ID – 10997 Session 2022
A1 – ROTATING ELECTRICAL MACHINES
PS2 / ASSET MANAGEMENT OF ELECTRICAL MACHINES

Performance and Reliability of the Wind Turbines at Lam Takong Jolabha Vadhana Power Plant: A Review

Prapapong VANGTOOK*, Panu SUWICHARCHERDCHOO, Jarudate VORASEE
Electricity Generating Authority of Thailand
Thailand
prapapong.v@egat.co.th

SUMMARY

Renewable energy in Thailand has experienced significant growth in the last decade, especially wind energy. Moreover, Power Development Plan: PDP2018 Revision 1 does develop to emphasize improving the energy sector's security, economy, and ecology by reducing the reliance on energy generation from fossil-based resources and increasing the share of renewable energy. In addition, the commitments that Thailand has made to reduce greenhouse gas emissions require concerted actions for the decarbonization of the energy sector. The paper will present an overview of wind hydrogen hybrid combined with fuel cell for the first time in Asia to enhance renewable energy capabilities at Lam Takong Learning Center, Electricity Generating Authority of Thailand (EGAT) in Nakhon Ratchasima Province. After a successful wind turbine phase 1 project of two sets of 1.25 MW wind turbines installed in 2008 at Lam Takong. The annual average wind speed was 5-6 m/s over the upper reservoir of Lam Takong Jolabha Vadhana Power Plant in Khlongphai Sub-district, Sikhio District, Nakhon Ratchasima, which does consider to be good enough for the development of a wind turbine farm. Later, on 8th June 2017, the EGAT developed a wind turbine phase 2 project which installed an additional 12 wind turbines with a total capacity of 24 MW or 2 MW each to make a total power capacity of 26.5 MW.

Each turbine tower is 94 meters high with a blade diameter of 116 meters, and the budget for the project costs 1,407 million baht. EGAT operated the Lam Takong wind turbine project phase 2 on 3rd January 2018. Electricity generation from this wind turbine farm contributes to many households around that area. Wind energy produced from 2018 to 2021 is 45.11, 67.72, 71.14, 49.69 (as of October 2021) GWh or has a capacity factor of 21.92%, 32.83%, 31.43%, respectively. The performance and reliability of the wind turbines do inspect two times/a year, such as the generator drive system, wind turbine power system, turbine blade control system and structures, etc. It must be planned before maintenance so the wind turbines are ready to supply electricity at any time without interruption to keep an average availability of 76.75% (2019), 93.98% (2020), and 88.23% (as of October 2021). The wind turbine phase 2 project also enhances performance using hydrogen fuel cell technology with a magnitude of 300 kW.

Energy production from wind turbines is used to separate water into hydrogen and oxygen. The hydrogen flows to the fuel cell system to generate electricity. The EGAT Learning Center in the same area receives electricity from this system. The EGAT wind hydrogen hybrid system with fuel cell technology was considered to be not only the most significant project in Thailand but also the first country in ASIA. The total cost of the fuel cell system was around 234 million baht. Another research project is a 20C discharge C-rate & pole solid-state battery (lithium-ion phosphate microfilm battery). These two projects will stabilize energy generation of renewable energy with high efficiency.

KEYWORDS

The wind power plant, Fuel cell system, 20C discharge C-rate & pole solid-state battery

1. Introduction

Renewable energy sources have been gaining momentum in electrical energy generation over the past decade due to decreasing costs and a significant breakthrough in renewable energy technologies. Furthermore, many countries have committed to achieving a clean, secure, reliable environment. The affordable energy transition for all to satisfy is the 17 Sustainable Development Goals agenda (SDG 17). During the 26th session of the Conference of Parties (COP 26), Commitments were made to the United Nations Framework Convention on Climate Change (UNFCCC) in Glasgow 2021. The facilitation of renewable energy resources integration is required to mitigate climate change in the energy sector. Global electricity consumption is expected to grow exponentially soon and will lead to an increase in electrical energy generation. Renewable energy resources will play a significant role in fulfilling demand and sustainable energy transition. Thailand has also seen considerable growth in electricity consumption due to continued economic growth, including population growth. Therefore, Thailand revived Power Development Plan 2015 (PDP2015) as PDP2018 Revision 1 to develop electricity generation planning consistent with the increasing electricity consumption and keeping up with renewable power generation technology improvements.

