IMPACT OF WIND POWER PROJECT ON THE SOC TRANG POWER SYSTEM

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ABSTRACT

Wind energy is one of the renewable energy sources and available in nature. To exploit this energy source, it is necessary to determine the potential of wind energy at each specific location and its impact on the power system. The main objective of this study is to determine the wind energy potential of Soc Trang province and the impacts of planned projects on the provincial power system. The research used Etap software to simulate power flow and impact on the power system of wind power plants after connection. The results show that Soc Trang province has 3 wind power planning areas with a total area of 37,340 ha with a capacity of 1,470 MW. The average wind speed is 6-6.5 m/s at an altitude of 74 m. After connecting wind power plants to the system, there is no significant impact on the stability of the voltage and frequency of the system, but the reliability index is significantly improved such as SAIFI, SAIDI, and CAIDI are 9.6%, 11.5%, and 4.4% respectively. The research is an important document to serve as a basis for investors and managers in formulating and approving investment projects for wind power plants in Soc Trang province.

Keyword: *Soc Trang Wind project, wind energy potential, planning wind farm, transient stability.*

1. INTRODUCTION

In the past decade, there has been a rapid development of wind energy worldwide. The year 2020 is considered the most developed wind power, with the increase of up to 93 GW of newly installed wind power, raising global wind power installed capacity to 743 GW. China and the US are still the world's largest markets. At the regional level, the year 2020 is also a record year for Asia Pacific, North America, and Latin America. The above three regions have installed 74 GW of wind power, an increase of more than 76% compared to the previous year. Europe grew only 0.6% with new wind power added. In developing markets such as Africa and the Middle East installed 8.2 GW in 2020, roughly the same as in 2019 [1].

In recent years, the potential of wind power and the impact of wind power on electrical power systems are topics of interest to many researchers. Research [2] analyzed data at 12 wind measuring stations in Taiwan during 2001-2010. The results show that wind speed at 100 m altitudes in Taiwan ranges from 1.7 m/s to 4.3 m/s, and power density from 5 W/m2 to 75 W/m2, contributes to the global vision of wind energy potential in Taiwan. In the study [3], meteorological data was used to calculate using the Weibull distribution function, as well as wind energy and energy density. Research [4] shows that India is a country with the potential for wind energy, thereby providing a solution to maximize the use of renewable energy sources to help solve social needs and poverty. Research [5] investigated a 20 MW wind farm in Saudi Arabia. A significant amount of nearly 59,073 GWh was produced annually, representing 33.7% of the plant's capacity. The research and application of wind energy have been conducted a lot, but most of it is research into the application of large-capacity power generation, connected to the national grid and the goal is to serve commercial purposes.

Vietnam is assessed as a country with potential for wind energy development, but currently, the data on Vietnam's wind energy potential has not been fully quantified because of the lack of investigation and measurement. According to [6], wind energy is developed over a large area of approximately 31,000 square kilometers. The results of the research [7] show that the annual average wind speed in Nha Trang, Ca Mau and Quy Nhon is 11.15 m/s, 10.14 m/s, and 9.13 m/s, respectively. The study [8] evaluated the wind energy potential of the Bac Lieu wind farm with a capacity of 99 MW that can generate 332 GWh. According to reports, Vietnam's wind energy potential is most concentrated in the central coast, the South, the Central Highlands, and the islands.

This research analyzes wind energy potentials such as average wind speed, wind direction, frequency of wind direction, feasible area for wind power planning, the capacity of specific projects in each location of the province. In addition, the study also used Etap software to analyze the impact of planned wind power projects on the province's power system such as power flow analysis, short circuit calculation, transient stability, and reliability of the electrical power system before and after wind power projects are connected.

2. LOCATION DESCRIPTION AND PLANNED WIND FARM

2.1 Natural condition

Soc Trang is a coastal province located in the south of the Hau River mouth of the Mekong Delta region, with an area of 323,590 ha. Soc Trang has administrative boundaries adjacent to 3 provinces of the Mekong Delta: Hau Giang province in the northwest, Tra Vinh province in the northeast, and Bac Lieu province in the southwest. The coordinate position is at 9°12'-9°56' North latitude and 105°33'-106°23' East longitude (Fig-1).

According to statistics in 2019, Soc Trang's population is 1,199,528 people. The average population density is 362 people per square kilometer. In which, the highest population density is in Soc Trang city (1,807 people/km^2) and the lowest is in Cu Lao Dung district (221 people/km^2). The rural population accounts for about 67.61% of the province's population [9].

Fig -1: Administrative geographical map of Soc Trang province

2.2 Power system 110 kV of Soc Trang province

The 110 kV power grid in Soc Trang province includes 07 110/22 kV substations, distributed in 07 locations (Fig-2). Specifically, as follows: Soc Trang city: 02 substations, capacity of 2x63 MVA with 09 exposed 22 kV; My Tu district: 01 transformer station, capacity 25 MVA with 04 exposed 22 kV; Long Phu district: 01 transformer station, with a capacity of 25 MVA with 4 exposed 22 kV; Tran De district: 01 transformer station, the capacity of 2x25

MVA with 622 kV outputs; Thanh Tri district: 01 transformer station, the capacity of 40 MVA with 4 outcrops of 22 kV; Vinh Chau town: 01 transformer station, the capacity of 2x40 MVA with 422 kV outputs; Cu Lao Dung district: 01 transformer station, capacity 40 MVA.

