Received: July 27, 2022. Revised: February 19, 2023.

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

The Impact Study of Electrical Vehicle Charging Stations Loading to Thailand's Northeast Power System and DRG Integration Planning to Reduce Power Congestion

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Abstract: This article presents the impact study of electrical vehicle charging stations (EVCS) loading to the Thailand's North eastern power system. Main purposes of this paper are to find the maximum number of EVCS that can be loaded to power system and to rank the critical areas under EVCS load changing by using the repeated power flow calculation technique. Results from the calculation are for the integration planning of distributed renewable generators (DRG) to reduce system congestion. Typically, the critical areas are buses or devices that violate of system control limits. The system control limits are consisting voltage limit and load percentage limit of power transfer devices. All critical areas are needed to improve system stability and reduce system congestion for support the EVCS growing. In this study, The EVCS have been installed on main roads in Thailand's North-eastern area from Bangkok to Nong-Khai province with a length of 624 km. The EVCS were installed every 50 km, totally 11 stations, and connected to 115 kV substations in the system. The impact study results found that the system experienced with congestion problem on following elements: a) 11 critical buses at 115kV network, b) one critical bus at 230kV network and c) one transmission line is overload to 100 percent at 115kV network when each of EVCS station load increase to 30 MW. In addition, study results reveal that when installed DRG at the right and proper locations, these can reduce congestions situation, reduce system losses and enhance system stability.

Keywords: Electrical vehicle charging station (EVCS), Distributed renewable generator (DRG), Power congestion, Violation limit, Repeated power flow calculation.

1. Introduction

In Thailand, it is found that the consumption of electric vehicles (EV) continues to increase due to the current high fuel price situation. Which, other things following the widespread consumption of electric vehicles is the rise of Electrical Vehicle Charging Stations (EVCS) and it will affect inevitably to the power system security [1, 2], especially the power system during peak load periods. It is essential that future impact studies be carried out in order to plan for improving the power system stability [3, 4]. In addition, if considering the current and past versions of Thailand power development plan, it is found that the installed capacity for renewable generation capacity [5, 6] has a relatively high installed capacity and at present it is expanding very much. It would be ideal if alternative energy installations were planned by considering the areas affected or critical voltage areas [7, 8] under the electric vehicle charging stations loading [9, 10] in the system to increase the power system stability for supporting the variance of the EVCS load in the future.

In this study, it has focused on the expansion impact study of electric vehicle charging stations on

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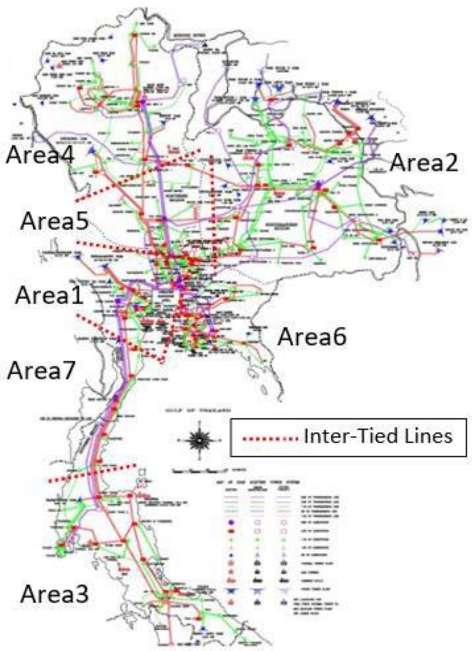

Figure. 1 Thailand power system overview

Table 1. Power generation and load capacity (MW)

Area	Generation	Loads	Losses
1	2379	10849.57	97.15
2	2858.22	3229.91	134.42
3	2088	2211.08	67.32
4	3517.61	3010.51	133.28
5	3972.1	3161.58	84.97
6	10133.05	4061.95	54.72
7	5333.7	3132.93	52.29
Total	30281.68	29657.53	624.15

a main road in Northeast of Thailand which it is an area capable of renewable energy generation, especially the solar power. The main road used in the study focuses on the road from Bangkok to Nongkhai province, which the length is 624 kilometers to support the expansion of electric vehicles user. In this case study was installed EVCS every 50 km with a total of 11 stations. The load capacity each of electrical vehicle station is 30 MW maximum. In this case study was installed EVCS every 50 km with a total of 11 stations. The connection of each station is connected to the 115 kV substation in the system. In this study, it was used the 2019 Thailand power system data at peak load period for system base case [11]. The Thailand power system overview has shown in Fig. 1. The generation and load capacity of system can be shown in Table 1.

From Table 1, it was found that the system has a power capacity of 30,281.68 MW, the load is 29,657.53 MW, and the power loss in the system is 624.15 MW. The study focused on the impact on the northeastern power system of Thailand, which has a capacity of 2,858.22 MW, the load capacity is 3,229.91 MW, and the power loss in the system is 134.42 MW.

