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Impact of Planned Solar Farms on the Power Transmission Systems in Hau Giang Province, Vietnam

Authors: Van-Tan Tran[a*], Minh-Thu Thai[a], Nguyen Duy Phuong Do[b], Thanh-Phong Đoan[a], Phuc-Vinh Nguyen[b], Thanh-Luu Cao[c]

[a]*Hau Giang Industrial Zone Authority, Hau Giang, Vietnam*
[b]*Can Tho University, Can Tho, Vietnam*
[c]*Vinh Long Vocational College, Vinh Long, Vietnam*
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Abstract

Solar power is a great potential of renewable energy to replace fossil fuel in the future. In recent years, new installed solar energy accounts for a very large proportion of the total renewable energy supplied to the load. However, the state of connecting large solar farms will affect the national power system stability and voltage quality in the local power system. Therefore, assessing impacts of solar farms on the power system is necessary to determine voltage stability, the limited capacity of solar power at each power system and the reliability of the power grid before and after solar power is installed. This study uses ETAP software to evaluate impacts of planned solar farms on the local power system in Hau Giang province in 2025. The simulation results show that the power system is stable in terms of power flow after solar farms operation, in which the system loss is significantly reduced. The voltages of the power system are not disturbed when the solar farms are available according to results of transient stability analysis. Power system reliability improves significantly after operating solar farms for specific loads. It is shown that SAIDI, SAIFI and CAIDI before and after solar farms are installed are 5,8524 and 4,9847 hours/customer/year respectively, 0,4134 and 0,3955 times/customer/year respectively and 14,157 and 12,602 hours/customer respectively. The results show that when 07 solar farms with total capacity of 265MW are put into operation, the solar farms have a positive impact on the power grid of Hau Giang province.

Keywords: Solar farm; impact of solar farms; solar farms in Hau Giang province.

1. Introduction

Solar energy is a form of clean energy because there is no harmful gas emission to the environment in the production and operation process. Solar energy can be considered as an inexhaustible energy source and is a very potential source of energy to replace fossil fuels that are gradually depleted today.

It can be seen in figure 1, about additional 115GW solar power was installed worldwide, contributing to a total global capacity of 627GW at the end of 2019. The top ten countries installing solar farms with total capacity of up to 84GW accounted for 84% of total worldwide in which China is the leading country with an additional capacity of 30,1GW, followed by the US (13,3GW),

*Corresponding author Email:

India (9,9GW), Japan (7,0GW) and Vietnam (4,8GW).

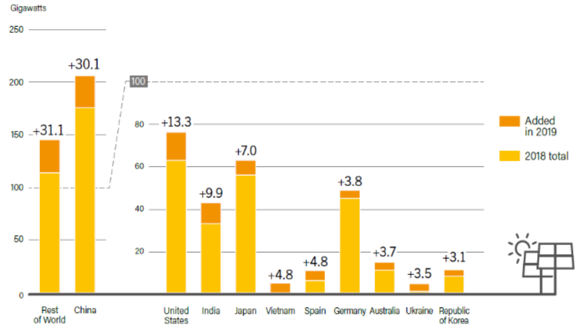

Figure 1: The increased amount of solar power capacity for top 10 countries in 2019 [1]

According to Vietnam Electricity (EVN), 3.426 MWp of solar energy was operated on national power system by the end of September 2020 in which there are 54 grid-connected solar power projects with the installed capacity of 2.674MWp in the provinces of Binh Thuan, Tay Ninh, Long An, An Giang, Ba Ria-Vung Tau and Ninh Thuan. The capacity is increased by around 90MWp compared to that in the previous month.

Vietnam is a country to be ranked in the top 10 countries installing solar energy in the world for the first period in 2019, showing that the Vietnamese Government is interested in developing this potential energy source. Figure 2 represents the planned and operated solar farms in Vietnam. According to BritCham's report in 2020, approximately 5.000MW of solar power capacity has been put into operation in which the capacity of up to 657,88MW belongs to 31.570 rooftop solar power projects. It can be said that in 2020 Vietnam is a booming country in solar energy [2].