This paper aims to provide an overview of the present condition, policy framework, potential, and challenges of wind energy development in Thailand. The article will have the following parts:

Section 2 provides the potential of wind energy in different regions in Thailand.
Section 3 discusses the challenges and prospects of wind energy integration in Thailand.
Section 4 examines the performance and reliability of the wind turbines at Lam Takong Jolabha Vadhana Power Plant as a case study.
Section 5 is the main conclusion.

2. The potential of wind energy in different regions of Thailand

Thailand is located near the equator line and has low to moderate wind speeds. The most significant wind energy potential is geographically in the northeastern, western, and southern regions of Thailand, with an annual average wind speed of about 6 m/s at an elevation of 50 meters [1]. Those areas are pretty far away from load centers and transmission lines. The technical potential of wind energy can reach 13 GW across Thailand [2]. Regarding offshore wind energy potential, the Gulf of Thailand has the most promising area with an estimated magnitude of 7 GW; more than half of the potential is located in the Bay of Bangkok – the northern part of the Gulf of Thailand. With the assumption of a capacity factor of 25% and at the height of 120 m, total energy generation would reach 15 TWh per year [3].

3. Challenges and the prospect of wind energy transition in Thailand

Thailand faces many challenges in the development and promotion of wind energy. Some of the challenges can be listed as follows:

First, land and community issues remain problematic for wind farm projects. The average wind speed in Thailand is low to medium range. The potential wind energy areas are around the Thai Gulf and higher-elevation regions, with an average wind speed of between 5-6 m/s at around 50 meters. Wind farms require large spaces to operate, and most of the potential areas with high average wind speeds are often located in mountainous terrain or reserved forests. Therefore, installing a wind turbine requires permission from a related government agency to use the area.

Second, wind farm projects require high capital investment costs, divided into wind turbine costs, grid connection costs, civil work, construction costs, and fixed and variable operating and maintenance costs. A reasonable energy tariff would be necessary for wind farm projects to break even within their lifetime.

Last, environmental impacts are inevitable around the area of a wind turbine. The wind turbines could cause the destruction of scenery, noise pollution, implications on animals, etc. A preliminary environmental impact analysis or EIA is required to settle issues among stakeholders to address these issues.

4. Case study: Performance and Reliability of the Wind Turbines at Lam Takong Jolabha Vadhana Power Plant

After a successful wind turbine phase 1 project, two sets of 1.25 MW wind turbines (Shanghai Electric) were installed in 2008 at Lam Takong. The annual average wind speed was 5-6 m/s over the upper reservoir of Lam Takong Jolabha Vadhana, which consider good enough for developing a wind turbine farm. Later, on 8th June 2017, EGAT developed a wind turbine phase 2 project which installed an additional 12 wind turbines (GE Energy, Model 2.0 MW - 116). It's called "LTK-W01 – LTK-W12", which has a total capacity of 24 MW or 2 MW each to make the full power capacity of 26.5 MW.

Each turbine tower is 94 meters high with a blade diameter of 116 meters, and the budget for the project costs 1,407 million baht. Table I shows the datasheet of the installed turbines. The EGAT operated the Lam Takong wind turbine project phase 2 on 3rd January 2018, as shown in Figure 1. Electricity generation from this wind turbine farm contributes to many households around that area. Annually wind energy produced by LTK-W01 – LTK-W12 from 2018 to 2021 was 45.11, 67.72, 71.14, and 49.69 GWh (as of Oct 2021), as shown in Figure 2 with a capacity factor of 22.91%, 32.54%, 31.43%, and 41.01%, respectively. The average capacity factor during these four years is 31.97%. The capacity factor depends on produced energy, rated power, and survey time. Survey time is the sum-up of turbine ok time, downtime, maintenance time, repair time, grid outage time, weather outage time, external stop time, external stop power time, and customer stop time. The availability average of wind turbine phase 2 projects from 2019 to 2021 were 76.75, 93.98, and 88.23 (as of Oct 2021), as shown in Figure 3. Availability factor depends on downtime, repair time, maintenance time, and survey time. Because we had the best wind turbine maintenance in 2020, the highest energy produced was 71.14 GWh, and availability was up to 93.98.

