POWER QUALITY AND GRID IMPACT ASSESSMENT OF OFFSHORE HYBRID RENEWABLE ENERGY SYSTEMS USING ETAP

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ABSTRACT

The global shift toward renewable energy has highlighted offshore hybrid systems as a promising pathway for sustainable and reliable electricity generation. Offshore wind turbines, wave energy converters, and floating photovoltaic panels, when integrated with battery storage and advanced power converters, provide complementary resource availability and reduced variability. While previous research has mainly addressed the techno-economic feasibility of such systems under policy scenarios such as carbon taxation, their long-term viability also depends on compliance with power quality standards and distribution network stability. Building on earlier work in which the economic and environmental impacts of carbon tax scenarios were analyzed using HOMER Pro, this study extends the analysis toward a technical validation perspective. The optimal configuration obtained under the most cost-effective carbon tax level (54 $/t) was implemented in ETAP for detailed load flow, short-circuit, and harmonic analyses. The offshore hybrid system was modeled at the point of common coupling (400 V bus) of a distribution network, with converter-level harmonic characteristics defined according to state-of-the-art technologies. Results demonstrate that, despite favorable economic indicators, such as a net present cost (NPC) of 180,609 $, cost of energy (COE) of 0.02672 $/kWh, and 80.9% renewable fraction (RF), the system introduces notable technical challenges, including elevated total harmonic distortion (THD) at the bus, significant branch losses, and power factor deviations. Harmonic spectra revealed particularly high contributions from the energy storage system and converter interactions, underlining the necessity of advanced filtering and compensation strategies. By bridging economic optimization with technical validation, this work emphasizes that offshore hybrid energy systems cannot be assessed solely on cost and emissions metrics but must also undergo rigorous power quality evaluation to ensure reliable grid integration. The dual perspective presented offers valuable insights for regulators, utilities, and policymakers, underscoring the importance of aligning economic incentives such as carbon taxation with the technical requirements of modern distribution networks.

Keywords: Offshore hybrid renewable systems, offshore wind turbines, wave energy converters, floating solar PV, power quality analysis, load flow analysis, short-circuit analysis, grid integration.

INTRODUCTION

The global transition toward renewable energy has significantly accelerated the deployment of offshore-based power systems, which integrate diverse technologies such as offshore wind turbines (OWT), wave energy converters (WEC), and floating solar photovoltaic panels (FSPV). OWT have already demonstrated substantial potential in improving grid stability, expanding generation capacity, and supporting large-scale decarbonization strategies (Wu et al., 2024). Alongside OWT, WEC and FSPV systems are increasingly gaining attention as complementary technologies, contributing to a more reliable and sustainable offshore hybrid energy mix (Li et al., 2023; Venkatesan et al., 2024). However, the integration of such hybrid offshore systems into existing power networks presents several technical and economic challenges, ranging from cost optimization and resource intermittency to system stability and power quality concerns (Wang et al., 2018; Liu and Zhao, 2022).

In Türkiye and other regions with high offshore potential, the large-scale deployment of OWPs has been analyzed in terms of grid code compliance, dynamic stability, and voltage control capabilities, with results showing that even under high penetration levels the power system can maintain operational stability (Yalman et al., 2022). Nevertheless, technical requirements for offshore integration remain a critical issue, as demonstrated in comparative analyses of European and Turkish grid codes, where improvements are needed in active power control, voltage regulation, and fault ride-through capabilities (Çelik et al., 2022). Furthermore, research has highlighted the importance of real-time stabilization strategies for offshore wind fluctuations, often requiring hybrid storage systems such as batteries and supercapacitors to meet grid connection standards (Chen et al., 2022). In parallel, ensuring harmonic compliance and power quality of offshore installations has become a pressing priority, as studies on modulation strategies, converter technologies, and harmonic filtering solutions reveal that poorly managed harmonics can hinder compliance with international standards (Ago, 2020; Ruiz et al., 2021).

