MINISTRY OF INDUSTRY AND TRADE
ELECTRIC POWER UNIVERSITY

SOCIALIST REPUBLIC OF VIET NAM
Independent– Freedom – Happiness

INFORMATION ON NEW CONCLUSIONS OF DOCTORAL DISSERTATION

(Information will be posted on the Website)

Name of dissertation: *A Study on Pricing Models for Solar Power Plants Integrated with Battery Energy Storage Systems in the Vietnamese Power System.*
Major: Energy Management Code No: 9510602
Name of PhD. Student: DO THI LOAN
Advisors: 1. Dr. Nguyen Ngoc Trung
2. Dr. Christy Hue Thanh Nguyen
Training Institution: Electric Power University.

Summary of new contributions of the Dissertation

This dissertation aims to identify an appropriate electricity pricing model for solar photovoltaic power plants integrated with battery energy storage systems (PV-BESS) within the Vietnamese power system, in a context where the share of renewable energy is rapidly increasing, and technical constraints of the power system are becoming increasingly pronounced. Based on a comprehensive literature review and the identification of scientific research gaps, the dissertation develops an analytical framework and models two pricing approaches - namely the Levelized Cost of Electricity (LCOE) model, and a Time-of-Use (TOU) pricing model combined with a capacity fee (TOU+F) to address five core research questions.

1. The dissertation clarifies the role of battery energy storage systems (BESS) under the assumed presence of transmission constraints at solar power plants.

Simulation results show that when transmission capacity is limited, the usable electricity output of PV systems can be significantly reduced due to curtailment. The integration of BESS allows a substantial share of potentially curtailed energy to be recovered, depending on storage configuration and the severity of transmission constraints. Moreover, these findings demonstrate that BESS is not merely a technical solution but a critical input variable in electricity pricing models, as it directly affects usable energy output - the key parameter determining the minimum electricity price required for PV-BESS systems.

2. Through the LCOE-based model, the dissertation identifies the minimum electricity price ranges (economic floor prices) required for PV-BESS systems to reach breakeven under different operating conditions.

The minimum electricity prices for solar power plants with storage range from approximately 4.58 to 7.4 US cents/kWh, depending on regional conditions, BESS configurations, and assumed transmission constraints. These results are direct outputs of the pricing model developed in the dissertation and reflect differences in solar resource availability, investment costs, storage configurations, and operational risks, rather than serving solely as financial feasibility assessments of individual projects.

3. The dissertation demonstrates that the TOU pricing model more effectively captures the energy-shifting value of BESS compared to the traditional LCOE approach.

Under transmission-constrained scenarios, the amount of electricity shifted from off-peak to peak periods increases significantly, contributing to higher revenues and a reduction in negative net present values (NPV). However, within the current electricity price cap framework, TOU pricing alone is insufficient to ensure breakeven for PV-BESS systems when the full lifecycle of storage is considered, highlighting the need for additional pricing components beyond energy-based tariffs.

4. Sensitivity analysis results indicate that PV capital expenditure ($CAPEX_{PV}$), transmission constraints, and BESS lifetime are the most influential variables affecting both LCOE and NPV, and therefore directly shaping electricity prices derived from the proposed models.

These findings confirm that the aforementioned techno-economic factors are not merely financial assumptions but essential input variables that must be explicitly incorporated into PV-BESS electricity pricing models, particularly in power systems with high renewable energy penetration.

5. Based on the modeling results, the dissertation proposes a combined TOU pricing and capacity fee mechanism (TOU+F) to compensate for the fixed costs of BESS and the risks associated with generation constraints under limited transmission capacity.

The required capacity fee levels to bring NPV to the breakeven threshold vary significantly across regions, reflecting differences in regional price caps, resource conditions, and operational characteristics of the power system.

Overall, the research demonstrates that electricity pricing for PV-BESS in Vietnam should adopt a flexible, model-based approach, in which pricing mechanisms fully reflect technical constraints, economic structures, and operational risks. The dissertation proposes a phased application of pricing models aligned with different stages of power system development: the LCOE-based model is suitable in the short term when system constraints are limited; a combination of LCOE and TOU is appropriate in the medium term as temporal oversupply begins to emerge; and the TOU+F model becomes necessary in the long term when renewable energy penetration is high and system flexibility requirements become critical.

The findings of this dissertation provide a scientific foundation for designing and refining electricity pricing mechanisms for solar power plants with energy storage in Vietnam, while offering policy-relevant guidance to support the sustainable deployment of PV-BESS in line with the national energy transition and long-term power system security.

Ha Noi, December 9, 2025

Advisors	**PhD. Student**
(Signature)	*(Signature)*