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The Effect of 7 MWp Selong On Grid Solar Power Plant (PLTS) on Electricity Network Stability in NTB

Farida Arinie Soelistianto[1], Farisan Robbani[2]
[1]Politeknik Negeri Malang
[2]Institut Teknologi Sumatera

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ABSTRACT

The transition toward renewable energy is critical to achieving global sustainability goals, with solar power playing a significant role in diversifying energy sources. This study examines the effect of the 7 MWp Selong On-Grid Solar Power Plant (PLTS) on electricity network stability in West Nusa Tenggara (NTB), Indonesia. Using a qualitative approach, data were collected through in-depth interviews with five key informants, including policymakers, technical experts, and community representatives. Thematic analysis was conducted using NVivo software to identify the operational impacts, challenges, and opportunities of solar integration. Results indicate that the Selong PLTS contributes positively to voltage stability, reduces reliance on fossil fuels, and diversifies the energy mix. However, challenges such as intermittency, infrastructure limitations, and the absence of energy storage hinder its full potential. The study highlights the need for technological upgrades, stakeholder collaboration, and community engagement to optimize renewable energy adoption in NTB. These findings provide actionable insights for enhancing grid stability in regions integrating renewable energy.

Corresponding Author:

Name: Dr. Farida Arinie Soelistianto., ST., MT
Institution: Politeknik Negeri Malang
Email: farida.arinie@polinema.ac.id

1. INTRODUCTION

Indonesia's push towards renewable energy, particularly solar power, is driven by abundant natural resources and the government's target of achieving 23% renewable energy consumption by 2025. Its geographical advantage, with ample sunlight, supports solar adoption, though technological and economic barriers persist. Economic incentives like cost savings and return on investment significantly influence adoption more than technological factors [1]. Solar-powered infrastructures, such as electric vehicle charging stations, highlight the economic viability of these projects, with promising returns over time [2]. The government is scaling up renewable energy through incentives and regulatory support to address high costs and infrastructure gaps, especially in remote areas [3]. Optimized Production Sharing Contracts (PSCs) aim to attract investment, reduce emissions, and drive economic growth [4]. With proper regulations and public-private collaboration, renewable energy can transform Indonesia's socio-economic landscape while significantly reducing reliance on fossil fuels, aiding the net zero emissions target by 2060 [4], [5].

The establishment of the 7 MWp Selong On-Grid Solar Power Plant (PLTS) in West Nusa Tenggara (NTB) marks a significant step in leveraging renewable energy to meet regional electricity demands, enhancing supply stability and reducing reliance on fossil fuels. Indonesia's potential for solar energy, with average solar radiation of around 4.8 kWh/m², underscores its viability as an environmentally friendly energy source [6]. The economic feasibility of solar power plants is well-documented, with studies showing positive Net Present Value (NPV) and Benefit-Cost Ratio (BCR) metrics, such as a PLTS system for a mosque in Jember yielding an NPV of Rp. 74,877,690.00 and a BCR of 2.61, and a hybrid PLTS system at YARSI Pontianak General Hospital demonstrating an NPV of Rp. 797,610,941.86 and a PI of 1.505 [6], [7]. Solar power plants also align with national energy policies by reducing carbon emissions and increasing the renewable energy mix [8]. The Selong PLTS is expected to stabilize the local electricity network, addressing fluctuating demands and ensuring consistent supply [9]. Successful projects, such as the floating solar power plant at Muara Nusa Dua in Bali and off-grid solutions in remote areas like Lembung Mangrove Ecotourism, demonstrate the adaptability and economic benefits of solar energy across diverse contexts [9], [10].

However, the integration of solar energy into existing power grids presents unique challenges, such as intermittency, grid reliability, and the need for advanced energy storage systems. Understanding these dynamics is critical for ensuring the effective operation and stability of the electricity network in NTB. This study investigates the effect of the 7 MWp Selong PLTS on the stability of the electricity network in NTB. Through qualitative analysis, the research seeks to uncover insights into the operational impacts, challenges, and opportunities associated with integrating solar power into the grid. The research focuses on the perspectives of key informants, including policymakers, grid operators, and technical experts, to provide a holistic understanding of the issue.

