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Reconstruction of Technology Development "Energy Independent Village Based on Vortex Hydro Power Plant (PLTHV)" through the Application of New and Renewable Energy Technology

Muhammad Hasan Basri[1*], Ilmirrizki Imaduddin[1], Bachtera Indarto[1], Dicky Mas'udi Soleh[1], Moh. Fathul Qorib[1], Muhammad Andriansah[1]

[1] Program Studi Teknik Elektro, Universitas Nurul Jadid, Paiton Probolinggo, Indonesia.

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Corresponding Author:
Muhammad Hasan Basri
basri83@unuja.ac.id

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Abstract: This community service program, funded by the Ministry of Education, Culture, Research, and Technology in 2025, was implemented in Duren Village, Probolinggo Regency, through collaboration between Nurul Jadid University (UNUJA) and the Institut Teknologi Sepuluh Nopember (ITS). The project aimed to develop an energy self-sufficient village by reconstructing the Hydro Vortex Power Plant (PLTHV) using renewable energy technologies such as the Electronic Voltage Stabilizer (EVS) and Power Circuit Breaker (PMT). The activities included field surveys, training, installation, testing, and mentoring. The reconstructed PLTHV successfully increased output capacity from 130 watts to 217 watts, improving energy efficiency and stability while reducing household electricity costs by approximately IDR 200,000 per month. Beyond technical improvements, the program enhanced community knowledge, encouraged active participation in managing renewable energy systems, and provided experiential learning opportunities for students. This initiative supports Sustainable Development Goal 7 (Affordable and Clean Energy) and demonstrates the potential of community-based renewable energy projects to reduce fossil fuel dependency and strengthen rural energy resilience.

Keywords: Hydro Vortex Power Plant, Renewable Energy, Community Empowerment.

Introduction

The equitable distribution of electricity in Indonesia remains a complex challenge, primarily due to the country's vast and diverse geographical conditions. Many rural and remote areas are difficult to electrify because of limited infrastructure, resulting in high energy supply costs. Under the national flat tariff policy, the government must subsidize low-income households consuming 450 VA and 900 VA electricity, which places a heavy burden on the state budget and limits expansion efforts for new electrification projects (Brown et al., 2019; Santoso & Salim, 2019). Despite ongoing initiatives, electricity demand continues to rise alongside population growth. With a population exceeding 260 million, Indonesia's electrification rate reached 94.91% in 2017; however, around 3.1 million households across 2,500 villages—approximately 7% of the total—remain without access to reliable electricity (Kementerian Energi dan Sumber Daya Mineral, 2017).

This situation reflects a broader structural dependency of Indonesian villages on fossil-based energy sources, an issue increasingly urgent in light of depleting reserves and environmental degradation. Although the National Energy Policy aims to achieve a 23% renewable energy share by 2025, fossil fuels such as

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coal, natural gas, and oil still dominate energy consumption (Bayu & Windarta, 2021; Maqdis et al., 2025). The continued reliance on non-renewable sources not only undermines energy resilience but also exacerbates air pollution and public health risks (Syam & Kurniati, 2022). In rural areas, dependence on fossil energy translates into high operational costs for households and small businesses, limiting economic growth and making energy increasingly unaffordable (Syaifullah et al., 2023; Yusuf et al., 2025). Therefore, transitioning toward renewable alternatives is not merely an environmental necessity but a socioeconomic imperative.

Probolinggo Regency in East Java exemplifies this dynamic. Geographically located between 112°50'–113°30' East Longitude and 7°40'–8°10' South Latitude, the area spans roughly 169,616 hectares, encompassing mountain ranges such as Semeru, Argopuro, Lamongan, and Tengger, as well as the iconic Mount Bromo (Badan Pusat Statistika, 2022). The region's topography, which varies from sea level to 2,500 meters above, provides significant hydrological potential. Rivers such as those in Duren Village flow from steep highlands, carrying a strong water discharge ideal for micro-hydropower generation. A field survey conducted by the Vortex Hydro team from Nurul Jadid University identified that Duren's river characteristics are particularly suitable for the development of a vortex hydropower plant due to its sediment flow and stable water volume (Basri et al, 2021).