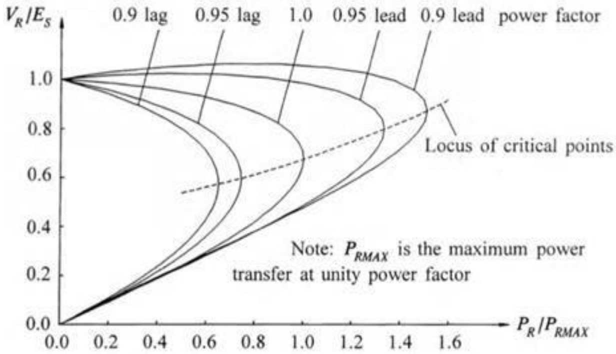

Figure. 2 Voltage- power (load bus) correlation graph

2. Power system control limit values

In the study of power systems, a control limit [12, 13] setting of power system is required, where the basic control limit is composed of the voltage limit and the loading percentage limit of the power transfer device to be used in the power system stability study can be described as follows.

2.1 Voltage limit

In this study, voltage limit value of system base case was set at 0.95-1.05 p.u. to study the effect on the system under the impact of the electric vehicle charging station load variance to find the voltage critical buses for improving system under various circumstances. If the system is unable to maintain the bus voltage in the system [14, 15], it can cause system instability as shown in Fig. 2.

2.2 Load percentage limit

The load percentage limit of the power transfer devices is the overloading control of the equipment, especially the transmission lines, transformers and generators. The transmission lines, transformers and generators, which the equipment overloading can cause damage to the equipment and cause power flow congestion problem [16-17]. If the device is critical to transfer power in the system, it will be causing system instability. In this study, the load percentage control of the power transfer device was controlled at 100 percent.

3. The study processes

The study process of this research can show a diagram of work as shown in Fig. 2. The study starts from the construction of power system to be used as the base power system. In this research, the power system was used in 2019 during the peak period because need to study the impact under the electric vehicle charging stations load variance to power system. The voltage violation limit was set at 0.95-1.05 p.u. and the power transfer device's load percentage was set at 100%.

If there is violate the control limit in the system, it will make adjustments the data in the power system such as Generator voltage, Tabs of voltage transformers and capacitor banks in the power system so that system control values are not violated. If there is no violation of the control in power system, a base power system will be obtained for use in the study. After the base power system is obtained, an electric vehicle charging stations will be installed into the system. In this study, the point for installation was determined as the main road from Bangkok to Nongkhai Province in North eastern of Thailand. Which, each of station is connected to power system at 115 kV substations. In this study, the installation distance each of EVCS is every 50 km with a total 11 stations. The increase step of the EVCS load to study the maximum loading value is 5 MW of each station at the same time until violation occurs in the system using repeated power flow calculation technique [18-19]. This step, the voltage violation limit was set at 0.90-1.10 p.u. and the power transfer device's load percentage was set at 100%.

If the electrical vehicle charging station load increases, it is examined for violations of the voltage limit and the loading percentage of transmission lines. In study results, we will analysis the critical areas affected from changes of the EVCS loading to determine the critical areas and ranking for installing renewable power generators into the system in order of critical areas ranking by 9 MW/Bus follow the maximum capacity for very small power plant (VSPP). After that, increase EVCS loading step, the voltage violation limit and the power transfer device's load percentage was set as same as the previous testing. In addition, they will be compared the power congestion impact in the system by considered the bus voltage, power transfer device's loading percentage and power loss in the power system.

4. EVCS installing on Bangkok-Nongkhai road

In this study, it has focused on the impact study of electric vehicle charging stations increasing in Thailand's north eastern power system. In This case study, the EVCS in this study will install on the main road from Bangkok to Nongkhai province, a total length of 624 km. The installation distance of the electric vehicle charging station is installed every 50 km, with a total of 11 stations as shown in Fig. 3. The EVCS is connected with the near substation of 115 kV transmission line network in Thailand's North eastern power system. The location diagram of the 115kV substation for connect the ECVS can be shown in Fig. 4.