The environmental and operational complexity of offshore systems further requires attention to hybrid optimization approaches that combine economic and technical analyses. Various works have underlined the role of techno-economic modeling tools such as HOMER Pro to assess the trade-offs between cost, emissions, and system reliability in hybrid renewable energy systems (HRES) (Johansen, n.d.; Zhao et al., 2022). Meanwhile, advanced decomposition and forecasting techniques, such as complete ensemble empirical mode decomposition with adaptive noise (CEEMDAN)- long short-term memory (LSTM) models and hybrid artificial intelligence (HAI) frameworks, have been applied for renewable generation forecasting, uncertainty modeling, and system optimization (Hong and Möller, 2011; Said and Ringwood, 2021; Fu et al., 2022). These methodological advances not only enable a deeper understanding of system behavior but also provide the foundation for informed decision-making in offshore hybrid energy planning.

Despite the progress, a critical research gap exists at the intersection of economic feasibility under environmental policies and technical validation under realistic grid conditions. Previous studies often focus on either economic optimization through carbon taxation scenarios or on technical assessments of grid integration and power quality. However, offshore hybrid systems demand an integrated evaluation approach. In this regard, the present study offers a novel contribution by extending previously published work (Terkes et al., 2025), which analyzed the impact of carbon taxes on the economic viability of an offshore hybrid system in a microgrid context at the Palau River region in Indonesia using HOMER Pro, into a more technical dimension. Using the optimal capacities derived under the most cost-effective carbon tax scenario, this work conducts detailed load flow, short-circuit, and harmonic analyses in ETAP. By linking economic optimization results with technical validation of grid impacts, particularly on voltage profiles, harmonic distortions, reactive power flows, and system losses, this study addresses both the financial and operational dimensions of offshore hybrid systems.

Such a dual perspective is crucial because while carbon taxation can promote economically viable renewable investments, the long-term success and acceptance of offshore hybrid systems depend equally on their

compatibility with power quality standards and grid stability requirements. By demonstrating the necessity of evaluating power quality impacts alongside economic outcomes, this work provides new insights for utilities, regulators, and policymakers on the deployment of offshore hybrid energy systems in real-world distribution networks.

METHODOLOGY

The methodology of this study employs a comprehensive two-stage framework that integrates economic optimization with detailed technical validation of an offshore HRES. In the first stage, the system was previously optimized in HOMER Pro under varying carbon tax scenarios. Different capacities of OWT, WEC, FSPV, and battery energy storage systems (ESS) were evaluated. The configuration minimizing net present cost (NPC) under a carbon tax of 54 $/t was selected as the reference for the current technical study. The HOMER optimization objective is expressed as:

$$min(NPC) = \sum_{t=0}^{N} \frac{C_{cap}(t) + C_{om}(t) + C_{fuel}(t) + C_{rep}(t) - R_{salv}(t)}{(1+i)^t} \tag{1}$$

where C_{cap}, C_{om}, C_{fuel}, C_{rep} are capital, operational, fuel, and replacement costs in year t; R_{salv} is the salvage value; i is the discount rate; and N is project lifetime. Levelized cost of energy (LCOE) is:

$$LCOE = \frac{NPC}{\sum_{t=0}^{N} \frac{E_{served}(t)}{(1+i)^t}} \tag{2}$$

Component-level Power Formulations

- Offshore Floating Solar PV (FSPV)

$$P_{FSPV}(t) = G_t . A_{PV} . \eta_{PV} . \left(1 - \alpha_p \left(T_c - T_{ref}\right)\right) \tag{3}$$

where G_t is incident irradiance, A_{PV} panel area, η_{PV} panel efficiency, α_p temperature coefficient, T_c cell temperature, T_{ref} reference temperature.

- Offshore Wind Turbine (OWT)

$$P_{OWT}(t) = \begin{cases} 0\,, & v < v_{ci} \ \ or \ v > v_{co} \\ P_{rated} \dfrac{v^3 - v_{ci}^3}{v_r^3 - v_{ci}^3}\,, & v_{ci} \le v \le v_r \\ P_{rated}\,, & v_r < v \le v_{co} \end{cases} \tag{4}$$

where v is hub-height wind speed, v_{ci} cut-in speed, v_r rated speed, v_{co} cut-out speed, P_{rated} turbine rated power.

- Offshore Wave Energy Converter (WEC)

$$P_{WEC}(H_s, T_e) = \eta_{WEC} . \rho . g^2 . H_s^2 . T_e . A_{eff} \tag{5}$$

with H_s significant wave height, T_e wave period, η_{WEC} WEC efficiency, ρ water density, g gravity, and A_{eff} effective capture area.

