COMPUTER-AIDED DESIGN ELECTRICAL SYSTEMS OF VEHICLES

АВТОМАТИЗИРОВАННОЕ ПРОЕКТИРОВАНИЕ ЭЛЕКТРИЧЕСКИХ СИСТЕМ ТРАНСПОРТНЫХ СРЕДСТВ

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Abstract: *The main issues are considered in this topic: creation of optimization algorithms electrical systems; development of specialized software; creating an effective method aided design of electrical systems of vehicles.*
KEYWORDS*: COMPUTER-AIDED DESIGN, VEHICLE, ELECTRICAL SYSTEM, OPTIMIZATION*

1. Introduction

Design of electrical systems of vehicles is currently impossible without use of software systems of CAD, CAM, CAE, CALS (PLM) technologies for the following reasons.
In today's global engineering the trend is observed for close interlink of the processes of design, production, marketing and operation of both: the vehicle as a whole and its constituent systems. In this context, the design of electrical systems of vehicle models is inseparable from the development of other systems of the same model, as well as from the subsequent technological preparation of production and operation.
Hence, modern CAD of electrical systems of vehicles, including subsystem of CAD, CAE should be integrated into CAM-systems and fitted to the overall process of documentary support of lifecycle, when using CALS-technologies. CALS-systems allow us to carry out information integration of all stages of lifecycle of products and systems in designing, manufacturing and operating the complex equipment [1], and modern computational tools allow one to implement support for such systems.
On the other hand, the requirements of the integration of project process in CALS–system, when developing the CAD of vehicle electric systems is complicated by such factors as:
- intensive innovation of models, modifications and complete sets of vehicles;
- increase of requirements to the quality of project documents and their compliance with international standards and regulations;
- development and complication of the structures of electrical systems, complication of optimal decision making, increase of the range and complexity of drawings;

Against the background of these requirements the problems associated with the human factor are contrasting:
- the need for a large number of engineering calculations;
- increase in the routine work of an engineer lowering the prestige of his work.

As a result, intensification of design work is observed in situation of acute shortage of qualified personnel. This leads to difficulties in implementation of projects by traditional methods in due time and increase of errors in documentation

2. Means for resolving the problem, discussion and results

To implement CAD of electric systems of vehicles, the efficient software tool is required that allows one with minimum of human resources and reduction of development time to ensure the required quality and competitiveness of the project. In addition, the CAD of electrical systems is a multiuser system. This means that for organization of the design process implemented in parallel by several designers the clear information interaction between them and the problems solved is needed.

The task of organizing the design process in a multi-user system requires optimal structuring the process and determining the logical connections between the design problems to be solved. The sequence of computer-aided design, which reflects the structure of design process of electric systems of vehicles, taking into account the factors mentioned is presented below.
The sequence is based on the analysis of the process of designing the electrical systems of vehicles of different types, generalizing the experience of scientific researches [2 - 5], and practice of developing the software systems in adjacent industries [6].
The sequence includes the following modules:
1. *Formation of the model of wiring space (MWS) of the vehicle.* Description of areas of possible deployment of elements of electrical equipment taking into account the structure of the vehicle.
2. *Schematic electrical diagram*. It contributes information on electrical connections of equipment components to the project.
3. *Optimal placement of electrical components taking into account the restrictions set by MWS of the vehicle*.
4. *Formation of the matrix of shortest distances between the elements of electrical equipment taking into account the restrictions set by MWS of the vehicle.*
5. *Formation of the model of bundle wiring (MBW).* The description of possible options of bundle wiring taking into account the restrictions set by MBW of the vehicle.
6. *Wiring of electrical circuits*. It solves the problem of optimal wiring the electrical circuit on the basis of minimum weight of wiring taking into account the limitations on the number of connected wires to the terminals of the elements.
7.*Development of wiring diagrams*. It includes the development of sketch of wiring diagrams, making changes as a result of wiring.
8. *Distribution of wires to the terminals of elements* is carried out taking into account the restrictions, for example, division of power circuits with control circuits.
9. *Issue of wiring diagrams and reports*.
10. *Formation of bundle design.* It is carried out according to MBW of bundles wiring taking into account the technological constraints on formation of the bundle.
11. *Determination of lengths of bundle sections according to the formed bundle design.*
12. *Specified calculation of lengths of wires taking into account the technological allowances.*
13.Formation of calculation modes of operation of line. Formation of the line design scheme taking into account the multi-mode operation of consumers (the program is developed in KNRTU-KAI).
14. *Formation of design scheme of feeders* for determining the wire sections and analysis of operation mode of feeder (the program is developed in KNRTU-KAI).
15. *Calculation of protection devices* (the program is developed in KNRTU-KAI).
16. *Calculation of feeder wire sections* (the program is developed in KNRTU-KAI).