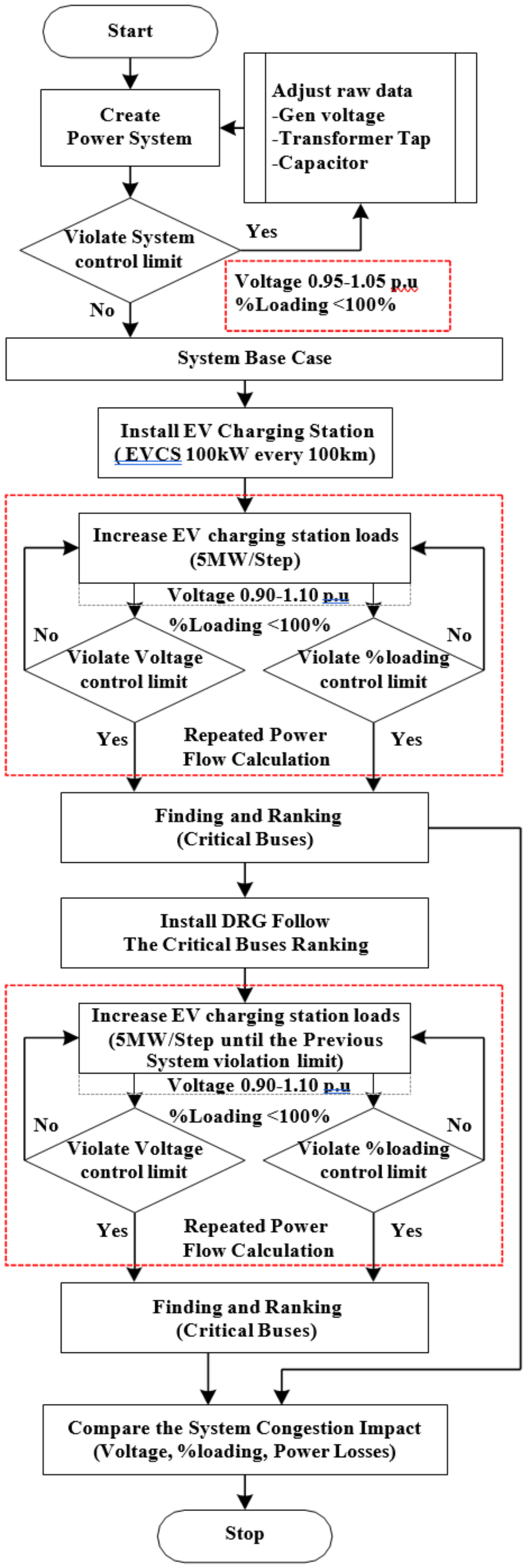

Figure. 3 Study flowcharts

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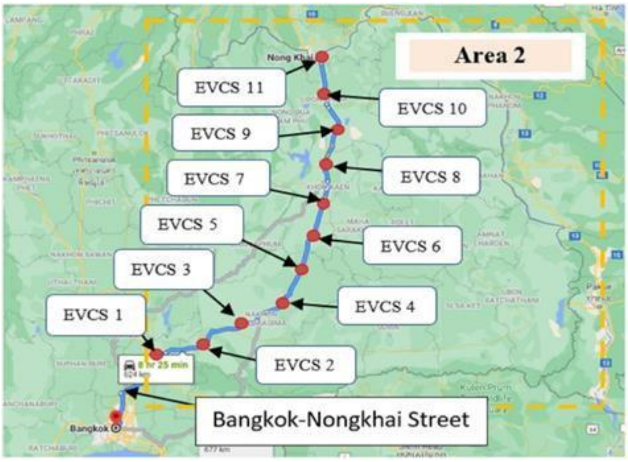

Figure. 4 The electric vehicle charging station location on main road from Bangkok to Nongkhai province

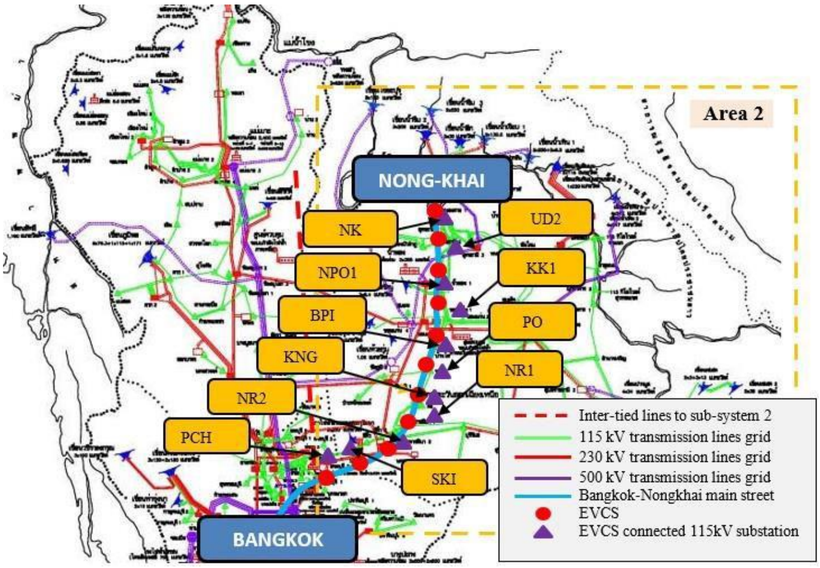

Figure. 5 The 115 kV substation and EVCS location in Thailand's north eastern power system

Table 2. The connection data of EVCS and 115 kV Substation

EVC Station	115 kV Substation	
	Name	No.
1	PCH	2701
2	SKI	2702
3	NR2	2703
4	NR1	2704
5	KNG	2708
6	PO	2709
7	BPI	2711
8	KK1	2712
9	NPO1	2730
10	UD2	2733
11	NK	2736

In Fig. 3 shows the EVCS location and the 115kV substation. For, the connection data each of EVCS and the 115kV substation can be shown in Table 2.

5. A study results

The study results have focused the impact study to find the maximum EVCS loading and ranking the critical buses in Thailand's North eastern power system for installing renewable generators under EVCS load variance. Which, the study results will compare the impact before and after install renewable power generator, as well as include the power loss in the system. The results of the study can be shown as follows.

5.1 The Impact study results on voltage in the power system

The impact study results on the voltage in the power system from the electric vehicle charging station load variance can be shown in Figs. 6-9.