- Battery-based Energy Storage Systems (ESS)

$$SoC(t) = SoC(t-1) + \frac{\eta_{ch} P_{ch}(t) - P_{disch}(t)/\eta_{disch}}{C_{ESS}} \quad (6)$$

where η_{ch}, η_{disch} are charging/discharging efficiencies, C_{ESS} ESS capacity.

- Converter

$$P_{AC}(t) = \eta_{inv} P_{DC}(t) \quad (7)$$

with η_{inv} inverter efficiency.

In previous HOMER simulations (Terkes et al., 2025), the economic and environmental analysis results were carefully evaluated. Building upon this work, the present study focuses on the assessment of the system's technical performance. The system model established in HOMER can be referenced in Figure 1. The HRES modeling and feasibility results based on carbon taxation can be found in detail in (Terkes et al., 2025).

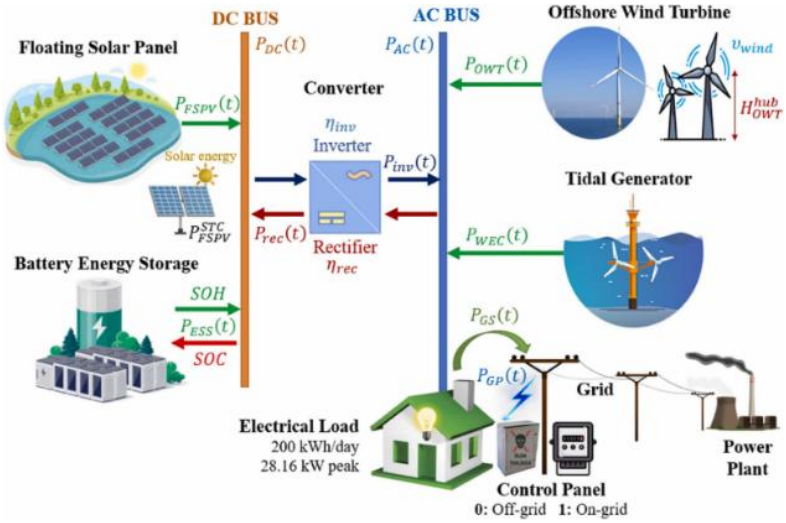


Figure 1. Offshore HRES Configuration with HOMER (Terkes et al., 2025)

Technical Analysis in ETAP

The second stage centers on detailed technical modeling in ETAP. The technical evaluation of the offshore HRES was carried out comprehensively in ETAP, focusing on power flow, short-circuit, and harmonic studies. These analyses were designed to ensure that the system operates safely, efficiently, and in compliance with international standards, particularly under varying operational conditions and fault scenarios.

- Load Flow Analysis

$$V_i^{(k+1)} = \frac{1}{Y_{ii}} \left(\frac{P_i - jQ_i}{V_i^{(k)*}} - \sum_{j \neq i} Y_{ij} V_j^{(k)} \right) \quad (8)$$

while the Newton-Raphson method linearizes the power flow equations and solves them using the Jacobian matrix:

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}=\begin{bmatrix}\frac{\partial P}{\partial Q} & \frac{\partial P}{\partial V}\\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V}\end{bmatrix}\begin{bmatrix}\Delta\theta\\ \Delta V\end{bmatrix} \quad (9)$$

Here, P_i and Q_i are the net active and reactive powers at bus i, V_i and θ_i are the voltage magnitude and angle, and Y_{ij} represents the elements of the bus admittance matrix. Both methods were cross-validated to ensure convergence under the diverse loading and generation conditions imposed by the FSPV, OWT, WEC, and ESS units.

- Short-Circuit Analysis

Fault studies were conducted according to the IEC 60909 standard to evaluate symmetrical and asymmetrical fault currents. The system was analyzed for three-phase faults, single-phase-to-ground, two-phase-to-ground, and two-phase faults, using the following general expression for the initial symmetrical short-circuit current:

$$I_k^{"}=\frac{c.U_n}{\sqrt{3}.Z_k} \quad (10)$$

where U_n is the nominal voltage, Z_k is the equivalent impedance seen from the fault location, and ccc is the voltage correction factor for maximum or minimum short-circuit scenarios. For asymmetrical faults, symmetrical components transformation was applied, separating the system into positive-, negative-, and zero-sequence networks, which allows accurate calculation of unbalanced fault currents.