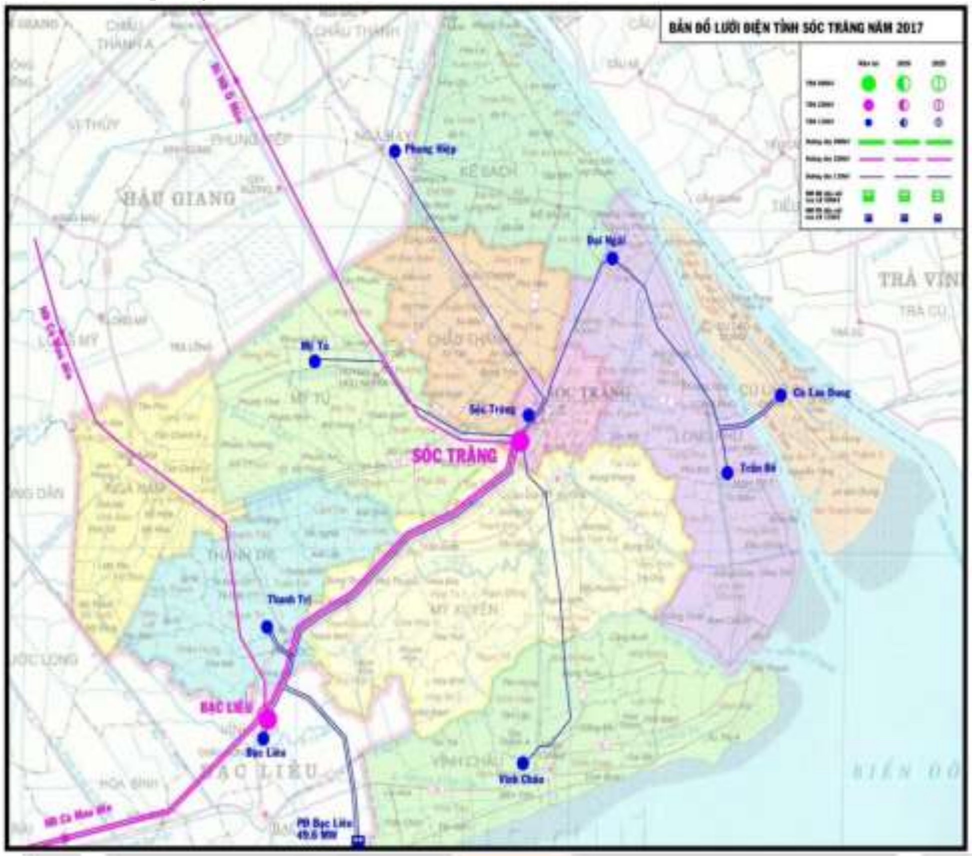

Fig -2: Electricity system of Soc Trang province

2.3. Planning of 110 kV power system in Soc Trang province up to 2025

According to Soc Trang province's electricity development plan for the period 2016 - 2025, with a vision of 2035. The power system planning for 110 kV: the province built 08 new 110 kV transformer stations with a total capacity of 366 MVA; renovated, expanded, and raised the capacity of 07 110 kV transformer stations with a total capacity of 305 MVA; new construction of 13 110 kV transmission lines with a total length of 163 km; renovating and raising the load capacity of 04 110 kV lines with a total length of 81.5 km. New construction of one cutting station with 110 kV exposed.

The new installation is synchronized with the wind power plants. Building 06 new 110 kV transformer stations with a total capacity of 263 MVA. New construction of 6 110 kV lines with a total length of 48.5 km, including 110 kV dual-circuit transmission line, 20 km in length, 2xACSR240 phase cross-section, connecting from wind power plant V2-2 to station 110 kV Vinh Chau to gather capacity of wind power plants V1-2, V1-3, V2-3, V2-2. New construction of 3 110 kV dual-circuit lines, 2xACSR240 phase-division cross-section, 0.5 km in length, connecting wind power plants V1-2, V1-3, V2-3 relayed on the 110 kV line from home wind power V2-2 to Vinh Chau 110 kV station [10].

2.4. Wind power potential in Soc Trang province [11]

Soc Trang province is one of the provinces with relatively high wind energy potential in Vietnam. According to the "Soc Trang province wind power development plan for the period to 2020, vision to 2030" approved by the Ministry of Industry and Trade, the wind potential of Soc Trang province is concentrated mainly in the coastal area and has a high speed. The average wind is from 6-6.5 m/s at an altitude of 74 m.

Wind direction as shown in Fig-3: From October to April next year, the wind direction is from the following directions: Northeast (ENE), East (E), East Southeast (ESE). From May to September, the wind blows in the following directions: Southwest (SW), West (W), Northwest Northwest (WNW).

