

Cable Cost Optimizer

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Abstract

Electrical installations are considered as an important section of modern buildings. The International Standard IEC 287-3-2 (Economical Optimization of Power Cables) specifies a method to select an optimum cable size to minimize the total costs incurred in such systems.

A manual calculation to estimate the economically optimized cable using this method would be tedious and requires handling a lot of information regarding available types of cables and specifications of the installation

Cable Cost Optimizer (CCOp) is the software solution, which addresses these issues by estimating the optimum cable and an economical analysis of costs over the lifetime. CCOp provides solutions to cables operating at a rated voltage of 3.3 kV or below. It is a valuable tool for designers and analyzers of electrical installations, consultants, personals in academia and engineering students.

Index Terms

Optimum, Economical, Power, Cable, Cost

1.0 INTRODUCTION

When selecting cables for Wiring Installation, in conventional designs, designer's consideration mainly focuses on the maximum permissible current and thus not to exceed the maximum permissible temperature, keep the voltage drop within the specified limits by the standards and prospective short circuit capacities of cables. But according to the present management concepts, one cannot really neglect the economic aspects of a design of wiring installations, as cost optimization is a must in modern project planning. This is not only by saving the initial installation costs but also considering the minimization of operational costs. In that sense it is very important to minimize the demand charge and energy cost that incurs due to the losses of the power cables (Conductor I^2R loss, Sheath/Screen loss, Armour loss, Dielectric loss etc.). To find the solution for this inquest, IEC 287, 853 and 502 provides the necessary guidelines. But it is a common truth that referring those standards is a real dilemma and time-consuming. Especially designers may not be prepared to allocate their precious time on this sort of exercises. They generally follow the conventional method.

The proposed solution of *Cable Cost Optimizer* software overcomes this problem by facilitating the designers to find the economically optimum cable in an easy way in accordance with the standards.

Another important aspect is the price of this type of software package in the international market. Generally this much of user-friendly and versatile software package costs about few millions. Therefore developing a software

package to facilitate the professionals here in Sri Lanka, in the field of power cable installation design, to a low cost is a substantial effort, not only because of it helps to select the economically optimum cable but also it saves the time of engineers and consultants that worth more than billions. Thus this endeavor was carried out as a final year project of electrical engineering degree course at University of Moratuwa. Microsoft Visual Basic-6 was used as the programming language for this software package. Databases were created using Microsoft Access and SQL was used to handle the databases with ADO and DAO objects. This software program supports continuous load calculations as well as cyclic load calculations up to the voltage level of 3.3 kV.

2.0 SELECTION OF CABLES - THE CONVENTIONAL METHOD

The conventional method of wiring installation design mainly based on 16th Edition of IEE regulations. In this regulation economical aspect of designing is hardly considered. Main focus has been kept only on the protection of individuals and equipment involved with the power circuits.

2.1 The Parameters Considered

In conventional method of design, at the beginning, the rated current of the path must be identified (I_R). Then the over current devices must be selected accordingly, at the same time considering the short circuit capacity of the path. Then by applying the de-rating factors according to the operating conditions and the installation environment we can calculate the design current (I_Z) through the path. Then the required type of cable can be selected with the help of ampacity tables. Then we must check for Voltage drop of the path. According to the regulations and practical experiences allowable percentage voltage drop must be less than 4 % of that path from the protective device to the equipment mains.

If the limitation of design current, voltage drop and prospective short circuit capacity are satisfied, that power cable is accepted as the cable that should be used for that installation.

2.2 Behavior of the Cost

In the conventional method there is no considerable focus on the losses incurred with the power cables. I.e. Conductor I^2R loss, Sheath/Screen loss, Armour loss, Dielectric loss etc. Also the long-term influence of these parameters on the energy cost; in the point of view of economics are not considered. If the amount paid for this energy loss for a period of lifetime of installation can never be ignored in any circumstances as it give-rise to

energy cost as well as demand charge. But by selecting the optimum power cable it is possible to save these unnecessary expenditures. In the following clause the way of saving is elaborated.

