

REVIEW

of a dissertation work for acquisition of the scientific degree "Doctor of Science" in the field of higher education 5. "Technical sciences", professional field 5.2. "Electrical Engineering, Electronics and Automation"

Author of the dissertation:

Assoc. Prof. Eng. Ilian Iliev, PhD

Dissertation title:

"Optimising the efficiency of electricity in reduced load mode and improving the quality and reliability of electrical power supply systems"

Reviewer:

Prof. DSc Eng. Galina Petkova Cherneva – Todor Kableshev University of Transport

1.Relevance of the problem developed in the dissertation work in scientific and applied scientific terms

The efficiency of electricity is an essential part of the European Union (EU) policy in the field of energy, climate and economic development. Issues related to methods, approaches and technologies for increasing energy efficiency correspond to the EU objectives and strategies related to renewable sources, energy taxation, emissions trading, etc. Energy-efficient decisions should be made at many levels - when choosing technologies, when implementing them in production, when repairing and modernizing enterprises. At the present stage, we are witnessing a dynamic change in energy resources, electrical equipment and services, and the formation and implementation of the price of electricity (EE). Innovative modern technologies are related to electrification, the introduction of new, more efficient drives and management of the electricity consumption process.

The relationship between the categories of electrical energy efficiency (EEEf) and energy quality requires consideration and analysis of numerous characteristics, quantitative and qualitative indicators (reactive energy magnitude, reactive load compensation, electromagnetic compatibility, non-sinusoidality, etc.). The quality of electrical energy, its standardization, control and management affect the stability and reliability of the electrical energy system as a whole. All these issues determine the problem area of the present dissertation work. It examines the possibilities for rationalizing electricity consumption in industrial facilities by searching for an optimal balance between the positive and negative sides of the process associated with the transfer of electrical energy from generating sources to consumers.

The aim of the dissertation is to investigate, systematize and analyze the theoretical propositions related to the concept of achieving EEEf, identifying the factors influencing this energy category, to be implanted in practical-applied research conducted under different criteria with the target function of rationalizing and optimizing the electricity consumption in the sectoral structure of the country

To achieve the set goal, the author has formulated seven tasks. They are related to research and analysis of factors influencing EEEf, the relationship between EEEf and some energy characteristics (power and energy losses, EE quality, reliability

of power supply, etc.), and establish the mutual influence of these indicators, practical studies of various energy processes in power supply systems (PSS) and their impact on efficiency, etc.

The topic is very relevant, given the continuous increase in energy costs, the environmental footprint of EEf and the need for economically feasible operating modes of the PSS.

The research conducted and the proposed new solutions for improving the EEf determine the relevance of the work in scientific and applied science.

The formulated goals and objectives and the broad scope of the problems considered correspond to the requirements for a dissertation for the acquisition of the scientific degree "Doctor of Sciences".

The submitted materials meet the requirements of the Regulations for the Terms and Procedures for obtaining scientific degree "Doctor of Science" and show that Assoc. Prof. Dr. Iliyan Iliev has achieved results that allow him to request opening a procedure for the defence of a thesis.

The dissertation was discussed and scheduled for defense by an extended seminar of the Laboratory "Robotic Systems in Energy" at the Institute of Robotics – BAS, with all procedural requirements being met.

3. Level of knowledge of the problem and creative interpretation

The bibliography of dissertation work is modern and adequately reflects the current state of the scientific issues under consideration. The dissertation work shows a good literary awareness of the autor. In the bibliography are cited 294 in number literary sources, of which 104 are in English and 190 are in Cyrillic.

It can be concluded that Assoc. Prof. Dr. Iliyan Iliev knows very well the problems of the electric power industry and the PSS, the legislation and regulatory documents in this area, and the methods for assessing the EEf.

4. Conformity of the selected research methodology with the aim and tasks of the dissertation

The goal and main tasks of the dissertation work determine the research methodology. To achieve the formulated tasks, a comprehensive theoretical study was conducted and a comparative analysis of different theories and approaches for assessing EEf was made. Experimental and simulation studies in the Matlab-Simulink environment were used, as a result of which specific innovative technical solutions for improving the EEf were proposed. The research process is based on the application of probabilistic-statistical approaches, innovative technological products and modern analytical methods.