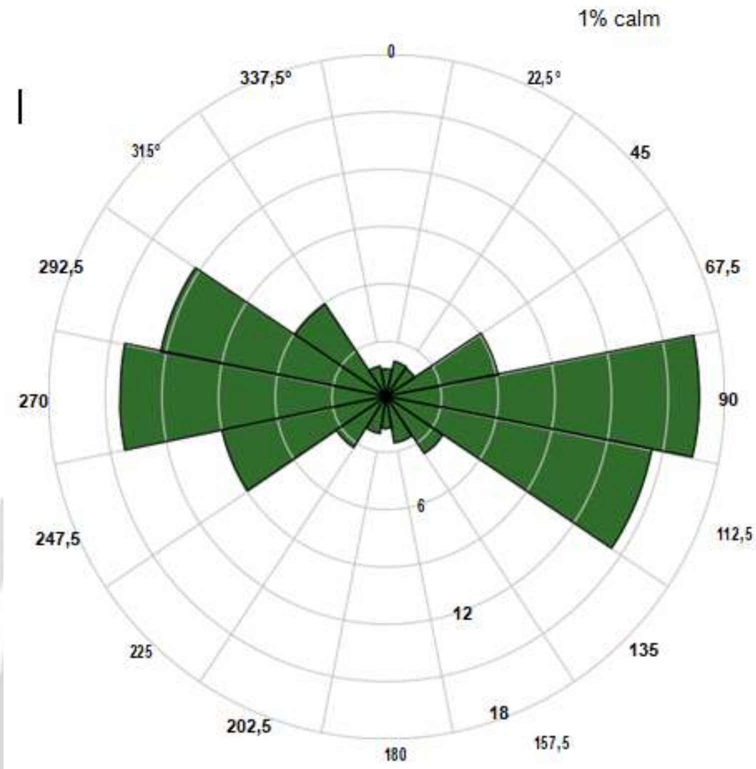

Fig -3: Wind rose 16 directions measured at an altitude of 74 m [11]

The total area with wind speed from 6.0 to 6.5 m/s is 200 ha, mainly concentrated in Nga Nam, Thanh Tri, My Tu, Ke Sach, Chau Thanh district, Soc Trang city, part of Long Phu and My Xuyen district. The total area with wind speed from 6.5 to 7.0 m/s is about 100 ha, mainly concentrated in Vinh Chau town, Tran De, and Cu Lao Dung districts. Vinh Chau town has the highest wind potential, followed by Tran De, Cu Lao Dung, My Xuyen, and Long Phu districts.
Region Distribution area (commune, ward, town) Total area (ha) Expected capacity (MW) Average wind speed/year

Table -1: Planning area for developing Wind power in Soc Trang province [11]

Region	**Region Distribution area**	**Total area (ha)**	**Expected capacity (MW)**	**Average wind speed**
Region 1	Coastal alluvium Vinh Chau town, Tran De and Cu Lao Dung districts	21,900	860	6.4
Region 2	Coastal mainland Vinh Chau town, Tran De district	7,500	295	6.0
Region 3	Mainland Vinh Chau town	7,940	315	6.2
Total		**37,340**	**1,470**	

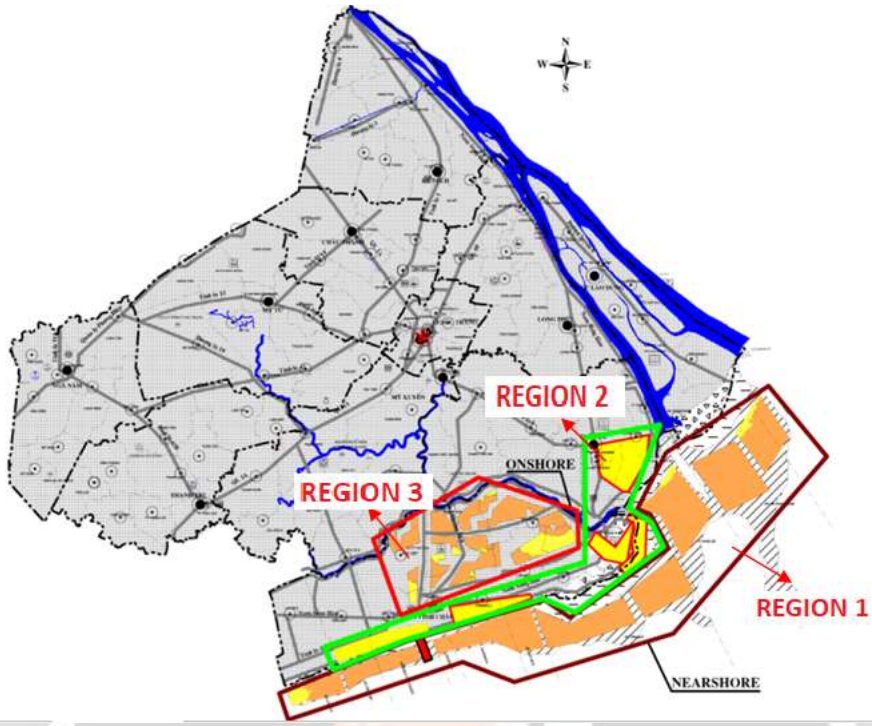

Fig -4: Map of regions for wind power development in Soc Trang province [11]

In which Regions 1 and 3 have the highest wind potential in the province, have favorable conditions for implementing wind power projects, and are given priority for development. According to the Soc Trang Province Wind Power Development Planning Project for the period to 2020, with a vision to 2030, the list of wind power plants has been approved as shown in Table-2.

