Micro turbine installations classification principles based on a systematic approach

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Abstract. This article reviews a novel approach toward classification of micro turbine installations based on a systematic approach. Classification principles are described, and general requirements to classification system are formulated. Novel classification system for micro turbine installations is proposed.

1 Introduction

In recent years, there has been a steady trend in the global energy sector for the advanced development of distributed energy resources. Micro turbine installation (MTI) is one of the most promising energy sources for distributed energy generation [1-10], but in order to develop commercially efficient durable energy sources based on MTI, a number of scientific and technology issues have to be resolved. Developing modern technology devices employs development and testing of mathematical models, called mathematical modeling [11-17]. The foundation for mathematical modeling approach is the system of classification, which is based on classification criteria [21-27].

2 Methods

This paper presents a novel approach towards the classification of MTI which is based on a systematic approach. The aim of classification is to limit the choice of system representation approaches, to match chosen classes with certain methods and rules of system analysis, and to recommend selection of method for the corresponding system class. Classification is always relative. In theory, any system in general can be characterized by a number of attributes and assigned to different classifications, which can be useful to selection of modeling method. Classification system may have a specific problem focus: design and manufacturing, operation, maintenance, disposal. Classification implies is creation of a metric space to be used in analysis and synthesis of systems. The unified classification system approach is hampered by the lack of a logical vector. In this case categorization of classifications (metric spaces) must be conducted at the first place. The flow chart of the MTI system classification method is presented on figure 1.
Various classification properties are used to form system classes. Systems are divided into real and abstract ones by nature of their elements. Depending on their origin, systems can be natural or artificial. Systems can be permanent or temporary, depending on their life span. Depending on variability of their properties, systems are divided into static and dynamic. Depending on the complexity of the system, they are divided into simple and complex. Depending on interactions with an ambient environment, systems can be isolated, closed, open-balanced and open-dissipative. Isolated systems do not exchange energy and matter with the environment. The entropy of an isolated system moves to its maximum value. Closed systems do not exchange matter with ambient environment, but can exchange energy. Open system exchange matter and energy with an ambient environment. The change in entropy of an open system $d_s$ is defined by algebraic sum of entropy produced inside the system $d_p$ and entropy coming from or leaving to an ambient environment, $d_c$. In a state of lasting equilibrium (steady state) $d_s=0$. Open in the equilibrium state are such systems that return to their steady state exponentially (without oscillations), when they deviate from the steady state. For open systems in equilibrium, the rule of entropy economy is observed according to the theory of I. Prigogine. Open dissipative systems are observed as a result of cooperative processes. Their behavior is nonlinear. The mechanism of dissipative structure formation is the following: subsystems fluctuate, sometimes reaching the point of bifurcation, after which the order of higher level may occur. Transitions to states of dynamic ordering, coherence, self-oscillations, autocatalytic reactions are similar to phase transition (as a result of increased fluctuations).

There are large numbers of classification properties for elements and systems. Common feature is the amount of information which the model carries. The distinctness of information determines the boundaries at which the model and the object preserve the homomorphism i.e. may be considered adequate in the sense of certain proximity criteria. The definition of hierarchy of characteristics of the classification system (Figure 2):

Area C1 – attributes that determine properties of the object as a system in general, regardless of its structure – systematic;
Area C2 – attributes that determine properties of the object, based on its structure (morphology) – structural;
Area C3 – attributes that determine properties of the object, based on its structural elements – elemental.
According to the general set theory, the inclusion of elements of a set being classified into a certain class, in respect to equivalence of an element attribute to a certain class attribute, is determined by the axioms of reflexivity, symmetry and transitivity. Then classification is determined as a partition of a set (of objects) into subsets (classes) by similarities or distinctions in accordance with methods (rules) chosen. Classification system is an aggregate of classification methods and rules, and their results.

The hierarchical classification method is a consistent division of a set of objects into subordinate classification groups. The faceted classification method is a parallel division of a set of objects into independent classification groups. Level of classification is the stage of classification in the hierarchical classification method, as a result of which a set of classification groups is obtained. The depth of the classification is the number of levels in classification. An attribute of classification is a property or characteristic of an object by which the classification is carried out. An aspect, property, characteristic of an object can be used as attributes for identifying a given object. In the faceted (parallel) classification, the set of data is divided into independent groups according to properties, aspects, characteristics. Each facet is formed according to essential attribute that corresponds to the analyzed one.

The number of facets can be increased without affecting the existing facets. Classification inside facets is mainly based on a hierarchical principle. Hierarchical sequential classification principle establishes a subordination relation between the classification groups based on the following logical division laws:

1. Only one principle of division should be applied at one particular level of classification. Therefore, the simplest division is the enumeration, or listing of classification groups. Division of elements by ranking of attributes is also common;
2. The number of levels of classification (depth of classification) is equal to the number of attributes selected for classification as the basis for division;
3. Any element of the divisible set may be present only in one classification group;
4. The sum of the elements of division should equal the original set.

This classification structure of information is a type of the systematic approach, which is called “tree-like” hierarchy. “Tree-like” hierarchy is the type of information system structure that allows, if necessary, to supplement it with the additional data (information).

3 Results and Discussion

Summing up what has been mentioned above and having described the purpose of the classification system and its functions, we can formulate the following basic requirements for the classification system of the TS MTI:

1. All the information should be divided into separate classification groups according to one attribute or a certain combination (set) of attributes;
2. All objects should be divided among classification groups according to a common attribute that is typical for similar objects, and attributes that can distinguish objects from one another;
3. Classification groups should be independent of each other;
4. Objects and features must be uniquely determined for each corresponding classification groups;
5. The classification system should be general and should provide for problem execution;
6. The system should be flexible: inclusion of new classification groups and objects or exclusion of existing ones should be made without deconstruction of the system;
7. Properties that determine the quality of the group of objects or a particular object should be taken as a characterizing attribute.