- Harmonic Analysis

Harmonic studies were performed to evaluate voltage and current distortions introduced by the power electronic converters of the FSPV, OWT, WEC, and ESS units. Additionally, harmonic emissions produced by power electronic converters must comply with limits defined by IEEE 519 or IEC 61000 standards, quantified as total harmonic distortion (THD) for current and voltage:

$$THD_I=\frac{\sqrt{\sum_{h=2}^{\infty}I_h^2}}{I_1}100\% \quad , \quad THD_V=\frac{\sqrt{\sum_{h=2}^{\infty}V_h^2}}{V_1}100\% \quad (11)$$

where I_h and V_h are the rms values of the h-th harmonic current and voltage, and I_1 and V_1 are the fundamental components. Individual harmonic injections for each subsystem were set according to typical characteristics of modern converter technologies, enabling the assessment of non-linear effects on the network.

- Voltage Drop and Loss Assessment

Distribution losses and voltage drops were computed across the system, including cables, transformers, and converters, using the standard expressions:

$$\Delta V=I.(R.\cos\phi+X.\sin\phi) \ , \quad P_{loss}=3.I^2R \quad (12)$$

where I is the branch current, R and X are the resistance and reactance of the line segment, and ϕ is the phase angle between current and voltage. These calculations enabled the identification of critical nodes where voltage support or reactive power compensation may be necessary.

By integrating these technical analyses, the study provides a comprehensive validation of the hybrid system's operation, confirming that the combination of offshore FSPV, OWT, WEC, and ESS can maintain acceptable voltage profiles, comply with fault ride-through requirements, and minimize harmonics and losses under realistic operational scenarios.

- Technical Constraints for Offshore Renewable Energy Integration

Following the detailed ETAP analyses, it is essential to ensure that the offshore HRES operates within specific technical limits and regulatory requirements. These constraints encompass voltage and frequency limits, current carrying capacities, fault ride-through capabilities, and harmonic distortion thresholds, all of which are critical for maintaining power quality and system stability. The active and reactive power outputs of OWT, WEC, and FSPV units must be carefully regulated to prevent bus voltage violations and to keep branch currents within their rated capacities. The ESS must operate within prescribed state-of-charge (SoC) boundaries to avoid overcharging or deep discharging, thereby protecting battery health and prolonging operational lifetime.

Harmonic distortion caused by power electronic converters must remain within the limits defined by international standards, typically not exceeding 5% for both voltage and current THD, to prevent equipment malfunction and ensure stable grid interaction. Voltage drops along feeders and distribution lines must be minimized, ideally maintained below 5% of nominal voltage, while network losses should be kept as low as possible to maximize energy efficiency. Additionally, the system must comply with short-circuit and fault ride-through requirements as specified in IEC 61400-21, being capable of sustaining three-phase, single-phase-to-ground, two-phase-to-ground, and two-phase faults without disconnection or damage to generation and storage units.

By rigorously enforcing these technical constraints, the offshore hybrid system can achieve safe, reliable, and efficient operation, ensuring high-quality power delivery, minimizing operational losses, and supporting long-term stability and resilience of both the generation assets and the energy storage components.

- Offshore HRES Configuration with ETAP

The offshore HRES under study integrates FSPV, OWT, WEC, and a ESS, all interconnected within a meshed distribution network (see Figure 2). The system is connected to the main grid, which has a short-circuit capacity of 6000 MVA, through a 154 kV feeder bus protected by a high-voltage circuit breaker (CB1). From there, the energy is stepped down via a 100 MVA transformer to 34.5 kV, distributed through underground lines to secondary transformers, and further reduced to standard low-voltage levels (0.4 kV) for delivery to individual generation units and loads.

The FSPV units are directly connected through their integrated converters, while OWT and WEC units are interfaced via dedicated power electronic converters to ensure synchronized operation and compliance with grid codes. The ESS is connected through DC cabling and a controlled charger to manage charge–discharge cycles safely, maintaining SoC limits. Underground cabling is adopted for the majority of connections to enhance safety, reduce electromagnetic interference, and provide a reliable transmission pathway, while step-down buses and distribution transformers regulate voltage profiles across the network.