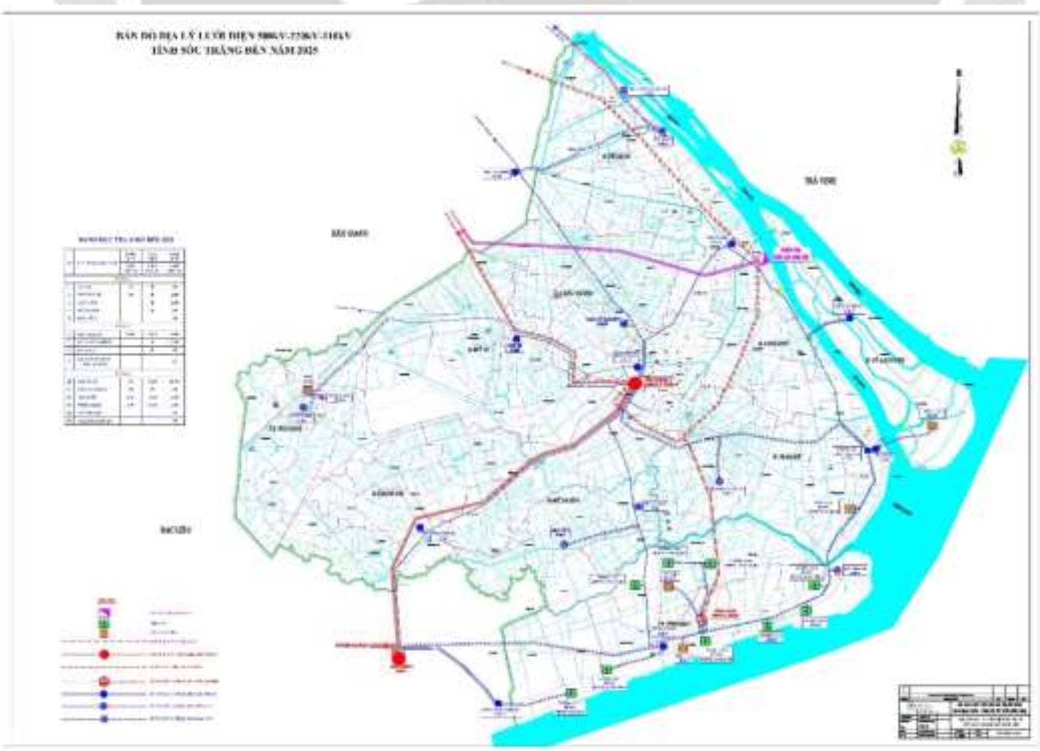

Fig -5: Geographic map of Soc Trang province's electrical power system to 2025

Table -2: List of planning wind power in Soc Trang province [11]

No	Name of wind power	Location	Expected capacity (MW)
Region 1	Wind power plant Region 1-1	Alluvial beach in Lai Hoa commune, Vinh Chau town	98
	Wind power plant Region 1-2	Alluvial beach in Vinh Tan commune, Ward 1, Vinh Chau town	170
	Wind power plant Region 1-3	Alluvial beach in Vinh Hai commune, Vinh Chau town	30
Region 2	Wind power plant Region 2-1	Coastal mainland in Vinh Phuoc ward, Vinh Chau town	80
	Wind power plant Region 2-2	Coastal mainland in Ward 2 and Vinh Hai commune, Vinh Chau town.	83
	Wind power plant Region 2-3	Alluvial beach in Trung Binh commune, Tran De district	30
Region 3	Wind power plant Region 3-1	Coastal mainland Khanh Hoa ward, Vinh Chau town	40
	Wind power plant Region 3-2	Coastal mainland in Hoa Dong commune, Vinh Chau town	40
	Wind power plant Region 3-3	Alluvial beach in Vinh Hiep commune, Vinh Chau town	20
Total			**591**

3. IMPACTS OF WIND POWER ON POWER SYSTEM

3.1 Power flow

Power distribution is an important problem to assess the impact of wind power plants when integrated into the grid in steady-state (static mode). From there, appropriate operating solutions are proposed, ensuring the stability of the power system as well as minimizing the generated losses [12]. To ensure accuracy, two software ETAP and MATLAB were used to simulate the power distribution of the system and compare the results. Simulation results of equal power distribution are shown in Fig-6 and Fig-7 and comparison results are given in Table-3.

