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Designing the wiring harnesses of the carrier vehicle

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Abstract. This article is about designing the wiring harnesses of lorry. To solve the problem of forming a configuration bundles the previously developed algorithm was used.

1. Introduction

The process of designing cable harnesses of modern land vehicles consists of solving many problems. The basis of the design phase is the development of circuit diagrams of the electrical energy distribution system. The main complexity is the task of determining the spatial position of the elements, their connections and the preparation of the relevant technical documentation: connection tables, specifications, etc. When designing inter-unit mounting, they correspond to the sequence of tasks of assembling and placing structural units, wiring electrical circuits, forming and tracing wire harnesses [1-3].

When solving the problems of accommodation, determining the configuration of the vehicle's electrical network, it is necessary to take into account the voltage loss in the wires and the multi-mode operation of the network. This leads to the fact that the design of all electrical systems is interconnected, that is, the design process is complex iterative in nature.

Drawing up sets (layout) of structural units and their placement on a truck is an important step. The location of structural units, restrictions on their volumes, etc. should be determined. The results of the decision determine the further nature of the wiring of electrical circuits, the formation and tracing of harnesses. The wiring of electrical circuits consists in determining the method of connecting equipotential outputs of the electrical circuit and is carried out taking into account the routes and the location of the elements of each circuit, reliability requirements, etc.

The task of forming the harnesses is to combine sets of wires, taking into account the restrictions on electromagnetic compatibility, type of current, manufacturability, geometric features, places of laying, etc.

After wiring the electrical circuits of the interblock installation, we have electrical connection diagrams in which the connections are realized by wires. Wires running in one direction (along one route) are assembled and bundled into bundles taking into account various design, production and operational considerations.

Electrical harnesses are produced mainly at specialized enterprises of cable and wire products. In the production process, the greatest difficulties are associated with the manufacture of electric harnesses, the complexity of which increases from year to year.

In this regard, there is rapid increase in the complexity of the production of wire harnesses, the number of members working and occupied by manufacturing wire harnesses production areas. This necessitates the introduction of advanced labor methods, means of mechanization and automation, based on the application of the most advanced methods of software control technology.

2. Main part

2.1 Design of cable harnesses.

The design of cable harnesses of the vehicle in accordance with the standard stages of designing complex technical objects begins with the formation of a terns of reference (TOR) and technical proposal (TP). TOR determines the main purpose of the design object, its main tactical and technical characteristics and the technical and economic requirements, and the conditions of design, production and operation. With regard to vehicles, TOR includes a list of the main functional units of the vehicle and their functional characteristics that must be implemented using cable bundles, as well as the main technical and economic requirements for cable bundles and the vehicle as a whole. Initial information for the compilation of technical specifications are: data on analogues and prototypes of the design object; the best indicators achieved in world practice for the corresponding class of objects; design and technological implementation capabilities; state and industry standards; operating conditions of the design object, including the impact of the external environment, etc. TOR can be supplemented and adjusted at the next subsequent design stages.

The big step is technical design. At this stage, the design implementation of the design object is mainly carried out. From the standpoint of design, longer and more accurate computational and experimental studies are carried out. In addition to designing, much attention is also paid to issues of production technology and operation of the design object.

The main tasks of technical design common to all cable harnesses are:

1. Laying wires and calculating their length. This task essentially boils down to placing a circuit diagram on a geometric model of the mounting space. Obviously, the solution will be more accurate the more accurately the geometric model reflects the configuration of the mounting space. Since in many cases the connections between the elements can be made by various combinations of permissible traces, in the general case the problem is optimization. As optimization criteria, you can use the total length of the wires, mass or cost. After selecting the routes along which the wires are laid, their lengths are calculated unambiguously.

It should be noted that for a more accurate solution to the problem, in addition to the geometric model of the mounting space, geometric models of the internal space of switchgears and boxes are also necessary. However, taking into account additional geometric models dramatically complicates the task. In addition, often the internal lengths of the wires are incomparably small compared to the external ones, except when the wire is entirely placed inside the device or box. Given these circumstances, in many cases, the internal wire lengths can be neglected. Since accurate geometric modeling of the mounting space is rather difficult, the problem under consideration is usually solved with subsequent refinement on the layout of the real mounting space.

