DETERMINATION OF BATTERY ENERGY STORAGE SYSTEM SIZING FOR HYBRID POWER SYSTEM IN PHU QUY ISLAND

XÁC ĐỊNH DUNG LƯỢNG PIN TÍCH TRỮ CHO HỆ THỐNG ĐIỆN TÍCH HỢP TẠI ĐẢO PHÚ QUÝ

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Abstract:

Currently, Phu Quy Island is being supplied by three power sources: a diesel plant, a wind power plant, and a solar power plant with capacities of 10 MW, 6 MW, and 0.8 MW respectively. The load is expected to achieve a capacity of 8.4 MW in 2025, and 14.9 MW in 2030. With the high increase in load demand, and far from the mainland, the Phu Quy power systems is difficult to get electrical energy from the national power grid. Renewable energy is being extended to meet the high load demand on the Phu Quy island. However, the issues of renewable energy often depend on weather conditions such as solar radiation and the wind's speed, therefore the diesel power plant is still the main energy supply that causes an increase in the power system operating cost. In order to meet the demand as well as the need for renewable energy using to be optimized in the future, the paper is devoted to determination of the Battery Energy Storage System (BESS) sizing to support Phu Quy hybrid in storage of renewable energy and decrease the operation cost for Phu Quy power system. The installation of renewable energy sources such as wind and solar is difficult to manage, between generation and consumption often has excess and shortage over time. The proposed BESS solution can store energy when there is excess from source and release it to the lines when load demand increases. It's suitable with the current status of power system on Phu Quy Island, as well as the development trend in the future, especially the COP26 and Power Development Plan VII.

Keywords:

Diesel power plant, wind power plant, solar power plant, BESS (Battery Energy Storage System).

Tóm tắt:

Hiện nay, đảo Phú Quý được cấp điện từ các nhà máy nhiệt điện diesel trên đảo với công suất 10 MW, nhà máy điện gió Phú Quý với công suất 6 MW và nhà máy điện mặt trời Phú Quý với công suất 0.8 MW. Nhu cầu phụ tải của đảo Phú Quý dự kiến đạt 8.4 MW đến năm 2025 và 14.9 MW đến năm 2030. Với nhu cầu tải tăng cao và do vị trí đảo nằm xa đất liền, đảo Phú Quý rất khó nhận nguồn cung điện từ lưới điện quốc gia, vì vậy giải pháp tiếp tục phát triển nguồn năng lượng tái tạo (NLTT) tại chỗ để cung cấp điện cho đảo là cần thiết và cũng là bài toán quy hoạch điện dài hạn của đảo. Tuy nhiên các nguồn NLTT lại phụ thuộc các yếu tố thời tiết như bức xạ của mặt trời, tốc độ gió, do đó nhà máy diesel Phú Quý vẫn là nguồn điện cung cấp chính cho đảo gây ra tăng cao chi phí vận hành hệ thống. Để đáp ứng nhu cầu phụ tải của đảo Phú Quý, giảm chi phí vận hành hệ thống cũng như tối ưu hóa sử dụng nguồn năng lượng tái tạo trong tương lai, bài báo đề xuất nghiên cứu lựa chọn dung lượng của hệ thống pin lưu trữ năng lượng (Battery Energy Storage System – BESS) để hỗ trợ hệ thống điện đảo Phú quý lưu trữ nguồn năng lượng tái tạo và giảm chi phí vận hành cho hệ thống điện huyện đảo Phú Quý. Việc lắp đặt các nguồn năng lượng tái tạo như gió, mặt trời thường khó quản lý, có thể có sự thừa và thiếu theo thời gian giữa thời điểm phát và tiêu thụ, do đó giải pháp sử dụng BESS có tác dụng lưu trữ nguồn năng lượng tái tạo khi dư thừa và phát lại khi nhu cầu phụ tải tăng cao phù hợp với thực tiễn tại đảo Phú Quý và xu hướng phát triển trong thời gian tới đặc biệt là tổng sơ đồ VIII và COP26.

Từ khóa:
Nhà máy điện diesel, nhà máy điện gió, nhà mát điện mặt trời, BESS, COP26.