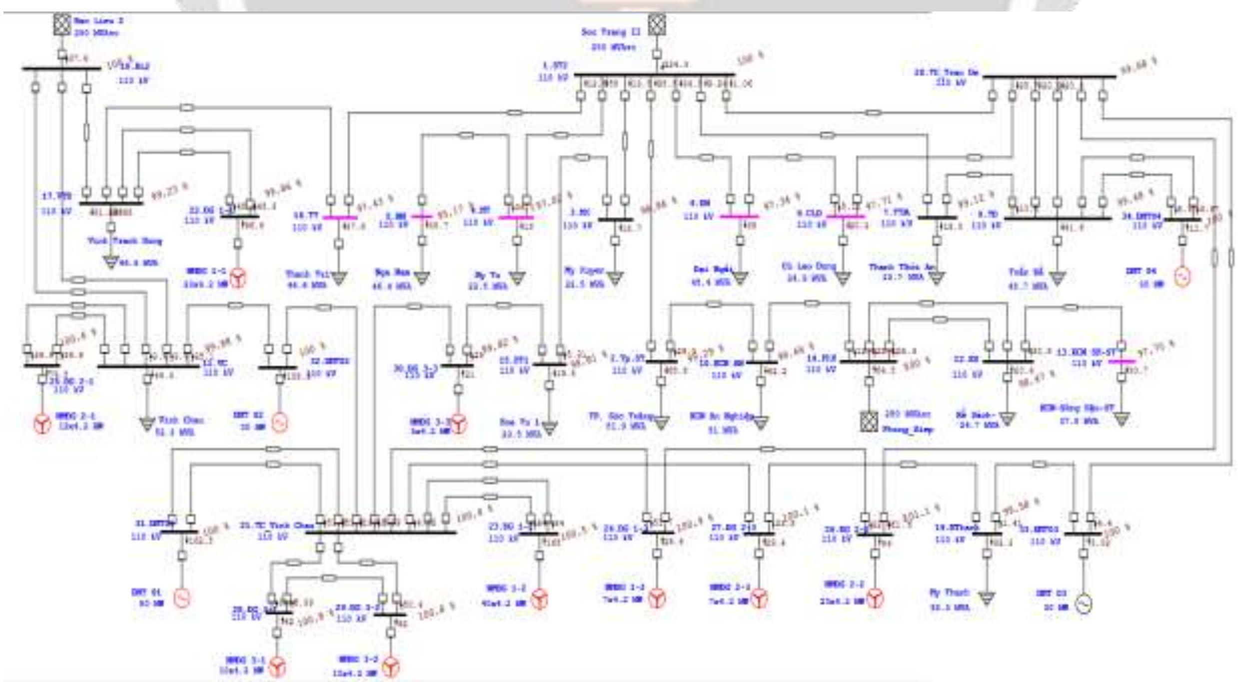

Fig -6: Power flow results using ETAP software

9/9/21 2:33 PM MATLAB Command Window 1 of 4

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>> HTD_SocTrang
            Power Flow Solution by Gauss-Seidel Method
              Maximum Power Mismatch = 0.00098115
                     No. of Iterations = 39
```

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	237.221	163.388	0.000
2	0.993	-0.292	68.626	42.531	0.000	0.000	0.000
3	0.990	-0.103	18.693	11.585	0.000	0.000	0.000
4	0.970	-1.209	18.001	11.156	0.000	0.000	0.000
5	0.952	-1.989	35.772	22.138	0.000	0.000	0.000
6	0.976	-0.478	38.979	24.157	0.000	0.000	0.000
7	0.975	-2.257	19.792	12.266	0.000	0.000	0.000
8	0.982	0.014	20.208	12.524	0.000	0.000	0.000
9	0.970	-3.426	41.666	24.693	0.000	0.000	0.000
10	0.987	-0.555	42.196	26.151	0.000	0.000	0.000
11	1.001	0.605	44.346	27.483	0.000	0.000	0.000
12	0.985	-0.633	20.356	12.616	0.000	0.000	0.000
13	0.977	-0.932	30.698	19.048	0.000	0.000	0.000
14	1.000	0.000	0.000	0.000	64.537	38.913	0.000
15	0.990	0.119	19.554	12.088	0.000	0.000	0.000
16	0.974	-0.067	37.651	23.353	0.000	0.000	0.000
17	0.992	1.228	38.999	24.169	0.000	0.000	0.000
18	1.000	0.000	0.000	0.000	-48.968	32.883	0.000
19	1.002	0.880	32.283	20.057	0.000	0.000	0.000
20	1.005	0.988	0.000	0.000	0.000	0.000	0.000
21	1.007	1.068	0.000	0.000	0.000	0.000	0.000
22	0.999	2.108	0.000	0.000	96.600	0.000	0.000
23	1.009	1.292	0.000	0.000	168.000	0.000	0.000
24	1.014	2.011	0.000	0.000	29.400	0.000	0.000
25	1.009	1.603	0.000	0.000	79.800	0.000	0.000
26	1.017	2.569	0.000	0.000	84.000	0.000	0.000
27	1.006	1.198	0.000	0.000	29.400	0.000	0.000
28	1.012	1.663	0.000	0.000	42.000	0.000	0.000
29	1.011	1.604	0.000	0.000	42.000	0.000	0.000
30	1.001	0.910	0.000	0.000	21.000	0.000	0.000
31	1.004	0.469	0.000	0.000	-162.831	10.232	0.000
32	1.003	0.419	0.000	0.000	-158.262	29.744	0.000
33	1.007	0.881	0.000	0.000	3.016	24.527	0.000
34	0.973	-3.427	0.000	0.000	11.740	28.441	0.000
Total			527.820	326.015	538.653	328.129	0.000

Fig -7: Power flow results of power system after connected wind power plant using MATLAB software

Table -3: Comparison of power flow results using ETAP software and MATLAB software

LOAD FLOW						
	Total Demand		**Total Static Load**		**Apparent Losses**	
	P demand (MW)	**Q demand (Vvar)**	**P load (MW)**	**Q load (Mvar)**	**P losses (MW)**	**Q losses (Mvar)**
ETAP	538.736	328.669	527.820	326.015	10.917	2.654
MATLAB	538.653	328.129	527.820	326.015	10.831	2.122

The power flow results of the two software Etap and Mathlab show that the voltage system at the bus regulator is within the allowable limit of ± 5% of the rated voltage. Besides, from the results of the power loss of the two software, the results show that the results have insignificant errors, specifically the effective power error of only 2%.