Duren Village itself has a historical precedent in renewable energy innovation. A local Vortex Hydropower Plant (PLTHV) was once established and operated for over a decade, providing electricity to Duren and neighboring villages not yet connected to the national grid. The plant required routine maintenance—such as cleaning the basin, turbine inspection, and generator calibration—carried out by local residents organized as a management community. Despite its success, the system gradually deteriorated due to the absence of long-term technical support. Yet, the experience demonstrates Duren's potential to pioneer the first renewable-energy village in Probolinggo Regency, given its abundant water resources and community readiness.

Addressing Indonesia's persistent energy inequality demands both technical and social solutions. Limited electricity access, high energy costs, and uneven energy distribution continue to constrain rural productivity and quality of life (Alhamzani & Burhan, 2025; Suryaprawira & Siregar, 2024). Many remote areas remain reliant on inefficient energy sources, while infrastructure development is often economically unfeasible. Studies have shown that community-based renewable technologies such as micro-hydro systems or solar hybrid panels can effectively expand access to clean energy in isolated regions (Ihsan et al., 2024; Wijaya et al., 2025). Furthermore, initiatives focusing on capacity-building and localized energy management can empower communities to sustain their own power systems, reducing both energy costs and dependency on central grids (Safi'i et al., 2024; Tauvana et al., 2025).

Among renewable options, the Vortex Hydropower Plant (PLTHV) presents a compelling solution. This technology utilizes a natural vortex created by flowing water to drive a low-head turbine, making it particularly efficient in small rivers and steep terrains. Compared with conventional hydropower, PLTHV requires lower water discharge and infrastructure investment, producing electricity sustainably with minimal ecological disturbance (Muttaqin et al., 2022; Saidah et al., 2023). From a social perspective, the system promotes community participation in maintenance and energy governance, enhancing local technical skills and fostering economic independence (Basri et al., 2022; Hendrasari & Nurlaeli, 2024). Thus, PLTHV is not merely an energy technology but a tool for social transformation and environmental stewardship

The reconstruction of PLTHV in Duren Village aligns strongly with Sustainable Development Goal (SDG) 7, which advocates for "affordable and clean energy." It also supports Indonesia's national priority for achieving energy self-reliance in rural areas (Puspita, 2024; Samosir et al., 2025). Collaborative initiatives between universities—such as Nurul Jadid University (UNUJA) and the Institut Teknologi Sepuluh Nopember (ITS)—alongside local stakeholders are essential to ensure technological sustainability. Through activities like community training, operation guidance, voltage stabilizer installation, and circuit breaker (PMT) implementation, the program aims to transform Duren into a self-sustaining renewable energy village. Ultimately, such projects not only advance rural electrification but also contribute to Indonesia's broader vision of equitable, low-carbon development and community-based energy sovereignty.

Method

The implementation method of this community service program follows several systematic stages designed to address the partner's challenges both directly and indirectly. The 2025 program focuses on developing an energy self-sufficient village and advancing Hydro Vortex Power Plant (PLTHV) technology in the partner region. These objectives are aligned with two major issues identified during the needs assessment: (1) the application of new and renewable energy technologies in the PLTHV system through an electronic voltage stabilizer, and (2) the application of a power circuit breaker (PMT) in the PLTHV system located in Dusun Sawah Kembang, Duren Village, Probolinggo Regency.

Program Stages

To solve the community's existing problems and implement the proposed solutions, the PKM program will be carried out through the following stages:

1. Field Survey
   The first stage involves conducting a direct field survey by the PKM implementation team, accompanied by several students. This activity includes mapping the hydropower site, documenting physical conditions, and identifying the root causes of the partner's problems to develop an appropriate solution.
2. Data Sampling and Problem Analysis
   After the survey, the team will collect both quantitative and qualitative primary data through scientific measurements and systematic observations. The recorded data will be processed and analyzed to form the basis for determining the most effective technical and managerial solutions to the partner's energy challenges.
3. Agreement with the Partner Institution
   Following the data analysis, the next step is establishing a formal agreement with the partner, represented by the head of the local community group. This process ensures mutual understanding regarding project objectives and responsibilities. The agreement will be documented through a signed memorandum of understanding (MoU) and remain valid for eight months, corresponding to the program's implementation timeline.
4. Focus Group Discussion (FGD)
   A Focus Group Discussion will then be held with the village leadership, PLTHV owners, and community members involved in the project. The FGD serves as a platform for introducing the PKM program, building rapport between the project team and the community, and explaining the goals, expected outcomes, and long-term vision of developing a sustainable energy village in Duren Village, Gading District, Probolinggo Regency.
5. Testing the PLTHV Technological System
   After completing installation and assembly, the PLTHV system will undergo a series of performance and accuracy tests to ensure operational reliability. The testing phase includes measuring output efficiency, assessing system stability, and identifying potential faults. Documentation in the form of videos and reports will be produced and shared through social media to promote transparency and public awareness regarding renewable energy innovation.
6. Assistance and Training for Community Partners
   The final stage involves capacity-building and mentoring activities to ensure that the PLTHV system operates sustainably at its optimal performance level. Local youth groups will receive hands-on training on system maintenance, repair procedures, and preventive care to protect the technological assets disseminated in Duren Village. This continuous mentoring process is crucial for fostering technical independence, ensuring the longevity of the hydropower system, and strengthening community ownership of renewable energy infrastructure.

Technology Implementation

1. Application of New and Renewable Energy Technology in Hydro Vortex Power Plants through the Electronic Voltage Stabilizer
   The reconstruction materials used for the Hydro Vortex Power Plant (PLTHV) include three powerhouses, three sets of instrumentation and electrical systems, three units of 5 kVA adjustable AC voltage regulators, one unit of 10 kVA voltage regulator, three units of TP-Link TL-MR6400 4G Wireless SIM Modem Routers, and four concrete pipes. The PLTHV system is designed to supply electricity to the local community, particularly households that are not yet connected to the national electricity grid (PLN).
2. Application of Power Circuit Breaker (PMT) in Hydro Vortex Power Plants in Dusun Sawah Kembang, Duren Village, Probolinggo Regency
   The design and development of the electrical, instrumentation, and control systems for each Hydro Vortex Power Plant follow. This technological enhancement integrates three PLTHV units in Dusun Sawah Kembang, Duren Village, as part of the initiative to establish an energy self-sufficient village based on renewable energy technologies promoted by the Indonesian government.
   This system integration aims to stabilize power distribution, improve efficiency, and enhance safety through the implementation of a Power Circuit Breaker (PMT). The use of PMT ensures automatic protection against overloads and system faults, which is essential for maintaining the operational reliability of the renewable power system.
3. Mentoring and Evaluation
   The mentoring and final evaluation stages focus on strengthening the community's soft skills and ensuring the sustainability of the program. These stages serve to analyze the effectiveness of the implemented activities and assess the extent to which the program benefits the partner community.

Evaluation outcomes will also guide decision-making for future project development and replication.

To ensure accuracy and accountability, several measurable performance indicators are used during the evaluation process, including:

1. Improvement of Technical Skills in Operating PLTHV Systems with Electronic Voltage Stabilizers
   The key performance indicator (KPI) for this evaluation is the degree of improvement in the participants' ability to operate and manage the PLTHV system. This is assessed through direct observation, data analysis, and interviews or questionnaires.

Figure 1. Presents The Design Of The Electronic Voltage Stabilizer Used In This Project

2. Enhancement of Power Stability through the Application of Power Circuit Breakers (PMT)
   The KPI in this aspect is the weekly stability of generator output. After the PLTHV units are fully operational, the generated power stability is measured and analyzed to determine the improvement in performance and system reliability.

Figure 2. Configuration of the Power Circuit Breaker (PMT) in the Hydro Vortex Power Plant.