3.0 ECONOMICAL OPTIMIZATION OF THE POWER CABLE SIZE

The finest solution is to select the cables considering wider economic grounds. The sum of the initial cost and the cost of the losses over the economic life of the cable should be minimized rather than minimizing the initial cost only. For this condition a larger size of conductor should be selected than otherwise which would be chosen based on thermal ratings. The larger sized cable will lead to lower power loss for the same current, thus making it less expensive when considered over its economic life

3.1 The parameters considered

Unconditionally the economically optimized cable size should not be less than that of the thermal ratings. This condition must not be violated for any estimated optimum cross section.

The cost of the losses is the key parameter considered for the selection of the economically optimized power cable size. The future costs of energy losses during the economic life of the cable can be calculated by making suitable estimates of load growth and cost of energy.

Parameters considered for the estimation are the details of the cable and the supply system. These can be divided in to three categories; *Load Data*, *Financial Data* and *Cable Data*.

Load data is basically the details of the load currents and operating voltage of the installation. Other minor details such as cable length and rated voltage of the cable also come under this category. These data are used to calculate the thermal equivalent current and thus the Joule loss.

Financial data is used to calculate the cost of losses and the total cost. Economic life, Operating time, Price of joule losses at end of first year, Demand charges, Cable and insulation cost per unit length, Annual increase of load, Annual increase of cost of energy and Annual discounting rate are the parameters considered under financial data.

Cable data are the technical details of the cable. The AC resistance of the conductor, armor and screen loss factors and permissible maximum temperature etc. come under this category. These parameters are necessary to calculate the apparent resistance of the conductor; which is a must to calculate the Joule loss.

3.2 Method of estimate

Estimate of the economically optimized cable size is done in accordance with the method specified by the international standard IEC 287-3-2. The objective of the specified method is to find the cable size which minimizes the total cost. In other words to find the conductor cross

section, where, the derivative of the total cost function with respect to conductor cross-section becomes zero. The simplified total cost function is as follows.

$$\text{Total cost (CT)} = \text{Installation cost (CI)} + \text{Cost of Joule losses (CJ)} \quad (1)$$

All the costs are brought to the present values at a given discount rate. The function for the cost of Joule losses is,

$$\text{Cost of Joule losses (CJ)} = (I_{eq})^2 \cdot R \cdot l \cdot F \quad (2)$$

I_{eq} is the 24 Hour thermal equivalent current on the cable during the first year, in amperes.

R is derived from the parameters specified by cable data. To calculate R it is necessary to know the values of DC resistivity of the conductor, the skin and proximity effect factors, the screen and armor loss factors, temperature coefficient of resistivity, conductor temperature and the conductor cross section. [11]

Length of the cable is represented by ‘l’. F is a complicated factor based on financial parameters. To define F it is necessary to know the values of the cost of one watt –hour of energy at the relevant voltage level, the demand charge per year, the discount rate, the increasing in load, the increase in cost of energy, the operating time and the number of phase conductors per circuit. [11]

The function for Installation cost can be stated as

$$\text{Installation cost (CI)} = l \cdot (A \cdot S + C) \quad (3)$$

A Variable component of cost
C Constant component of the cost

Then the optimize size S (ec) mm² can be obtained by equating to zero the derivative of the Total Cost equation with respect to S, giving:

$$S(ec) = 1000 \left[\frac{I_{eq}^2 \cdot F \cdot \rho_{20} \cdot B (1 + \alpha_{20} (\theta_m - 20))}{A} \right]^{0.5} \quad (4)$$

ρ_{20} Conductor resistivity at 20 C

α_{20} Constant mass temperature coefficient at 20° C/°C

θ_m Mean ambient temperature.

Factor B is derived considering the influence of skin effect factor, Proximity effect factor, armor loss factor and sheath/screen loss factor. [11]

Derivation of S(ec) is iterative and an initial assumption is needed to decide the values of the factors associated with the above equation. By selecting the cross section of the cable defined by thermal ratings we can arrive at a fairly good solution, which converges, to the root. [11]

The value given by S(ec) is compared with the cable cross sections available in the market and the closest cable size which gives the minimum total cost without violating the thermal constraints is selected (I.e. S).