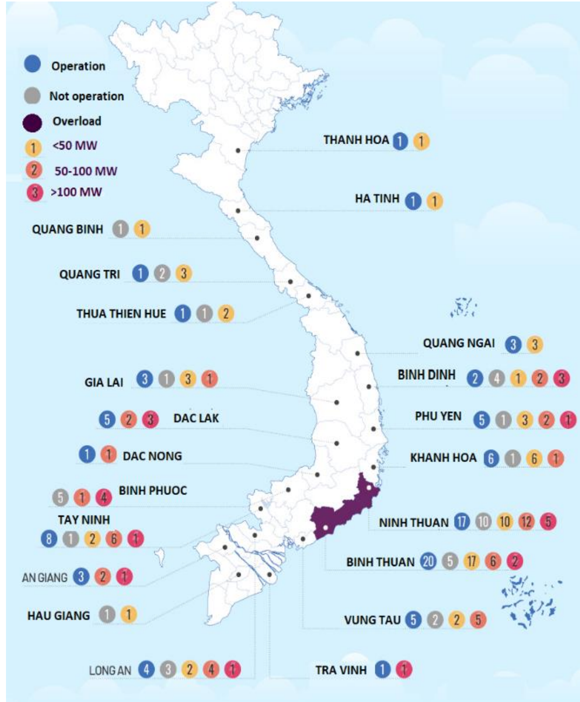

Figure 2: Solar projects in Vietnam

Due to increasing size and capacity of grid-connected solar power plants, assessing the impact of solar farms on the power system is a more and more interesting issue for researchers. Many studies have suggested that voltage fluctuation is the most important factor in limiting photo-voltaic (PV) penetration [3]. Specifically, there are no voltage-regulated devices in a 415V low-voltage network because the network depends on voltage regulators at 11kV or higher voltage networks. Therefore, voltage violations for low-voltage networks have occurred in many cases. In addition, the system frequency depends on the balance of power supply and load demand. As the demand increases, the power transmission system should increase to accommodate it. When the supply and demand do not match, the system frequency will be fluctuated [4]. Last but not least, power system parameters and PV installation position are the important factors in limiting PV integration. Aziz and Ketjoy found that only 2,5% of PV penetration would have breached the voltage limits if all PV farms were installed at the same point. However, this study shows that high PV penetration ratio of 110% can be achieved to meet voltage constraints if these PV systems are installed at different locations [5]. In Vietnam, there are also many studies on solar energy potential and impacts on the electricity system. Tran et al. evaluated the rooftop solar potential and impacts on the local electricity system. The results showed that the potential of rooftop solar energy in Hau Giang province is very large, if invested, it will contribute to the significant decrease of greenhouse gas emissions into the local environment [9].

To analyse impacts of solar farms on the power system and determine its maximum penetration, researchers used a variety of tools, models and assumptions for their specific purposes. These models and tools are very important because they help to determine the accuracy and validity of the results as well as give feasible solutions [6]. Iman Gharibshahian used a software called PVsyst to design and evaluate a 100kW grid-connected solar power system in Semnan city, Iran. The simulation shows that about 178,99MWh/year can be produced each year with about 170,3MWh/year supplied to Iran's electricity system [7]. In addition, Seyed Mohsen Salehi and his colleagues evaluated the power quality of a solar farm when connected to the Iranian power system by PSCAD software. The study also compared voltage distortion values with the specified limits in the standard IEEE STD 519-1992 [8].

This study utilizes the ETAP software to simulate and evaluate impacts of solar farms under the power planning of Hau Giang province up to 2025. Specific parts of the study are: following the general introduction, section two introduces the ETAP software; section three gives the solar power planning of Hau Giang province and the power transmission system of Hau Giang province to 2025; section four represents simulating the impact of solar power farms on the provincial power transmission system; and the final part is the drawn conclusion and results of the study.