5. Analytical characteristics of the dissertation work

The dissertation work is developed in a volume of 340 pages of text, containing 229 figures and 102 tables. Its structure includes an introduction, four chapters, a main conclusions from the dissertation work, a summary of the work's contributions, a list of publications and references. Conclusions and summary of results are formulated at the end of each chapter.

In the *first chapter* a general energy analysis of the different factors influencing electricity efficiency globally is presented. Classical methodologies and frameworks for EE assessment and quality are analysed, its organic relationship with the compensation for reactive power (CRP) is highlighted and the strong impact of this symbiosis on the efficient use of EE in the operation of energy facilities is emphasised. Based on a thorough literature study, the unresolved problems and the goal of this dissertation work are defined. At the end of the first chapter, representing a literature review, the main goal and the tasks to be performed on the topic of dissertation work are formulated.

In the *second chapter*, a comprehensive theoretical study of different formulations applying a differentiated approach to the assessment and analysis of different power and power losses in PSS is conducted, which is a prerequisite for the determination of the EEEf. A comparative analysis of different power theories is made. A complex multi-factor approach has been developed to obtain mathematical models describing the relationships between various indicators and characteristics related to EEEf, EE quality and the electromagnetic compatibility (EMC). A theoretical study has been conducted to establish the influence of the static characteristics of the load (CSL) on various performance parameters. Modern solutions for CRP based on flexible alternating-current systems (FACTS) are analyzed, as well as the prospective application of active and passive filters to regulate the processes with the powerful ESSs. An innovative approach based on instantaneous power theory for vector representation of voltage and current is presented, and different strategies are developed. A theoretical study has been conducted on the general nature of the quality of EE, EMC and EEEf. It is shown that the sources of electromagnetic interference in substations cause a significant degradation of the quality of EE, EMC and EEEf.

In the *third chapter*, the results of the conducted research in 167 industrial plants grouped into 9 industries are analyzed and the dependence of specific EE consumption on voltage regime, CRP levels and load (β) was established. Recommendations have been given for reducing the specific EE consumption in the reduced load mode ($\beta=0,16 \div 0,58$). Loss modelling of active power in multifactor space is performed. Based on expert analysis, four strategically significant SFs of overhead and circuit nature are identified. The "power balance equation" (δP^*) in the sectoral structure of the country is modelled. A methodology for achieving high EEEf in the PSS of the respective industries is developed. An original technical solution for optimizing the power transformer (PT) operation mode in four transformer substations is presented.

In the *fourth chapter* different optimization procedures are applied according to different criteria to achieve high EEEf in the sectoral structure of the country and for different industrial sites. The optimal distribution and location of the compensating capacities QK is achieved under the criterion of the minimum of the adjusted annual expenses. The methodology has been approbated in 44 industrial sites for which three types of limiting curves have been constructed. For seven industrial sectors, typical energy performance has been determined and the annual EE savings have been calculated for different $\cos\phi$ levels. A research process has been conducted to identify the possibility of increasing the EEEf through improving the quality of EE. For sites in the electrical, metallurgical, mining and cement industries, various characteristics reflecting correlations between EEEf and EE quality have been investigated. For sites in the electrical, metallurgical, mining and cement industries, various characteristics reflecting correlations between EEEf and EE quality have been investigated. Reliability forecasts for nine industry sectors are presented, and opportunities for improvement

are suggested. A study has been carried out and a quantitative assessment of the reliability of power supply for high power industrial sites has been given

6. Dissertation contributions

The main contributions of the overall development presented in dissertation work can be summarized in the following:

- proving with new means essential new sides in existing scientific problems;
- creation of new research methods and technologies;
- obtaining corroborating facts.

The author formulated 2 scientific and 7 scientific-applied contributions, which I accept.

The main *scientific* contributions can be listed as:

- formulation of the energy category "Electricity Efficiency" through a developed methodology in a multifactor space for determining mathematical models of various output parameters and their optimization;
- a scientifically based theoretical model for determining the energy balance at a given point of the PSS is proposed, through which the so-called energy balance equation (δP^*) is defined, which represents a set of different energy indicators united by a common goal;
- optimized bonding parameters on carbyne to obtain strong bonding connections with controllable and repeatable parameters;
- formulated and solved is an optimization problem of the type $\delta P^* < 0$ and the impact of various energy indicators on EEEf is analyzed.