1. INTRODUCTION

Recently, the development of renewable has become a global trend aimed to achieve zero carbon targets in the future. Renewable energy is a free energy source and friendly to the environment. However, it is not only depending on weather conditions such as solar radiation but aslo wind speed. In order to integrate renewable into the microgrid system, many researchers have suggested solutions using a Battery Energy Storage System (BESS) which can store excess energy from renewable sources and discharge it during periods of power shortage. Bogdan S. Borowy and his partners [1] studied methodology for optimally sizing the combination of a battery bank and PV Array in a Wind/PV hybrid system; Le Thi Minh Lien and her partners [6] indicated an optimal sizing of a battery energy storage system using particle swarm optimization for microgrid; José L.Bernal-Agustín and his partners [4] performed to simulations and optimization of a standalone hybrid renewable energy system and Thair Mahmoud [8] studied the optimal sizing of Battery Energy Storage Systems in microgrids.

This paper focuses on determining the sizing of a battery energy storage system (BESS) for a power system based on time-domain load-flow (TDLF) simulation using ETAP software. The procedure is applied to determine the appropriate size of the BESS for microgrids in the case of Phu Quy island in southern Vietnam. The paper is organized as follows:

The introduction is addressed in the first part. In part 2, authors present about battery energy storage system (BESS) model used in ETAP software; The procedure for determining the size of BESS for Phu Quy power system is proposed and discussed in part 3. Finally, part 4 presents the conclusions and perspective of the paper

2. BATTERY ENERGY STORAGE SYSTEM MODEL USED IN ETAP SOFTWARE

A battery model used for time domain simulation is given by following the differential function:

$$U_i = U_{nom}.u_{set} \qquad (1)$$

$$U_{DC} = U_i + I_{DC}.R_i + L_i.1000.\frac{dI_{DC}}{dt} \qquad (2)$$

where:

U_i: the internal voltage (kV);

U_{nom}: the nominal voltage of the battery (kV);

u_{set}: the voltage setpoint input signal (p.u);

R_i: the internal resistance (ohm);

L_i: the internal inductance (mH);

I_{DC}: the DC current (kA);

$\frac{dI_{DC}}{dt}$: the derivative of the DC current (kA/s);

U_{DC}: the DC voltage (kV)

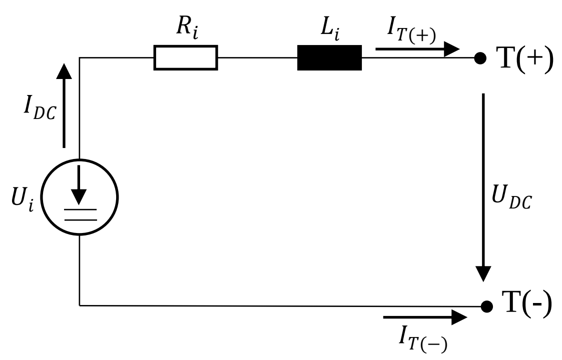

Figure 1. The Battery module used for time domain simulation [5], [11], [12], [13], [20]

Figure 2 presents the BESS model which is built into ETAP software.

The BESS module consists of various components with specific function of power storage units, inverters, and converters in order to convert DC to AC during the charging and discharging process. The AC components of the BESS system consist of various equipment as a step-up transformer which is useful for increasing the voltage from low to medium voltage, and a circuit breaker that connect and disconnect the BESS from the load.