3.3 Behavior of the cost

For the values of the financial and electrical parameters used in the standard IEC 287-3-2, which are not exceptional, the saving in the combined cost of purchases and operation is of the order of 50%.

A further important feature is that the savings possible are not critically dependent on the conductor size when it is in the region of the economic value. This has two implications.

- a) The impact errors in the financial data, particularly those which determine future cost is small. While it is advantages to seek data having the best practicable accuracy, considerable savings can be achieved using data based on reasonable estimates.
- b) Other considerations with regard to the choice of conductor size which feature in the overall economics of an installation, such as fault currents, voltage drops and size rationalization can all be given appropriate emphasis without losing too many of the benefits arising from the choice of an economic size.

4.0 CABLE COST OPTIMIZER 2004 SOFTWARE PACKAGE

4.1 An Insight

Cable Cost Optimizer (CCOp) is the windows based, user-friendly graphical interface software package for getting the most economical cross section area of cables for the user installations. The user has to enter some of the user installation data and then the software database supplies the remaining cable and other relevant data for internal calculations for getting the optimum solution. The software also facilitates the user to analyze and graph the results for getting an overall picture of the future installation.

This software package is a valuable tool for designers and analyzers of electrical installations, consultants, personals in academia and students. Cop avoids the ambiguous situations of following standards, huge manual calculations and making erroneous decisions. CCOp make it easier to designers of electrical installation systems to go for the economically optimal cable while providing the best solution to the investors. As we all know; at the end of the day, what really matters is the economics.

4.2 How to Manipulate CCOp

Commands and menu options of CCOp can be simplified into following main functioning areas.

1. *Projects*
2. *Data input & output*
3. *Analyze*
4. *Graphs*
5. *Data Base*
6. *Help & Supports*

4.2.1 Projects

Facility is provided to open a new project or an existing project. A new project is a fresh file where user can start from the scratch. Also the user can open an “existing project” to continue with or to edit previously entered installation data to get the most economical cable for the given installation under the given affecting conditions.

4.2.2 Data input & output

Data gathering and result displaying is done in four main steps.

The “Load details” window (step 1 of 4) is used to enter the installation details such as System voltage, Cable length, Cable voltage levels and line current values of the load curve for 24 hours of the system. The user is entertained with an option to select the given best-suited test cases for his installation to get a set of rough load current values to represent the user load curve pattern.

The “financial details” window (step 2 of 4) is used to enter the installation related financial details such as Economic life, Discount rate, Increase of Load, Increase of Cost of energy and Tariff data. User can choose between CEB tariff and his own tariff structure. The “Cable details” window (step 3 of 4) is used to enter the required cable’s Laying and Installation details such as Laying methods, Bonding type and methods of Transpositioning. Also the physical details of the cable such as Number of cores, No of Cables, Insulation material, Conductor material, Conductor shape, Type of the Metallic screen and Type of the Armor used.

The final output of the calculation for your system is displayed in the “Optimized of results” window (step 4 of 4). Results include the specified system details (installation, financial and cable details), result from the conventional method and the Economical optimized cable results. This economically optimized result includes Calculated Cross Section of the Conductor, Voltage Drop, Percentage Voltage Drop, Calculated economical cross section, Total Installation Cost, Cost of Joule losses for the life span, Total cost for the life span, Total Saving, Initial Incremental cost and the year of Break-even.

“Approximation mode calculation” (alternating step 3 of 4) is the alternating option for the user to continue the calculation process when the existing database has no data to mach the given installation pattern for preceding the remaining calculation process. User can enter the cable details from any cable handbook or by laboratory measurement.

4.2.3 Analyze

After obtaining results, user can analyze the results by using cost and savings graphs and tables. Variations can be obtained for different cross sectional values to get the overall picture of the cost of the future installations. At the end user can take a descriptive printed output based on the optimized solution for future references.

4.2.4 Data Base

The Database includes data tables for cable and tariff data Database is password protected and any modifications can be done only by authorized personnel.

