# Lam Takong Hybrid Power Plant with Fuel cell and Battery 20C: A Review

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**Abstract:** Renewable energy generation 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. Thailand has developed a variety of incentive schemes to promote the use of renewable energy sources and attract investments in renewable energy generation. This paper will provide the current status of electricity generation and the proportion of electricity generation from renewable energy sources in Thailand, especially wind energy. Moreover, this paper reviews the latest status and policy framework for wind energy in Thailand. The article also explores wind energy potential in different parts of Thailand. It identifies challenges of deployment and promotion needed to be addressed and plans for deploying wind energy in Thailand. Lastly, the paper will present an overview of the wind hydrogen hybrid combined with fuel cell for the first time in Asia to enhance renewable energy capabilities in Lam Takong Learning Center, EGAT at Nakhon Ratchasima Province.

***Keywords***— Wind energy, Fuel cell system, 20C discharge C-rate & pole solid-state battery

## I. 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 clean, secure, and reliable. Affordable energy transition for all to satisfy the 17 Sustainable Development Goals agenda (SDG 17) as well as to meet the commitments made during the 26th Conference of the Parties (COP 26) to the United Nations Framework Convention on Climate Change (UNFCCC) in Glasgow 2021. To meet the goals, 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 shortly 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 substantial 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.

Electricity generation in Thailand has been highly dependent on fossil fuel sources which are natural gas accounting for approximately 60 percent of electricity generation, followed by coal or around 20 percent. In contrast, the rest of the energy sources are from renewable energy and imported from neighboring countries, accounting for 10% and 10%, respectively [1]. However, renewable energy generation in Thailand has seen significant growth for the past decades, primarily from solar and wind energy. The increase is due to the Thai government having developed policies to facilitate renewable energy integration through subsidies/incentives schemes, tax reduction, Feed-in Tariff (FiT) mechanisms, etc. The current proportion of electricity generation from wind energy is marginal; however, the contribution to sustainable energy transition from wind energy is expected to increase significantly. According to PDP2018, electricity generation from renewable energy will contribute 30 percent of the national electricity generation by 2036.

This paper aims to overview the current status, policy framework, potential, and challenges of wind energy

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development in Thailand. The article is organized in the following manners: the current status and policy framework of wind energy and subsidies/ incentives mechanisms in Thailand are explained in Section II. Section III provides the potential of wind energy in different regions in Thailand. Section IV discusses the challenges and prospects of wind energy integration in Thailand. Section V examines the wind hydrogen hybrid combined with fuel cell, taking Lam Takong Jolabha Vadhana Power Plant as the case study. Finally, the main conclusions are given in Section VI.

## II. Current Status of Wind Energy and Policy Framework in Thailand

Global electricity generation from wind energy has increased exponentially every year. In 2019, 60.4 GW of new installations brought global cumulative wind power capacity up to 651 GW, an increase of about 10 percent compared to 2018, as shown in Fig. 1. China and US have the most significant share of wind energy capacity accounting for 237 GW and 105 GW, respectively [2]. The trend is expected to remain increasing in the coming year. Electricity generation from wind energy in Thailand began as a pilot project at Laem Phromthep in Phuket Island in 1983 by the Electricity Generating Authority of Thailand ( EGAT) with a total capacity of 170 kW. EGAT chose this location because the annual average wind speed throughout the year is around five m/ s. The wind farm has still contributed to electricity generation until now. After the successful pilot project, EGAT continues exploring potential locations to install new wind turbines. In 2008, EGAT established two sets of 1.25 MW wind turbines – with a total capacity of 2.5 MW, which became the largest wind farm in Thailand. The wind farm has an annual average wind speed of about 5-6 m/s. It is located at the upper reservoir of Lam Takong Jolabha Vadhana Power Plant in Khlongphai Sub- district, Sikhio District, Nakhon Ratchasima [3]. However, the deployment of wind power generation in Thailand has grown at a moderate rate due to the relatively low wind speeds.

