REVIEW

of a dissertation for awarding the scientific degree "Doctor of Sciences"

Author of the dissertation: Assos. Prof. Dr. Eng. Ilian Hristov Iliev

Dissertation topic: "Optimizing power efficiency in reduced load mode and improving the quality and reliability of power supply systems"

Field of higher education: 5. Technical sciences, Professional direction: 5.2. Electrical engineering, electronics and automation;

Prepared by: Prof. Dr. Eng. Nikola Vichev Kolev, DrSci.

1. RELEVANCE OF THE PROBLEM DEVELOPED IN THE DISSERTATION AND GROUNDS FOR ITS DEFENSE

The topic of the dissertation work is relevant for the electronization of power supply systems, because it is indisputable the requirement for high electrical efficiency of the electropower system in any country.

The responsibility towards the environment necessitates the economical consumption of electricity resources, which is associated with a more efficient management of the sources of electricity transmission.

Relationships with electricity resource providers have changed, a new market for electricity services has emerged, there has been a change in the ownership of electricity distribution companies, and the philosophy of electricity pricing has also changed.

There has been a growing interest in environmental protection and public attention has been focused on studying energy factors more and more thoroughly in order to use electricity economically and efficiently. The data and information gathered is needed by researchers and professionals forming solutions for society as a whole to make changes needed to preserve and maintain the electricity industry for a healthy environment for generations.

The results of the dissertation research allow to propose new approaches and structures of electricity management systems with improved technical characteristics. There are not many dissertations in this field of knowledge and I hope that this dissertation will have a good reception in scientific circles and among practitioners.

The research is divided into four main sections:

1. A general energy analysis of the factors influencing electricity efficiency is presented;

2. Research based on estimation of electrical power losses;

3. Studies to establish the dependence of energy consumption on voltage modes, CRT levels and on load;

4. Studies to establish a universal regulatory framework that considers lighting as a production and ergonomic factor with an electrical energy focus.

A review of the table prepared by the author on the minimum requirements for the right to defence, according to the Regulations of the BAS, shows that Assoc. Ilian Iliev has achieved the results that entitle him to request the opening of the procedure for the defence of the dissertation prepared by him for the award of the degree of Doctor of Technical Sciences.

2. DEGREE OF KNOWLEDGE OF THE STATE OF THE PROBLEM AND CREATIVE INTERPRETATION OF THE LITERARY MATERIAL:

The state-of-the-art assessment of the study area critically reviews the existing power management systems used for various applications to improve the quality and reliability of power supply systems.

The objective of the work, in my opinion, is to establish an approach to rationalize and optimize the electricity consumption in the country.

In order to fulfill the defined objective, the dissertation has set several more important tasks, including: to analyze the relationship between the electricity system and its main energy characteristics, including power and electricity losses, power quality, power supply reliability and other such; to evaluate the legislation in the country and in Europe in the field of electricity efficiency; to practically evaluate the various energy processes in the power system and determine the elements of the power balance in the multi-factor space; to evaluate the operating modes of multi-transformer substations and to propose criteria for optimal operation of the stations.

to evaluate classical and modern theoretical approaches in relation to electricity efficiency, by

The dissertation has a length of 430 pages and consists of 4 chapters, conclusions and a conclusion with contributions, and a list of literature used, including 294 sources, of which 104 in Latin.

3. COMPLIANCE OF THE CHOSEN RESEARCH METHODOLOGY WITH THE STATED AIM AND OBJECTIVES OF THE DISSERTATION WITH THE ACHIEVED CONTRIBUTIONS

The dissertation research is structured in such a way as to achieve the necessary solutions to the tasks set in the dissertation. A theoretical analysis is made, followed by simulation and experimental studies, graphical and mathematical processing of the obtained results.

Assoc. Prof. Iliev develops the idea of a differentiated approach to the assessment of power and electrical energy losses in the power supply system, classifying them into two main groups -conventional and mode.

Developments in the field of the dissertation work, included in the author's publications, are properly methodologically constructed with a sequence that provides positive solutions to the set tasks.

Methodologies have been applied and refined to model processes occurring throughout the power system.

Experimental results were obtained using standard electrophysical methods for measuring current, voltage, magnetic induction and frequency, some of them modified according to the specifics of the research.

