Proceedings of CONF-FMCE 2026 Symposium: Artificial Intelligence and Smart Sensing for Mechanical and Electrical Systems
DOI: 10.54254/2755-2721/2026.BA35480

A Brief Discussion on the Applications of Smart Grid 2.0 Combined with Traditional Island Micro Grid Models

Shuqiao Zhang

School of Electrical Engineering, Xi'an Jiaotong University, Xi'an, China
1924514232qq.com@stu.xjtu.edu.cn

Abstract. Based on the pain points of traditional isolated island micro grids, such as insufficient reliability, strong fluctuations in renewable energy, and the possibility of load shedding under extreme conditions, this chapter focuses on the idea of integrating "Smart Grid 2.0 with traditional isolated island micro grids."First, the article gives the overall design structure of the intelligent isolated micro grid.Subsequently, in terms of power generation and energy storage, this paper summarizes the issues of power quality and energy storage configuration caused by the intermittency of generation methods such as photovoltaics and wind power, and lists the applicable technologies. On the transmission, distribution, and electricity usage side, the article explains measures such as solid-state transformers, multi-voltage level settings, and other advanced algorithms that can reduce size and losses, and improve safety and compatibility. On the user end, this paper constructs a model framework that can support demand response, load management, and fair billing through smart meters and higher-frequency sampling. Regarding the central information processing system, this paper establishes the corresponding central platforms responsible for real-time monitoring, risk assessment, fault self-healing, and cross-domain coordination.Finally, the article takes relevant examples to demonstrate the feasibility of the model presented in this paper.

Keywords: Smart Grid 2.0, Traditional Island Micro Grid Models, Bornholm island, El Hierro

1. Introduction

To address the issues of low reliability of independent power supply in remote areas and ecological protection zones, as well as to improve power supply quality, the construction and improvement of Island micro grids (IMG) models is urgent. Traditional IMG models mainly rely on renewable energy sources such as wind and solar power, which are random and fluctuating. In severe cases, to ensure grid balance, issues such as "load shedding" may occur. Smart Grid 2.0 is a technology that, based on the first-generation smart grid, uses advanced technologies to realize bidirectional flow of energy and information, significantly enhancing the intelligence of the grid [1]. Smart Grid 2.0, on the foundation of the smart grid, utilizes AI and big data models to achieve autonomous decision-making and multi-party collaboration, further improving the efficiency and reliability of the grid. The conceptual diagram of Smart Grid 2.0 is shown in Figure 1:

DOI: 10.54254/2755-2721/2026.BA35480

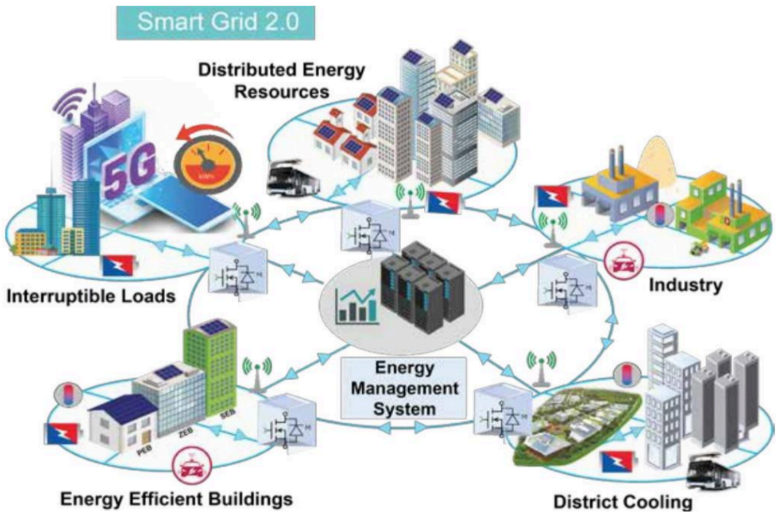

Figure 1. The conceptual diagram of Smart Grid 2.0 [2]

Smart Grid 2.0 utilizes a high proportion of renewable energy, which aligns with the actual conditions of the IMG. Its high stability, reliability, safety, and strong self-healing ability match the practical needs of isolated IMG. The 'data-driven' and 'AI-assisted decision-making' aspects of Smart Grid 2.0 provide innovative solutions to address randomness and volatility. Integrating Smart Grid 2.0 with traditional IMG models plays an important role in improving energy resilience, enhancing power quality in remote areas, and promoting low-carbon development.