This configuration enables comprehensive ETAP simulations, including Gauss-Seidel and Newton-Raphson load flow analyses, IEC-compliant short-circuit assessments for three-phase, single-phase-to-ground, two-phase-to-ground, and two-phase faults, as well as harmonic analyses to quantify the impact of non-linear power electronic converters. Key performance indicators, such as bus voltage profiles, branch current loading, THD, active and reactive power losses, and voltage drops, are monitored to ensure that all system components operate within their rated capacities and comply with international standards. This integrated approach demonstrates a deep understanding of offshore hybrid system behavior under realistic operational and fault conditions, providing a robust foundation for both technical validation and future optimization studies.

RESULTS

The performance evaluation of the proposed offshore HRES was conducted in two complementary stages. In earlier work, the techno-economic feasibility of the system was extensively analyzed in HOMER Pro under various carbon tax scenarios, where a tax level of 54 $/t was identified as the most cost-effective case. In the present study, only the key outcomes of the HOMER optimization are briefly highlighted to provide context, while the main emphasis is placed on the second stage. Here, the optimized configuration is implemented in ETAP to validate its technical viability through detailed load flow, short-circuit, and harmonic distortion analyses.

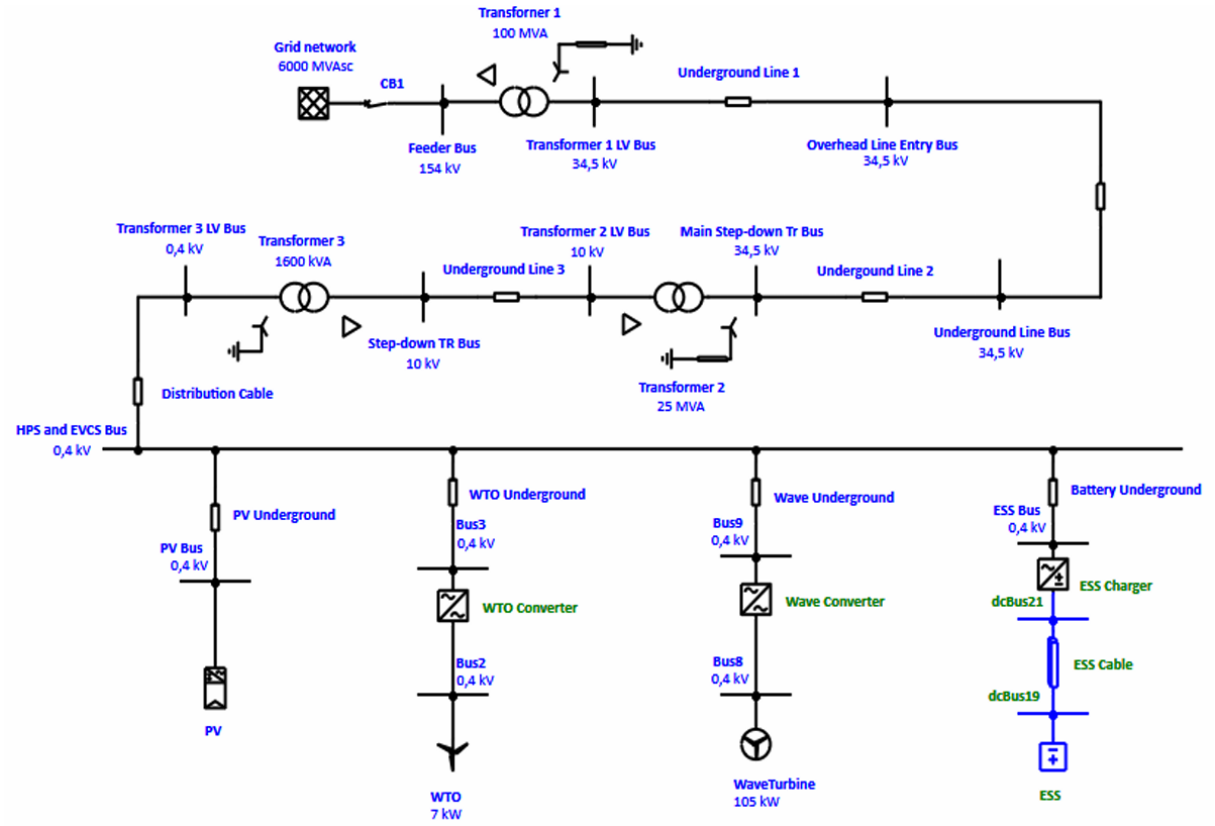


Figure 2. Offshore HRES Configuration with ETAP

Economic and Energy Performance

The HOMER-based optimization yielded an optimal configuration consisting of 2.61 kW FSPV, 10.5 kW OWT, 105 kW WEC, and a 3.67 kWh ESS supported by a 0.552 kW PCS (see Table 1). The system achieved an LCOE of 0.02672 $/kWh and a NPC of 180,609 $, confirming its competitiveness against conventional alternatives. The renewable fraction reached 80.9%, with clipped energy losses limited to 1.82%, demonstrating efficient utilization of the installed renewable capacity. The payback analysis further indicated that the investment is financially viable, with a simple payback of 6.41 years and a discounted payback of 7.72 years. Annual CO_2 emissions were reduced to 78,225 kg, confirming the environmental benefits of the hybrid design under the specified carbon pricing regime.

Load Flow and Power Quality

The ETAP load flow results (Table 2) showed stable operation at the low-voltage distribution level, with the hybrid power system (HPS) bus operating at 0.401 kV, supplying 113.53 kW of active power and 37.31 kVAr of reactive power. The system maintained a leading power factor of 0.95, within acceptable grid code limits. Active branch losses were limited to 3.6 kW, while reactive losses were approximately –50.5 kVAr, indicating efficient reactive power compensation by converter-interfaced units. The overall voltage drop was measured as 5.9 V, corresponding to less than 1.5% of nominal voltage, well within international standards.

