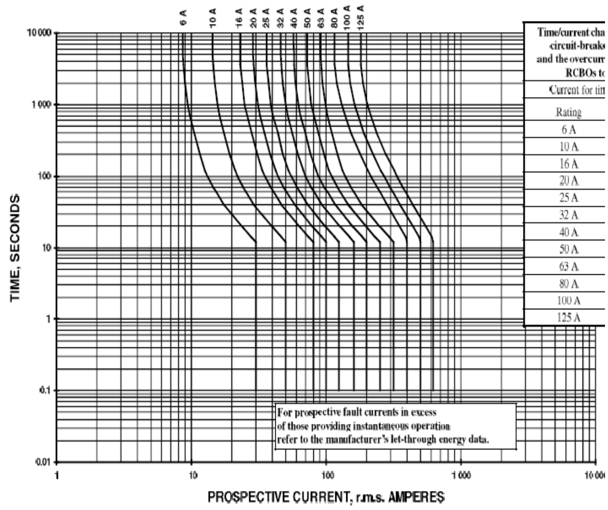
$$I_k = \frac{S_k}{2.U_r} \quad \text{Two phases short circuit} \quad (4)$$

E. Protection Curves

Protection Curves are used for short-circuit calculations. General curves based on IEC and BS standards are being considered to obtain related line equations.

- Fuse Protection Curves:

F. ElecDesigner computes the fuse calculations according to *Figure 3: Approximate linear equation with several segments*



[3]. In order to obtain the curves equations, each curve as shown in Figure 4 is approximated with a number of segments. For each segment, we have the following relations:

$$t = AI + B \tag{5}$$

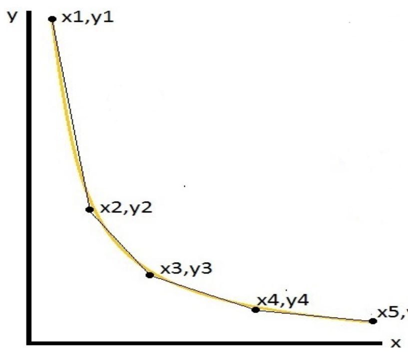


Figure 3: Approximate linear equation with several segments

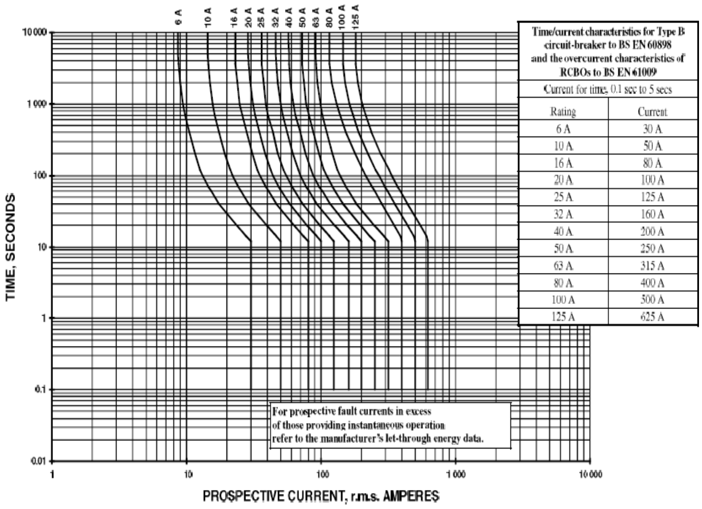


Figure 4: MCB curve, Type B.

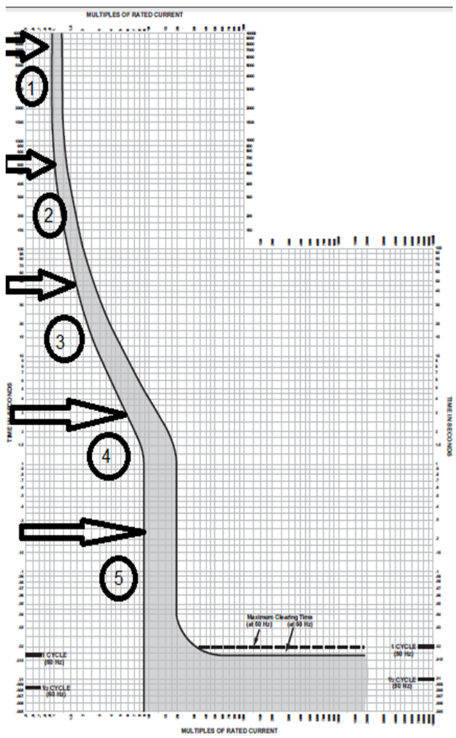


Figure 5: Compact switches curve

Table 3: Curve equations for Compact Switches

x_1	y_1	x_2	y_2	A	B
					$i < 1.15 I_n \rightarrow t = \infty$
1.1	1500	1.2	300	$\frac{1200}{1.1K_1 - 1.2}$	$\frac{330K_1 - 1800}{1.1K_1 - 1.2}$
1.2	300	2	30	-337.5	805.7
2	30	K_2	1.2	$\frac{28.8}{2 - K_2}$	$\frac{2.4 - 30K_2}{2 - K_2}$
					$\frac{I}{I_n} > K_2 \rightarrow t = 0.1$