Based on the randomness, volatility, and other challenges faced by IMG, this paper creatively integrates the main structure of Smart Grid 2.0 with the specific case of IMG, applies SST technology, block chain technology, and the prosumer model (a grid operation mode where users both produce and consume energy, participating in grid coordination through pricing and scheduling mechanisms) [3], and other concepts, to optimize the traditional IMG model and build a central information processing system to improve the stability of IMG.

2. Research on the integration of traditional Island Micro Grid models and Smart Grid 2.0

2.1. Introduction to the drawbacks of traditional models

Traditional IMG mainly relies on photovoltaic power generation (PV), wind turbine generation (WT), and tidal power generation. PV and WT are overly dependent on weather, while tidal power generation is more dependent on water resources, which can be summarized as the volatility and intermittency of renewable energy. The start and stop of wind turbines cause voltage fluctuations, and multiple inverters connected in parallel trigger resonance, which can be summarized as power quality issues. Power generation and energy storage equipment have a high wear rate, so their initial investment, operation and maintenance costs, replacement costs, and environmental costs are relatively high, which can be summarized as high equipment cost issues. Traditional energy storage systems have capacity limitations, response delays, and safety risks due to chemical materials, which can be summarized as energy storage system bottleneck problems.

To reduce energy loss, power grids generally adopt high-voltage transmission modes. Undeniably, this mode has large transmission capacity, low loss, and high compatibility. However, constructing high-voltage transmission systems is expensive, and related safety accidents occur

DOI: 10.54254/2755-2721/2026.BA35480

frequently. Table 1 shows the number of deaths worldwide caused by high-voltage electricity from 2019 to 2023.

Table 1. This caption has one line so it is centered

Year	Number of global deaths	Data source
2019	4800-6200 people	International Labour Organization (ILO) "Occupational Safety Report" WHO Electrocution Statistics Supplement
2020	4500-5800 people	EU ESAW Database, US BLS, China's Ministry of Emergency Management
2021	4600-6000 people	ILO "Work-Related Death Report", India National Crime Records Bureau (NCRB)
2022	4900-6500 people	WHO Global Injury Statistics (GIS), US CPSC Electrocution Report
2023	5100-6800 people	ILO Preliminary Report and Annual Bulletins of National Electricity Regulatory Authorities

From transmission to distribution, traditional power grids use transformers to convert high voltage to low voltage. Traditional transformers apply the principle of electromagnetic induction, generate a lot of heat, and have high requirements for equipment quality.

2.2. Presentation of the smart Isolated Micro Grid model

The general concept of the intelligent IMG model is shown in Figure 2.

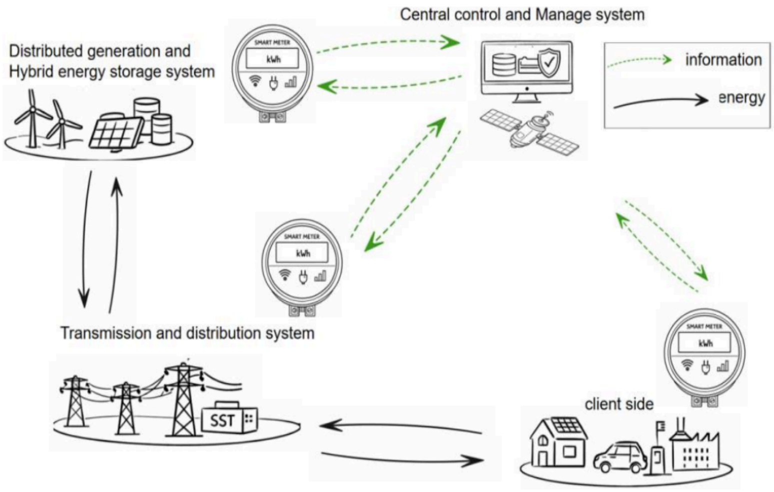

Figure 2. Concept of the Intelligent Island Micro Grid model (self-made)