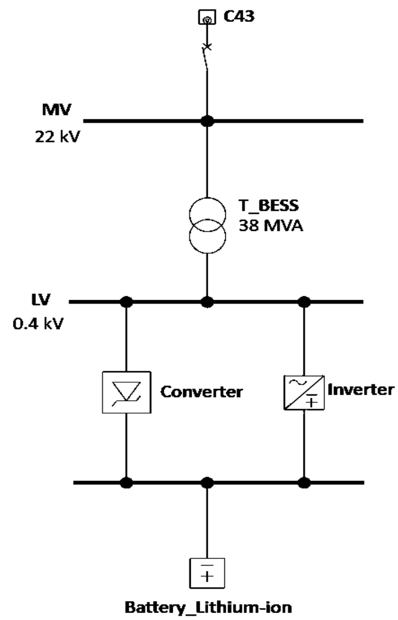

Figure 2. The BESS module in ETAP software

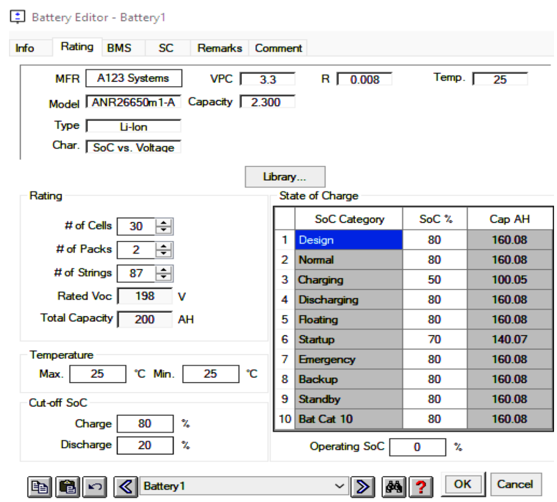

Figure 3. The rating parameters of battery

In these cases, the BESS charges from the excess energy from power renewable sources and discharges energy when there is insufficient power supply in the islands. These processes support the load demand requirements and reduce the power generated from diesel power plants. The Lithium-Ion based technology battery is used to simulate effectiveness of

BESS in the paper. Figure 3 provides recommendations for the rating parameters of the BESS in ETAP software [2], [3], [9], [10], [11].

3. DETERMINATION OF BESS SIZING FOR PHU QUY POWER SYSTEM

3.1. Methodology for selecting the size of BESS

The procedure for determination of BESS sizing is proposed including 05 steps as below:

- Step 1: Run TDLF and build the power of loads and sources characteristic in 8,760 hours by ETAP software.
- Step 2: Determination the amount of excess energy from the renewable sources (E_{Ex});
- Step 3: Determination of the typical daily load curve of power system from the TDLF result. It is a daily load curve which is most probability occurring in a year.
- Step4: Determination of the power required of BESS form daily load curve.
- Step 5: Determination of BESS capacity (E) following formula 4.

$$\begin{cases} E_{BESS} = \dfrac{P_{required} \times \tau}{\%DOD \times \eta} \\ E_{BESS} \le E_{Ex} \end{cases} \quad (4)$$

Where:

E_{BESS}: BESS capacity required (MWh);

E_{Ex}:Excess renewable power capacity (MWh);

$P_{required}$: The maximum power of diesel power plant generated that is determined from the typical daily load curve (MW);

$\%DOD$: Depth of discharge (%);

η: Efficiency of battery;

τ: Total time for discharing.

3.2. Case study of Phu Quy Power system

Phu Quy island is currently being supplied by three power sources: a diesel plant, a wind power plant and a solar power plant with capacity of 10 MW, 6 MW and 0.8 MW respectively. The load is expected to achieve a capacity of 8.4 MW in 2025 and 14.9 MW in 2030. The single-line diagram of the planned Phu Quy power system is presented in Figure 4.

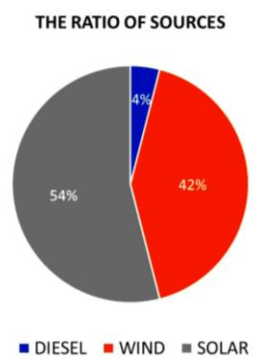

Figure 4. The ratio of sources chart

The paper conducts a simulation of the power system in Phu Quy island for a duration of 8,760 hours by using ETAP software based on the collected data, which includes a single-line diagram of the power system, cables and transformers impedances, load curves and power generating curves of different resources.

The load demand is 57,960 MWh per year with the loss load is 787.3 MWh per year. Figure 4 indicates the ratio of sources in a chart.

In Figure 4, the shares of the wind energy, solar energy, and diesel energy are 42%, 54% and 4% respectively of the total energy source. Figure 5 presents the load-flow result in 8,760 hours of Phu Quy power system.