The study results showed that each ECVS station could only increase the load by 5 MW when set voltage limit at0.95-1.05 p.u. and increase the

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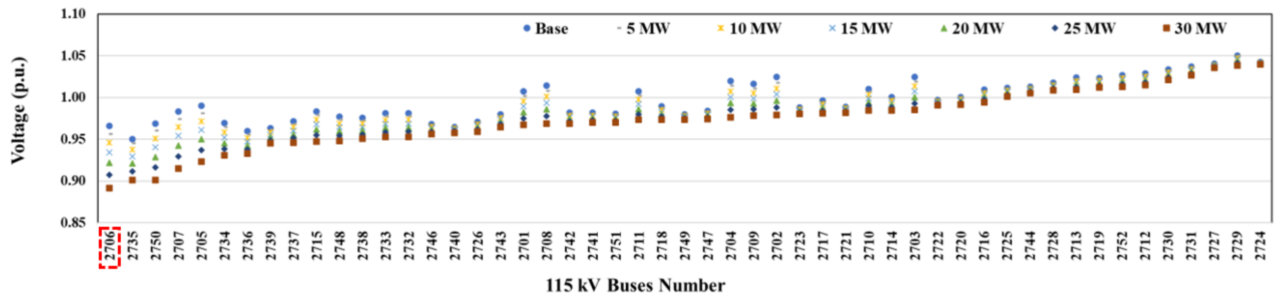

Figure. 6 The critical voltage buses ranking of 115 kV network during EVCS loading

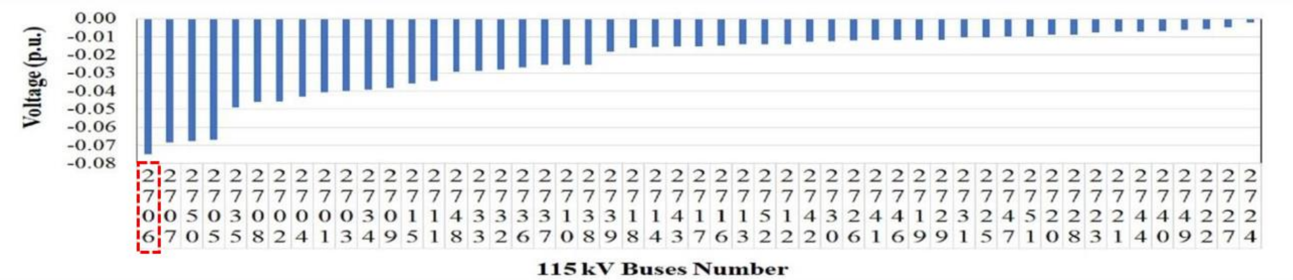

Figure. 7 The high impacted voltage bus ranking of 115 kV network during EVCS loading

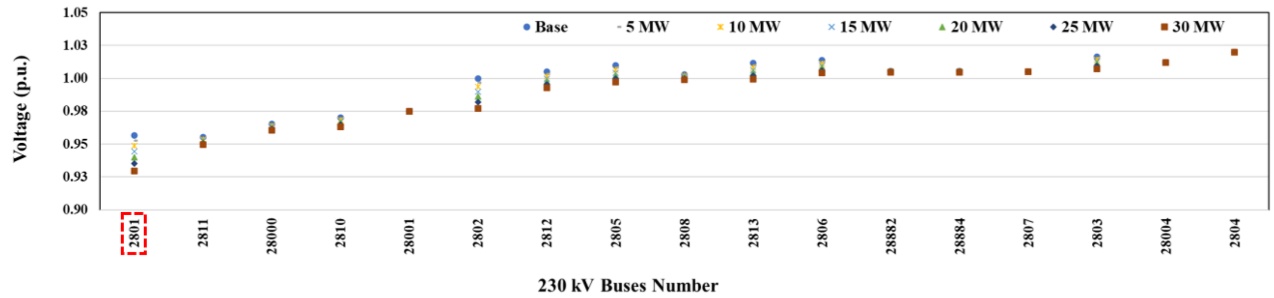

Figure. 8 The critical voltage buses ranking of 230 kV network during EVCS loading

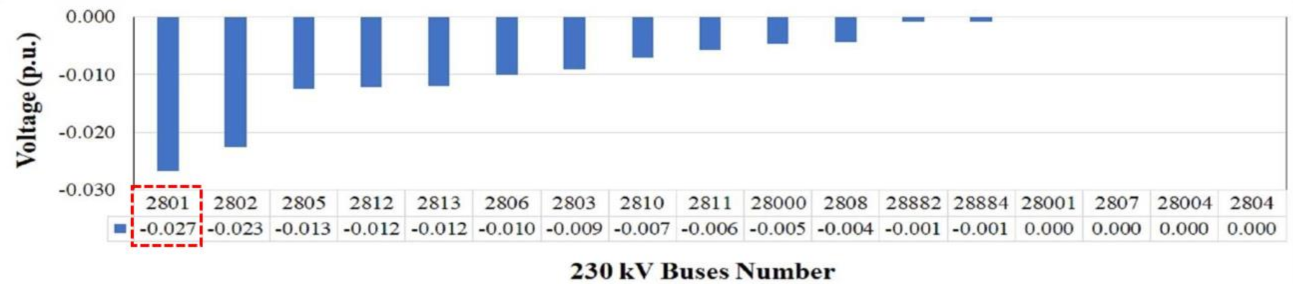

Figure. 9 The high impacted voltage bus ranking of 230 kV network during EVCS loading