4. BRIEF ANALYTICAL CHARACTERISTICS OF THE DISSERTATION

In the first chapter of the dissertation work, the author has presented a general energy analysis of the various factors influencing the power efficiency on a global scale. A general overview of the power losses and quality of the power system, considered as components of the power efficiency, has been made and a detailed investigation of the conventional methods for compensation of reactive loads has been carried out in order to study and explain their operational features. Classical methodologies for the assessment and quality of the power efficiency have been analyzed, the strong impact of the efficiency in the operation of the power facilities has been emphasized. This chapter examines the basic concepts, influencing factors and requirements for the reliability of the power supply and formulates important indicators, dependencies and characteristics of the failure flow for recoverable elements. An assessment of the duration of the power supply interruption and planned repairs has been made.

The losses of industrial facilities from power outages are analyzed in detail, taking into account the various parameters and dynamics of the processes. This analysis allows for adequate coverage of events related to the reliability of power supply. The analysis of the legislation and other regulatory documents in the field of electricity efficiency shows that the standards adopted in the EU, the USA, China, Bulgaria and other countries are informative in nature and are not mandatory, but only recommendatory. There are no regulatory documents in the nature of directives for the analysis and implementation of specific instructions and recommendations for electricity efficiency, which, according to the author, is a significant omission. The standards related to energy information systems provide instructions for the architecture, structure and principles of their construction. In addition, they recommend monitoring and analysis of parameters and characteristics of a general nature related to production management systems and various activities in the field of administration, environmental protection, etc. According to the author, it is necessary to define electrical energy efficiency as an independent energy category, by marking and formulating basic parameters, characteristics and criteria reflecting the physical nature of electrical energy processes and phenomena. This requires the creation of a complex regulatory framework that will optimize the regulatory framework and create adequate standards of importance for the development of the electrical energy industry.

The second chapter of the dissertation includes results from a differentiated approach applied by the author for the assessment and analysis of different powers and losses of power and electrical energy in the electrical energy system.

A comparative analysis of different power theories has been made, divided into two groups - power theory in the time domain and in the frequency domain. The discrepancies of the different formalizations for determining the effective values of currents and voltages have been shown and a conceptual approach to normalizing the quality indicator is presented, in which it is proposed that quality be assessed by comparing ineffective quantities related to the imbalance and deformations of voltages and currents with the useful active power. The research conducted by the doctoral candidate using the GINAPT computer product shows that the full power can be determined without using the phase angle between current and voltage. The active current is the one that feeds the load and is determined for the reactive load compensation process. Optimal compensation can be achieved by injecting an inactive current with the opposite sign from the active filters, but there is also a possibility that the inactive current can be represented by components that can be compensated by the active filters.

The research also shows that all theories of instantaneous power based on GINAPT do not distinguish between individual harmonics, but evaluate their general action and in this sense they do not provide an opportunity for a differentiated analysis of electromagnetic processes. The definition of active power losses only by losses through the value of $\cos\varphi$ does not allow for a complete control of the studied power consumption processes and to assess additional power losses from deteriorated power quality. The presence of deformation and pulsating power, as well as the deviation and fluctuation of voltage and current, have their influence on the occurrence of additional losses and a change in the structure of total active losses. According to the author, losses from deteriorated quality indicators are comparable to conventional ones and therefore, when creating a complex methodology for assessing electrical energy efficiency, this fact must be taken into account. In this regard, it is advisable to recommend that when creating complex methodologies for assessing electrical energy efficiency.

The conducted research on an integral approach for the assessment and analysis of power and electricity losses is applicable to low, medium and high voltage. The methods are mainly deterministic in nature, using data from laboratory measuring instruments and circuit information for the parameters of the lines (cross-sections, lengths, resistances), as well as information about the operating parameters. The accuracy of the methods is determined by the reliability of the information, which is very often incomplete, depends on subjective factors, so in addition to being systematic, it also has a random nature. Of great importance are the obtained multifactor regression mathematical models, with which various circuit changes can be taken into account, as well as the dynamics of the operating parameters, which characterizes them with high reliability and accuracy. Another positive feature of the method is, according to the author, that the number of factors can be increased, which increases the reliability of the information. The study itself with such a large number of factors is not a problem when using modern software.

The author proposes a complex multifactorial approaches, with the help of which mathematical models can be derived, describing dependencies between various indicators and characteristics related to electricity efficiency and system quality. By applying it in a multifactorial space, the simultaneous impact of multiple significant factors on the output parameters is realized, which achieves speed and savings of funds and resources.