Figure 3 proved that the average availability of LTK-W01 – LTK-W12 was 89.73% at the maximum percentage in December 2019 (energy produced 6.45 GWh with a capacity factor of 36.03), in contrast to 57.29 % in January 2019 as the average minimum percentage of LTK-W01 – LTK-W12 (energy produced 3.29 GWh with capacity factor 20.57). The 2019 annual average was 76.75%. In August 2020, the maximum average availability of LTK-W01 – LTK-W12 was 97.22 % (energy produced 8.84 GWh with a capacity factor of 50.22), and the minimum average availability was 87.65 % in April 2020 (power produced 3.90 GWh with capacity factor 22.79). The 2020 annual average value was 93.98%. Over the years, variations in wind speed had the maximum effect on the performance parameters. For this reason, wind speed is the most efficient factor that affects energy produced. It proposes identifying monthly and annual performance indicators. Figure 4 shows the monthly wind speed (m/s) performance indicators between 2018 and 2019.

Figure 5 shows the monthly performance indicators energy (kWh) from 2018 to 2021. In Figures 4 and 5 in 2018 and 2019, from May to September in both years, the wind speed value was from 4 to 10 m/s, which corresponds to the energy produced changing. The total electricity supplied by the wind farm to the power grid starting from 3rd January 2018 to 31st October 2021 was 233.66 GWh. As the energy charge is 2.9097 baht/kWh, the revenue is 679.88 million baht, and the project cost is 1,407 million baht. Without operation and maintenance costs, the revenue will be covered by the project cost of 48.32%.

Table I The Datasheet of the Installed Turbines

Turbines Model 2.0 MW -116	Value	Unit
Swept area	10.569	m^2
Specific area	5.29	m^2/kW
Number of blades	3	
Speed regulation	Electric drive pitch control with battery backup	
Aerodynamic brake	Full feathering of blade pitch	
Wind Farm Control System	WindSCADA	
Cut-in wind speed	3	m/s
Rated wind speed	10	m/s
Cut-off wind speed	25	m/s
Generator type	Doubly Fed Asynchronous Generator with a partial power converter system	

Figure 1 Wind Turbines Phase 1 & 2 Project around Lam Takong Reservoir

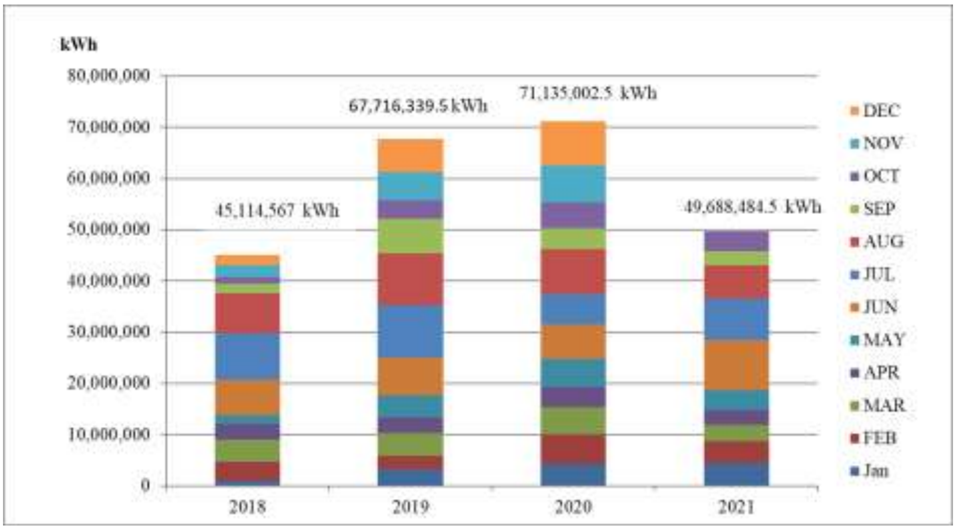
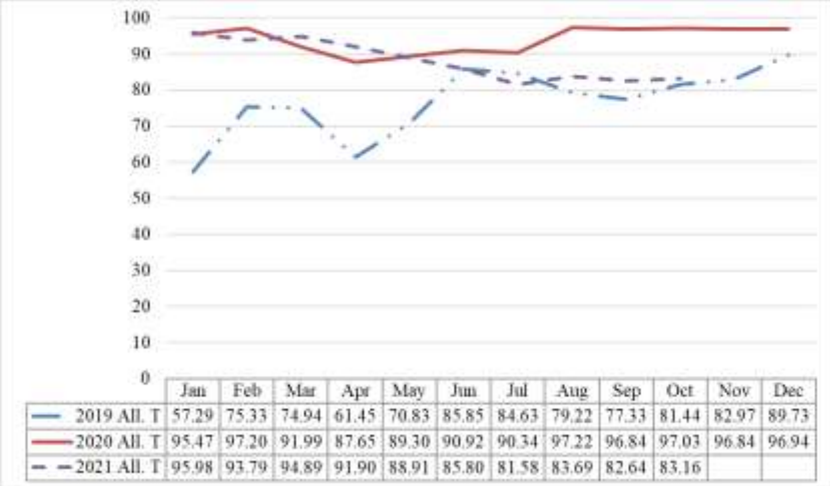