Partner Participation in Program Implementation

The university partners are responsible for providing qualified lecturers and experts from the Electrical Engineering and Science (FMIPA) departments, supported by three active students from Nurul Jadid University (UNUJA). The village youth group partners provide venues for training and workshops, coordinate local participants—including PLTHV owners—and ensure logistical support for all program activities. This collaboration ensures that the implementation of the PKM program runs effectively and inclusively, involving all relevant community stakeholders.

Program Evaluation and Sustainability

The evaluation process covers all stages of implementation, beginning from the field survey to mentoring and technical assistance. The sustainability of this PKM initiative will extend beyond the current program, with potential applications in other technological domains and community development projects. The partner universities will continue to provide both direct and indirect support, ensuring long-term monitoring, innovation adaptation, and the continuous improvement of renewable energy systems in the target villages.

Result and Discussion

The Community Service Program funded by the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) in 2025 was successfully implemented in Duren Village, Probolinggo Regency, through collaboration between lecturers from Nurul Jadid University (UNUJA) and the Institut Teknologi Sepuluh Nopember (ITS), together with UNUJA students. This program focused on advancing the concept of an energy-self-sufficient village by developing and reconstructing the Hydro Vortex Power Plant (PLTHV) technology. Through a series of structured activities—ranging from training and technological installation to mentoring and evaluation—the program aimed to empower local communities to manage renewable energy systems independently and sustainably.

Implementation of Renewable Energy Technology through the Electronic Voltage Stabilizer

The primary activity involved the application of a new and renewable energy technology—the Electronic Voltage Stabilizer (EVS)—in the PLTHV system. This initiative sought to enhance community knowledge and technical skills in renewable energy management, particularly in the operation and maintenance of small-scale hydropower systems.

Figure 3. Electronic Voltage Stabilizer Training and Workshop

Figure 3 shows the workshop session where participants were introduced to the principles of voltage stability and energy efficiency. The integration of the EVS system improved the consistency of electrical output and reduced fluctuations that often occurred in micro-hydro operations.

This practical training also strengthened community understanding of energy sustainability, emphasizing the importance of using environmentally friendly and efficient technologies in rural settings. Similar initiatives have been highlighted in previous research, showing that community-based renewable energy projects significantly contribute to reducing rural dependence on fossil fuels while enhancing local technical capabilities (Bayu & Windarta, 2021; Weddakarti et al., 2023; Artiyasa et al., 2021).

Application of the Power Circuit Breaker (PMT) in the PLTHV System

The second stage involved the implementation of a Power Circuit Breaker (PMT) in the PLTHV located in Dusun Sawah Kembang, Duren Village (Figure 4). The training sessions introduced participants to the function and operational principles of the PMT within the hydropower electrical system. The PMT device was designed to ensure system reliability and operational safety, automatically disconnecting the circuit in cases of electrical overload or fault.

Figure 4. Power Breaker Training and Workshop

This training improved the participants' technical competence in installation, testing, and maintenance of electrical protection systems, thereby enhancing the reliability of the PLTHV power distribution network. The inclusion of PMT and EVS technologies transformed the previously unstable energy supply into a more consistent and safe system, promoting community confidence in locally managed energy generation. Such technological adaptations are aligned with findings by Alhamzani & Burhan (2025) and Ihsan et al (2024), who emphasize that simple yet effective renewable technologies can significantly improve rural electrification and reduce energy costs in off-grid regions.

Quantitative Outcomes and Technical Improvements

Before reconstruction, the existing PLTHV system generated approximately 130 watts of power at 1,600 rotations per minute (rpm). After the reconstruction—integrating the electronic voltage stabilizer and PMT components—the output increased to 217 watts at 2,700 rpm, marking a 67% improvement in energy generation efficiency. This technological upgrade not only enhanced electrical stability but also improved the quality and durability of the powerhouse structure.

The impact of this innovation extended beyond technical outcomes. For the local community, the reconstructed PLTHV system reduced monthly electricity expenses by approximately IDR 200,000 per household, a significant economic relief for residents not yet connected to the PLN national grid. For the participating students, this project served as a practical learning experience equivalent to six academic credits (6 SKS), aligning with Indonesia's higher-education performance indicators (IKU) for experiential learning.