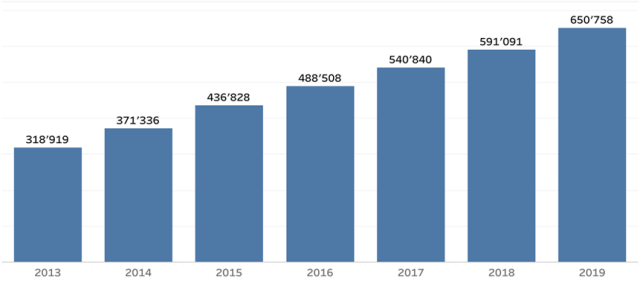


Fig. 1. The total global capacity of wind energy (MW)

### A. Current status of wind energy in Thailand

Wind energy in Thailand has continuously grown over the past decade, as shown in Fig. 2. From 2017 onwards, it can be seen that wind turbine installations have increased exponentially with a growth rate of about 70 percent per year. In 2019, Thailand had new installations of wind turbines of 404 MW, bringing the cumulative capacity of wind power generation up to 1,506.82 MW [4]. The 1,506.82 MW is halfway toward achieving the 3 GW set under the PDP2018 and Alternative Energy Development Plan (AEDP) target. More than half of new wind turbine installations were in the northeastern region of Thailand, followed by the southern region, northern region, and central region, respectively.

### B. Wind energy and PDP2018

The security of energy has been an essential issue for Thailand. More than half of energy production in Thailand has relied on natural gas over the past decades. With the depletion of natural gas reserves, Thailand's government has stepped up to diversify electricity generation from renewable energy resources, particularly solar energy and wind power generation capacity. This poses a significant challenge for the Thailand government to develop solid long-term electricity portfolios, including considering the COP21 commitments and creating a portfolio that includes various renewable energy sources in the scenarios that can complement each other in resource availability. Therefore, PDP2015 was revived as PDP2018 to ensure that the power generation in Thailand is corresponded to changing economy and energy consumption, including reflecting on the 20-year strategy plan by considering electricity demand and energy resources availability by regions. This will assure energy security, economy, and ecology across Thailand.

From 2020 to 2033, wind energy is expected to be at a standstill, according to PDP2018. From the year 2034 to 2037, however, wind energy will be integrated by 1,485 MW, as shown in Fig. 3. This will undoubtedly help boost the country's wind energy production and generation. The revision is a positive step to promote wind energy production and generation in Thailand and attract investments in the wind energy industry. PDP2018 is set to increase electricity generation from renewable energy resources to 30 percent of the country's electricity generation. This makes renewable energy one of Thailand's top energy priorities.