Figure 6 shows the power generation curves of the Phu Quy wind power plant (represented by the red area), the Phu Quy solar power plant (represented by the green area), and the Phu Quy diesel power plant (represented by the purple area), as well as the load curve of the Phu Quy power system (represented by the blue line), over a period of 8,760 hours (one year). The yellow areas above the blue line, which is the amount of excess renewable energy. Based onthe Figure 6, the paper determines excess renewable of the Phu Quy power system is 3,094 MWh per year. As mentioned in part 3.1, the Phu Quy power system requires the use of

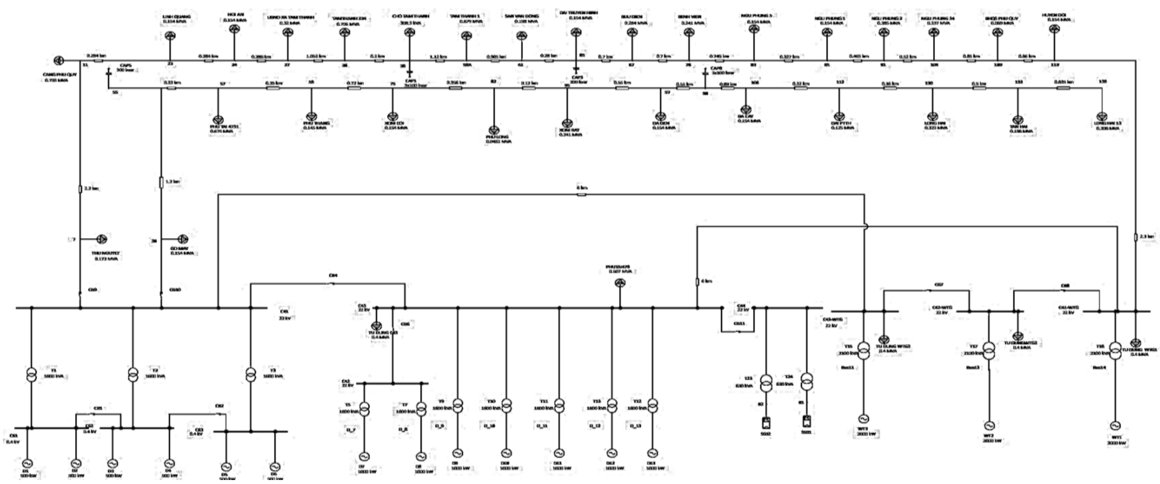

Figure 5. A single-line diagram of current Phu Quy power system

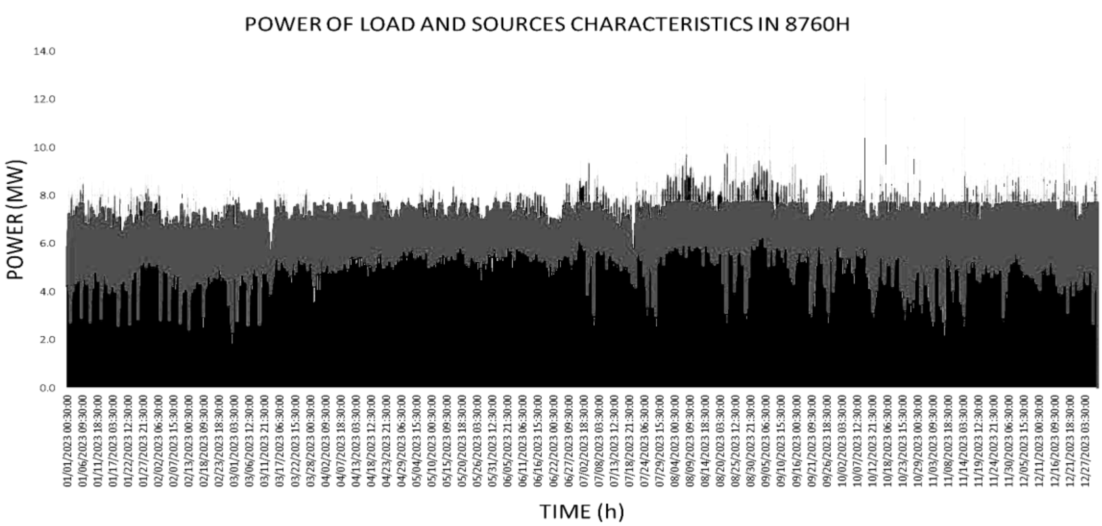

Figure 6. The load-flow result in 8760 h of Phu Quy power system

BESS to store those excess renewable.