Discussion: Reducing Fossil Fuel Dependence and Promoting Local Energy Sovereignty

The project outcomes directly respond to Indonesia's ongoing struggle with fossil fuel dependency, particularly in rural areas where access to national electricity infrastructure remains limited. Despite the government's target to achieve 23% renewable energy use by 2025, fossil-based energy such as coal, natural gas, and oil still dominate national consumption (Bayu & Windarta, 2021; Maqdis et al., 2025). This dependency has led to increasing energy costs and negative environmental impacts (Syam & Kurniati, 2022). Through renewable technologies like PLTHV, rural communities can reduce reliance on non-renewable resources while contributing to national energy security and environmental sustainability (Syaifullah et al., 2023; Yusuf et al., 2025).

Moreover, the hydropower vortex system takes advantage of local water resources, which have often been underutilized despite their vast potential for small-scale energy generation (Putra & Winarso, 2022). In regions like Duren Village—situated near rivers with high gradients—this system can serve both as a sustainable electricity source and a catalyst for community empowerment. Prior studies highlight that water-based renewable energy systems not only improve access to electricity but also enhance agricultural productivity and local economic resilience (Anggayudha & Hakim, 2022; Munir, 2021; Zevri, 2022).

Community Empowerment and Sustainable Development Alignment

The PLTHV reconstruction and training activities have proven to be an effective model for integrating technology transfer, education, and community participation. The project aligns with Sustainable Development Goal 7 (Affordable and Clean Energy), promoting access to reliable and sustainable energy for rural populations. Additionally, it contributes indirectly to SDG 1 (No Poverty) by reducing household expenditures and improving livelihood opportunities through the availability of affordable electricity (Akhiriyanto et al., 2025; Puspita, 2024).

These outcomes affirm the argument of Basri et al (2022) that community-based renewable energy initiatives must combine technical innovation with capacity building to ensure long-term sustainability. By involving youth groups in system maintenance and empowering local residents to manage the PLTHV independently, the program fosters a culture of self-reliance and collective responsibility—key aspects of achieving rural energy sovereignty.

Implications and Broader Relevance

The integration of PLTHV with electronic voltage stabilizers and PMT technology demonstrates a scalable model for renewable energy deployment in remote regions. It offers not only environmental and economic benefits but also educational and social advantages. The program strengthens university–community partnerships and creates a living laboratory for students and researchers to develop and refine renewable energy systems.

This aligns with national priorities under Indonesia's Renewable Energy Roadmap and supports the broader agenda of energy decentralization—where rural communities actively participate in managing their own clean energy systems (Samosir et al., 2025; Sunardi et al., 2021). As such, the Duren Village initiative represents a significant step toward realizing a resilient, low-carbon, and community-driven energy transition in Indonesia.

Conclusion

The implementation of the community service program on the reconstruction of the Hydro Vortex Power Plant (PLTHV) in Duren Village successfully demonstrated how the integration of renewable energy technologies, such as the Electronic Voltage Stabilizer (EVS) and Power Circuit Breaker (PMT), can enhance both the technical and socio-economic resilience of rural communities. The program effectively increased the power output from 130 watts to 217 watts, improved system reliability, and reduced household electricity expenditures. Beyond the technological outcomes, the project strengthened local capacity through training and mentoring, empowering residents to independently operate and maintain renewable energy systems. This outcome confirms that community-based renewable energy projects can play a vital role in addressing rural electrification gaps and promoting sustainable energy access.

Furthermore, the program aligns closely with the national and global agendas for sustainable energy development, particularly Sustainable Development Goal 7 (Affordable and Clean Energy). By utilizing local hydropower potential and involving multiple stakeholders—universities, local youth, and government institutions—the initiative has created a replicable model for achieving village energy self-sufficiency. The collaboration between academic institutions and local communities serves as a catalyst for broader adoption of environmentally friendly technologies, reducing dependence on fossil fuels, and strengthening rural economic independence. In the long term, this program contributes to Indonesia's transition toward a low-carbon economy and the realization of inclusive, community-driven energy sustainability.

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