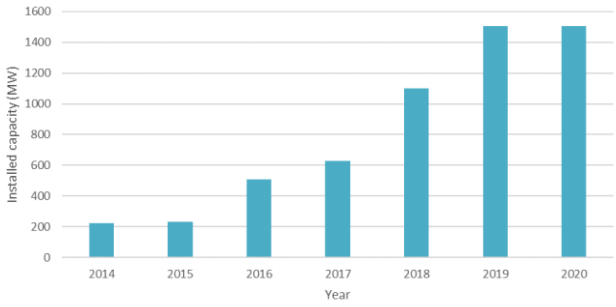


Fig. 2. Wind installed capacity in Thailand between 2014-2020

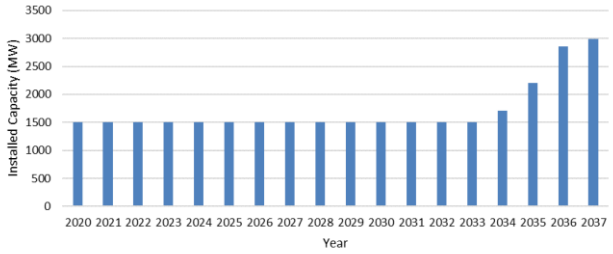


Fig. 3. Wind energy, according to the power development plan 2018

*C. Financial incentives and subsidies mechanisms*

The previous wind energy subsidy scheme (Feed-in Tariff – FiT) was launched in 2015 with a 6.06 baht/kWh energy tariff for 20 years [5]. The subsidy scheme was considered successful because the project attracted several developers, and more than the magnitude of 1,500 MW was applied to the subsidy scheme. The previous wind energy subsidy schemes have expired, and no new subsidy schemes have been introduced for the new wind generations. However, the new FiT scheme is expected to be lower than the previous subsidy schemes and competitive bidding schemes due to the drastic cost reductions for wind turbine technologies. This will allow wind energy markets to determine the actual price that wind energy projects should be paid and minimize the risk of excessive subsidizing. The essential issues to attract the development of wind energy industries is to increase the level of subsidies and strong partnership with the wind energy industry. This will undoubtedly strengthen wind energy production and generation capacities across Thailand.

## III. Potential of Wind Energy in Different Regions of Thailand

Thailand is located near the equator line and has low to moderate wind speeds. Thailand's northeastern, western, and southern regions have the most significant wind energy potential. An annual average wind speed is about 6 m/s at 50 meters [6]. However, those areas are pretty far from load centers and transmission lines. The technical potential of wind energy can reach 13 GW across Thailand [7]. 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 percent and at the height of 120 m, total energy generation would reach 15 TWh per year [8].

## IV. Challenges and Prospects 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:

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

Secondly, wind farm projects require high capital investment costs, divining into wind turbine costs, grid connection costs, civil work and 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.

Lastly, environmental impacts are inevitable around the area of the 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 the problems among stakeholders to address the issues.

Even if average wind speeds in Thailand are considered low to moderate, wind turbine technologies have been improved rapidly to generate electricity efficiently and are suitable for wind energy potential in Thailand. Moreover, an optimistic future for wind power generation and renewable energy in Thailand is realized with the ambitious effort of the Thai government to combat climate change by reviving PDP every few years to keep up with the growing economy and renewable energy technology improvements. The introduction and enforcement of PDP2018 and various supportive schemes will significantly promote wind energy development in Thailand. In addition, Thailand has set a direction towards becoming a power trading hub of ASEAN as it shares region borders with Laos, Malaysia, Cambodia, and Myanmar. In addition, the connection can be linked to Singapore and China through neighboring countries.

## V. Case Study: Lam Takong Jolabha Vadhana Power Plant

Lam Takong power plant is a Renewable energy power plant that comprises three kinds of power generation 1**)** Lam Takong Jolabha Vadhana Power Plant, pumped hydropower plant with an underground powerhouse, a total capacity of 1,000 MW 2**)** Lam Takong wind farm, there are 14 Wind turbines with a total capacity of 26**.**5 MW**.** 3**)** Hybrid power generation comprises 3**.**1**)** Hydrogen-wind hybrid using Fuel cell generation capacity 0.3 MW 3**.**2**)** Battery 20C - Wind hybrid using 20C discharge C-Rate & pole solid-state battery **(**lithium-ion phosphate microfilm battery**)** total capacity 1 MWh**.** These two projects will stabilize energy generation of renewable energy with high efficiency**.**

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, which was considered to be good enough for the development of wind turbine farm. Later, On 8$^{th}$ June 2017, EGAT developed a wind turbine phase 2 project which installed additional 12 wind turbines with a total capacity of 24 MW or 2 MW each

to make the total power capacity of 26.5 MW. Each turbine is 94 meters high with a diameter of 116 meters [9], and the budget for the project costs 1,407 million baht. Lam Takong wind turbine phase 2 project was operated on 20th April 2018, as shown in Fig. 4. The energy production from the wind turbine farm has been contributed 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. Performance (availability and yield) and reliability of wind turbines can make the difference between the success and failure of wind farm projects and those factors are vital to decreasing the cost of energy [10].