2. ETAP program software

ETAP is a specialized software for electrical system design and simulation both offline and real-time application. The software was developed by the Institute of Operations Engineering in Irvine, California, USA. In this study, ETAP software is used to simulate the power system of Hau Giang province before and after solar farms are connected to the system. In addition, the study uses crash analysis tools and system stability assessment when there are simulation failures [10].

3. System description

3.1 Planned solar farms in Hau Giang province

According to the proposed plan in Hau Giang province, there are 07 projects of planned solar farms with a total capacity of 265MW at locations near the load for the period of 2020 - 2025 and 01 project with a capacity of 35MW was operated at the end of 2020. All projects are shown in figure 3.

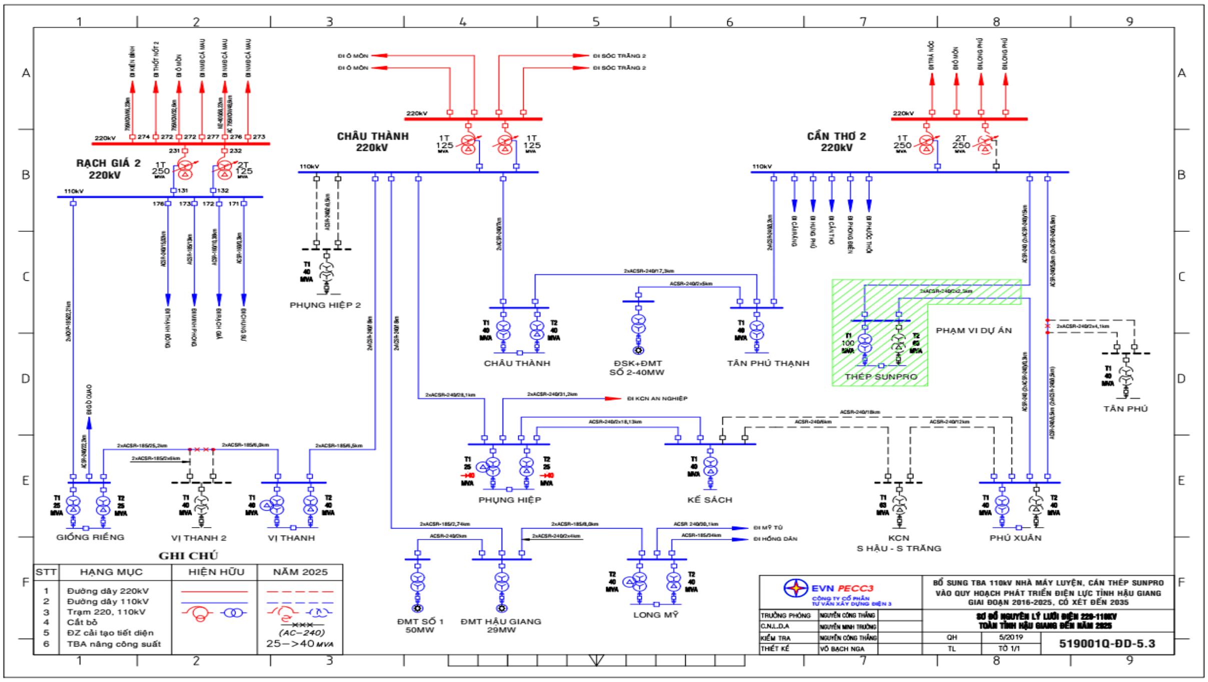

Figure 3: Hau Giang power grid and planned solar farms in 2025

3.2 Hau Giang power transmission system

The 110kV stations of Hau Giang province are supplied with electricity through the following 110 kV lines:

The 110kV line from 220kV station Rach Gia-2 – Giong Rieng – Vi Thanh – Long My – Hong Dan – An Xuyen: the line is to connect to the 220kV Ca Mau-2 station with a very long length conductor (ACSR-185) and is power supply for 5 stations of 110kV. Therefore, if there is a problem at one end of the line, the other side will be seriously overloaded and the voltage quality of the terminal station is not guaranteed. In normal operation mode, the 110kV Vi Thanh and Long My stations receive electricity entirely from the 220kV Rach Gia-2 station and the 110kV line from the 110kV Long My station to the 220kV Ca Mau-2 station is just a communication line.