Harmonic Analysis

Nonlinear behavior introduced by power electronic converters was assessed through harmonic distortion analysis. THD_I was found to be 13.49% for the ESS, 10.50% for the OWT, and 11.25% for the WEC, whereas the FSPV maintained a negligible contribution due to its integrated converter design. At the low-voltage transformer bus, $THD_I^{\text{Transformer LV Bus}\leftrightarrow\text{HPS}}$ peaked at 32.57%, indicating that the aggregation of multiple converter-based sources

amplifies distortion at common coupling points. THD_V at the HPS bus was 1.67%, well below the 5% threshold set by IEEE 519, confirming compliance with power quality standards.

Table 1. Optimal System Configuration and Key Techno-economic Indicators Derived from HOMER Pro

Specification	Value	Unit
CT	54	$/t
FSPV capacity	2.61	kW
OWT capacity	10.5	kW
WEC capacity	105	kW
ESS capacity	3.67	kWh
PCS capacity	0.552	kW
LCOE	0.02672	$/kWh
NPC	180,609	$
Simple payback	6.41	yr
Discounted payback	7.72	yr
CO_2	78,225	kg/yr
RF	80.9	%
Clipped energy	1.82	%

As presented in Table 3, detailed harmonic spectra revealed that current harmonics were dominated by the 11th and 13th orders across converter-connected units, with the ESS exhibiting the highest magnitudes (8.68% and 7.29%, respectively). Higher-order harmonics (23^{rd}–49^{th}) were significantly attenuated, remaining below 4%. On the voltage side, distortions remained consistently below 1% for all sources except the ESS, where values between 3.4% and 4.0% were observed, suggesting that mitigation strategies such as active filters may be beneficial for large-scale storage integration.

Short-Circuit Performance

Fault analysis confirmed the robustness of the system under various contingencies (see Table 1). The initial symmetrical three-phase fault current was calculated as 32.66 kA with a peak value of 70.22 kA, while single line-to-ground and double line-to-ground faults produced slightly higher breaking currents of 32.77 kA and 32.85 kA, respectively. Line-to-line faults resulted in a lower fault current of 28.29 kA. These values remain within the withstand ratings of the protection devices specified for the network, ensuring that the system can be safely isolated under severe disturbances.

Integrated Assessment

The combined results demonstrate that the offshore HRES is both economically viable and technically reliable. The optimized configuration offers a competitive cost of energy and significant CO_2 reduction potential while maintaining acceptable power quality indices under realistic operating and fault conditions. Although current harmonics from the ESS require attention, the overall harmonic distortion levels and voltage profiles comply with IEEE and IEC standards. This dual-stage evaluation framework confirms that the system is not only optimal in terms of investment but also feasible for real-world deployment, thereby bridging the gap between economic feasibility analyses and operational validation.