2. The choice of voltages, currents, brand and cross-sections of wires, the choice of protection devices. From a design point of view, this task requires only the choice of wire cross-sections, provided that the lengths are already known and the network-wide restrictions on allowable voltage drops and maximum wire currents on the way from sources to power receivers are fulfilled. The latter circumstance does not allow solving the problem for each wire separately. At the same time, when considering the network as a whole, there are many options for the distribution of permissible voltage deviations at the node points of the network and, consequently, the corresponding choice of wire sections. Thus, the problem is an optimization one and connects two types of calculations at the same time: current and voltage calculations at the nodal points of the circuit diagram (a typical problem in the theory of electrical circuits) and calculation of the wire cross section according to the given values of voltage length and voltage drop. The choice of the brand of wires is usually carried out on a narrow nomenclature for a particular design object. In most cases, the brand of wire (group of wires) is considered known in solving the problem.

3. The formation of electrical harnesses and electrical connectors. This is a rather complex and time-consuming task, which includes several interrelated subtasks:

• the combination of wires and cables laid along one route (sequence of routes) in a bundle while satisfying a number of requirements (belonging to one or more related functional systems, electromagnetic compatibility, adaptability of installation, etc.);

• selection of electrical connectors (connectors, couplings) and connecting wires to the terminals of electrical connectors;

• technological installation of the bundle (choice of delivery methods, laying and fastening of the bundle) and wires (welding, soldering wires to the terminals).

If we also take into account the existing variety of harnesses (simple, attached to only two electrical connectors, complex, connected to three electrical connectors or more, components consisting of several technologically separated parts, etc.) and the need for their attachment to the geometric model of the installation space, then it is easy to imagine a large number of possible options and the optimization character of the problem being solved.

4. Development of connection diagrams. The connection diagram is a detailed image of all wired and cable connections. Unlike the circuit diagram, the connection diagram shows all the terminals of the element and the wires (cables) connected to them, indicating the addresses of the terminals of the elements and electrical connectors with which these connections are made. Connection diagrams are used to build more detailed wiring diagrams and step-by-step control of cable harness installation.

5. Development of mounting devices. Mounting devices include switchboards and boxes, relay boards and boxes, fasteners (clamps, consoles, etc.), etc. This task arises when well-known technological mounting devices do not satisfy the designer and you need to design new ones.

In general, the technical design is completed with the release of new documents - wiring diagrams, assembly drawings of harnesses, specifications of protective switching devices, etc.

The full scope of design documentation is issued at a specially allocated stage of detailed design. The full set of working documentation, in addition to the documents obtained at the preliminary design and technical design stages, also includes explanatory notes on the description of the design object and the substantiation of the decisions made, figures and data tables, routings, material specifications, a list of standards applicable to this design object, set operational documents, etc. All this documentation, called a working draft, after appropriate approval is the basis for continuing the life cycle of the design object (implementation and operation).

2.2. Formation of bunched wires configuration. To solve the problem of forming a configuration bundles the previously developed algorithm was used. [4].

Suppose that a set of connecting devices $N_q = \{q_1,...,q_s,...,q_n\}$ ordered as to coordinate x connected by conductors with the branch points and a set of positions $L = \{l_1,...,l_t,...,l_f\}$ to locate the branch points from the set $P = \{p_1,..., p_j,..., p_n\}$. The set of positions $L = \{l_1,...,l_t,...,l_f\}$ is formed by the trunk points, evenly or unevenly spaced (by decision of the designer) between the cutting planes. The step between positions is selected depending on the desired accuracy and computational capabilities of the computer used.

At the first step of the algorithm, we determine the best position to place the first branch point sequentially in zones $Z^{(\xi)}, \xi = \overline{1,m}$ and from it we conditionally «attach» the wires from connectors located in these areas. Thus, we find the value of target function:

$$F_1 = \min_{l_t \in L} \sum_{k \in N_1^{\xi}} (x_k + y_k) \cdot s_k \tag{1}$$

Where $N_1^{\xi} = \{n_i; n_i \in N_q; x_k \le x^{(\xi)}\}$ - subset of connectors located in the zone $Z^{(\xi)}$.

At *j-th* step recursion expression is used:

$$F_j(\xi) = \min_{\psi}\left[F_j(\xi,\psi) + F_{j-1}(\psi)\right], \xi = \overline{j,m}; \psi = \overline{j-1,\xi-1} \quad (2)$$

Where $F_{j-1}(\xi)$ - the optimal value of the target function computed at the previous step, when placing *j-1* branches in the zone $Z(\psi)$;

The value $F_j(\xi,\psi)$ of target function, when placing the *j-th* branch in the zone $Z(\xi)$ with coordinates $x^{(\psi)} \le x(\xi) < x^{(\xi)}$ and attaching the *j-th* branch to connectors with these coordinates.

Each *j-th* step of the computational process corresponds to the formation of *j* branches and determination of their composition as to connecting devices using all *m* zones. Following *n* steps we will have *n* options of synthesis of bunched wire configuration, among them we choose the option with the least value of the target function. Then the reverse is performed, resulting in determination of location of each branch, and composition of its constituent connectors.