Figure 2 The Yearly Energy Production in 2018 - 2021 (kWh)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019 All. T	57.29	75.33	74.94	61.45	70.83	85.85	84.63	79.22	77.33	81.44	82.97	89.73
2020 All. T	95.47	97.20	91.99	87.65	89.30	90.92	90.34	97.22	96.84	97.03	96.84	96.94
2021 All. T	95.98	93.79	94.89	91.90	88.91	85.80	81.58	83.69	82.64	83.16		

Figure 3 The Average Monthly Availability of Turbine 1 - 12 (LTK-W01 – LTK-W12) in 2019 – 2021

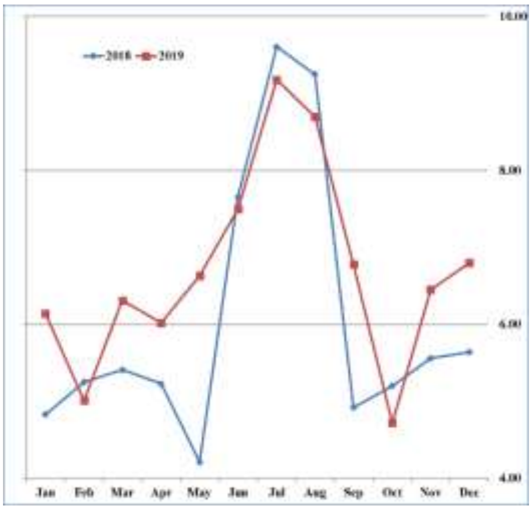


Figure 4 The Average Wind Speed (m/s) in 2018 - 2019

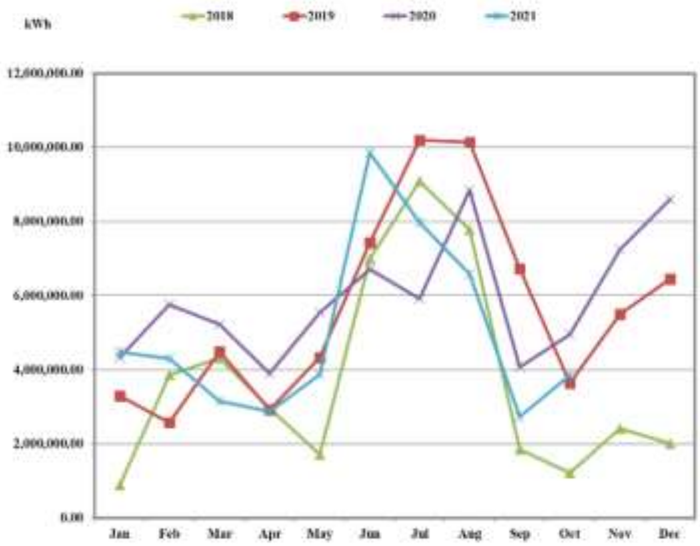


Figure 5 Monthly Energy Production for 2018 - 2021 (kWh)