From there, we have a basis to ensure the accuracy of the power system parameters of Soc Trang province when calculating the transient stability of the power system and evaluating the system's reliability before and after connecting the plant. wind electricity.

3.2 Short circuit analysis at bus

Etap software calculates short circuits according to ANSI/IEEE standards. The study assumes that a three-phase short circuit occurs at bus 21.TC_VC (Vinh Chau breaker station) the results are shown in Fig-8 and Fig-9.

SHORT-CIRCUIT REPORT

3-Phase fault at bus : **21.TC_Vinh Chau**

Nominal kV = 110.000 Voltage c Factor = 1.10 (User-Defined)

i = total fault current,
Idc = dc component,
ienv = top envelope of current-wave,
Iac(rms) = rms value of ac component,
Idc(%) = percentage value of dc component

t (cycle)	i (kA)	Idc (kA)	ienv (kA)	Iac (kA, rms)	Idc (%)	t (cycle)	i (kA)	Idc (kA)	ienv (kA)	Iac (kA, rms)	Idc (%)
0.000	0.000	32.168	64.336	22.746	100.00	0.100	3.584	29.416	61.345	22.578	92.13
0.200	17.148	26.941	58.635	22.411	85.01	0.300	34.434	24.712	56.171	22.245	78.55
0.400	47.962	22.699	53.926	22.081	72.69	0.500	51.873	20.877	51.873	21.918	67.33
0.600	44.116	19.224	49.992	21.756	62.48	0.700	27.161	17.723	48.264	21.596	58.03
0.800	6.987	16.355	46.673	21.437	53.95	0.900	-9.239	15.108	45.203	21.280	50.20
1.000	-15.903	13.969	43.843	21.124	46.76	1.100	-11.064	12.927	42.583	20.969	43.59

Fig -8: Results of short circuit current value at bus 21.TC_VC

Short-Circuit Summary Report

3-Phase Fault Currents

Bus		Short Circuit Current (kA, rms)		
ID	kV	Subtransient	Transient	Steady State
21.TC_Vinh Chau	110.000	22.746	22.746	2.380

Fig -9: Current short circuit result at bus 21.TC_VC

Simulation results show that the value of short circuit current at busbar 21.TC_Vinh Chau is 22.746 kA, which is smaller than the allowable short circuit current at 110 kV voltage level (which is 31.5 kA) and less than the limiting short-circuit current of the protective device at the station.

3.3 Transient stability analysis

Transient stability of a system is a property that allows a system to maintain equilibrium in normal operation and reach an acceptable equilibrium after being subjected to disturbances. The consequences of system instability can cut off a series of units, the loads can disintegrate the system and cause serious damage to the economy. Therefore, it is necessary to study stability while designing and operating the system to ensure: Stability in all normal and post-fault operating situations. The study assumes fault cases such as a 3-phase short circuit at Bus and simultaneous disconnection of all wind power plants to analyze voltage and frequency fluctuations of the system.

3.3.1 Three-phase short circuit at Bus Hoa Tu 1

