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ELECTROTECHNICAL COMPLEXES OF HELIOTECHNICAL DEVICES: A GENERALIZED CLASSIFICATION

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The need to systematize the existing electrotechnical complexes of heliotechnical devices (ECHD) is due to their growing quantity, diversity, and element base. In the proposed publication, a generalized classification of the ECHD is made over a wide range of parameters that characterize the ECHD as a separate class of devices, as their diversity and features are sufficient to describe the ECHD as such. The classification herein proposed analyzes in detail the whole structure and possible layout solutions, an effort enabled by the well-developed modern elemental base for the design of the ECHD. Using this classification enables a more precise, detailed and verified structural synthesis of the ECHD, which will help the solar engineering engineer to better understand and justify a set of technical solutions in the design, construction and operation of ECHD classes. Only electric drives are considered.

Keywords: electrotechnical complexes, heliotechnical devices, solar panels, collectors, rotary mechanism, electric motor, sun-tracking sensor, control system, systematization, classification.

Introduction

The need to systematize and classify the ECHD at the present stage is due to the growth of their quantity, diversity, and also the element base. Until now, there has been no generalized and most detailed classification of the huge diversity of the ECHD. There have been attempts to classify ECHD both in our country and abroad [1–14]. However, in the process of studying them, incompleteness of these classifications was revealed: they consider either a single classification feature or a narrow group of classification characteristics.

Thus, in [2] a classification is considered only in terms of power. The need to systematize and classify the ECHD as of today is due to their growing quantity, diversity, and element base. Until now, there has been no generalized and sufficiently detailed classification of the diverse ECHD available. Both Russian and non-Russian scientists have made attempts to classify the ECHD [1–15]. However, thorough analysis reveals the incompleteness of such classifications, as they consider either a single classification feature or a narrow group of classification characteristics. Thus, paper [2] presents a classification based solely on power. Only rotary mechanisms are considered in [1, 5, 7]. Papers [3, 4, 6, 12, 14, 15–18] present a rather broad review of literature, while still being obsolete as of today as they do not include a number of new classification characteristics (type of rotary mechanism, type of sensor and algorithm). Papers [10, 19] present only a sensor classification, whereas paper [19] ignores some of the new developments that existed at the time of writing it. Paper [11] presents a rather narrow classification of some mathematical algorithms for controlling the positioning of the receiving surface of the ECHD by means of stepper motors.

Statement of Problem

The authors hereof attempt to classify all the diversity of the ECHD existing both in Russia and abroad, to expand and supplement the existing classifications.

The paper presents the basic groups, into which electric drives may be divided by the 14 most common criteria:

1. Power [2].
2. Trigger type [20].
3. Support-rotary mechanism type [7, 21].
4. Coordinate motion type [20].
5. Gearbox use [20].
6. Type of servomotor-to-actuator transmission (gear drives only) [20].
7. Type of electric machine used [4, 12, 21–31].
8. Sun-tracking sensor type [14].
9. Sensor-signal type [14].
10. Spatial position control algorithm type (for controlling the electric drive coordinates) [2, 32–38].
11. Type of communication with the main control computer (if any) [39].
12. Place of installation [18].
13. Foundation type [18].
14. Environment type [18].

Theory

According to GOST R 57229–2016 (IEC 62817: 2014) *Photo-Electric Systems. Devices for Tracking the Sun. Technical Specifications* [18], the photovoltaic system is a system that converts solar energy into electrical energy by direct conversion and uses it to partially or completely cover the electrical loads of the consumer and / or transmit it to the grid.

Each of the photovoltaic solar tracking systems can be divided into categories by the number and direction of the axes, actuator layout solutions, drive types, climatic version, the type of vertical installation and foundation, control type, type of sun-vector signal generation, etc., including the characteristics below [18].

The aforementioned GOST, despite its relative completeness, does not extend to the non-mechanical factors of the ECHD and does not cover the structural features of the ECHD.

As there are increasingly more ECHD, and they are becoming ever more diverse while their element-base available to developers is expanding, it is imperative to somehow classify this diversity.

Practice

What makes creating a detailed classification imperative is the rapid growth of engineering developments in this field and the creation of numerous laboratory specimen that could potentially go to mass production. These developments are made by designers, but they also use the products of progress in adjacent fields (photovoltaics is interlaced with electric drives and the theory of automatic drive control).

To appropriately evaluate the novelty and quality of the proposed design developments, we have made this classification that enables a full and detailed analysis into the basic engineering, technical, and structural features of the ECHD. In addition, such a classification can be used for making a database of the existing technology, which will help avoid duplicating the existing designs in the future while enable specialists to focus on advanced developments, which is also the classification authors' plan.