In addition, the wind turbine phase 2 project was enhanced by the hydrogen fuel cell technology with the 300 kW magnitude DC power, and the other specifications are shown in Table II. The energy production from wind turbines is used to separate the Demin water into hydrogen and oxygen by the 1 MW hydrogenic PEM electrolyzer (HyLYZER-200-30). Hydrogen (99.998%) at 146 Nm^3/h with 30 barg pressure flow to the 50 kW hydrogen compression by the Hofer 2 stage diaphragm compressor and stored in the hydrogen storage tank at a total volume of 14.7 m^3 (use hydrogen mass 253 kg at 270 barg and 40-degree Celsius). The hydrogen specification is 0 – 312 Nm^3/h, and the pressure among 5.5 – 8 barg (by pressure reduction station with fire protection of automatic depressurization of storage), then flow to the Proton Exchange Membrane (PEM) fuel cell to generate electricity at 0 – 330 kW. Figure 6 shows Hydrogen Fuel Cell System. The EGAT Learning Center in the same area receives electricity from this system. Figure 7 shows the layout of the hydrogen hybrid plant. The wind hydrogen hybrid system can also be used to provide minimal firm generation during periods of no wind power generation. The hydrogen hybrid plant will increase availability and reliability. Hydrogen will be generated during off-peak hours at night and used during peak hours in the daytime. The total cost of the fuel cell system was around 234 million baht.

Table II Fuel cell specification.

Characteristics	Value	Unit
Fuel cell (PEM)	300	kW
Startup time of fuel cell	2.5	minutes
Startup time of electrolyzer	1	minutes
Rated hydrogen gas generation	146	m^3/hr
Round trip efficiency at rated	30	%

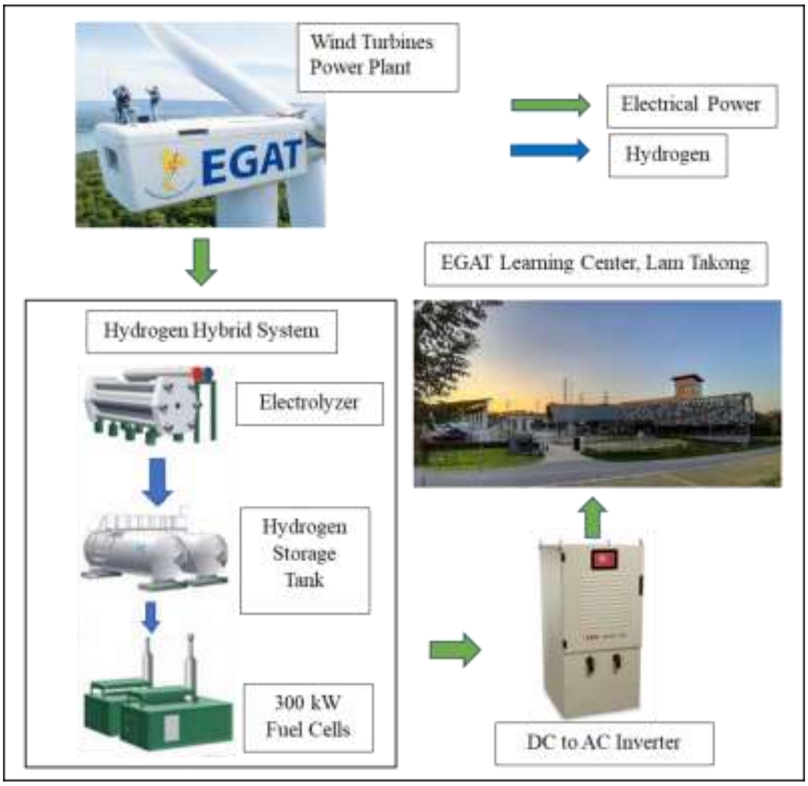


Figure 6 Hydrogen Fuel Cell System [5]