2.3. First section

Power generation and energy storage systems can be improved through methods such as material improvements, algorithm optimization, and structural optimization. In terms of algorithms, literature [4] proposes an IMGHESS system capacity planning method based on stochastic optimization but lacks specific considerations for practical application. Literature [5] provides a defense mechanism for maintaining the stability of cyber-physical systems (CPS) under false data injection (FDI) conditions, but it does not discuss IMG-specific cases. Integrating AI algorithms to improve existing algorithms can achieve near-zero-cost system optimization and is relatively easy to implement economically. In terms of materials, new materials can reduce costs and increase efficiency, enhance

DOI: 10.54254/2755-2721/2026.BA35480

capacity, and reduce latency. With the development and improvement of the materials science system, the cost of some storage methods will significantly decrease. For example, if a room-temperature superconductor is discovered, superconducting energy storage technology will no longer require cooling, greatly improving usability and adoption rates.

For transmission and distribution systems, it is recommended to introduce Solid State Transformers (SST). Compared with conventional frequency transformers, SSTs are smaller and lighter, and generate less heat during voltage transformation. Replacing conventional frequency transformers with SSTs can also reduce the size of substations and the additional costs of their construction and maintenance. Structurally, it can be improved into a multi-voltage-level transmission and distribution system. For example, Singapore, located next to Malaysia and surrounded by the sea, has geographical conditions similar to an island. The Singapore distribution system has five voltage levels, as shown in Figure 3: 6.6kV, 22kV, 66kV, 230kV, and 400kV.

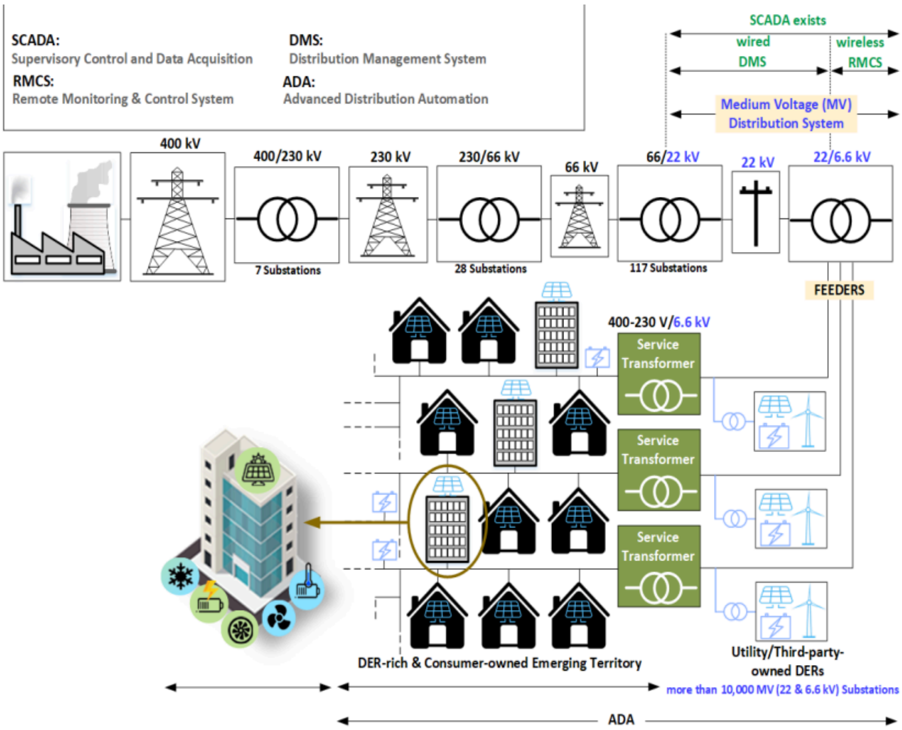

Figure 3. Singapore hierarchical transmission diagram [2]

Setting multiple voltage levels based on this classification method can directly meet the power demand of multiple voltages. For example, household electricity is usually 100V-240V, electric vehicle charging voltage is usually around 500V, and ultra-high voltage is used in some industrial manufacturing.