Fig. 4. Wind Turbines Phase 1 & 2 Project around Lam Takong Reservoir

In addition, the wind turbine phase 2 project was enhanced with the technology of hydrogen fuel cell with the magnitude of 300 kW and other specifications, as shown in Table I. The energy production from wind turbines is used to separate water into hydrogen and oxygen. The hydrogen is then transferred to the fuel cell to generate electricity. The fuel cell was intended to supply the EGAT learning center in the same area, as shown in Fig. 5. The total cost of the fuel cell system was around 234 million baht.

TABLE I.
FUEL CELL SPECIFICATION

| Characteristics | Value | Unit |
|---|---|---|
| Fuel cell | 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 | % |

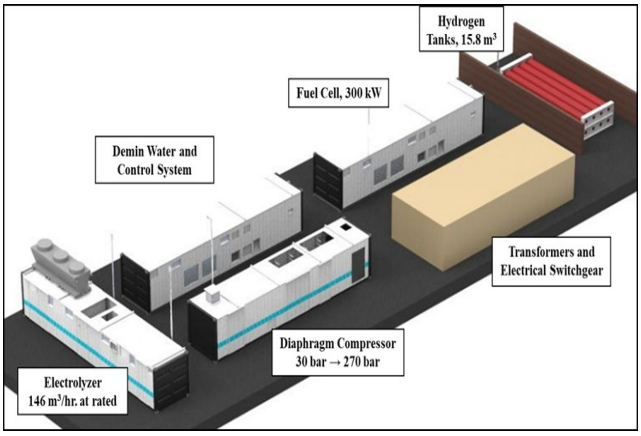


Fig. 5. Hydrogen fuel cell system [11]

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.

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 $m^3$ [12].

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. This system is compiled by the wind turbine (Loop B) 10 MW (5×2 MW) at 22 kV, 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 [13].

## VI. CONCLUSIONS

Thailand's demand for electricity will continue to grow in line with the economy, with increasing investment in business and industry resulting in rising electricity consumption. Renewable energy will play a vital role in fulfilling rising energy consumption and sustainable energy transition. The study can be concluded that a great deal of wind energy potential in Thailand remains untapped. Wind energy can 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 is expected to increase. By the end of 2036, new wind energy integration is expected to be about 1,485 MW, leading 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 sources of energy, according to PDP2018. Wind energy integrations have continuously increased over the past decade in both state and private sectors. The study also indicates that area around the Gulf of Thai and the northeastern region of Thailand has the highest wind energy potentials, with an average annual wind speed of 5-6 m/s at 50 meters. The other possible areas are the upper southern regions, the western coast of the Thai Gulf, the eastern coast of the Thai Gulf, the west coast of the south (Andaman sea), and the northern mountainous areas. The pathway toward sustainable energy transition cannot be achieved without cooperation from the state and private sectors.

## REFERENCES

[1] Energy Policy and Planning Office 2018 and Power Development Plan 2018
[2] Global wind energy council Global Wind Report 2019
[3] https://www.egat.co.th/home/en/lamtakong-pp (June 2022)
[4] Department of Alternative Energy Development and Efficiency 2020 Performance on Alternative Energy Policy: January - May 2020
[5] Energy Regulatory Commission 2015 Feed-in Tariff Scheme for renewable energy project
[6] C. Sakkarin, W. Somchai, 2014 Renew. Sust. Energy. Rev. 18-312 31
[7] International Renewable Energy Agency 2017 Renewable Energy Outlook Thailand
[8] W. Jompob, L Mathieu, G Yves, 2015 Renew. Energy. 26-609 81
[9] GE's 2MW platform, http://www.gerenewableenergy.com
[10] S. Pfaffel, S. Faulstich, and K. Rohrig, Performance and Reliability of Wind Turbines: A Review, energies, Nov. 2017
[11] R. Yosapol, 2021 "Lam Takong Wind Hydrogen Hybrid Project for Improving Stability of Wind Generation" Progress Report of Electricity Generating Authority of Thailand
[12] 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
[13] P. Ampere, 2021 "20C Discharge C-Rate & Pole Solid State Battery (Lithium Ion Phosphate Microfilm Battery Research Project)" Final Report of Electricity Generation Authority of Thailand

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