The methodological statement explains the conditions, considerations and prerequisites for selecting and determining the output parameters of the models. The methods and criteria for adequacy and significance of mathematical models and significant factors in first and second order planning are indicated, as well as for assessing the variance of errors. The method makes it possible to solve optimization problems by defining optimal areas of change of the output parameters and significant factors and managing the process as a whole.

A theoretical study was conducted to establish the influence of the load regulating effect, on the basis of which to determine the optimal compensating power and the optimal transformation coefficient of the power transformer, as well as the power balance equation, representing the change in the consumed power during simultaneous voltage regulation and compensation of reactive loads. The optimal distribution over time of electrical consumers in order to form a uniform load schedule is carried out by applying the mathematical theory of correlation. The probabilistic-statistical formulation is a methodology for reducing the dispersion component of power losses, which also minimizes total losses.

The operation of one power transformer and in parallel operation of several power transformers with the same and different powers was theoretically studied. The concept of "relative power losses in power transformers" was defined and graphical dependencies were constructed for them at different powers. Approaches for optimal technical and economic mode of compensators have been developed, such as in the reduced consumption mode it is appropriate to use synchronous motors as adjustable sources of reactive power. Modern solutions for compensation of reactive loads based on flexible alternating current systems have been analyzed, as well as the prospective application of active and passive filters for regulating processes in powerful power systems.

An innovative approach based on the theory of instantaneous power for vector representation of voltage and current has been proposed, and three strategies have been developed, with the help of which the application of active filters for compensation of unbalance and nonlinearity in power systems is justified, and for this purpose a simulation in the Matlab-Simulink environment of the studied processes has been carried out.

The significant improvement of the electrical energy efficiency of the system from the development has been proven. A theoretical study on the quality of the system has been conducted and it has been shown that the sources of electromagnetic interference in substations cause a significant deterioration in the quality of the system. Various technical measures are proposed to improve the operating modes, including various circuit solutions such as circuits with paired reactors, three-winding power transformers, etc. circuit solutions with good effect.

The application of longitudinal compensation of reactive loads reduces, on the one hand, the asymmetry and voltage loss, and on the other, limits the fluctuation of current and voltage. Such an approach is also used for consumers with sharply variable loads, such as electric furnaces, welding units, rolling mills, electrolysis plants, etc. The failure intensity of the gamma distribution, the nominal and exponential law of time has been theoretically determined.

The third chapter is devoted to the study of energy processes in the power system, related to the determination of active power losses in the multifactor space by industry. It is based on data samples that are processed using the methods of mathematical statistics. In the large-scale study conducted in 167 industrial enterprises, grouped into 9 industries, the dependence of the specific consumption of electric energy on the voltage regime, the levels of compensation of reactive loads and on the load was established. By applying probabilistic-statistical approaches, the stationarity of the studied stochastic processes was proven. To reduce the specific consumption of electric energy in the reduced load regime (β =0.16÷0.58), the application of an effective technical measure "voltage regulation" in the range U=(0.9÷1) UH can be recommended. The dissertation has also established that the compensation of reactive loads is a very good means of increasing electrical energy efficiency. The dissertation applies methodologies combining the use of objective measuring instruments and analytical approaches, at very low load (β =0.16÷30) predicted levels of conventional losses in the range $\Delta PK = (19÷21\%)$ and losses from deteriorated quality indicators $\Delta Pb = (5÷6)$, as these values apply to all industries.

The author has modeled active power losses in a multifactor space and based on expert analysis has determined four strategically significant factors of a regime and circuit-technical nature. He has applied a complex multifactor approach, with the significant factors varying at 3 levels, and the mathematical models have been determined for 5 main industries in the country. A graphical interpretation in 2D and 3D space of these dependencies is presented, the relevant detailed conclusions are made and opportunities for optimization of the factors are marked. The analysis shows that in a reduced load mode, it is expedient, from the point of view of improving the electrical energy efficiency, to regulate the voltage deviation towards "negative" values.

In the fourth chapter, the author proposes optimization procedures according to various criteria for achieving higher electrical energy efficiency of the system. The complex multifactorial approach in the analysis and optimization of electrical energy processes is expressed in the creation of a mathematical formulation for the simultaneous impact of the essential factors on the output parameters of the electrical energy system. This achieves optimization of the system management, savings of funds, time and labor, and also obtaining clear and accurate characteristics of the studied objects. Therefore, the complex multifactorial approach is evaluated as an approach with the highest efficiency, adequacy, identity and justification.