2. LITERATURE REVIEW

2.1 Renewable Energy Transition and Solar Power

The global energy transition is driven by solar energy's role in reducing greenhouse gas emissions and enhancing energy security. Solar photovoltaic (PV) systems, known for scalability and declining costs, are among the fastest-growing renewable technologies. However, their intermittent nature challenges grid stability, particularly in regions without advanced storage solutions. Solar energy reduces fossil fuel reliance, as shown by the rise in the Index of Sustainable Energy Transformation (ISTE) from 2011 to 2023, aligning with SDG 7's goal of expanding renewable energy [11], [12]. Robust storage technologies, such as hydrogen storage, are needed to stabilize grids [13]. Strategic policy planning and international cooperation, including green bonds, are essential to overcome investment barriers, particularly in developing countries [12].

2.2 Integration of Solar Power into Electricity Networks

Integrating solar power into electricity networks promotes energy diversification and reduces carbon footprints, especially in regions with high solar irradiance. It offers a cost-effective solution to reduce fossil fuel reliance, supported by advancements in solar technology and government incentives [14], [15]. Solar integration enhances grid stability and cuts emissions, contributing to sustainability (Howlader, 2024). However, challenges like voltage fluctuations, frequency instability, and grid congestion require robust control strategies and advanced management systems [16], [17]. Infrastructure gaps, regulatory hurdles, and high initial costs demand streamlined policies and better financial access [14], [18]. Collaboration among stakeholders, improved infrastructure, and real-time monitoring are essential for optimizing solar integration [16].

2.3 Grid Stability in Renewable Energy Systems

The integration of intermittent renewable energy sources like solar power challenges grid stability, requiring solutions such as energy storage systems, smart grid technologies, and demand-side management. Distributed energy resources (DER), battery energy storage systems (BESS), and hydrogen units enhance grid resilience, with hybrid DC/AC connectivity improving stability through separate transformer connections [19]. Smart grid technologies like decentralized smart grid control (DSGC) manage power flow and energy integration using predictive models such as long short-term memory (LSTM) for accurate stability forecasts [20]. Deep learning further improves voltage stability by detecting instability in real-time and optimizing control strategies [21]. Control strategies, including virtual adaptive resistors in microgrids and distributed control frameworks for DC microgrids, ensure stability and scalability through innovative approaches like singular perturbation theory [22].

2.4 Research Gap and Contributions

While there is a substantial body of literature on renewable energy integration and grid stability, few studies have focused on the specific challenges and opportunities in the Indonesian context. Moreover, qualitative analyses exploring stakeholder perspectives on solar power integration remain scarce. This research contributes to filling these gaps by providing an in-depth analysis of the Selong PLTS and its impact on grid stability in NTB. The findings are expected to offer practical insights for policymakers, grid operators, and researchers working to optimize renewable energy systems in similar settings.

3. METHODS

3.1 Research Design

This study employs a qualitative research approach to explore the impact of the 7 MWp Selong On-Grid Solar Power Plant (PLTS) on electricity network stability in West Nusa Tenggara (NTB). The qualitative approach is chosen to capture the nuanced perspectives of key stakeholders and uncover the complexities involved in integrating solar power into the grid. A case study design is used to provide an in-depth understanding of the specific context and operational dynamics of the Selong PLTS.

3.2 Data Collection

The primary data for this study were collected through in-depth interviews with five key informants directly or indirectly involved with the operation and management of the Selong PLTS, including a representative from the regional electricity utility company, a technical engineer responsible for the Selong PLTS operations, a local policymaker involved in renewable energy development, an energy consultant with expertise in grid stability, and a community representative familiar with the impacts of PLTS operations. The interviews were conducted using semi-structured guides to ensure consistency while allowing flexibility to explore specific areas of interest. Each session lasted approximately 45–60 minutes and was recorded with the participants' consent to facilitate accurate transcription and analysis.

3.3 Data Analysis

The collected data were analyzed using NVivo software, a qualitative data analysis tool, through thematic analysis to identify recurring patterns and themes in the interview data. The analysis process involved several steps: first, data familiarization was conducted by reviewing transcribed interviews multiple times to gain an initial understanding of the content; second, key phrases and ideas were coded to organize the data into meaningful categories; third, related codes were grouped into broader themes that aligned with the research objectives; and finally, these themes were analyzed to derive insights into the impact of the Selong PLTS on electricity network stability.

4. RESULTS AND DISCUSSION

The thematic analysis of the data collected from the five informants revealed several key findings regarding the impact of the 7 MWp Selong On-Grid Solar Power Plant (PLTS) on electricity network stability in NTB.

These findings are categorized into three main themes: operational impacts, challenges, and opportunities.