17. *Calculation of wire sections of the line.* Requirements and optimality criterion must comply with the calculation of cross sections of feeder wires (the program is developed in KNRTU-KAI).
18.Analysis of operation modes of feeder design scheme is carried out in order to check the ensuring the required quality of power supply to consumers and system protection during short circuits.
19. *Analysis of the line operation modes* is carried out to check the ensuring the required quality of power supply to consumers taking into account their multimode operation (program is developed in KNRTU-KAI).
20. *Calculation and selection of structural elements of the bundle.*
21. Issue of bundle drawing, tables of wires.
22. *Preparation of samples* from the output tables of the bundle.
23. *Issue of bundle specification*. The list of items included in the design of the bundle.
24.*Constructing the bundle mounting*. Constructing the elements of bundle fixing to the vehicle structure.
25. Issue of bundle mounting drawing.
26. Issue of bundle mounting specification.
In the sequence, are identified two blocks: invariant and adjustable. Invariant block is only slightly dependent on the characteristics of the design of different vehicles, and includes:
- a series of operations for designing the circuit of electrical connections and forming the bundle structure (operations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13);
- calculation programs for identifying the cross sections, choice of protective devices and analysis of operation modes (operations 14, 15, 16, 17, 18, 19, 20).
The invariant block can be considered as a basic part, which is performed with the help of such CADs, as E^3.Series and Siemens NX and requires relatively little adjusting to the project process of specific vehicle.
The adjustable block includes calculation and selection of structural elements of the bundle, issue of bundle drawing, tables of wires, bundle specifications, designing the bundle mounting, issue of mounting drawing and specification, different sampling from the output tables. The adjustable block much takes into account the specificity of particular vehicle and requires separate researches and developments.
Analysis of this sequence reveals that operations 1, 2, 3, 7, 9, 10, 11, 22, 25, 26 may be implemented with existing CAD systems. Operations 4, 5, 6, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 27 are developed and adapted to the design process by the Department of Electrical equipment of KNRTU-KAI.
Integration of developed CAD of electrical equipment of vehicles with programs of other stages of the life cycle is supposed to be carried out with the help of CALS software, which provides engineering data management and their synchronization, allows the use of common models in the digital environment of the lifecycle.
Fig. 1 is a block diagram of CAD of electrical systems of truck with existing and created special software.
The structural parts of CAD of electrical systems, reflecting the design problems are the following modules: layout of design nodes, placing the structural nodes, wiring the electrical circuits of interblock mounting, forming the bundles of interblock mounting, tracing the bundles, analysis of operation modes of electric energy distribution system, choice of protective devices, optimization of wire cross sections, electrical energy balance calculation.
By present time it is developed the specialized software in the form of the following modules: "Analysis of operation modes of power supply system" module, "Selecting protective devices" module , "Optimization of wire cross sections" module.
The module "Analysis of operation modes of power supply system" provides analysis of operation modes of electric network of the vehicle in order to check the ensuring the required quality of power supply to consumers and network protection against short circuits. During the analysis the following problems are solved:
- calculation of the currents in the areas of supply circuits and voltages at the nodes of calculation scheme for normal modes taking into account the changes in current distribution as to the modes of consumption;
- determination of the maximum currents of sections and minimum voltages of circuit nodes;
- calculation of current short circuit;
- checking the wiring as to permissible current and ability to be protected by fuse;
- checking as to permissible rated voltage at the terminals of consumers;
- checking the selection of fuse as to rated current;
- determination of maximum off time for the short circuit by fuse with the minimum short-circuit current;
- checking the selection of fuse in overload in case of electric motor loads;
- checking the sensitivity of the fuse.
Module "Selecting the protective devices" provides:
calculation of the rated current of protective device at maximum workforce of load current of consumers taking into account: the nature of the current load of consumers; multi-mode of feeders operation; typical modes of operation of consumers;
- calculation of the maximum response time of protection device.
- checking the protection devices as to conditions of: correspondence of rated current to the load current for all calculated modes of feeder operation; ability of wires of all sections of the feeder to be protected during normal and emergency modes; sensitivity of protection device.
The module of "Optimization of wire cross sections" ensures the calculation of the currents of sites of design scheme for all calculated modes; calculation of minimum wire sections of sites as to the allowable current, protection devices and conditions of mechanical strength; optimization of wire cross sections according to the selected criterion and restrictions as to allowable values of voltage, taking into account multi-mode operation.
CAD modules of electrical systems are identified as to some attributes of the parts of CAD, providing the obtaining of complete design solutions and appropriate design documents. The structural integration of the modules in the system is carried out by means of special relations between the components of CAD.