load by 30 MW when set voltage limit at 0.90-1.10 p.u. of 115kV network, causing the equipment in the system to violate the system controls. When, we considered the critical voltage buses ranking and the high impacted voltage bus ranking of 115 kV network as shown in Figs. 6 and 7 that found voltage bus no.2706 it has highest critical voltage by voltage drop from 0.96 to 0.89 p.u. and highest voltage changing rate by the voltage changing rate is -0.07 p.u. during EVCS loading. In addition, if considered the critical voltage buses ranking and the high impacted voltage bus ranking of 230 kV network as shown in Figs. 8 and 9 that found voltage bus no.2801 has highest critical voltage by voltage drop from 0.96 to 0.932 p.u. and highest voltage change rate by the voltage changing rate is -0.028 p.u. during EVCS loading.

5.2 The Impact study results on %loading of transmission line in the power system

The impact study results on %loading of transmission lines in the power system from the ECVS load variance can be shown in Figs. 10-13.

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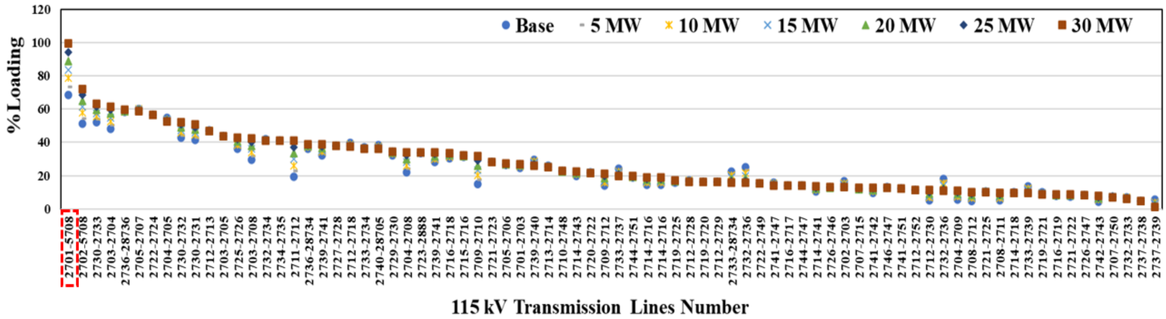

Figure. 10 The critical transmission line ranking of 115 kV network during EVCS loading

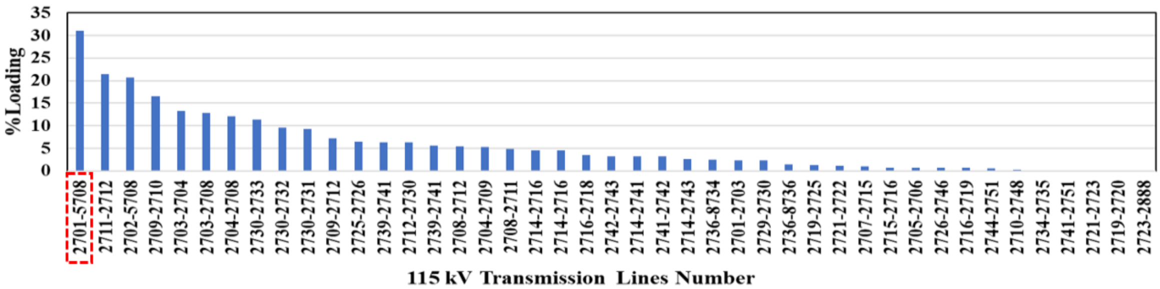

Figure. 11 The high impacted transmission line ranking of 115 kV network during EVCS loading

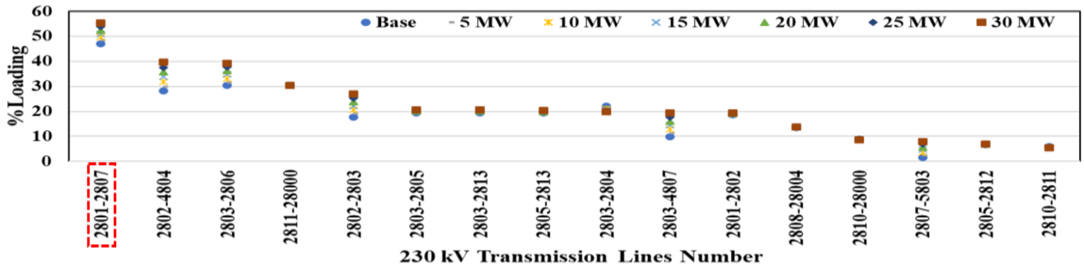

Figure. 12 The critical transmission line ranking of 230 kV network during EVCS loading