In the case of a 3-phase short circuit at Bus Hoa Tu 1 connected to power plant 3-3. Assume the fault occurs at time 1 s, at Hoa Tu bus 1. When the fault occurs, the voltage at Hoa Tu bus 1 drops to 0, and the voltage at bus NMĐG 3-3 drops to 15% in short circuit time. However, when clear fault from the system at 1.2 s, the system returns to a steady state. The system frequency has slight oscillation at time 1s and returns to steady-state at 3 s. The results are shown in Fig-10.

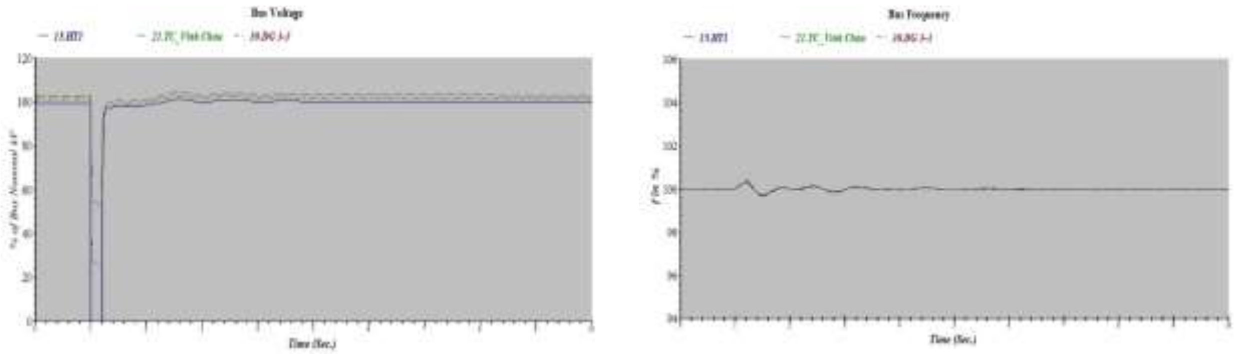


Fig -10: Voltage and frequency at Hoa Tu Bus 1 when short circuit occurs

In case of 3-phase short circuit at the bus at Vinh Chau breaker station connected to power plant 1-2, power plant 1-3, power plant 2-2, power plant 2-3, power plant 3-1, power plant 3-2. When there is a fault in the voltage system at the bus at Vinh Chau breaker station, the voltage drops to zero, and the voltage at wind power plants drops to 15% during the short circuit period. When a clear fault from the system, the system returns to a steady state at 1.2 s after the fault. Because this bus has many power plants connected, the steady-state recovery speed is longer and the voltage overshoot is higher than the short circuit at Hoa Tu Bus 1. Similarly, when a system frequency failure occurs. The system has slight oscillations and quickly returns to a steady-state. The results are in Fig-11.

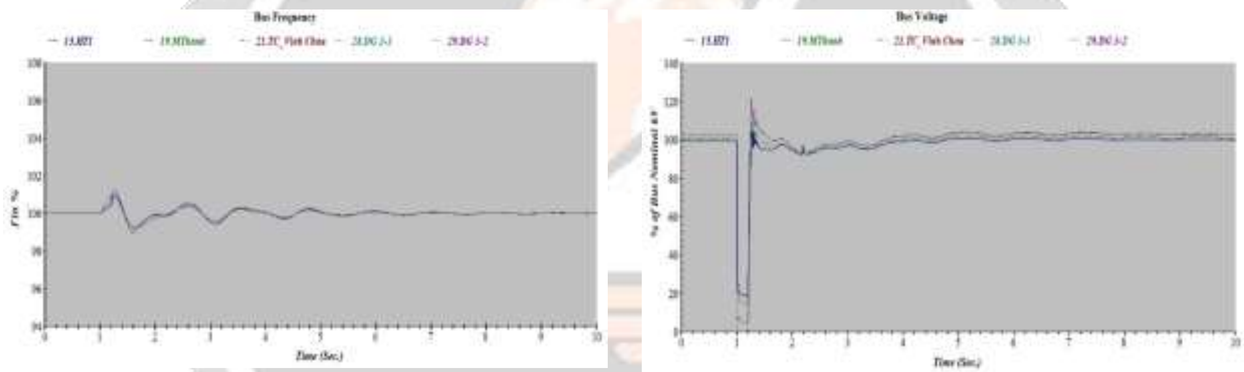


Fig -11: Voltage and frequency at bus stops at Vinh Chau when three-phase short circuit

Thus, when a three-phase short circuit occurs in the two cases above, it shows that the voltage and frequency values at the buses can recover quickly, the system still operates stably and does not affect much to the power system.

3.3.2 Cut off the wind power plant

The study analyzes two hypothetical cases: Case 1 cuts off Wind Power Plant 3-3 at Hoa Tu bus 1 (15.HT1); Case 2 cuts off the wind power plant, wind power plant 3-1, 3-2 at bus 21.TC_VC.

- Cut off power plant 3-3 at Hoa Tu 1 bus:

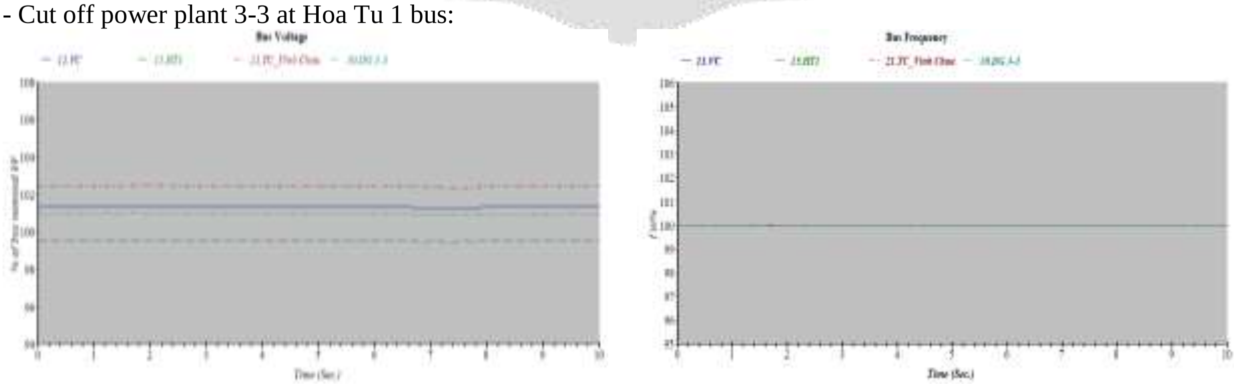


Fig -12: Voltage and frequency at Bus Hoa Tu 1 and other buses when cutting power plants 3-3

- Cut off power plant 3-1 at the bus station at Vinh Chau cutting station:

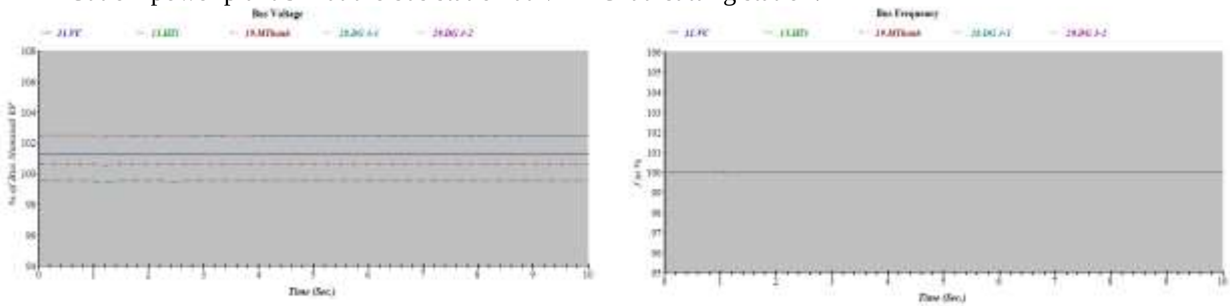


Fig -13: Voltage and frequency at Vinh Chau Bus and other buses when cutting power plants 3-1

The above results show that, when cutting any power plant out of the system, the voltage and frequency only fluctuate slightly at the time of cutting, not affecting the stability of Soc Trang province's power system.

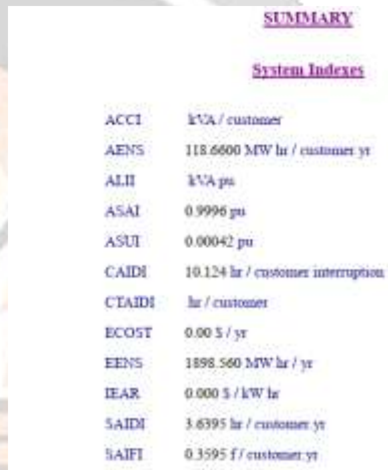
3.4 Evaluation system reliability before and after connecting the wind power plant

SUMMARY

System Indexes

ACCI	kVA / customer
AENS	133.0339 MW hr / customer.yr
ALII	kVA pu
ASAI	0.9995 pu
ASUI	0.00047 pu