Assoc. Prof. Iliev offers an opportunity to optimize losses from deteriorated parameters of the energy efficiency coefficient in the creation of models. The numerous industrial sites studied allow the databases to be grouped for individual typical consumers and the optimization parameter is determined through an active-passive experiment, with deterministic and probabilistic statistical methods.

In power plants, there is always a group effect of factors and therefore, the adopted approach and the obtained results adequately and correctly reflect the real processes in power systems. The author offers various optimization procedures according to criteria for achieving high power efficiency in the sectoral structure of the country and for various industrial sites. It offers a methodology for the optimal distribution of compensating capacities according to the criterion of minimum of the reduced annual costs. The methodology has been tested in 44 industrial sites, with characteristic energy indicators determined for seven branches of industry and the annual savings of electricity for different levels of $\cos\varphi$ have been calculated. Based on the theory of instantaneous power, new theoretical approaches are given for representing the current vector, with the help of which a combinatorial topology is synthesized for three-phase four-wire systems with an asymmetric load. Modeling and simulation in the Matlab-Simulink environment show that the active filter compensates for the input current and as a result the loss decreases from 22.59% to 4.41%.

The author proposes the possibility of increasing the power efficiency by improving the quality of the system. The weight of influence of each of the factors and the effects of their interaction are determined, and the nonlinear deformations for some of the studied groups are also analyzed.

For objects from the electrical industry, the metallurgical industry and the mining and cement industries, the author has studied various characteristics reflecting the correlation between power efficiency and the quality of the power system. It has been proven that in the reduced load mode there is a possibility of escalation of current resonance at higher resonant frequencies. A complex effect of minimizing the asymmetry of currents and voltages has been achieved, as well as a significant effect of compensation of reactive loads, as a result of which power losses are limited to $(4\div7)$ %, increasing the stability and reliability of the system operation.

5. SCIENTIFIC AND SCIENTIFIC-APPLICABLE CONTRIBUTIONS OF THE DISSERTATION

I accept the contributions formulated by Ass. Prof Iliev, emphasizing that they are well-founded, but verbose, and I report them edited by me, as follows:

SCIENTIFIC CONTRIBUTIONS

1. A methodology has been developed in a multifactorial space for substantiating mathematical models of various output parameters and their optimization, which was created with the main goal of serving as a criterion for defining the energy category "Electric energy efficiency" by testing the synthesized approach in conducting a scientific research innovative experiment.

2. A theoretical model has been proposed for determining the power balance at a given point in the power supply system, through which the so-called "power balance equation, which represents a set of different energy indicators, united by a common goal. The model allows, by combining the functions of heterogeneous in nature quantities, to obtain a positive trend of the energy impact. The relationships between the individual energy indicators are complex, therefore, achieving the desired effect requires the use of precise mathematical apparatus.

3. An innovative approach is proposed, based on the theory of instantaneous power for vector representation of voltage and current, and three strategies have been developed, with the help of which the application of active filters for compensation of unbalance and nonlinearity in power systems is justified, and for this purpose a simulation in the Matlab-Simulink environment of the studied processes has been carried out.

SCIENTIFIC AND APPLIED CONTRIBUTIONS

1. The expediency of the electrical equipment in the power supply system to operate at voltage levels lower than the nominal ones regulated in the standard has been proven, in which the effect of this action is manifested in an improvement of the electrical energy efficiency of the system, increasing the reliability of the power supply in the reduced load mode.

2. Mathematical models have been developed for several industries that allow for a more precise assessment of conventional power losses from all indicators of electrical energy efficiency, and they can be used in design and research practice.

3. An approach has been proposed for determining partial power losses, the theoretical basis of the methodology being built on the theory of instantaneous active power in the reduced load mode.

4. A new concept has been developed for determining asymmetric and non-sinusoidal modes, which reflects the energy impact of the load on the quality indicators and has been successfully tested in a number of objects.

5. To suppress resonance phenomena in the power system, approaches have been developed for their assessment taking into account the influence of the load, in which the application of the methodology allows for increasing the reliability and sustainability of the power supply.

6. The correlation between the reliability of power supply and the regime characteristics of power supply, and in particular with reactive load compensation, is substantiated.

7. Predictive results for reliability indicators in major industries are obtained, as reactive load compensation in the power system is assessed and the active application of synchronous motors to improve system reliability is justified.