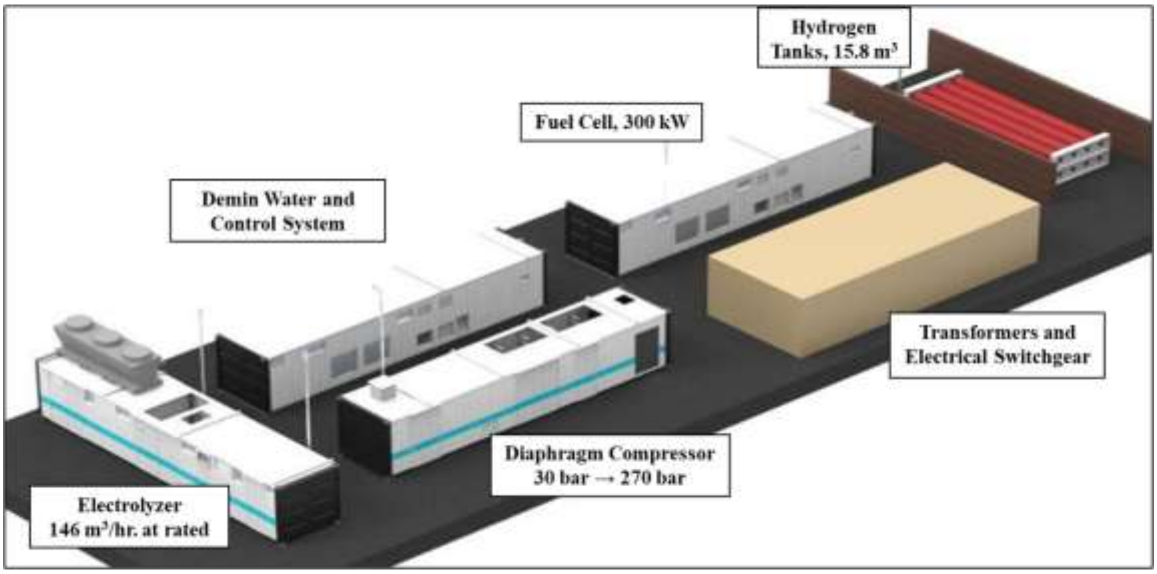


Figure 7 The Layout of The Hydrogen Hybrid Plant [5]

It is similar to the Raggovidda wind-hydrogen system site reference in Norway. There is a 45 MW Raggovidda wind farm, a 2.5 MW PEM electrolyzer, a 120 kW PEM fuel cell, and a stain steel storage tank of 65 m^3 [4].

Another research project is a 20C discharge C-rate & pole solid-state battery (lithium-ion phosphate microfilm battery). It supports and improves the stability of energy generation from wind energy and supplies the electricity generation responsibility to the grid. Battery Energy Storage System (BESS) was installed at 1 MW / 1 MWh, which consists of 2 sets of Power Conversion System (PCS) 500 kW, 1 set of Energy Management Software (EMS), 16 strings of battery module with Battery Management System (BMS) and also the air conditioning system in BESS will control the internal air temperature. The technical parameters and electrical diagram of the Wind Battery Hybrid System are shown in Table III and Figure 8, respectively. This system is complied by the wind turbine (Loop B) 10 MW (5×2 MW) at 22 kVA, installed in containers wide of 2.438 meters, length of 12.192 meters, and height of 2.896 meters. It also manages the electric production by fluctuation smoothing function. When the production capacity exceeds the electricity demand, the system will be automatically charged into the storage. When the production capacity is lower than the electricity demand, it will be instantly discharged. Even with the high electricity demand, the system with electrical distribution will be in standard quality control.

Figure 9 shows the varied of recorded data on 16 November 2020; the BESS power (P_BESS, Red line), which affects the electrical energy produced by wind turbines (P_WIND, Green dotted line), then will be slightly smooth of the net electric power supplied to the grid (P_NET, Blue line). The electricity generation system is managed under the power smoothing BESS function. If the power production is over or less than the demand, the BESS system will be stored or discharged automatically and conform to the supply for the quality distribution system.

Table III The technical parameters of the Wind Battery Hybrid System [6]

Technical Parameters		
Type of battery	3.2V 5.5AH LFP cell (Optimum Nano)	
Capacity	1135.4 kWh	
Rated output power	1 MW	
Voltage of connected point	AC315 V	
Frequency of connected point	50 Hz	
With or without secondary source	With secondary source	
Secondary source voltage of BMS	DC24 V	
Parameters of management system	Type of management system:	BMS (Optimum Nano)
Parameters of battery pack	614.4 V 115.5 Ah battery pack	16 packs
Parameters of battery box	Number	128 boxes
	Size	441.8*562.2*250.2 mm
	Material	Strength steel plate
	Installation	Cradle, screw fixing
Communication	CAN2.0B for BMS and PCS, RS485 for BMS and EMS	
Air conditioner	Door-mounted industrial air conditioner	
Fire control system	Fire Alarm and Protection System for Lithium Battery box	
Height above sea level	≤2000 m	
Environment temperature outside	-30 ~ +55 ^{o}C	

