

REVIEW

By Prof. Dr. eng. Ivan Petrov Petrov, University of transport "Todor Kableshev"

On the dissertation submitted for the award of the educational and scientific degree "doctor"

In the field of higher education 5 "*Technological sciences*"
professional field 5.2 "*Electrical engineering, electronics and automation*"

Author: M. eng. Petar Ivanov Petrov

Title of dissertation: "*The Influence of Load on Reactive Power under Asymmetrical and Non-Sinusoidal Regimes*"

1. Brief Biographical Data and Professional Profile

The doctoral candidate in this competition, M. eng. Petar Ivanov Petrov, completed his higher education between 1995 and 2000, obtaining both Bachelor's and Master's degrees in *Electronic Engineering* at the University of Ruse "Angel Kanchev".

By Order №92B/18.10.2024 of the Director of the Institute of Robotics, BAS, M.Eng. Petrov was enrolled as a doctoral student (part-time form of study) in the doctoral program "Elements and Devices of Automation and Computing Technology", professional field 5.2 "Electrical Engineering, Electronics and Automation." His scientific supervisor is Assoc. prof. DSn. eng. Iliyan Hristov Iliev.

According to the attached documents, since August 2024 he has been employed as an Assistant at the Institute of Robotics, BAS. He has good command of English and excellent computer proficiency, including experience with specialized software products.

The candidate possesses solid knowledge in the field of energy, teamwork abilities, and strong communication skills acquired through work with clients, as well as state and private institutions.

He has successfully fulfilled the requirements of his individual study plan, passed all prescribed examinations with excellent results, and has actively participated in scientific forums. His personal qualities and deep expertise in the specialty have supported the successful development of the present dissertation and its orientation toward a timely and forward-looking research topic.

2. Relevance of the Research Problem in Scientific and Applied Terms. Scope and Significance of the Issues and Specific Tasks Addressed in the Dissertation

The topic of the dissertation is highly relevant and is dedicated to the introduction of new technologies in the design and reconstruction of compensation systems.

The work considers the use of advanced dry or semi-dry capacitor banks, the implementation of specialized batteries for heavy-duty operation, as well as regulators

with optimized control modes. It also examines detuning inductors for polluted networks and specialized low-voltage compensation equipment for capacitive loads.

Furthermore, the dissertation addresses the application of microprocessor-based regulators with single-phase or three-phase voltage measurement, the use of SF₆ contactors for capacitor banks serving auxiliary needs, and the implementation of high-power specialized power electronic modules in cases requiring the compensation of rapidly varying dynamic loads.

3. Analysis of the Structure and Content of the Dissertation

The dissertation comprises 180 pages and is structured into an introduction, which provides a concise overview of the work, four chapters, and concluding remarks. At the end of each chapter, the main findings are summarized.

Chapter One presents a literature review on the dissertation topic. Following this, the aim and the principal tasks of the research are formulated.

The dissertation also includes the author's stated contributions, a record of the dissemination of the dissertation results, and a bibliography containing 129 references in both Cyrillic and Latin script.

4. Candidate's Familiarity with the State of the Problem and Evaluation of the Literature

M. Eng. Petar Ivanov Petrov demonstrates profound knowledge of the subject addressed in the dissertation. In Chapter One, which essentially serves as a literature review, he examines both conventional and advanced high-tech methods for the compensation of reactive loads.

From this analysis and the conclusions drawn, the aim and principal tasks of the dissertation are formulated, which in turn define the direction of the subsequent research. The findings clearly show that existing methods for reactive power compensation significantly lag behind European standards. An analysis is provided of innovative high-tech technical solutions for compensation, along with an evaluation of opportunities to achieve intelligent and adaptive solutions with very high efficiency.

In my opinion, the author adequately assesses the current state of development and the key challenges in this field. On this basis, he has precisely formulated the aim and objectives of the dissertation, as well as the trajectory of further research. After this clear formulation of goals and tasks, the work progresses through all levels of development— theoretical, methodological, and experimental— in order to achieve maximum validity and effectiveness.

The main research tasks, which also include extended experimental investigations and optimization solutions, are methodically developed in the subsequent chapters of the dissertation.

5. Can the Chosen Theoretical Approaches Provide Adequate Answers to the Aim and Objectives of the Dissertation?

The answer to this question is grounded in the chosen theoretical approach. The applied theoretical framework for determining the effective values of certain electrical quantities related to reactive load compensation adequately addresses the dissertation's objectives. A comparison of different power theories has been carried out. Based on

this theoretical formulation, a comprehensive critical analysis was made, which serves as the basis for selecting appropriate methodologies and optimal solutions.

The conclusions in Chapter Two focus on two approaches for analyzing asymmetrical and nonlinear regimes, demonstrating the energetic impact of load conditions on power quality and energy efficiency indicators. Objective, practically oriented approaches are also presented for the application of reactive load compensation.

In Chapter Three, reactive load compensation under nonlinear and asymmetrical conditions was studied in real facilities. A methodology for investigating reactive loads based on energy efficiency criteria was developed. The methodology is of pronounced practical character, with universal applicability across facilities from different industries and with varying energy characteristics.

This methodology was tested on a large industrial site. The results of the analysis justify the assumption that the applied technical means are equivalent. Partial losses of active power caused by pulsating, hidden, and distortion power were determined separately. Their sum proved to be comparable to conventional active losses, making them highly inefficient and highlighting the necessity of revising current concepts in line with the proposed methodology. To this end, studies using infrared thermography were conducted, examining various elements of compensation systems. The graphical results confirmed the presence of defective capacitor banks, which proved ineffective.

