Study Committee A1

Rotating Electrical Machines

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

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Motivation

- 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. 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.

Method/Approach

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:

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

Objects of investigation

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.
- 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, a preliminary environmental impact analysis or EIA is required to settle issues among stakeholders to address these issues.

Experimental setup & test results

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- 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. It's called "LTK-W01 – LTK-W12", which has a total capacity of 24 MW or 2 MW each. Table I shows the datasheet of the installed turbines.

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	

- 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%.

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

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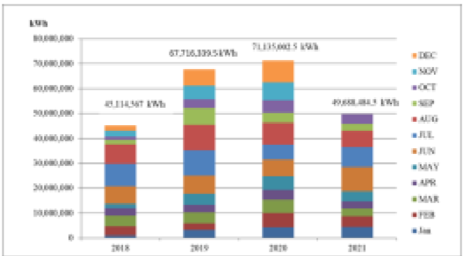
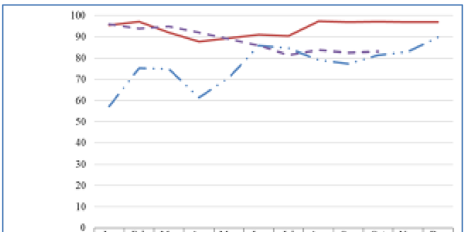


Figure 2 The Yearly Energy Production in 2018 – 2021 (kWh)

- 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.



	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 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%.

- Wind speed is the most efficient factor that affects energy produced. It proposes identifying monthly and annual performance indicators. 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%.

- 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). Figure 4 shows Hydrogen Fuel Cell System. The EGAT Learning Center in the same area receives electricity from this system. 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.

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	%

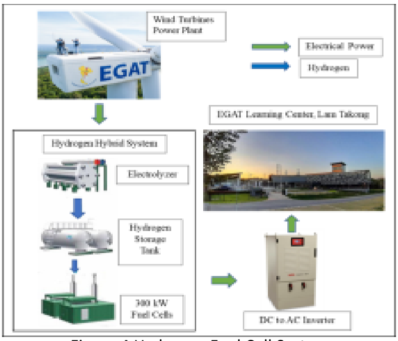


Figure 4 Hydrogen Fuel Cell System

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- 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 electrical diagram of the Wind Battery Hybrid System are shown in Figure 5. This system is complied by the wind turbine (Loop B) 10 MW (5×2 MW) at 22 kV. 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

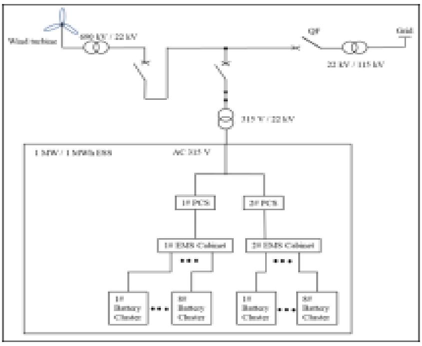

Figure 5 Electrical Diagram of the Wind Battery Hybrid System

- Figure 6 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.

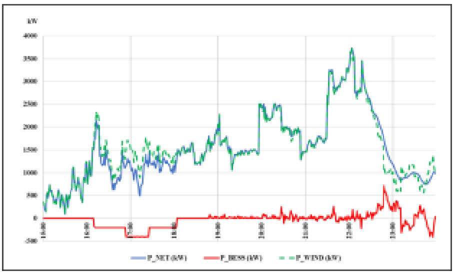

Figure 6 The Layout of The Hydrogen Hybrid Plant

Discussion

- 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).

Conclusion

- 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.
- The BESS system can be applied to various renewable energy systems, and it also enhances the capacity and stability of power generation with high efficiency.
- Thailand Greenhouse Gas Management Organization set the coefficient of Greenhouse Gas (GHG) emission factors from 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 break-even, which does not include operation and maintenance costs.