The 110kV line from Tra Noc 220kV station - Hung Phu Industrial Park - Chau Thanh - Phung Hiep: In normal operation mode, Chau Thanh 110kV station receives power from Tra Noc 220kV station and Phung Hiep 110kV station receives electric power mostly from 220kV Tra Noc station and part from 220kV Soc Trang-2 station. The 110kV transmission line at 220kV Can Tho-2 station to Phu Xuan station supplying electric power to 110kV Hung Phu station and Phu Xuan station detailed in the table 1 and figure 4.

Table 1: The tramission lines power in Hau Giang province [11]

No	Name	Type	Length (km)	P_{max} (MW)	I_{max} (A)	Load (%)
Tranmission line 110kV						
1	Hung Phu - Chau Thanh	ACSR-240/32	29,26	39,7	306,5	50,66
2	Chau Thanh - Phung Hiep	ACSR-240/32	32,63	30,6	157,6	26,04
3	Phung Hiep - Soc Trang	ACSR-240/32	28,42	29,4	151	25,05
4	Giong Rieng - Vi Thanh	ACSR-185/29	31,2	46,1	239	46,86
5	Vi Thanh - Long My	ACSR-185/29	17,24	18,2	95,7	18,76

Table 1: The tramission lines power in Hau Giang province [11]

No	Name	Type	Length (km)	P_{max} (MW)	I_{max} (A)	Load (%)
6	Long My - Hong Dan	ACSR-185/29	33,97	18	94,1	18,45
7	Can Tho 2 - Phu Xuan	ACSR-240/32	15,2	21	106	17,52

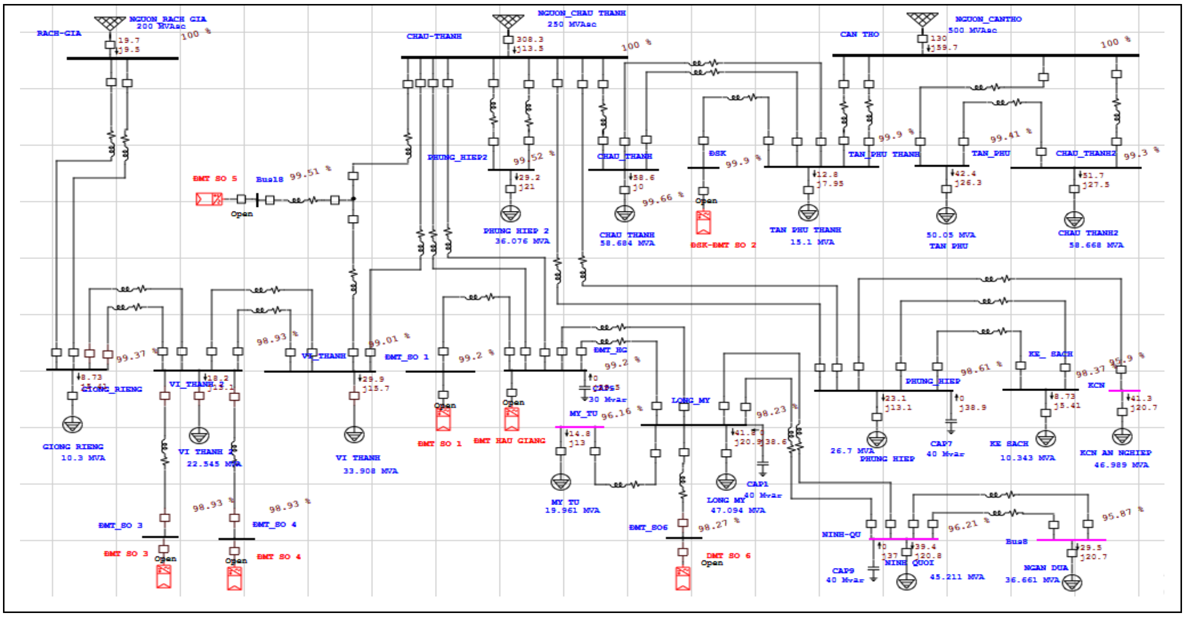

Figure 4: The online transmission lines of Hau Giang power system

4. Impacts of solar farms on the power transmission system

4.1 Power flow analysis

From the results of table 2, it can be seen that before connecting the solar farms, the national power system must provide the power system of Hau Giang province with a capacity of 458MW and 76,16Mvar at peak. This shows that the power plants in Hau Giang province connecting to other province's 110kV power network have not yet provided the required amount of capacity and load.