4.1 Operational Impacts

The integration of the Selong PLTS into NTB's grid has improved voltage stability, particularly during peak sunlight hours. Informants noted that the PLTS helps maintain consistent voltage levels, reduce the frequency of outages, and improve power quality.

"The solar plant has brought more stability to the grid during daytime. We no longer experience the same voltage fluctuations we used to before the PLTS was operational." (Informant 2, Technical Engineer)

By displacing fossil fuel-based generation, the PLTS has significantly reduced greenhouse gas emissions in the region. This has been particularly beneficial in achieving environmental targets set by regional authorities.

"We've noticed a marked decrease in diesel usage since the PLTS began contributing to the grid. This aligns with our sustainability goals and reduces costs." (Informant 1, Utility Representative)

The introduction of solar energy has diversified NTB's energy mix, enhancing its resilience to external supply shocks.

"Having solar power in the grid has reduced our dependence on fuel imports. This diversification is a game-changer for NTB's energy security." (Informant 3, Policymaker)

4.2 Challenges

One of the main challenges highlighted by informants is the intermittency of solar power. Cloudy weather and variations in sunlight affect the consistency of energy output, which impacts overall grid stability.

"On overcast days, the energy output drops drastically. This puts strain on the grid, as we have to rely on diesel generators to make up for the shortfall." (Informant 2, Technical Engineer)

The current grid infrastructure in NTB is not fully equipped to accommodate renewable energy integration, leading to energy losses and inefficiencies.

"The infrastructure here wasn't initially designed for renewable energy. Upgrading the grid to handle fluctuations is essential." (Informant 4, Energy Consultant)

The lack of energy storage solutions, such as batteries, limits the PLTS's ability to store excess energy for use during periods of low sunlight.

"Without proper storage systems, a lot of the energy generated during peak hours is wasted. This is a missed opportunity." (Informant 1, Utility Representative)

4.3 Opportunities

Informants emphasized the need for smart grid technologies to optimize energy management and enhance stability.

"A smart grid system could dynamically adjust to fluctuations in solar power generation, making the grid much more efficient." (Informant 4, Energy Consultant)

The introduction of battery storage systems was seen as a critical opportunity to enhance the PLTS's impact on grid stability.

"With proper storage, we could use the excess energy generated during the day at night or during cloudy periods, which would greatly improve stability." (Informant 3, Policymaker)

Involving local communities in renewable energy projects could foster greater support and utilization of solar power.

"Educating communities about the benefits of solar energy could drive more acceptance and encourage energy-saving practices." (Informant 5, Community Representative)

DISCUSSION

The findings highlight the potential of solar power to improve grid stability and reduce emissions. The Selong PLTS has proven to be a valuable asset in diversifying NTB's energy mix and reducing dependency on fossil fuels. These results align with studies by [14], [23], which emphasize the benefits of renewable energy in enhancing voltage stability and grid resilience. However, intermittency remains a significant challenge, as noted by multiple informants. This is consistent with global literature that underscores the need for energy storage systems and advanced grid infrastructure to address the variability of solar energy. Upgrading NTB's grid infrastructure and adopting smart grid technologies are critical steps toward mitigating these challenges.

Policy support and stakeholder collaboration are essential for optimizing renewable energy projects. Aligning government policies with technological advancements and community needs will enable NTB to maximize the benefits of its solar power initiatives. The active involvement of stakeholders in planning and decision-making ensures a holistic approach to addressing the challenges of solar integration. Moreover, the Selong PLTS contributes to Indonesia's Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). By overcoming these challenges, the PLTS could serve as a model for other regions aiming to integrate renewable energy while maintaining grid stability.

5. CONCLUSION

The 7 MWp Selong On-Grid Solar Power Plant (PLTS) has significantly strengthened electricity network stability in NTB, contributing to improved voltage stability, reduced fossil fuel dependence, and enhanced energy diversification, aligning with Indonesia's sustainable development goals. However, its overall effectiveness is hindered by challenges such as solar power intermittency, outdated grid infrastructure, and the absence of energy storage systems. Addressing these issues requires investments in smart grid technologies, battery storage systems, and infrastructure upgrades. Collaboration among stakeholders, including policymakers, energy operators, and the local community, is crucial for the successful integration of renewable energy projects. Furthermore, fostering public awareness and community engagement can support broader adoption and optimization of solar energy in the region. By addressing both technical and social dimensions of renewable energy integration, NTB can fully harness the potential of solar power, paving the way for a sustainable and resilient energy future. The insights from this study offer valuable guidance for similar renewable energy initiatives in Indonesia and beyond.

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