The introduction of the producer and marketing model allows users to grasp the initiative in producing electric energy, weakens the concept of centralized power generation, and makes the power equipment self-sufficient by installing solar panels, and even reverse power supply in special cases, so as to realize the two-way exchange of energy information. In terms of materials, try to improve silicon-based materials, and use new materials such as silicon carbide and gallium nitride, which can effectively reduce energy loss.

For example, in Ref. [4], the distribution of flexible load of time-of-use tariff scheduling users is formulated through the double-layer electricity price response program, and the special situation of

DOI: 10.54254/2755-2721/2026.BA35480

IMG is simulated for analysis and verification. Ref. [6] proposed a study on the upper and lower boundary measurement schemes for the risk of information leakage, but did not conduct a detailed analysis based on the particularity of islands. At the same time, the mechanical meter is improved into an intelligent electronic meter, which can improve the lightness and sampling frequency of the meter. The sampling frequency of the new meter can reach 30min-1h/time, or even 1min/time, 60 times/s. Through high-frequency measurement, smart meters can obtain the user's power-time curve, and decompose the total electricity consumption curve according to the characteristic curve of each appliance through AI algorithms, and even obtain the electricity consumption of each appliance. At the same time, users can connect to information networks such as Ethernet through new smart meters, so as to realize the two-way circulation of information.

Build a central information processing system on the basis of the traditional model: the central information processing system is the main brain that regulates the power grid, responsible for collecting and sorting out the data information of each part of the power grid, and then distributing the information to each unit through the central brain processing operations, so as to achieve the purpose of comprehensive processing of information and optimal allocation of resources. The central information processing system plays an important role in smart grid 2.0, which can be divided into four aspects, as shown in Table 2:

Table 2. The role of central information processing system

Function Name	Detailed explanation	Examples of Key Technologies
Accurate Perception Measurement	Realize real-time online synchronization of various data, serving as a prerequisite to establish a data foundation for subsequent calculations and decisions.	High-precision sensing and measurement, online monitoring, data collection and uploading, network-wide time alignment, real-time data synchronization
Precise Risk Assessment	Improve computer performance so that it has sufficient computing power to support the system in taking timely measures to prevent losses before a danger occurs.	Advanced prediction and evaluation algorithms, risk upper and lower bound estimation, computing power enhancement and real-time computation
Fault Self-Healing	Enable the power grid system to maintain basic operations after a fault occurs, in order to protect important information data or meet the electricity supply needs of critical areas.	Buffer/redundant devices, isolation and reconstruction strategies, fault-tolerant control, (optional) blockchain to ensure the consistency and traceability of key data
Cross-Domain Collaboration	Although IMG is not convenient for wiring connections with the outside world, it can still indirectly connect to the ground through satellite communications using devices such as PMUs.	PMU and other synchronized phasor measurements, satellite communication links, remote operation and maintenance, and dispatch interfaces

The central information processing system is connected to various components through smart meters. Its location can be either within the island or on a distant continent, connected to the island via wireless technology. In short, the central information processing system is an important reference for distinguishing traditional IMG from smart IMG, and constructing the central information processing system is significant for the intelligence of the IMG model.