Table 2: Summary the Power flow before and after installing solar farm

	Before add Solar farms		**After add Solar farms**	
	MW	Mvar	MW	Mvar
Swing bus	458,013	82,764	187,831	76,164
Source	0,000	0,000	270,011	0,000
Total demand	458,013	82,764	457,842	76,164
Motor load	362,666	186,727	362,666	186,727
Static load	87,600	-99,118	88,760	-102,33

Therefore, the power network must always receive power from the national power transmission system. After the connection of the solar farms, the power flow of the system is changed. When the solar farms are put into operation, the burden of the power system is partially shared with the solar farms due to their installed capacity of 270,01MW (included 10MW Rice husk power plant). The transmission system now only provides a lower active power of 187,83 MW than that of 458,01MW without connecting the solar farms.

4.2 Short-Circuit analysis

To ensure that the circuit breakers and protection devices work efficiently and operate within the allowable limits of rated current. The short-circuit currents are simulated at connected bus of all solar farms.

From the simulation results in table 3, we see that maximum of peak short-circuit current of 19,05kA is smaller than the allowable short-circuit current (31,5kA) at 110kV voltage level —which is less than the short-circuit current withstand level of circuit breaker is 85kA.

Table 3: Short Circuit Summary report

3-Phase, LG, LL, LLG Fault Currents

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
Solar 1	110,000	8,493	16,207	4,772	2,830	5,400	2,830	2,830	7,355	14,036	7,355	7,355	7,685	14,667	7,685	7,685
Solar 2	110,000	9,307	17,945	4,969	3,007	5,798	3,007	3,007	8,060	15,541	8,060	8,060	8,407	16,210	8,407	8,407
Solar 3	110,000	6,838	13,517	4,472	3,079	6,087	3,079	3,079	5,922	11,706	5,922	5,922	6,236	12,327	6,236	6,236
Solar 4	110,000	7,228	14,146	4,793	3,123	6,112	3,123	3,123	6,260	12,251	6,260	6,260	6,653	13,020	6,653	6,653
Solar 5	110,000	7,228	14,146	4,793	3,123	6,112	3,123	3,123	6,260	12,251	6,260	6,260	6,653	13,020	6,653	6,653
Solar 6	110,000	9,656	19,051	5,713	4,003	7,898	4,003	4,003	8,363	16,499	8,363	8,363	8,826	17,413	8,826	8,826
Solar 7	110,000	3,891	6,650	2,834	1,477	2,524	1,477	1,477	3,370	5,759	3,370	3,370	3,582	6,121	3,582	3,582

4.3 Transient stability analysis

4.3.1 Three phase bus fault

To analyze voltage fluctuations at the buses adjacent to the solar farm (Solar F3) when the bus connecting the solar power plant fails, we assume a three-phase short circuit at bus Solar F3.

From the results of figure 5, it is shown that when the fault occurs before connecting the solar power plant, the voltage value at the Solar F3 bus is zero and the voltage values at the neighbouring buses decrease in the range from 24% to 44,8%. After deducting the fault, the voltage value at the Solar F3 bus comes back to 99,4%. The voltage value at the neighbouring buses ranges from 98,6% to 100%.

