

REVIEW
of the dissertation of
Chen Linfei
on the topic «Improving the Operating Modes of the Electrotechnical
Complex of Hydrogen Supply Using Intelligent Control
in the Electric Transport System»,
submitted for the degree of Doctor of Philosophy
in the field of knowledge 14 Electrical Engineering
in specialty 14.01 Electric Power Engineering, Electrical Engineering and
Electromechanics

Relevance of the dissertation topic.

The problem addressed by this dissertation research is extremely relevant in the context of the current functioning of Ukraine's energy infrastructure. Prolonged disruptions in the operation of the unified energy system, caused by a shortage of generating capacity, damage to networks, and unstable power supply, impose new requirements on the autonomy, flexibility, and reliability of engineering facilities in the energy and transport sectors. These challenges are particularly acute in the field of electric transport infrastructure, where interruptions and fluctuations in power supply directly affect the operation of critically important equipment – in particular, hydrogen production electrolysis complexes, which are sensitive to thermomechanical loads and prone to accelerated degradation under conditions of unstable, intermittent power supply.

Under such conditions, there is a growing need to introduce energy-efficient control technologies that are resilient to external disturbances and capable of ensuring the uninterrupted, prolonged operation of electrotechnical complexes for hydrogen supply. Electrotechnical systems of refueling stations with grid-integrated electrolyzers, capable of flexibly coordinating hydrogen production with the unstable generation of renewable energy sources and with the current state of the power system, are regarded as one of the most promising directions for the modernization of transport and energy infrastructure. However, the efficiency of such complexes largely depends on the quality of intelligent control algorithms and the system's ability to proactively adapt to stochastic changes in load, rather than merely reacting passively to an imbalance that has already occurred.

The dissertation is devoted to the comprehensive solution of these problems through the development of a multi-level automated intelligent electrolyzer control system (AECS), which, based on deep learning predictive models, ensures coordinated interaction between the stochastic demand of electric transport, the storage subsystem, and the production equipment, thereby completely eliminating destructive «start-stop» cycles. This approach makes it possible not only to increase the energy efficiency and reliability of hydrogen refueling complexes, but also to transform the electrolyzer from a rigid industrial load into a flexible energy resource

capable of participating in the regulation of the frequency and power of the energy system – which is directly consonant with Ukraine's pressing need for distributed, controllable loads capable of increasing the resilience of the power system under conditions of a generation deficit.

Given the strategic importance of ensuring the energy autonomy and flexibility of electric transport infrastructure facilities, as well as the need to introduce modern methods of intelligent control of hybrid electrotechnical complexes under conditions of stochastic and unstable power supply, the topic of the dissertation is timely, socially significant, and fully corresponds to the current scientific and applied tasks of the field of electric power engineering, electrical engineering, and electromechanics.

Assessment of the validity of the dissertation's scientific results, their reliability and novelty.

The scientific results presented in the dissertation are logically substantiated and confirmed by a set of theoretical and applied studies. The reliability of the conclusions obtained is ensured by the use of correct mathematical models of the vehicle's longitudinal dynamics, the real gas equation of state for hydrogen (accounting for the compressibility factor based on the NIST REFPROP database), the M/M/S/N queueing model, and the deep recurrent LSTM neural network architecture, as well as by the application of Monte Carlo simulation, which covers a wide range of operating regimes – from standard daily load profiles to extreme stress-test scenarios exceeding the nominal design parameters of the station.

The consistency between the theoretical propositions and the simulation results is confirmed by multi-level verification: the calculated mean value of a single refueling (4.285 kg/vehicle), obtained analytically in Chapter 2, is confirmed by the statistics of the synthetic 366-day dataset with a relative error of only 0.35%, which testifies to the physical correctness of the constructed multi-scale model. The LSTM prediction model was validated on an independent test set (chronological data split, which excludes data leakage), and the closeness of the quality metrics on the training and test sets (RMSE, MAE, R^2) confirms the absence of overfitting and the sufficient generalization capability of the model. The obtained control results (elimination of «start-stop» cycles, power smoothing, reduction of the cost of hydrogen) are consistent with the physical limits of the system, set by the storage volume, the rated power of the electrolyzer, and the load ramp-rate constraints, which testifies to the adequacy of the chosen methods and the correctness of the formulated assumptions.

The scientific novelty of the results of the dissertation research consists of the following:

1. The methodology of intelligent control of the operating modes of electrolyzer plants has been further developed through the use of an adaptive algorithm based on

a neural network with an LSTM architecture, which makes it possible to forecast hydrogen demand from electric transport and to optimize the fuel production schedule in real time.

2. A comprehensive mathematical model of the electrotechnical hydrogen supply complex has been developed which, unlike existing models, accounts for the interrelation between the dynamic characteristics of power converters and the non-linear electrochemical processes in the electrolyzer during operation from renewable energy source (RES) power installations.