3. Conclusion

The introduction of this technique and developed software in industrial operation allowed us to significantly reduce computational time and laboriousness in designing the electrical systems, to increase the reliability of calculations because of elimination of mechanical errors of non-automated designing, operatively make changes to documents, to release the engineers from routine work. In addition, the use of design and project information as input data for the programs to obtain product documentation for manufacturing and control of components of electric systems of vehicles also helps to speed up the development of product by manufacturer. Thus, the certain economic benefits are achieved, which are provided by reducing the design time by 8-12%.

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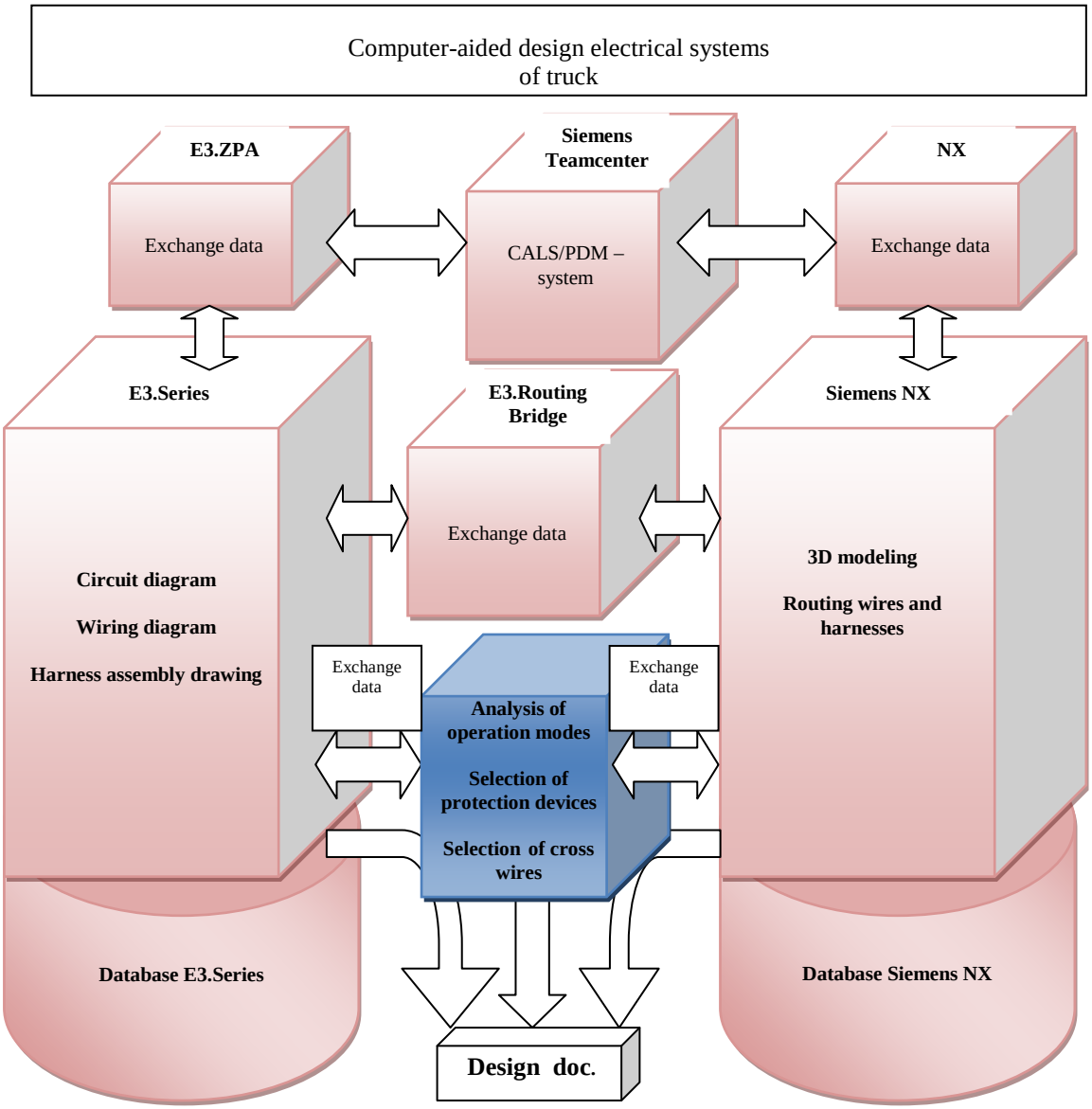

Fig. 1. *Computer-aided design electrical systems of truck*