CAIDI	10.592 hr / customer interruption
CTAIDI	hr / customer
ECOST	0.00 $ / yr
EENS	1995.508 MW hr / yr
IEAR	0.000 $ / kW hr
SAIDI	4.1125 hr / customer.yr
SAIFI	0.3883 f / customer.yr

Before connecting the wind power plant



SUMMARY

System Indexes

ACCI	kVA / customer
AENS	118.6600 MW hr / customer.yr
ALII	kVA pu
ASAI	0.9996 pu
ASUI	0.00042 pu
CAIDI	10.124 hr / customer interruption
CTAIDI	hr / customer
ECOST	0.00 $ / yr
EENS	1898.560 MW hr / yr
IEAR	0.000 $ / kW hr
SAIDI	3.6395 hr / customer.yr
SAIFI	0.3595 f / customer.yr

After connecting the wind power plant

Fig -14: Reliability assessment results of power system before and after connecting wind power plant

Table -4: Summary of system reliability index before and after conneting wind power plant

Index	Before	After	Difference	Improve
SAIFI (f/customer.yr)	0.3883	0.3595	0.0324	9.6%
SAIDI (hr/customer.yr)	4.1125	3.6395	0.473	11.5%
CAIDI (hr/customer interruption)	10.592	10.124	0.468	4.4%
ASAI	0.9995	0.9996	0.0001	0%

The above results show that the damage caused by power failure and the reliability criteria according to IEEE 1366 standard after having wind power plants have significantly improved. Specifically: the SAIFI index increased only 9.6%, the SAIDI index increased 11.5%; the CAIDI index increased by 4.4%; The ASAI index did not improve.

4. CONCLUSIONS

The study assessed the potential of wind power as well as the impact of wind power plants when connected to the Soc Trang power system. The study achieved the following results:

- Soc Trang has 3 wind power planning areas with a total area of 37,340 ha, with a capacity of 1,470 MW. Wind potential is concentrated mainly in the coastal area and has an average wind speed of 6-6.5 m/s at an altitude of 74 m. The wind direction mainly comes from two main directions: the wind from the east accounts for 17% and the wind from the west accounts for 15%, blowing in two seasons of the year.

- The generated capacity when connecting to the grid is always larger than the load demand by 2025. It shows that the construction of wind power plants will contribute to solving the local electricity demand and at the same time. contribute to the development of tourism and associated services.
- Simulations of short circuits, electromagnetic transients, wind power plant shut down as well as system reliability in the presence of wind power plants all ensure the steady-state recovery of the system after the fault. System reliability improved significantly after connecting wind power plants to the system.
- The research results serve as a basis for investors to research and decide to invest in wind power projects in the province, contributing to reducing the time and cost of investing in wind power plants in Soc Trang province.

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