3. A dual-mode intelligent optimization model has been proposed, integrating the Arithmetic Optimization Algorithm (AOA) and the African Vulture Optimization Algorithm (AVOA), and constructing an AO–AVOA–BP neural network model for the high-precision forecasting of the technical state of lithium-ion batteries.

The scientific research was carried out by the applicant at the Department of Automation of Electrotechnical and Mechatronic Complexes of Igor Sikorsky Kyiv Polytechnic Institute.

Thus, the scientific task set in the dissertation (the development and study of a multi-level system of intelligent control of the electrotechnical complex of hydrogen supply for electric transport based on deep learning predictive models) has been fully accomplished, and the applicant has demonstrated full command of the methodology of scientific activity.

Assessment of the content of the dissertation, its completeness, and compliance with the principles of academic integrity.

In terms of its content, the dissertation of the applicant Chen Linfei fully complies with the Higher Education Standard in specialty 141 Electric Power Engineering, Electrical Engineering and Electromechanics, and with the research directions of the corresponding educational program.

The dissertation is completed scientific work and testifies to the personal contribution of the applicant to the scientific field of Electrical Engineering.

Having reviewed the similarity report obtained from checking the dissertation for textual coincidences, it can be concluded that the dissertation of Chen Linfei is the result of the applicant's independent research and does not contain elements of falsification, compilation, fabrication, plagiarism, or unattributed borrowing. The ideas, results, and texts of other authors that were used are properly referenced to the corresponding sources.

Language and style of presentation of the results.

The dissertation is written in English and is characterized by a consistent, logically structured presentation of the material. The author adheres to a scientific

style, uses correct technical terminology, and provides a sufficient level of detail for understanding the methods and results of the research. The text is characterized by clarity of formulation, the absence of superfluous descriptive elements, and an orientation towards an analytical approach. The graphical materials, formulas, and tables are presented in a structured form and organically complement the main content.

The dissertation consists of an introduction, **five chapters**, conclusions, and a list of references comprising 84 titles. The total volume of the work is 190 pages, of which the main text (introduction, Chapters 1–5, conclusions) occupies approximately 139 pages.

The **introduction** substantiates the relevance of the topic, formulates the research hypothesis, defines the purpose, objectives, object, and subject of the research, and presents the scientific novelty and practical significance of the results obtained.

Chapter 1 provides a review of the current state of the problem of improving the efficiency and reliability of electrotechnical systems for the hydrogen supply of electric transport. A classification of modern electric vehicles and refueling station infrastructure is presented, the degradation mechanisms of PEM electrolyzers under unstable power supply modes are analyzed, and a SWOT and PEST analysis is carried out, which made it possible to substantiate the necessity of transitioning from passive hysteresis control to proactive intelligent control.

Chapter 2 presents a multi-level mathematical model of the formation of the station's hydrogen load – from the parametric matching of the vehicle's powertrain (micro-level), through accounting for the influence of traffic conditions (meso-level), to the thermodynamic model of the refueling process based on the real gas equation of state (interface level) and the stochastic M/M/S/N queueing model at the station level (macro-level).

Chapter 3 develops an automated electrolyzer control system (AECS): a discrete-time model of the controlled object is constructed, the objective function of multi-criteria optimization is formulated, a hierarchical hardware architecture is designed, and a predictive neural network model based on a deep LSTM is developed for short-term demand forecasting. The results of comparative simulation are presented, confirming the elimination of «start-stop» cycles and the smoothing of power fluctuations.

Chapter 4 performs a multi-physical (electrochemical and thermal) verification of the proposed control system on a model of an electrolyzer cluster using an equivalent electrical circuit and a thermal model, which confirmed the physical feasibility of the «hot standby» mode and the stability of the temperature and voltage characteristics in transient regimes.

Chapter 5 performs a techno-economic assessment of the proposed solution and develops recommendations for engineering implementation, regarding the interaction of the complex with the power grid (participation in primary frequency regulation, load profile flattening).

The dissertation is formatted in accordance with the requirements of Order No. 40 of the Ministry of Education and Science of Ukraine dated January 12, 2017, «On the Approval of Requirements for the Formatting of Dissertations.»

Publication of the results of the dissertation research.

The scientific results of the dissertation are presented in 4 scientific publications of the applicant, including: 2 articles in Ukrainian professional («category B») scientific journals (System Research in Energy); 2 articles in periodical scientific journals indexed in the international scientometric databases Scopus and Web of Science (quartile Q2) – the journals Sustainability and Machines.

The results of the dissertation were also presented at 5 scientific conferences, including the XXV and XXVI International Scientific and Practical Online Conferences «Renewable Energy and Energy Efficiency of the 21st Century» (Kyiv), the X International Scientific and Technical Conference «Energy Management: State and Prospects of Development – PEMS'2025» (Kyiv), the X International Scientific and Technical Conference on Problems of Chemmotology (Kyiv), and the 8th International Scientific and Technical Conference «Modern Technologies of Fossil Fuel Processing» (Kharkiv).