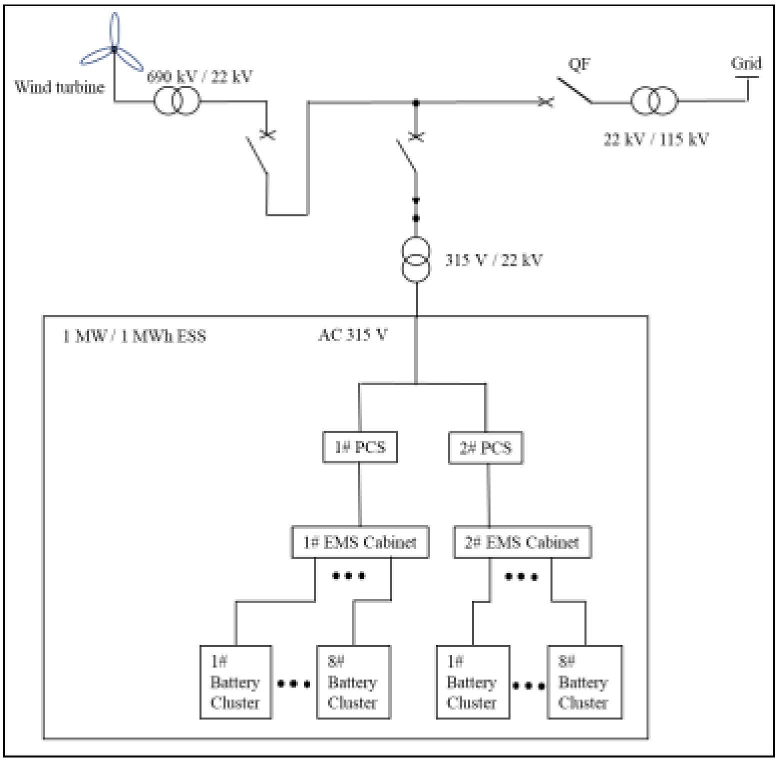


Figure 8 Electrical Diagram of the Wind Battery Hybrid System [6]