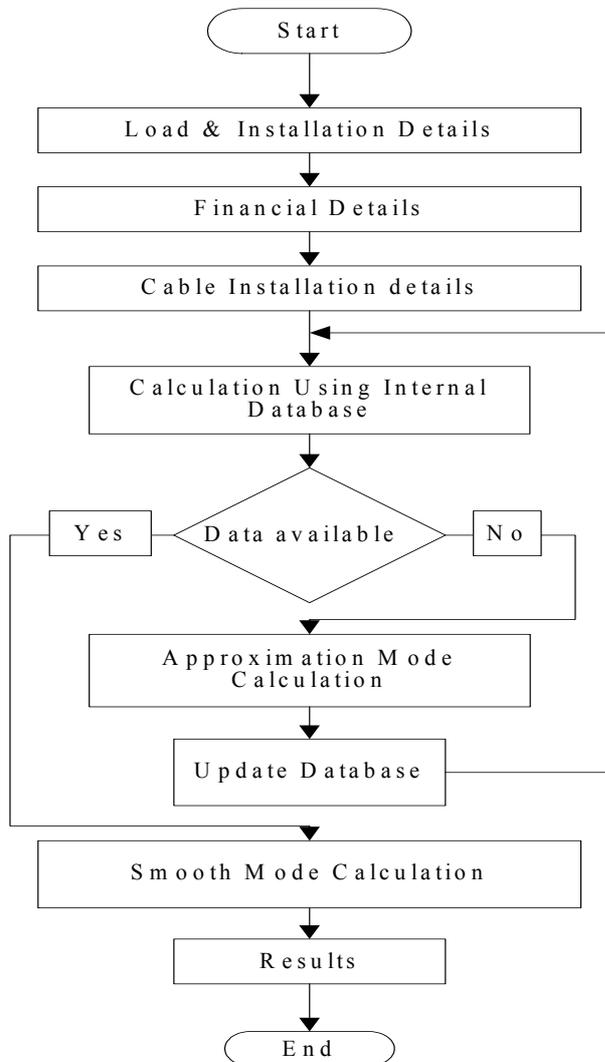
4.3.5 Help & Supports

CCOp by design is user-friendly software. Several help options are available to assist the user. A “Help Assistant” feature is available to provide descriptive & more technically detailed Help topics. A side-by-side online view of function Tips are displayed to navigate all of the functions of the user interface.

4.2 How CCOp Performs

Cable Cost Optimizer 2004 software package has three main Data collecting windows and a main result-displaying window. Results of analyses in terms of cost and savings are displayed in the form of tables and graphs. Database updating facilities are also provided.

The following flow diagram simplifies the steps of the operation of the software calculations and data entering.



Basic Steps of Operation

5 CONCLUSION

Objective of the Cable Cost Optimizer is to provide a reliable and convenient method to estimate the economically optimum cable sizes for a given installation. The solution provided not only improves the economical status but also the quality and the safety of the installation.

The solution CCOp provides is not limited to the optimum cable size. It is capable of providing a range of useful details relevant to the suggested cable size. For example the percentage voltage drop, the break-even period for the additionally incurred cost, cost of the joule losses, installation cost and many more.

It also make a comparison of these values of the cable used otherwise based on thermal ratings.

An analysis and graphical representation of variation of costs and savings for both the cables over the expected lifetime eliminates the tiresome work of a manual calculation and also wins the favor of investors.

Inbuilt database rules out the need for information gathering and provides the user the versatility of analyzing the system using different cable sizes.

Undoubtedly CCOp is a useful tool for analytical and design purposes. It is targeted for an audience of designers and analyzers of electrical installations, consultants, personals in academia and engineering students. Its reliability is guaranteed since the software is designed based on the International Standard IEC 287-3-2.

6 SUGGESTIONS

- A financial risk analysis can be included to make the financial analysis more comprehensive.
- Range of the software can be extended to include the medium voltage levels below 33 kV.
- Capability of the software package can be improved by updating the database records where they're no records.
- The capacity of the calculation can be improved by introducing the calculations of Oil filled, Pipe type and other types of cables.
- By introducing the effect of the solar radiation, can further increase the accuracy of calculation for the cables lay in free air.
- By including a form to obtain the suggestions and problems of the users through the Internet, the dynamic nature of the software package can be improved. Also the links of the cable manufactures can be provided to access and obtain necessary updates of cable industry.

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