Three-phase facilities were also investigated. The results indicate that conventional reactive power compensators yield lower values than standardized indicators. The research proposes that reactive power compensation in such facilities should be assessed using the power factor, rather than $\cos \varphi$, and provides a formulation for more precise calculations.

Chapter Four examines opportunities for optimizing reactive load compensation through the combined use of synchronous motors and capacitor banks. A case study of an industrial facility is presented, including a description of its technological processes and an analysis of its energy system. Optimization of reactive loads revealed that the facility exhibited a low energy performance index and low $\cos \varphi$ values.

The operation and parameters of the main equipment at the site were analyzed, and a quantitative assessment of the generated reactive energy was conducted. Based on these findings, the real possibilities for using synchronous motors as reactive energy compensators were determined. An optimization problem was defined with the criterion "Minimum of adjusted annual costs" under four limiting conditions. The developed optimization methodology is maximally adapted to the circuit and technical characteristics of the facility and designed for the simultaneous use of synchronous motors and capacitor banks.

The synthesized methodology was tested on Sections I and II of the Main Step-Down Substation 3 of the case-study facility. The obtained results show that the proposed optimization approach is feasible under real operating conditions. Its technoeconomic effectiveness has been convincingly demonstrated.

The sequence of the research approach confirms that the chosen methodology, the conducted analytical and experimental studies, and the results obtained provide an

adequate response to the central aim and objectives formulated at the end of Chapter One of the dissertation.

6. Analytical Characteristics of the Material and Assessment of its Reliability

The reliability of the material presented in the dissertation is high, stemming from the comprehensive manner in which the research problem has been investigated and the main results presented. The dissertation is written in a concise and logical way. The author has sought opportunities to formulate innovative theoretical and methodological frameworks.

The validity and reliability of the work are further confirmed by the fact that all the proposed methods, studies, and analyses have been implemented and validated on a real industrial facility.

7. Scientific and/or Applied Contributions of the Dissertation. Nature and Significance of the Contributions

The author of the dissertation has formulated two scientific and three applied contributions, with which I am in full agreement.

The principal contributions of the dissertation can be summarized as follows:

- The scientific contributions are defined as innovative theoretical formulations under the criterion of "*Energy Efficiency*," offering a differentiated approach for determining the components of active losses arising from non-active power elements. In addition, a methodological framework has been developed for the assessment of three-phase, power-weighted indicators.
- The applied contributions encompass the study of major industrial consumers that introduce significant disturbances into the power system, investigations into reactive power compensation under conditions of varying reduced load, and the optimization of a large industrial facility in the chemical industry, based on the criterion of "*Minimum Adjusted Monetary Costs*."

No evidence of plagiarism or unacknowledged use of the work of other authors has been found.

8. Assessment of the Extent to Which the Dissertation and Contributions Represent the Candidate's Own Work

I assess the degree of the doctoral candidate's personal involvement in the stated contributions as very high. The publications, their authorship structure, and the forums where they were presented clearly demonstrate that the reported contributions are the direct work of the candidate or have been achieved with his decisive participation.

9. Evaluation of the Publications Related to the Dissertation

In accordance with the procedure for obtaining the doctoral degree, the candidate has presented a total of five publications in Bulgarian. All of them are published in the proceedings of international conferences held in the country (ISSN). The candidate is the sole author of one publication, while in the others he is listed as

second author. I consider that in these collective publications the candidate has played a leading role.

The presented publications reflect the most substantial and significant aspects of the dissertation research.

10. Applicability of the Dissertation Results

As mentioned above, the conducted studies, the developed methodologies, and the obtained results, in my opinion, will have significant applicability in the field of power engineering facilities for reactive load compensation. This provides grounds to state that the candidate possesses the ability to formulate engineering problems and to conduct independent scientific research.

The analytical and experimental studies carried out, together with the results obtained, demonstrate that the proposed original theoretical approaches and the developed methodologies for solving optimization tasks enable the analysis and resolution of specific practical problems.

I consider the dissertation to represent a thorough scientific investigation. Its relevance stems from the fact that the modern dynamic development of technology requires flexibility in compensating reactive loads across various industrial facilities. The degree of applicability of the achieved results is high.

11. Evaluation of the Abstract and the Bibliography

The abstract fully and clearly reflects the main aspects of the dissertation, allowing an assessment of the relevance of the addressed problems, the approaches employed for their solution, and the results obtained. The bibliography of the dissertation is up to date and adequately represents the current state of the scientific issues under consideration. My assessment of the candidate's knowledge of the relevant literature is positive.

12. Opinions, Recommendations, and Remarks on the Dissertation

My recommendations to the candidate are as follows:

- To continue his scientific research in this promising field of technology;
- To work actively on solving tasks related to reactive load compensation;
- To structure and consolidate the content of the dissertation in the form of a teaching aid, so that it can be used both in the educational process and by specialists in practice.

I consider the dissertation to be highly relevant. The developed methodologies, optimization tasks, and obtained results, in my view, will have wide applicability in the fields of industry, transport, and energy.

Conclusion

I consider the dissertation, in terms of both scope and significance of the research, to represent a thorough and completed scientific study that fully meets the criteria and requirements set forth in the Law on the Development of Academic Staff in the Republic of Bulgaria with respect to volume, structure, and content.

The dissertation submitted by M.Eng. Petar Ivanov Petrov, entitled "*The Influence of Load on Reactive Power under Asymmetrical and Non-Sinusoidal Regimes*", fully satisfies the requirements of the law and its regulations, and may be admitted to public defense.

I recommend to the esteemed Scientific Jury that M.Eng. Petar Ivanov Petrov be awarded the educational and scientific degree "Doctor" in professional field 5.2 *Electrical Engineering, Electronics and Automation*.

1 September 2025

Reviewer: ..

/Prof. Dr. eng. Ivan Petrov/