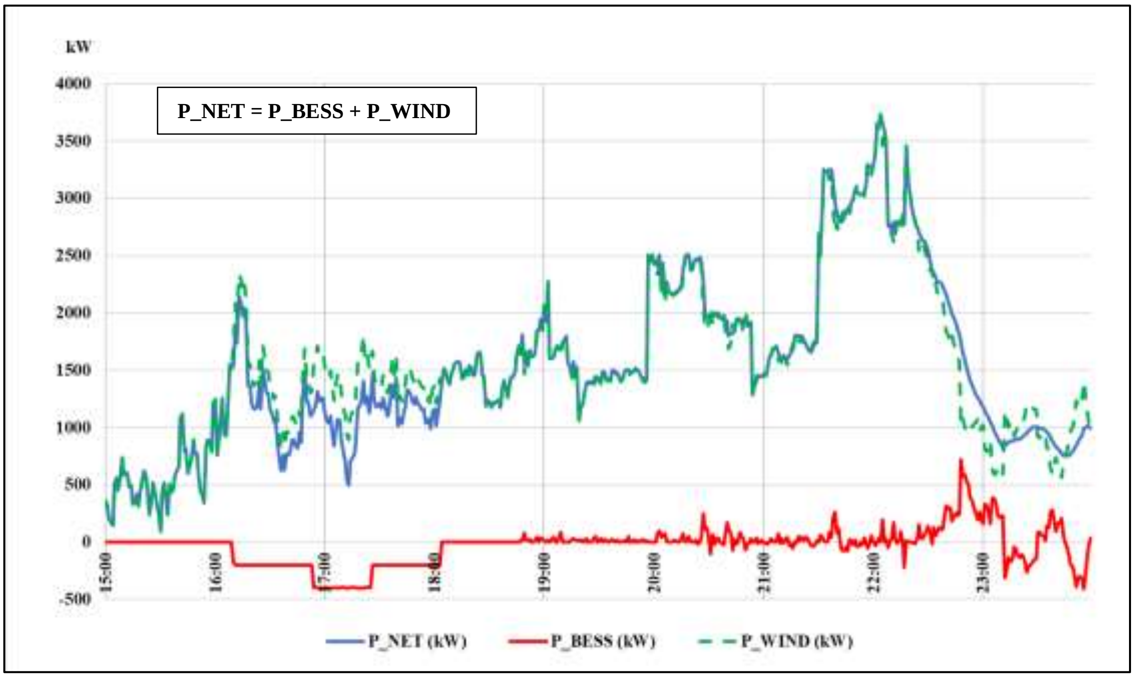


Figure 9 Electric Power from Wind Turbine [Loop B], Electric Power from BESS, and Net Electric Power from Fluctuation Smoothing Function supplied to the grid [6]

5. Conclusions

This case study concludes that a great deal of wind energy potential in Thailand remains untapped. Wind energy will help meet total energy consumption in the country. In 2019, new installations of wind turbines were at 404 MW, bringing the cumulative capacity of wind power generation to about 1,506.82 MW. The growth rate of wind energy between 2017 and 2019 is around 75 percent each year and expects to increase. By the end of 2036, new wind energy integration will be about 1,485 MW, which will lead to a national cumulative capacity of wind power generation up to 3 GW or accounting for 30 percent of the country's total power generation from alternative energy, according to PDP2018. This paper presents a performance analysis of a 24 MW wind farm installed at Lam Takong Jolabha Vadhana power plant. The results conclude that most wind turbines operate optimally with slight variation due to the seasonal wind variation of speed and direction. The capacity factor of this wind farm represents a high value of 31.97%, which shows that our power plant is quite efficient in Thailand.

On the other hand, availability is unstable and needs improvement, varying between 57.29 in January 2019 and 97.22 in August 2020. The reasons came from (1) force outage with issue spare part replacement requirements (almost all spare parts purchased from OEM supplier), (2) force outage with issue line to ground fault (this issue takes time to investigate and repair), and (3) plan outage with yearly inspection (semiannual and annual inspection). In perspective, future work will monitor another wind farm's performance in Thailand. The EGAT wind hydrogen hybrid system with fuel cell technology was considered to be not only the most significant project in Thailand but also the first country in ASIA. The project will help stabilize energy generation from renewable energy and diversify the mixture of electricity generation in response to the government's policy. Currently, the technology of electric energy storage with batteries is very interesting. The BESS system can be applied to the various renewable energy systems, and it also enhances the capacity and stability of power generation with high efficiency.

The electricity generated from a wind turbine as the renewable energy in the Lam Takong Jolabha Vadhana Power Plant can supply about 0.8% of Nakhon Ratchasima province's electricity demand. This will comply with the commitments made during the 26th session of the Conference of Parties (COP 26).

Thailand Greenhouse Gas Management Organization set the coefficient of Greenhouse Gas (GHG) emission factors from the electricity generation as 0.5692 tCO_2/MWh. The CO_2 has reduced by 132,996.08 tCO_2 from January 2018 to October 2021. During the 46 months of operation, the wind turbine can produce electricity, and the revenue covers 48% of the installation cost as a fixed cost. After the next five years, EGAT will reach the break-even, which does not include operation and maintenance costs.

BIBLIOGRAPHY

[1] Sakkarin C, Somchai W. 2014 "Critical review of the current status of wind energy in Thailand" Renewable and Sustainable Energy Reviews 31 pages 312-318

[2] International Renewable Energy Agency 2017 Renewable Energy Outlook Thailand

[3] Jompob W Mathieu L Yves G 2015 "Offshore wind power potential of the Gulf of Thailand" Renewable Energy 81 pages 609-626

[4] I Marino, M Santos 2020 "Hydrogen-Aeolic Energy with Optimised electrolyzer Upstream of Substation" D8.1 Protocols for demonstration of energy-storage strategy pages 9-10

[5] Yosapol R 2021 "Lam Takong Wind Hydrogen Hybrid Project for Improving Stability of Wind Generation" Progress Report of Electricity Generating Authority of Thailand

[6] Ampere P 2021 "20C Discharge C-Rate & Pole Solid State Battery (Lithium Ion Phosphate Microfilm Battery Research Project) " Final Report of Electricity Generating Authority of Thailand