3. Conclusion

To evaluate the results, testing of design procedures was carried out - checking the compliance of the characteristics with functional and other, individual types of requirements set forth in the terms of reference for the design of Electrical Distribution System (EDS) of a cargo vehicle.

According to the developed [4] method of computer-aided design of harnesses, the design of a modification of a lorry was carried out. A schematic electrical diagram of the EDS of the vehicle, an electrical diagram of the connections of the EDS of the vehicle, an assembly drawing of the EDS harness using CAD tools of the Siemens NX and E^3 Series electrical systems have been developed. The calculation of the optimal cross-sections of the EDS wires, the analysis of the EDS operating modes, the selection and verification of the EDS protection devices of the vehicle are carried out. The calculations were carried out using the software developed at the Department of Electrical Equipment ("Analysis of the operating modes of the power supply system of electrical vehicle complexes", "Optimal selection of wire cross-sections of the power supply system of vehicle electrical complexes", “Selection of protection devices for the power supply system of electrical vehicles complexes and verification of their operation”) based on the created databases (“Database of design information for electrical complexes of perspective vehicles”, “Database of regulatory and reference information for electrical complexes of perspective vehicles”).

The developed procedures were tested on modifications to the cargo vehicle. The total operating time of the developed procedures with the formation of the output documentation amounted to:

- calculation time 35.42 sec;
- time to create output documentation 55.71 sec.

According to the calculation results, shortcomings (errors) and recommendations were also identified when designing the cable system of the investigated vehicle:

1. Protection devices through which current exceeds the rated current;
2. Over-sized wires;
3. The selectivity of the operation of protection devices when a short-circuit.

Evaluation of the effectiveness of the developed methodology for computer-aided design of a vehicle harness system depends on the main parameters of the task, and is determined by the accuracy of the solution and the time it was received.

The introduction into commercial operation allowed to significantly reduce the calculation time and laboriousness in the design of the electrical complex (10%), increase the reliability of calculations due to the elimination of mechanical errors in manual design, reduce the mass of wiring (3%), promptly make changes to documents, free engineers from routine work. In addition, the use of calculated and design information as input for programs for obtaining production documentation for the manufacture and control of components of the vehicle’s electrical complex also helps to accelerate the development of the product by industrial production. Thus, a certain economic, technical and social effect is achieved.

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References

[1] Nizamov R 2017 Computer-aided design onboard cable network of unmanned aircraft *Gagarin's reading* pp 103-4
[2] Nizamov R, Khayrullina G, Shakirzyanova N 2015 Specialized software for automated design of electrical equipment *The future of russian engineering engineering* pp 1065-67
[3] Fedorov E, Tereshchuk V and Ferenetz A 2015 Wiring of complicated electrical circuits of interblock assembling in automated design of aircraft *Russian Aeronautics* **58**, pp 96-99
[4] Fedorov E, Tereshchuk V and Ferenetz A 2015 Technique of computer-aided design of power supply system of vehicles *Journal of Engineering and Applied Sciences* **10** pp 110-7
[5] Metelev I, Dvorkin D and Isakov R 2017 Different load types modeling using MatLab *IOP Conference Series: Materials Science and Engineering* **240**
[6] Metelev I, Isakov R, Ferenetz A, Gilmanshin I, Gilmanshina S and Galeeva A 2018 Using of functional capability of RTDS hardware and software complex in the educational process of electrotechnical cpeciality master's training in ecomony global digitalization conditions *IOP Conf. Series: Materials Science and Engineering* **412**
[7] Isakov R, Davletbaev A and Suleymanova N 2017 Observability of electric power networks factoring in (n-1) security *ICIEAM*
[8] Isakov R and Ferenets A 2017 Research of remote backup protection functioning at the software and hardware complex RTDS *ICIEAM*
[9] Fedorov E and Ferenetz A 2015 Computer-aided design electrical systems of trucks *Machines, technologies, materials* **6** pp 7-9
[10] Fedorov E and Gorodnov A 2016 Software instruments for computer-aided design onboard cable network of the aircraft *International Journal of Applied Engineering Research*
[11] Fedorov E and Ferenetz A 2017 Computer-Aided design of vehicle electrical harnesses *ICIEAM*
[12] Magdowski M *et al* 2018 Electromagnetic Field Coupling to Transmission Line Networks of Double-Wire Lines in a Reverberation Chamber *IEEE International Symposium on Electromagnetic Compatibility*
[13] Kasper J *et al* 2018 Electromagnetic field coupling to planar and triangular multiconductor transmission lines in a reverberation chamber *IEEE International Symposium on Electromagnetic Compatibility and APEMC 2018*