DOI: 10.54254/2755-2721/2026.BA35480

3. Typical case analysis

3.1. Bornholm Island

Bornholm Island is a holiday-oriented island in Denmark in the Baltic Sea. The structure of the power grid is shown in Figure 4 & 5. Since 2007, when the European Commission set the "20-20-20" target, which stipulates that 20% of the EU's energy consumption will come from renewable sources by 2020, Bornholm Island has embraced large-scale clean energy generation [7]. Here's what the Smart IMG is built for:

The power generation and energy storage system includes: 14 sets of 34 megawatt diesel generators, 1 set of 25 megawatt steam turbines, 1 x 37 megawatt steam turbines, 35 sets of 29 megawatt wind turbines, 1 x 2 megawatt gas turbine, and a battery energy storage system with a scale of about 30MW/43MWh connected to the grid by EWII. The above power generation and energy storage systems combine the geographical advantages of Bornholm Island to account for a large proportion of new energy generation and energy storage. Among them, the penetration rate of wind power generation is as high as 30%.

The transmission and distribution system adopts multi-voltage levels of transmission and distribution systems, including 60kV grid, 10kV grid, and 0.4kV grid. Swedish 132/60kV substation, 60/10 kV OLTC transformers, 1,006 10/0.4 kV transformers (268 MVA). The transmission and distribution system can meet the needs of users such as households, industries, and trams.

On the user side, Bornholm Island has a variety of electricity needs, such as building power, tram power, etc., with a total electricity demand of about 28,000kWh and a peak of 55MW.

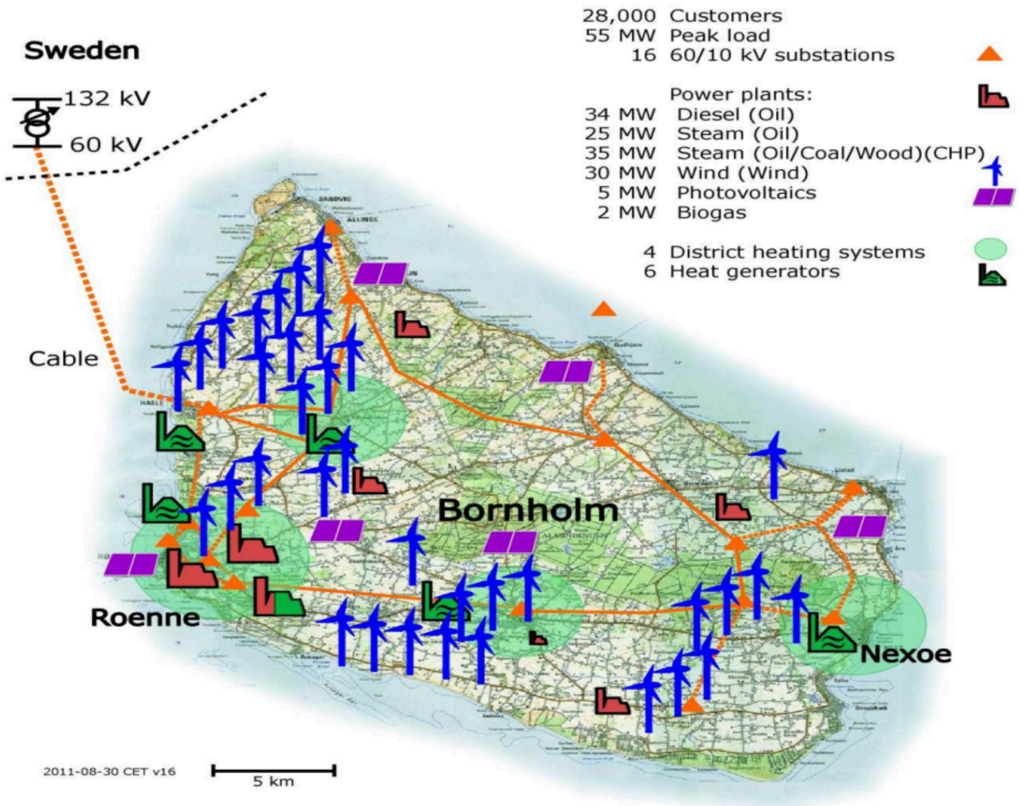

Figure 4. Distribution map of the Bornholm Island power grid [8]