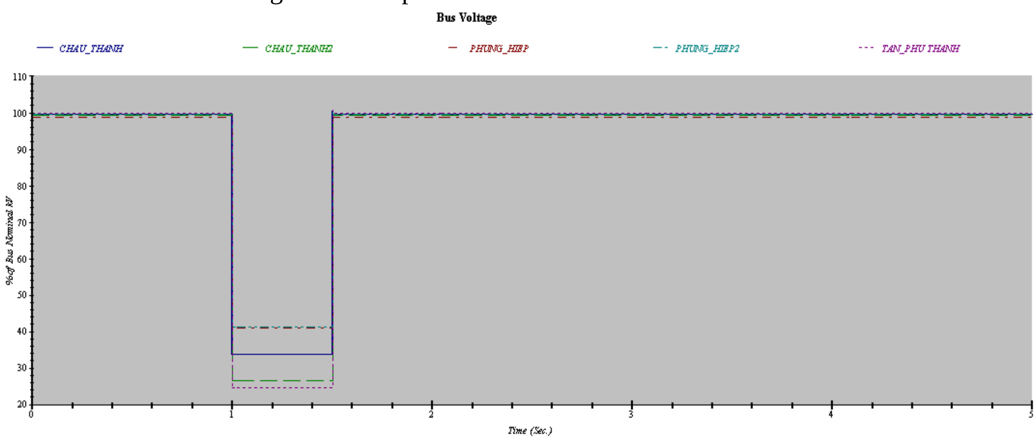

Figure 5: The bus voltages when the fault occurred before installing the solar farms

Similarly, the three phase bus fault after installing the solar power plant is observed to compare with normal condition in figure 6. When the fault occurs, the voltage value at the Solar F3 bus get zero and the voltage value at the neighbouring buses has a reduced value ranging from 29,5% to 64,6%. After getting rid of the fault, the voltage value at the Solar F3 bus become the normal working condition of

100%. The voltage values at neighbouring buses range from 99,3% to 100%. It can be seen that after the fault is clear, the voltage values at the buses can recover quickly and the system can operate stably without affecting the power system much.

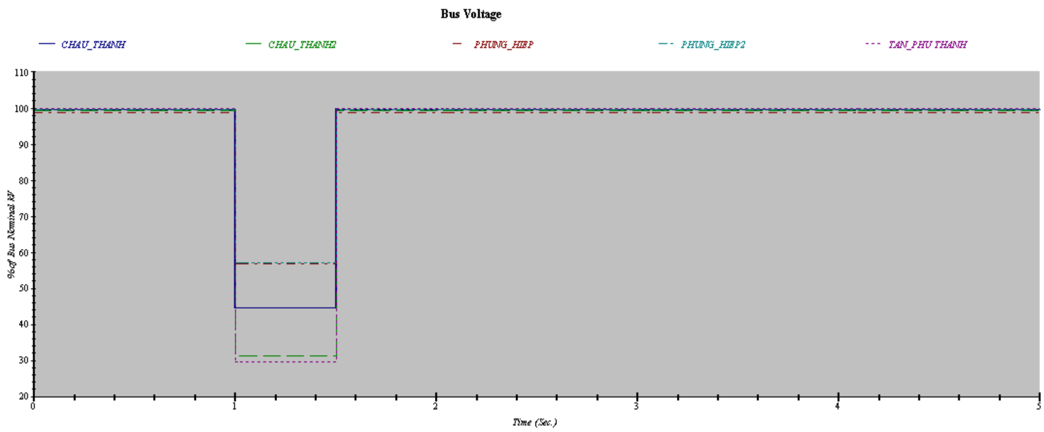

Figure 6: The bus voltages when the fault occurred after installing the solar farms

4.3.2 Tripping off solar farms

From the results of figure 7, it is straightforward to see that when the solar farms are tripped off in a certain period of time, the voltage values at the connected buses are not changed and still remain within the allowable limit. All bus voltages of the system are stable as well as the whole power system is not affected.