Problems that may arise when producing even a single specimen of such technology are quite obvious. Design and operation problems are not yet solved [39]. Table 1 presents a generalized classification that covers the maximum range of parameters for evaluating

Table 1

Electrotechnical complexes of heliotechnical devices: a generalized classification

№	Classification feature	Characteristics
1	Power	a) Small (power output from fractions of kW to 1 MW)
		b) Average (from several MW to 10 MW)
		c) Large (> 10 MW)
2	Trigger type	a) Individual ECHD
		b) Combined ECHD (e.g. as part of a solar farm)
3	Support-rotary mechanism type	1. Uniaxial:
		a) Horizontal-axis
		b) Vertical-axis
		c) Inclined
		2. Biaxial:
		a) Horizontal main axis
		b) Vertical main axis
		c) Inclined main axis
		3. Modified biaxial mechanisms:
		a) With passive supports and posts
		b) Rotary
		c) Coordinate-interdependent
4	Coordinate motion type	a) Rotational
		b) Translational (linear)
5	Gearbox use	a) Gear drive
		b) Gearless drive
6	Type of servomotor-to-actuator transmission (gear drives only)	a) Worm drive
		b) Cylindrical drive
		c) Bevel gear
		d) Planetary gear
		e) Eccentric gear
		f) Screw (screw-nut gear)
7	Type of electric machine used	a) DC (commutator) motor
		b) Stepper motor;
		c) Brushless DC motor (switched reluctance motor)
		d) Asynchronous motor with squirrel-cage rotor
		e) Linear electric motors

Table 1 (end)

№	Classification feature	Characteristics
8	Sun-tracking sensor type	a) Differential four-quadrant
		b) Collimator
		c) Pyramidal
		d) Spatial multi-channel
		e) Video and web camera with a vision system
9	Sensor-signal type	a) Analog
		b) Digital
10	Spatial position control algorithm type (for controlling the electric drive coordinates)	1. Open-loop (astronomical and mathematical algorithms for calculating the solar position)
		2. Closed loop:
		a) Linear algorithms
		b) With artificial intelligence methods (neural networks, fuzzy logic etc.)
		c) Automatic optimization systems (terminal control)
		3. Combined control algorithms
11	Type of communication with the main control computer (if any)	a) Wired
		b) Wireless
12	Place of installation	a) on the ground
		b) on the water;
		c) on a building (roof, wall) or another facility
		d) integrated in the building/facility
13	Foundation type	a) deep foundation
		b) on-surface foundation
14	Environment type	a) clean
		b) conditionally pure
		c) industrial
		d) maritime
		e) maritime-industrial

the great ECHD diversity. Note that only electric drives are covered.

This classification fully covers and structures the entire diversity of the ECHD. Using this classification enables more precise, detailed, and verified structural synthesis of the ECHD in an objective manner, helping the solar technician to better understand and justify the set of solutions used in designing, creating, and operating new ECHD classes.

The generalized classification helps to systematically formulate the requirements to the performance characteristics and design features of the ECHD being developed while drafting the statement of work (SoW) and specifications. Apparently, the classification will be useful for testing and evaluating both the existing and future specimen. Besides, such evaluation can be done at any stage of creating an ECHD.

The classification can be fundamental to new targeted developments in specific areas, such as ECHD motors, safety requirements to all ECHD groups, etc.

The principles and some points of this classification have already become topics of specific research and engineering development both in the field of ECHD and in adjacent scientific disciplines and developments. The classification is necessary for streamlining the matters of standardization and certification of related products while furthering the ECHD production. This classification can be fundamental to developing the ECHD principles and codes, or any necessary additions and amendments to the existing standards [20].

The structure of this classification can serve as a basis for preparing a curriculum for the related engineering majors, training programs in all related majors of different levels, teaching aids, textbooks, and study guides.

When analyzing different approaches to classifying innovations, it should be borne in mind that generalizing and systematizing classification features to create a scientifically robust classification of innovations is of considerable practical significance, as such an effort can potentially detail all the characteristics of this or that progressive innovations. This in its turn is necessary for micro- and macro-level innovations It is such classifications that enable more specific evaluation of the innovations created by economic actors, an assessment of performance, and further determination of innovation areas that need readjustments or additional support; besides, classifications help reveal the non-homogeneity of innovations and choose such management methods that better suit each specific innovation process.

Conclusion

The proposed generalized classification can used to analyze and study the existing designs, as well as to draft SoW and specifications for designing and developing future ECHD. It can also be used for creating curricula to train specialists in related majors.

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ЭЛЕКТРОТЕХНИЧЕСКИЕ КОМПЛЕКСЫ ГЕЛИОЭНЕРГЕТИЧЕСКИХ УСТАНОВОК: ОБОБЩЕННАЯ КЛАССИФИКАЦИЯ

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Необходимость систематизации существующих электротехнических комплексов гелиоэнергетических установок (ЭТК ГУ) обусловлена ростом их количества, разнообразия, а также элементной базы. В предлагаемой публикации сформирована обобщенная классификация ЭТК ГУ по широкому спектру параметров, характеризующих ЭТК ГУ как отдельный класс устройств благодаря их многообразию и особенностям. Рассматриваемая в статье классификация в достаточно широком объеме анализирует всю структуру и возможные компоновочные решения благодаря развитой современной элементной базе для проектирования ЭТК ГУ. С использованием этой классификации станет возможным более точный, детальный и выверенный структурный синтез ЭТК ГУ, что поможет инженеру-гелиотехнику наиболее четко осознать и обосновать совокупность технических решений в области проектирования, создания и эксплуатации новых классов ЭТК ГУ.

Ключевые слова: гелиоэнергетические установки, солнечные батареи, коллекторы, поворотный механизм, электродвигатель, датчик слежения за Солнцем, система управления, систематизация, классификация.

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