As a summary of the *scientific-applied contributions*, the following can be mentioned:

- the appropriateness of the electrical equipment in the PSS to operate at voltage levels lower than the nominal ones regulated in the standard it has been proven;
- developed mathematical models of static load characteristics for assessing the quality of electrical energy;
- proposed approach and developed methodology based on the theory of instantaneous active power for determining partial power losses;
- a new concept is developed to determine the asymmetric and non-sinusoidal modes, and they are estimated using power-weighted unbalance and nonlinearity coefficients;
- to suppress the resonance phenomena in PSS, approaches have been developed to evaluate them considering the influence of load;
- the correlation of the reliability of power supply with the mode characteristics of the power supply and specifically with the CRT and the quality of EE is substantiated;
- predictive results of reliability performance in 9 industry sectors are obtained.

The obtained results represent an original contribution to science and practice and they fully meet the requirements for a dissertation to acquire the scientific degree "Doctor of Science".

7. Assessment of dissertation publications

On the topic of dissertation work have been attached a total of 12 publications. 4 of them have been presented at conferences with international participation in our country and abroad, and are indexed in Scopus.

One of the publications is independent, the rest are co-authored, and Assoc. Prof. Iliev is the first author of 3 of them.

The performance of the main indicators for area 5. "Technical sciences" are calculated in Table 1 presented below.

A group of indicators	Minimum number of points	Number of points of the candidate	Number of points by main indicators of a group
A	50	50	Diploma № 21/14.10.2014г. - 50
Б	100	100	
В	-	-	
Г	100	110,01	Г7. 46,6
			Г8. 63,35
Д	100	139	Д12. 40
			Д14. 99
Total	350	399,01	

The evidence presented shows that he repeatedly exceeds (399.01 points) the national requirements (350 points) for occupying the scientific degree "Doctor of Science" in professional field 5.2. "Electrical engineering, electronics and automation".

All research papers have significant theoretical and applied contributions and are in the field of the dissertation work. It is obvious that the results of the dissertation have become available to the scientific community at home and abroad.

In addition to what is presented in Table 1, Assoc. Prof. Dr. Iliev is the author of 7 monographs – 4 independent and 3 co-authored and a participant in the working groups of 10 research projects.

8. Assessment of the degree of personal participation of the author in the contributions

Based on the research presented, the authorship of the publications on the dissertation, I consider that it is an independent work of Assoc. Prof. Dr. Iliev.

9. Assessment of the qualities of the abstract

The abstract fully and clearly reflects the main points of the content and contributions of the dissertation. The requirements for preparation of the abstracts on the dissertation works have been met.

10. Using the results of the dissertation work in science and practice

The analytical and experimental studies carried out and the results obtained show that the proposed original methodologies provide an opportunity for analysis and solution of specific problem tasks in the EEf. The research carried out, the created products and the obtained results, in my opinion, will have great application in the field of EE. The results are also related to tasks in the 3 research projects in which the doctoral student participates. Some of the developments serve the educational process.

Confirmation of the relevance of the results obtained by the author are a total of 139 points of citation of his publications.

I believe that the proposed dissertation work represents a thorough scientific research work with a high degree of relevance. The degree of applicability of the obtained results is high.

11. Opinions, recommendations and remarks on the dissertation work

The dissertation work is an extensive scientific work on the researched issues. It is well structured and clearly arranged. The author has carried out a serious volume of scientific research work, containing both experimental and analytical parts. I don't have critical remarks.

My recommendation to Assoc. Prof. Dr. Iliev is to continue his successful research activities in the field of EEf.

12. Conclusion

The dissertation work of Assoc. Prof. Dr. Iljan Iliev contains analytical and simulation results, through which the tasks set in it are solved. My overall rating is positive. There are sufficient scientific and applied contributions that meet the requirements of the ZRASRB, as well as the Rules of the Law for the award of the scientific degree "Doctor of Science".

I suggest to the respected members of the Scientific Jury to give high marks and vote for the awarding of Assoc. Prof. Dr. Iljan Iliev for the scientific degree "Doctor of Science" in the field of higher education 5. "Technical sciences", professional direction 5.2. "Electrical engineering, electronics and automatics".

02.06.2025

Reviewer:...../.

/Prof. D.Sc. G. Cherneva/