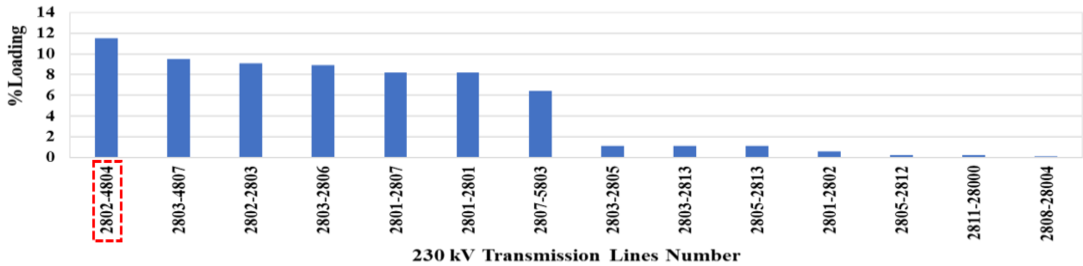

Figure. 13 The high impacted transmission line ranking of 230 kV network during EVCS loading

As the same condition, each ECVS station could only increase the load by 30 MW and causing the equipment in the system to violate the system controls. When, considered the critical transmission line ranking and the high impacted transmission line ranking of 115 kV network as shown in figure 10 and 11 that found transmission line no.2701-5708, it has highest critical loading percentage by %loading increase from 68.60 to 100% and highest %loading changing rate by the voltage changing rate is 31.4% during EVCS loading. In addition, if considered the critical transmission line ranking and the high impacted transmission line ranking of 230 kV network as shown in Figs. 12 and 13 that found transmission line no.2801-2807, it has highest critical loading percentage by %loading increase from 47.1 to 55.3%. On the other hands, for the highest %loading changing rate is transmission line no.2808-2804 by the %loading changing rate is 11.5% during EVCS loading.

5.3 The study results of the 115 kV critical voltage buses ranking

This study results show that the 115 kV critical voltage buses under voltage buses have violated

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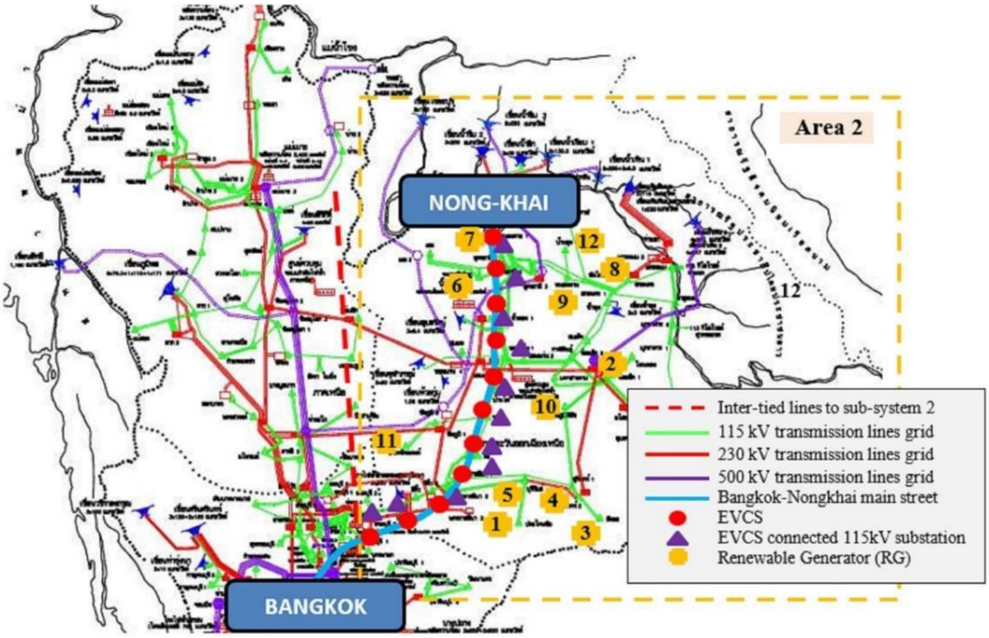

Figure. 14 Integration locations for distribution renewable generators (DRG)