DOI: 10.54254/2755-2721/2026.BA35480

Central Information Processing System: The SCADA system of a 132/60 kV substation in Sweden measures the following values: voltage, megawatt active power, reactive power in MVAr, using smart meters connected throughout the grid. The 10 kV side of a 60/10 kV transformer measures the following values: voltage, current, power factor, transformer tap switching position. E-ON, Østkraft's SCADA system has the following profiles: 10-second instantaneous value (14 days), 1-minute average (1 month), 1-hour average (1 year). By measuring and backing up the above information, the central information processing system can automatically or artificially control the tap-changer of 60/10kV transformers, capacitor banks of 60/10kV substations, the active power and voltage reference values of some equipment, the frequency regulators of some equipment, and the power reference of wind turbines to achieve the purpose of controlling the overall power grid.

Suggestions for Improvement:

The hardware facilities on the island are easily corroded due to the sea wind, which can be alleviated through material improvements. Consider using higher-grade cores of low-loss oriented silicon steel, and prioritize corrosion-resistant coating systems (such as tin/silver plating) for joints, combined with waterproof heat shrink and sealing adhesive, to reduce contact resistance rise and heat generation in a saline environment. Sleeves/pillar insulators can use silicone rubber composite insulation (good hydrophobicity, strong pollution flashover resistance). Appropriate additional insulation layers can also be applied to further enhance corrosion resistance. Additionally, the current transformer hardware facilities on the island are relatively outdated. Installing SSTs at key nodes of power transmission and transformation can help the grid have the potential to meet higher user demands in the future.

3.2. El Hierro

El Hierro is a "quiet" volcanic island located in Spain that is less developed. El Hierro was the first island in the new century to be designated as a UNESCO Biosphere Reserve, and it also supports the sustainable development plan officially approved in 1997, which aims to make El Hierro one of the first islands in the world to achieve 100% renewable energy (RES)[9]. Here's what the Smart IMG is built for:

In terms of power generation and energy storage systems, renewable energy generation includes a 280kW wind farm connected to the grid, an independent photovoltaic system with a total installed capacity of 6.5 kilowatts, and 362 square meters of solar hot panels. Traditional energy generation includes: a conventional diesel system thermal power station with an installed capacity of 8,285 megawatts. Energy storage: Since the law of the Canary Islands stipulates that the proportion of wind energy connected to the grid cannot exceed 12%, the implementation of a combined wind and hydropower power plant project is expected to be a solution to achieve the goal of 100% renewable energy utilization. The specific approach of the combined wind and hydropower power plant project is to take advantage of the geographical advantage of El Hierro's huge difference in altitude (about 1,200 meters of undulation), and the microgrid system in the area uses excess wind power to pump water uphill and release water to generate electricity when needed, so as to solve the problem of water shortage for residents while achieving efficient energy storage and smooth output [10].

In terms of transmission and distribution systems, the voltage levels of the whole island are divided into 20 kV medium voltage and 0.4 kV low voltage. The wind power generation energy is collected to the 20 kV backbone line of the island network through the 0.4/20 kV step-up transformer in the engine room or tower, and then directly enters the 20 kV distribution backbone from the power supply side and then distributed to each load point, and finally the 20 kV is gradually reduced to 0.4 kV through the transformer for user power supply. However, public

DOI: 10.54254/2755-2721/2026.BA35480

information generally believes that El Hierro does not have an independent high-voltage transmission network, so the voltage graded transmission and distribution system of the above grid still needs to be improved.

On the user side, similar to Bornholm Island, El Hierro has a variety of electricity needs, such as building power, tram power, etc., and with the increase in the development of El Hierro, the type and intensity of user demand are bound to gradually increase, which will pose a certain challenge to El Hierro IMG's goal of achieving 100% renewable energy.