8. Optimization procedures are proposed according to various criteria, including a complex multifactorial approach to achieving higher power efficiency of the system.

The contributions formulated by the author with the dissertation work belong to the creation of new methods, models and tools, and obtaining new and confirmatory facts and data, and therefore, in my opinion, have a scientific and applied scientific nature.

6. EVALUATION OF THE DEGREE OF THE PERSONAL PARTICIPATION OF THE DISSERTATION STUDENT IN THE CONTRIBUTIONS

I do not know Assoc. Prof. Iliev personally, but I know the creative atmosphere in which he works at the Institute of Robotics.

From what I have read in the dissertation, I assess that Ass. Prof. Iliev uses the theoretical analysis and experimental results of the developments as justification, and the presentation of the results in several scientific forums prove his active presence in the scientific life of the Bulgarian Academy of Sciences. This gives me reason to assume that the developments are supervised and are the personal work of the author.

7. EVALUATION OF THE PUBLICATIONS ON THE DISSERTATION THESIS

Assoc. Prof. Iliev's dissertation work is built on 12 scientific publications, of which 1 is independent and 11 collective. In 4 of the publications, Assoc. Prof. Iliev is the first author.

In my opinion, the publications on the dissertation are not many, they are all reports from scientific conferences, but they reflect the main parts of the dissertation work.

I have carefully read the scientific works on the dissertation, and I accept that they reflect the work. The publications are well-founded, analytical and complete, and 4 are written in good English.

The works have been published in reports from national and international scientific conferences: 16-th Scientific Conference "BulEF 2024"; Scientific and Technical Conference, Varna 2023; International Scientific Conference "UNITEH23"; International Scientific Conference of MGU "St. Ivan Rilski" 2023; 15th Elektrical Engineering Faculty Conference (BulEF) 2023; International Scientific Conference "Üniteh 2018"; Energy Forum 2017, National Technical Committee for Energy.

It can be assumed that the results of the dissertation are known to the scientific community in our country and abroad, since all publications are included in peer-reviewed collections of reports of national and international scientific conferences registered in Scopus.

The author has noticed 15 citations of 11 of his publications.

I have no common publications with the dissertation author and I am not a related person within the meaning of paragraph 1, item 5 of the Additional Provisions of the Law on the Protection of Energy Resources of the Republic of Bulgaria.

I did not find elements of plagiarism in the materials of the dissertation.

8. USE OF THE RESULTS OF THE DISSERTATION WORK IN SCIENTIFIC AND SOCIAL PRACTICE

The dissertation includes results of research on energy parameters of the national power system. Results of the dissertation research have been used in 10 successfully completed scientific projects and can be used in innovative solutions with multifunctional applicability related to the management of electricity efficiency in the national power system.

9. ASSESSMENT OF THE COMPLIANCE OF THE ABSTRACT WITH THE REQUIREMENTS FOR ITS PREPARATION

I have carefully read the abstract and accept that it presents the text of the dissertation. The abstract is in the volume required by the Regulations, briefly reflects the content of the dissertation work and its contributing elements.

10. OPINIONS, RECOMMENDATIONS AND NOTES:

1) The dissertation and the abstract do not indicate the scientific specialty in which the dissertation is to be defended;

2) All chapters of the dissertation cite literary sources, which makes it difficult for the reader to determine which of the original contributions are his or her own;

3) The contributions to the dissertation are verbose;

4) Many abbreviations have been introduced into the text of the dissertation, which make it difficult for the reader to understand, and some are not explained;

5) The publications on the dissertation are 12 and reflect all parts of the dissertation, but do not have the necessary representativeness, because they are only reports from scientific conferences, and not publications in representative scientific journals with an impact factor or high rank;

6) The author has only one independent publication, and in 4 he is the first author;

7) There is not abstract in English in the end of the autoreferat.

11. CONCLUSION

I support the presented content of the dissertation and the contributions formulated in it, accepting that the publications are few and are not included in reputable journals, and appreciating the importance of the topic of electric power engineering and the results of the development of the dissertation work on the topic "Optimization of electric power efficiency in reduced load mode and improving the quality and reliability of power supply systems" in the scientific direction 5.2. Electrical engineering, electronics and automation, I propose to the Scientific Jury to make a decision to award Assoc. Prof. Dr. Eng. Iliyan Hristov Iliev the scientific degree "Doctor of Technical Sciences".

10.06. 2025 Sofia Prof. Dr. Eng. Nikola V. Kolev, DrSci.