Table 2. Technical Performance Indicators of the Offshore HRES

Specification	Value				Unit
$THD_I^{\text{FSPV}\leftrightarrow\text{HPS}}$	-				%
$THD_I^{\text{ESS}\leftrightarrow\text{HPS}}$	13.49				%
$THD_I^{\text{OWT}\leftrightarrow\text{HPS}}$	10.50				%
$THD_I^{\text{WEC}\leftrightarrow\text{HPS}}$	11.25				%
$THD_I^{\text{Transformer LV Bus}\leftrightarrow\text{HPS}}$	32.57				%
THD_V	1.67				%
Power factor	0.95 (leading)				-
Voltage	0.401				kV
Current	172				A
Active power	113.53				kW
Reactive power	37.31				kVAr
Active branch losses	3.6				kW
Reactive branch losses	-50.5				kVAr
Voltage drop	5.9				V
Three-phase symmetrical fault current (Initial--Peak--Steady-State)	32.66	70.22	-	32.66	kA
Single line-to-ground fault current (Initial--Peak--Breaking—Steady State)	32.77	70.46	32.77	32.77	kA
Line-to-line fault current (Initial--Peak--Breaking--Steady-State)	28.29	60.81	28.29	28.29	kA
Double line-to-ground fault current (Initial--Peak--Breaking--Steady-State)	32.85	70.62	32.85	32.85	kA

Table 3. Current and Voltage Harmonic Distortion Profiles of Offshore HRES Components

Harmonic	Bus-Order	11	13	23	25	35	37	47	49	Unit
Current	FSPV	-	-	-	-	-	-	-	-	%
	OWT	7.88	6.03	2.45	2.14	0.81	0.70	0.30	0.19	
	WEC	8.26	6.65	2.77	2.29	0.80	0.61	0.21	0.20	
	ESS	8.68	7.29	4.09	3.80	2.78	2.59	2.03	1.94	
	HPS	15.83	23.23	11.58	9.73	4.91	2.64	2.32	2.34	
Voltage	FSPV	0.44	0.78	0.77	0.72	0.58	0.34	0.44	0.47	
	OWT	0.45	0.79	0.77	0.72	0.58	0.34	0.44	0.47	
	WEC	0.54	0.88	0.84	0.77	0.59	0.32	0.43	0.48	
	ESS	3.42	3.99	3.86	4.02	3.88	3.60	3.56	3.48	
	HPS	0.44	0.78	0.77	0.72	0.58	0.34	0.44	0.47	

CONCLUSION AND FUTURE SUGGESTIONS

This study proposed and comprehensively evaluated an offshore HRES integrating FSPV, OWT, WEC, and ESS within a meshed distribution network. A two-stage assessment framework was employed: HOMER Pro optimization, whose detailed results were reported in a previous study (Terkes et al., 2025), was first used to determine the economically optimal system configuration under carbon tax conditions, and ETAP simulations were subsequently carried out to validate its technical feasibility under realistic grid operation and fault scenarios.

The HOMER results highlighted that under a carbon tax of 54 $/t, the hybrid system achieves a highly competitive cost of energy (0.02672 $/kWh), an NPC of 180,609 $, and a RF of 80.9%. The system demonstrated short and

attractive payback periods while reducing annual CO_2 emissions by 78,225 kg, thus aligning both with economic efficiency and environmental sustainability targets.

The ETAP analysis confirmed that the optimized configuration operates within international technical standards. Load flow results showed acceptable bus voltage stability, minimal losses, and compliant voltage drops. Harmonic analysis indicated that while THD in current was significant at certain coupling points, particularly for the ESS, voltage distortion remained within IEEE 519 limits. Short-circuit analysis demonstrated that fault currents were within the withstand capability of protection devices, ensuring safe system operation under disturbances.

Overall, the findings emphasize that economic optimization alone is insufficient to ensure the real-world viability of hybrid offshore renewable energy systems. Instead, an integrated economic–technical evaluation, as presented in this study, is essential for confirming both financial attractiveness and operational reliability. The proposed methodology provides a replicable framework for policymakers, planners, and engineers seeking to accelerate offshore hybrid system deployment under carbon taxation and other policy instruments.

Future research should focus on developing advanced harmonic mitigation strategies, incorporating larger-scale storage, and testing dynamic performance under transient disturbances and grid-forming scenarios. Expanding the model to include demand-side management and multi-objective optimization would further strengthen the applicability of this approach for next-generation hybrid offshore renewable systems.

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