When building a central information processing system, SCADA/EMS is used as the core to collect data including: wind power, pumped storage (reservoirs/turbine pumps), diesel units and 20kV distribution network voltage, frequency, power flow and switching status. The central information processing system will combine wind speed and load prediction to optimize output and pumping and storage conditions, and realize the overall framework of "wind priority, pumping and storage balance, and diesel bottom". The scope of authority of the central information processing system: control of reactive power, voltage, frequency, fault alarm and isolation, black start and load removal policy execution. Finally, the central information processing system will record the operation log and KPI report of some hardware to evaluate the proportion of renewable energy and power supply reliability.

Figure 5. Layout of the Gorona del Viento electric production system. Not shown on the picture is the Llanos Blancos diesel plant located near the coast close to the pumping plant [11]

Improvement Suggestions:

There is still a long way to go to achieve the 100% renewable energy target, so that some scholars have reasonably questioned the feasibility of this goal based on recent grid data from El Hierro [10]. On the basis of Bornholm Island, combined with the special situation of El Hierro, it is recommended to further improve IMG's high-voltage transmission system and further subdivide the voltage levels to enhance its functionality and stability. At the same time, the utilization of solar resources can be increased to offset the volatility of wind power, and AI algorithms can be used to achieve complementarity between the two, thereby further improving grid stability and the proportion of renewable energy generation.

DOI: 10.54254/2755-2721/2026.BA35480

4. Conclusion

This paper focuses on the intelligentization of the IMG model combined with the concept of Smart Grid 2.0. It first analyzes the special circumstances of island microgrids and the adaptability of the Smart Grid 2.0 concept, then explains the advantages and disadvantages of each component of the traditional IMG. Based on its shortcomings and combined with the Smart Grid 2.0 concept, optimization solutions are proposed. Finally, the model's rationality is validated through the power grids of Singapore, Bornholm Island, and El Hierro. With the construction of continental power grids gradually improving, the development and utilization of oceanic islands become a future trend. For islands that are under development or have partially completed facilities, adopting the findings of this study is expected to build a more stable power grid system while improving user satisfaction. In the future, research can be refined on the practical application of the algorithms and facilities mentioned in each part of this paper under the special conditions of islands, explore the implementation of this model in different island scenarios, and construct a complete algorithm system to systematically apply the Smart Grid 2.0 concept to the actual construction of island micro grids.

References

[1] Liao, Y. (2013). Germany: Embracing the 'smart grid 2.0 era'. *Energy, 08*, 77–79.
[2] SPECS Smart Grid + Power Electronics Consortium Singapore. (n.d.). Grid 2.0. Nanyang Technological University, Singapore.
[3] Wang, Z. C., Guo, M. Y., Liu, B., et al. (2026). Shared energy storage and power transactions between producers and consumers based on a strategic two-way auction mechanism. *Electr. Power Autom. Equip., 46*, 1–15. https://doi.org/10.16081/j.epae.202507017.
[4] Yin, J. (2025). *Research on capacity planning and optimal scheduling of hybrid energy storage systems in isolated island microgrids* (Master's thesis). Guizhou University.
[5] Hu, S. D. (2025). *Research on false data injection attack detection in smart grids* (Master's thesis). Guangxi University, School of Electrical Engineering.
[6] Tian, T. S. (2025). *Research on risk assessment and response strategies of smart power distribution network project cluster* (Master's thesis). Guangzhou University, School of Management.
[7] European Commission. (2010). Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage.
[8] Yang, G. Y., Østergaard, J., Kjær, S. B., et al. (2011, October 24). Smart integration of photovoltaic power systems on the island of Bornholm. *1st International Workshop on Integration of Solar Power into Power Systems*, 1. Aarhus,Denmark.
[9] Doniz-Páez, J., & Becerra-Ramírez, R. (2022). *El Hierro Island Global Geopark*. Springer International Publishing. Spain.
[10] Morales, J. (1999). Sun, wind and water: The new El Hierro island's allies. *Cabildo de El Hierro*.
[11] Flocard, H. (2016). Can El Hierro be 100% electric-renewable? *Sauvons Le Climat*.