The scientific level of the applicant's publications is high and fully complies with the requirements for the publication of the results of dissertations for the degree of Doctor of Philosophy (or Candidate of Sciences). A publication in a periodical indexed in the international scientometric database Scopus testifies to the international recognition of the research results, while the articles in Ukrainian professional «category B» journals confirm the thoroughness of the theoretical and practical conclusions within the domestic scientific discourse.

The principles of academic integrity have been observed by the applicant in all scientific publications. The works contain no facts of plagiarism, fabrication, or falsification of data. All borrowings from the works of other authors are accompanied by proper references. The applicant demonstrates objectivity in presenting the results and respect for the intellectual property of colleagues.

Thus, the scientific results described in the dissertation are fully reflected in the applicant's scientific publications.

Shortcomings and remarks on the dissertation.

1. Attention is drawn to a discrepancy between a number of key quantitative indicators in the abstract (introductory part) of the work and the results presented

directly in the relevant chapters. Thus, the value of the root mean square error (RMSE) of the predictive LSTM model is stated as 8.37 kg in the introduction, whereas Chapter 3 and the conclusions give a value of 6.7454 kg. Similarly, the number of «start-stop» cycles of the electrolyzer in the baseline (reference) scenario is 37 (reduced to 0) in the introduction, but 61 (reduced to 1, corresponding to a reduction of 98.3–98.4%) in the main text and conclusions. The indicator for the reduction of the standard deviation of electrolyzer power output is likewise presented in three different variants – 51.2% (introduction), 35.7% (Chapter 3), and 40.7% (conclusions).

2. From a methodological standpoint, the comparison of the proposed LSTM model with traditional forecasting methods (in particular, ARIMA) is presented only in qualitative form, without a corresponding quantitative table of metrics (RMSE/MAE/R²) for the comparison method, which somewhat weakens the argumentation in favor of the chosen architecture. Furthermore, the choice of an exponential distribution of service time in the M/M/S/N model is justified as a «worst-case» scenario, but there is no sensitivity analysis of the station design result (S=3, N=13) with respect to alternative service-time distributions, which, by the author's own admission, may more accurately reflect the actual refueling process.

3. The scientific novelty claimed in the dissertation with respect to its third point – the development of the AO–AVOA–BP model for forecasting the technical state of lithium-ion batteries – is not disclosed in any way in the main chapters of the dissertation (1–5), which are devoted exclusively to the control of the electrolyzer of a hydrogen refueling station. In this regard, it would be advisable either to present this result briefly directly in the text of the dissertation, or to more clearly define its place within the overall structure of the scientific novelty as an adjacent, rather than a principal, result of the research.

4. The input economic parameters of Chapter 5 (electricity tariffs, the LCOE of solar generation, the CNY/USD exchange rate, the depreciation cost of the electrolyzer per cycle) are presented without a direct reference to their source or the date of applicability, which complicates the verification of the reproducibility of the techno-economic indicators obtained.

5. The work contains typographical errors and formatting flaws, in particular an erroneous heading of the introductory section («INRTODUCTION» instead of «INTRODUCTION»), an inaccuracy in the name of the specialty on the title page («Electrical Engineering» instead of «Electrical Engineering»), as well as the repeated use of a single sequential number for different formulas (Equation 2.1).

I consider that the remarks made are not decisive and do not diminish the overall scientific novelty and practical significance of the results, nor do they affect the positive assessment of the dissertation.

Conclusion on the dissertation.

I consider that the dissertation of the applicant for the degree of Doctor of Philosophy Chen Linfei on the topic «Improving the Operating Modes of the Electrotechnical Complex of Hydrogen Supply Using Intelligent Control in the Electric Transport System» has been carried out at a high scientific level, does not violate the principles of academic integrity, and is a completed scientific study, the totality of the theoretical and practical results of which solves a scientific problem of substantial significance for Electrical Engineering. In terms of relevance, practical value, and scientific novelty, the dissertation fully complies with the requirements of the current legislation of Ukraine, as stipulated in paragraphs 6–9 of the «Procedure for Awarding the Degree of Doctor of Philosophy and Revoking a Decision of a One-Time Specialized Academic Council of a Higher Education Institution or Scientific Institution on the Award of the Degree of Doctor of Philosophy,» approved by Resolution No. 44 of the Cabinet of Ministers of Ukraine dated January 12, 2022.

The applicant Chen Linfei deserves to be awarded the degree of Doctor of Philosophy in the field of knowledge 14 Electrical Engineering, specialty 141 Electric Power Engineering, Electrical Engineering and Electromechanics.

Reviewer:

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