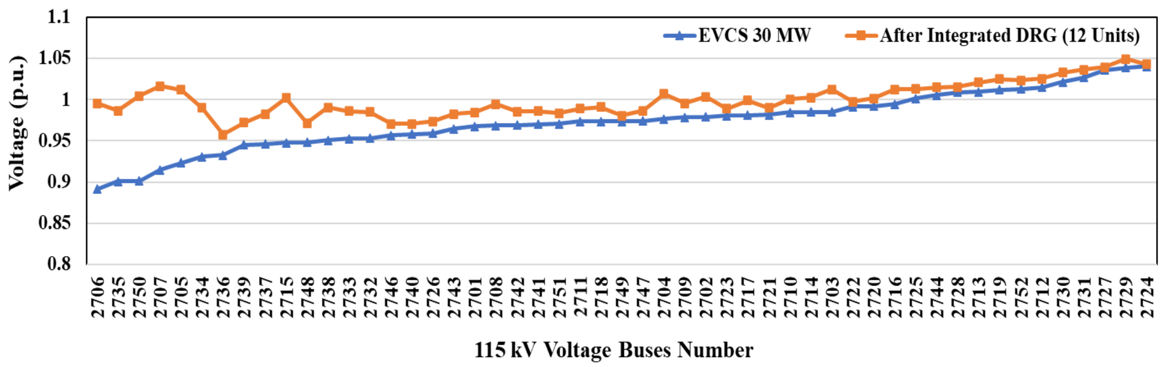

Figure. 15 The voltage profile of 115kV network after integrated DRG 12 units

Table 2. 115kV Substations for connecting DRG

115 kV Substation			
No.	**Number**	**Name**	**Voltage (p.u.)**
1	2706	PKC	0.8912
2	2735	LE	0.9009
3	2750	SKA	0.9014
4	2707	SU	0.9148
5	2705	BR	0.9231
6	2734	NBL	0.9306
7	2736	NK	0.9328
8	2739	PHK	0.9451
9	2737	NH	0.9462
10	2715	PYK	0.9475
11	2748	BNN	0.9481
12	2738	BDG	0.9498

voltage control limit of power system control. The study results can show in Table 2. In Table 2 found that the 12 critical voltage buses of 115 kV transmission line network at ECVS load 30MW which voltage level lower 0.95 p.u. and the highest critical voltage bus must be improving the voltage stability is bus no. 2706.

5.4 The study results of the impact to the power system after installing the DRG follow the critical voltage buses

The study results have compared the effects on the power system after install the DRG following the critical voltage buses ranking as shown in Table 2. The study results have focused to comparison of bus voltage and %loading of transmission lines in the system at 115 kV and 230 kV, as well as a comparison of the power losses in the system. The DRG integration location in power system as shown in Fig. 14 and the study results as shown I Figs. 15-17.

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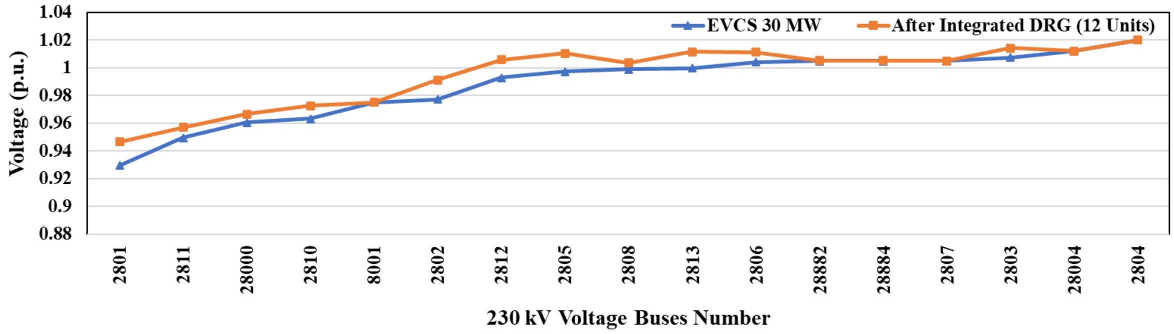

Figure. 16 The voltage profile of 230kV network after integrated DRG 12 units

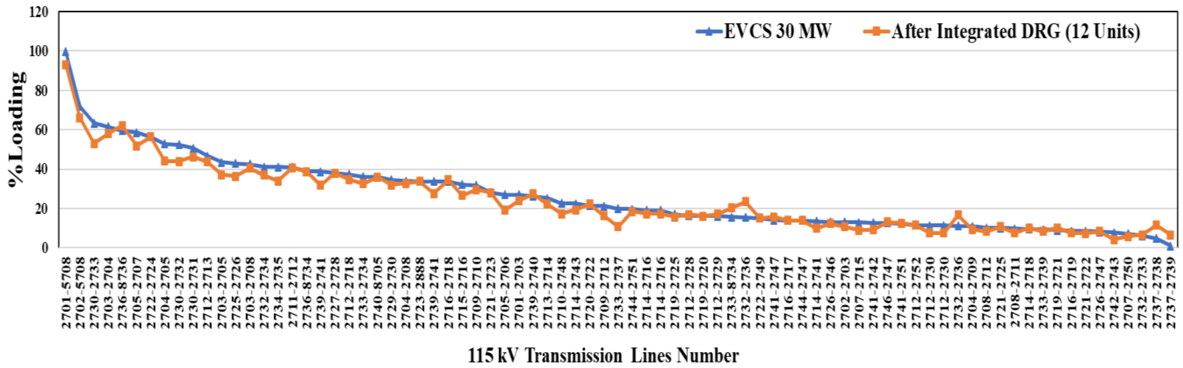

Figure. 17 The %loading of transmission lines of 115kV network after integrated DRG 12 units