Figure 7 is a typical daily load curve of Phu Quy power system. The blue line represents the total load, the green area represents the solar plant generation, the orange area represents the diesel plant generation, and the grey area represents the wind plant generation. The amount of excess wind power is 7.6MWh per day; The maximum power of diesel power plant generated that is 1.4MW. The paper determinate BESS (The battery chosen is lithium-ion) capacity based on formula 4.

$$\mathbf{E_{BESS}} = \frac{\mathbf{P_{required}} \times \boldsymbol{\tau}}{\mathbf{\%DOD} \times \boldsymbol{\eta}} = \frac{\mathbf{1.4 \times 2}}{\mathbf{80\% \times 95\%}}$$

$$= \mathbf{3.68MWh \approx 4MWh}$$

$E_{BESS} \leq E_{Ex} \Leftrightarrow 4 \leq 7.6$

The Size of BESS is determined to be 4 MWh; The type of battery is lithium-ion.

The BESS model mentioned in part 2 is showed in figure 8.

The investment cost range of BESS using Lithium-Ion technology is from \$150/kWh to 250\$/kWh and it is predicted to be below \$100/kWh by 2025 [15]. In this paper, the chosen investment cost of BESS is \$250/kWh, Table 1 shows the investment of BESS with 4MWh and the payback period of the project.

Based on the results is shown in Table 1, the installation of BESS for the Phu Quy power system enables it to meet the load demand by 2025 and helps saving \$130,000/year (The saving cost per year after installing BESS in Phu Quy power system). Therein, the energy generated by the Phu Quy diesel power plant decreases