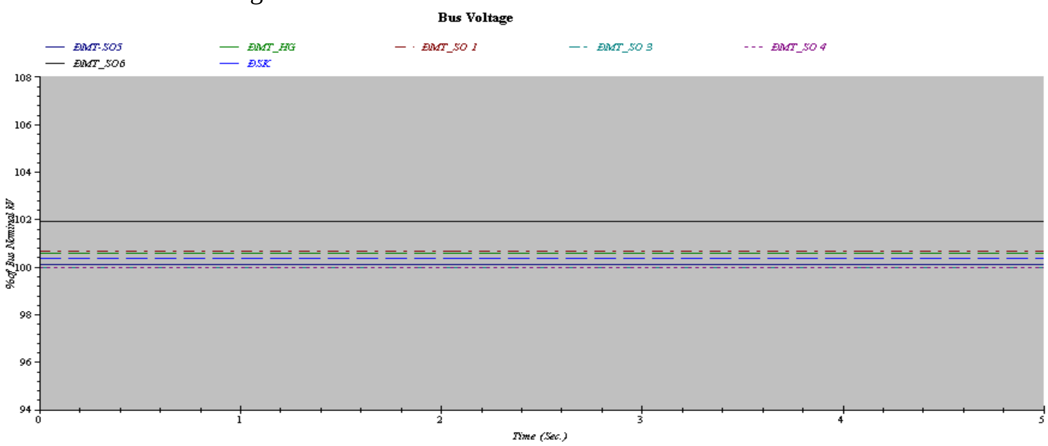

Figure 7: Bus voltages when tripping off all Solar farms

4.4 Reliability analysis

From the table 4, it is shown that before and after there are the connected solar farms: The average total outage time of SAIDI (System Average Interruption Duration Index) are 5,8524 and 4,9847 hours/customer/year respectively; Average power failure frequency of SAIFI (System Average Interruption Frequency Index) is 0,4134 and 0,3955 times/customer/year respectively; and the average outage time index of CAIDI (Customer Average Interruption Duration Index) is 14,157 and 12,602 hours/customer respectively, which represents the average time it takes to restore power supply to customers during an outage. It means that the power system achieves the more reliability when connecting the solar farms.

Table 4: Reliability system index before and after installed solar farms

System indexes	Before	After
CAIDI (hr/Customer)	14,157	12,602
SAIDI (hr/Customer.yr)	5,8524	4,9847
SAIFI (f/Customer.yr	0,4134	0,3955

5. Conclusion

The study has simulated the power system of Hau Giang province before and after connecting solar farms in terms of observing power flow, analysing short circuit, transient stability and tripping off all solar farms at the same time as well as evaluating the reliability of the power network.

The results show that the power grid of Hau Giang province is planned to connect with a solar energy source of up to 265MW to provide clean energy for the locality. Although the proportion of solar energy is larger than the province's load demand, the grid responds well to system failures. Specifically, the power distribution of the grid before and after connecting the solar power does not change bus voltages much. When shutting down all solar power plants at the same time, the voltage and power flow fluctuate and instantly recover to a stable state after the fault is clear.

Basing on the power flow, it can be seen that before solar power is available, the national power system must supply the local power system of Hau Giang province with a capacity of 458,013MW and 76,164Mvar at peak times. Due to the connected solar farms, power flow is invertible, becoming capacitive. When the solar farms generating 270,01MW is put into operation, the burden of the system load supplied to the local grid is partially shared. The active power from the national power system supplying to local power system is reduced from 458,013MW to 187,831MW.

Following to short circuit analysis, the value of short-circuit current at the Solar 6 bus is about 19,05kA, which is less than the allowable short-circuit current at 110 kV voltage.

In case of 3-phase short-circuit at the Solar F3 bus, the voltage value at the Solar F3 bus is zero and the voltage value at the neighbouring buses is also equal to zero. The reduced value ranges from 29,5% to 64,6%. After clearing the fault, the voltage values at the buses can be recovered quickly: The voltage value at the Solar F3 bus reach to 100,3%, the voltage values at the neighbouring buses ranges from 99,3% to 100%. It means the faults do not change the voltage of buses connected to solar farm and do not affect the local and national power system. The power system gets the higher reliability: total SAIDI is 4,9847 hours per customer per year; SAIFI is 0,3955 times/customer per year; and CAIDI is 12,602 hours per customer.

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