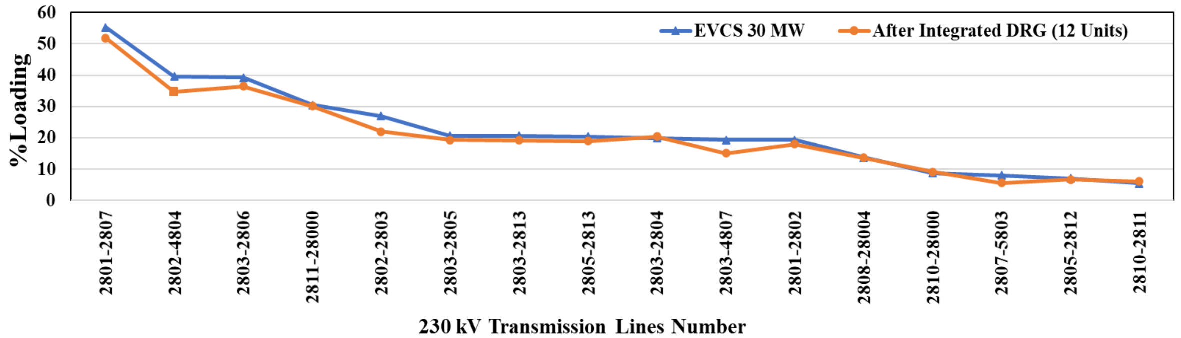

Figure. 18 The %loading of transmission lines of 230kV network after integrated DRG 12 units

The Fig. 15 shows the voltage profile of 115 kV network after integrated DRG 12 units that found the buses voltage in system was increased and all critical voltage buses were increased in system limit control. Especially, Voltage of bus no. 2706 was increased from 0.89 to 1.0 p.u. which can recovery system back to normal. For, the Fig. 16 shows the voltage profile of 230 kV network after integrated DRG 12 units found the buses voltage level was increased. In the Fig. 17 shows the %loading profile of transmission lines of 115 kV network after integrated DRG 12 units that found the %loading of transmission lines was decreased. Especially, a critical transmission line no. 2701-5708 was decreased from 100 to 92.90%. For the Fig. 18, it was shown the %loading profile of transmission lines of 230 kV network after integrated DRG 12 units that found the %loading of transmission lines in system was decreased. In addition, the study results have compared the power loss changing of system as shown in Fig. 19. In the Fig. 19, it found that the power loss increases from 134.42 to 177.18 MW under EVCS loading to 30 MW. After integrated the DRG, the power loss was decreased continuous every integrated the DRG follow critical voltage bus ranking by decreasing from 177.18 to 143.69 MW after integrated DRG 12 units.

6. Conclusions

This article presents the impact study of electric vehicle charging stations installed to the Thailand's North eastern power system and DRG integration planning to reduce power congestion for supporting the EVCS explanation in future. The purpose of this

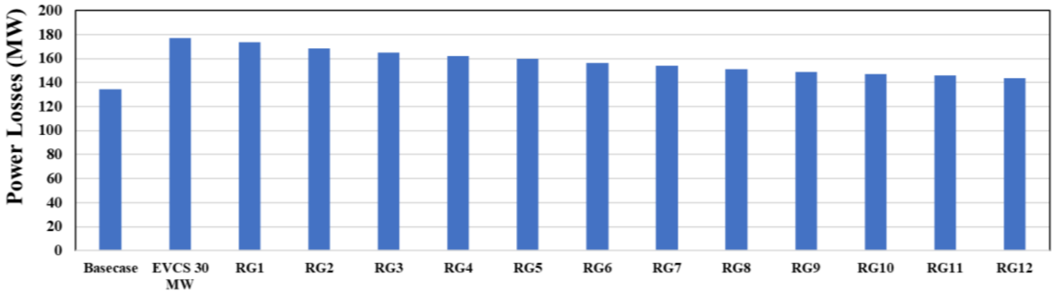

Figure.19 The power loss changing of system after integrated DRG 12 units

paper is the impact study under EVCS loading to determine the maximum EVCS loading and ranking the critical areas by using the repeated power flow calculation technique for DRG integration planning to reduce system congestion and increase system security.

This study has focussed the impact study in case the EVCS installed on the main road in North-eastern of Thailand. The main road for study is the Bankok-Nongkhai road with a length 624 km. The EVCS installed every 50 km with a total 11 stations. The EVCS have connected at 115 kV substation of 115 kV transmission line network. The study results have focused to determine the maximum EVCS loading and compared voltage and %loading of transmission lines changing during EVCS loading include finding the critical buses for DRG integration planning as well as the power loss changing in the system.

The study results found that each ECVS station could only increase the load by 5 MW when set voltage limit at 0.95-1.05 p.u. and increase the load by 30 MW when set voltage limit at 0.90-1.10 p.u. of 115kV network. It is caused that the power flow was congested. This condition, the study results can find the 12 critical voltage buses for DRG integration. In addition, the study results found that the voltage of critical voltage buses were increased, The %loading of critical transmission lines were decreased and power loss in system was decreased continuous every integrated the DRG follow critical area ranking.

Beyond purpose, this study results data can apply to Thailand power development plan (PDP) for determine the optimal integration areas of renewable power generation in future for improving Thailand power system stability.

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