Modern MTI constitute complex technical system (TS) consisting of a large number of interconnected elements. These systems interact with ambient environment and other systems [19-20]. To describe the structure of the MTI system let us define the “structural element” of MTI. Structural element is a technical object (part of the MTI system), that has functional independence in relation to the whole system. The indivisibility of an element will be considered as criteria for disregarding internal structure of such element in regard to the model. Structural elements of MTI, for example, are: turbine, compressor, generator, bearings, control block. To select the class of the system, the principle of the hierarchy of characteristics of the classification system is used. Three levels of attributes are determined.

Upper level (1st level) systematic attributes are such attributes that determine the properties of an object as a system in general, regardless of its structure. Middle (2nd) level is structural attributes that determine properties of an object, based on its structure (morphology). Bottom (3rd) level is elemental attribute that determines properties of an object based on its structural elements. Within one level, we apply a parallel (faceted) structure of classification attributes. Therefore, for 1st level of systematic attributes facet features are determined:

- Purpose – by fields of application, mobility and types of application;
- Functional – by the type of general function carried out;
- Technical – by technical properties (power, efficiency, etc.)

The result of a valid selection of classification attributes of MTI was the classification system shown in figure 3.
4 Conclusions

The validity of the selected set of classification attributes is supported by its relevance to all requirements for classifying technical systems. This approach to the classification of MTI allows to perform R&D based on analysis and synthesis of MTI as a complex technical system.

References

[1] Barskov V, Besedin S, Besedina K, Rassokhin V, Smetankin A and Nikiforova O 2018 J. of Advanced Research in Dynamical and Control Systems 10 pp 384-92
[2] Asgari H, Chen X, Menhaj M and Sainudiin R 2013 J. of Engineering for Gas Turbines and Power 135 p 092601
[3] Asgari H, Chen X and Sainudiin R 2013 Int. J. of Modelling, Identification and Control 20 pp 253-70
[4] Mohammadi E and Montazeri-Gh M 2015 J. of Engineering for Gas Turbines and Power 137 p 071202
[5] Duan J, Sun L, Wang G and Wu F 2015 Energy 91 pp 168-75
[6] Duan J, Fan S, An Q, Sun L and Wang G 2017 Energy 134 pp 400-11
[7] Saha A, Chowdhury S, Chowdhury S and Crossley P 2009 IEEE Transactions on Energy Conversion 24 pp 529-38
[8] Sun Y, Zhang C, Chen H, Lin P and Xu X 2018 IEEE Access 6 p 8409454
[9] Cagnano A and De Tuglie E 2018 Electric Power Systems Research 157 pp 145-56
[10] Peirs J, Reynaerts D and Verplaetsen F 2004 Sensors and Actuators A: Physical 113 pp 86-93
[11] El-Khattam W and Salama M 2004 Electric Power Systems Research 71 pp 119-28
[12] Barskov V, Besedin S, Besedina K, Zabelin N, Matveev Y, Rassokhin V, Lavrov N and Fokin G 2017 Int. j. of advanced biotechnology and research 8 pp 1708-15
[13] Breńkacz L, Żywica G and Bogulicz M 2017 Mechanisms and Machine Science 60 pp 223-35
[14] Fu L, Feng Z and Li G 2018 Microsystem Technologies 24 pp 2333-47
[15] Fu L, Feng Z and Li G 2018 Microsystem Technologies 24 pp 1433-42
[16] Peirs J, Reynaerts D and Verplaetsen F 2003 J. of Micromechanics and Microengineering 13 pp 190-5
[17] Fu L, Shi Y, Deng Q and Feng Z 2009 Hsi-An Chiao Tung Ta Hsueh/Journal of Xi'an Jiaotong University 43 pp 15-9
[18] Epstein A, Senturia S, Al-Midani O and Anathasuresh G 1997 28th Fluid Dynamics Conference 12
[19] Arav B L, Besedin S N and Yaichnikov M Yu 2012 Young Scientist 4 pp 57-62
[20] Gaides M A 2005 M. GLOBE-PRESS p 201
[21] Mamrayeva D, Stybaeyeva A and Tashenova L 2018 Economic Annals-XXI 167 pp 4–7 doi:10.21003/ea.V167-01
[22] Iben U, Makhnov A and Schmidt A 2018 J. of Physics: Conference Series 1038 doi:10.1088/1742-6596/1038/1/012128
[23] Vdovin R A, Smelov V G, Sufiiarov V S and Borisov E V 2018 IOP Conference Series: Materials Science and Engineering 441 doi:10.1088/1757-899X/441/1/012058
[24] Vatin N, Gorshkov A, Nemova D and Tarasova D 2014 Applied Mechanics and Materials pp 633 p 634
[25] Konakov V G, Kurapova O Y, Lomakin I V, Novik N N, Sergeev S N, Solovyeva E N, Zhilyaev A P, Archakov I Y and Ovid’Ko I A 2017 Reviews on Advanced Materials Science 50 pp 1-12
[26] Yaichnikov I K and Suschenko V P 2014 Teoriya i Praktika Fizicheskoy Kultury pp 30–32
[27] Barsi D, Perrone A, Qu Y, Ratto L, Ricci G, Sergeev V and Zunino P 2018 J. of Thermal Science 27 pp 259–69 doi:10.1007/s11630-018-1007-2