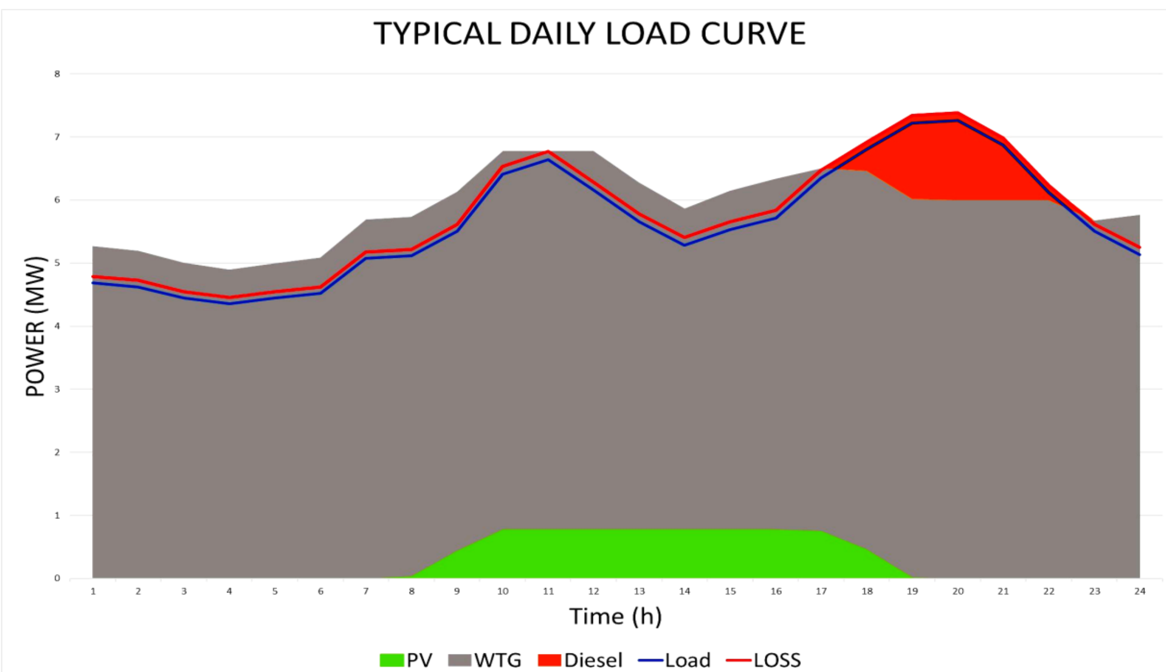

Figure 7. The typical daily load curve in Phu Quy Power system

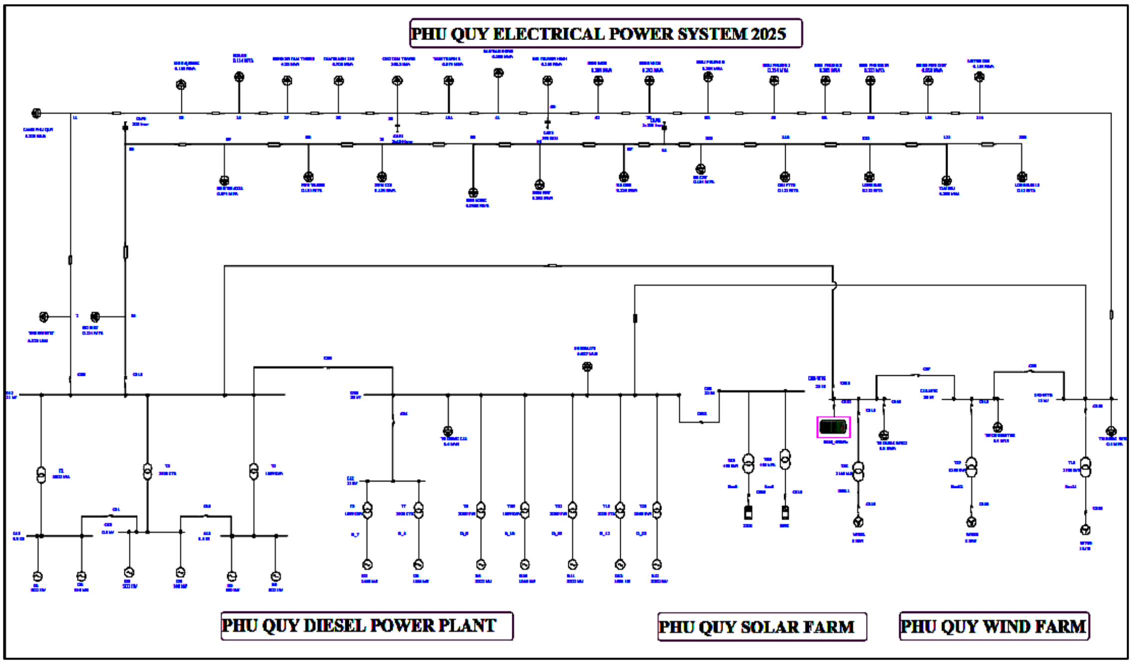

Figure 8. A single-line diagram of Phu Quy power system after installing BESS

from 27,041 MWh to 26,741 MWh which is equal to $108,000 (the cost of energy from Phu Quy diesel power plant is $0.36/kWh). The amount of Carbon dioxide (CO_2) emission decreased about 252 tons of CO_2 per year. They were guided by Ms. Nguyen Thi Xuan Hanh and her partners [19] with the emission factor (EF) of Viet Nam electrical power system is 0.8401. The Phu Quy power system will save $22,000 with the cost of Carbon credits is about $15/tCO_2$ to $96/tCO_2$, and the paper chooses the cost of carbon credits which is $87/tCO_2$ (The cost of carbon credits is in the EU).

4. CONCLUSIONS

Renewable energy is an abundant and environmentally friendly source that plays a key role in achieving the zero-carbon target 2050. However, renewable energy sources are not consistent as they depend on weather conditions, which can result in excess energy production. To address this issue, it is necessary to install a BESS in the Phu Quy power system to store excess wind power. The proposed procedure for determination of BESS sizing shown that there was a significant reduction in power generation from the Phu Quy diesel power plant, from 27,041 MWh to 26,741 MWh.

Table 1. The benefit of Phu Quy power system after/before installing BESS

The investment cost of BESS ($)	The saving cost per year ($)	The payback period (year)	The life of project (year)
1,000,000	130,000	7,69	15

Note: the investment cost of BESS is 250$/kWh [15]

This reduction has resulted in annual savings of $130,000 over the 15-year life of the project.

For future work, it is recommended to conduct the dynamic simulation of BESS integration in order to enhance the stability of the Phu Quy power system.

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