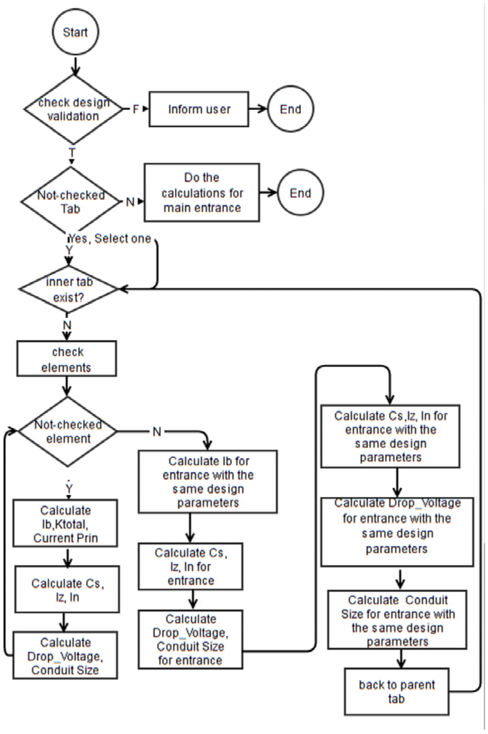


Figure 6: The flowchart of first calculation step (button-up)

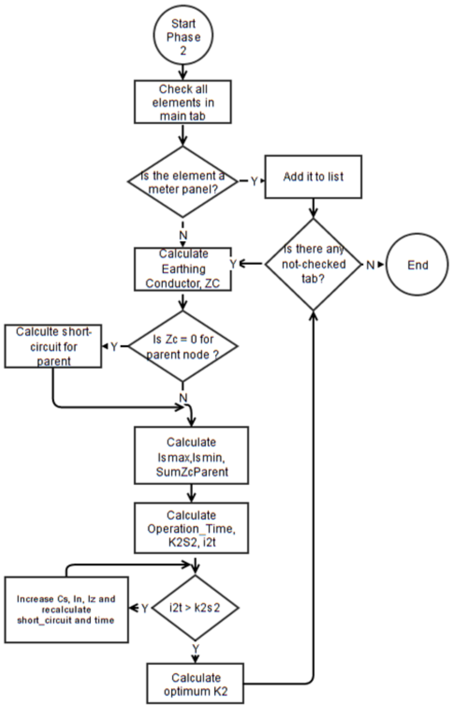


Figure 7: The flowchart of second calculation step (top-down)

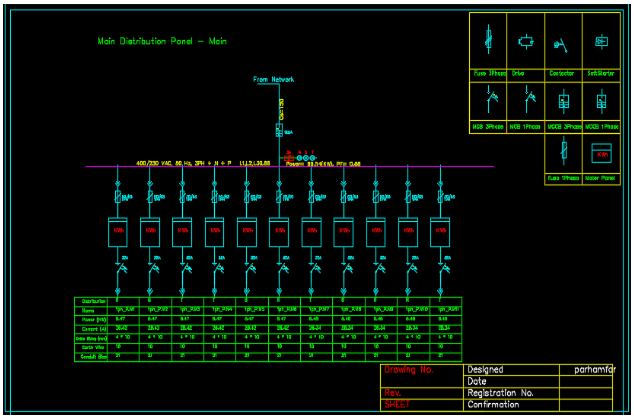


Figure 8: sample of single line diagram exported in AutoCAD

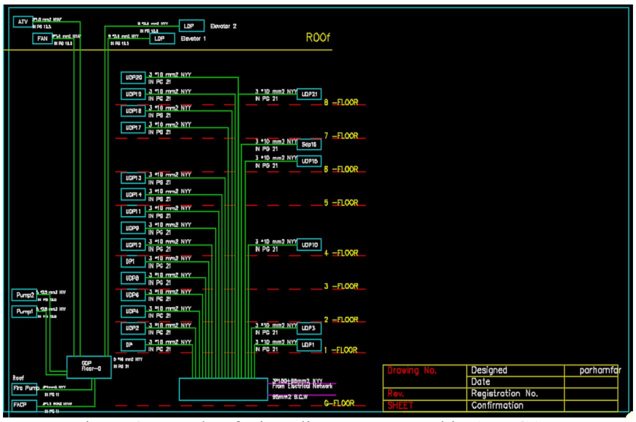


Figure 9: sample of Riser diagram exported in AutoCAD

$$A = \frac{y_1 - y_2}{x_1 - x_2} \quad (6)$$

$$B = \frac{x_1 . y_2 - x_2 . y_1}{x_1 - x_2} \quad (7)$$

- MCB Protection Curves:

  Figure 4 is extracted from BS EN60895 standard. All MCB types are considered to approximate the segments.

- MCCB Protection Curves:

To determine the related equations for compact switches, the curve would be divided to five segments which three of them are constant and the others are changing depends on K_1 and K_2. K_1 is the current setting of short-circuit relays and K_2 is the current settings of overload relays. K_1 is usually between $0.4I_n$ and $1I_n$and K_2 is between $4I_n$ and $10I_n$. In high quality Switches, K_1 is between $0.2I_n$ and $1I_n$ and K_2 is between $2I_n$ and $10I_n$.

If the switch is set on 4In, for $I_{sc} < 4I_n$ the switch is worked based on delayed curve and for $I_{sc} > 4I_n$ the definite curve with the constant value of time 0.1 sec. the resulting equations are shown in table 3.

IV. Applied Algorithms in the Software

There are two categories of button-up and top-down calculations in the proposed software. In order to calculate the current and cable sizing of up-stream Network, down-stream currents are required. In other hand, short-circuit calculations needs to be done top-down. It starts from up-stream elements and reaches down-stream ones hierarchically. Figures6, 7 demonstrate the flowcharts of performed calculations in the software.

V. Software Output

The most important features of the proposed application are providing Microsoft Word document of performed calculations and a DXF file contains single line and Riser diagrams in AutoCAD. Figures 8, 9 demonstrate sample outputs of the application.

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