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Enhancing voltage stability index after adding EVs charging station by using PV system

Dalal B. Azhar [1] Omar Muwafaq Al-Yousif [2]

[1,2]Department of Electrical Engineering, Mosul University, Iraq.

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Corresponding Author: Dalal B. Azhar

Email:
dalal.23enp28@student.uomosul.edu.iq

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Voltage stability, power system analysis, Electric Vehicle, Charging Station, PV system.

ABSTRACT

This research paper presents a comprehensive study of a modular system that has previously hosted electric vehicle charging stations. This research focuses on addressing the impact of incorporating these chargers through renewable energy sources, given their role in mitigating global warming and reducing dependence on conventional energy sources. Therefore, photovoltaic energy systems were used and integrated into a modular system using the ETAP program, after adding five charger stations at different power levels, which led to the voltage stability index dropping to less than 90%. An integrated photovoltaic system was modeled and added to the IEEE 30 Bus standards, incorporating chargers. Voltage stability analyses were conducted for both voltage analysis types in the sensitivity analysis and P-V and Q-V analyses. Detailed results were obtained, the most important of which was that the voltage stability index of the weakest conductors reached more than 95% after adding PV station, which is explained in detail in this paper.

Introduction

Increasing awareness among local and central governments is essential to harness the renewable energy sources available in our country, particularly photovoltaic (PV) energy. Iraq's proximity to the equator and its long, hot summers with abundant sunshine make PV energy a sustainable option[1], [2]. It can enhance the system's reliability and flexibility, especially given the current rise in demand, inadequate supply, and weak grid infrastructure. [1] PV energy offers numerous advantages that lead local engineers to prefer it over other renewable sources. Besides its capacity to convert sunlight into electricity, It has many advantages, including no moving parts, being pollution- and noise-free, and having a long lifespan. All of this makes it highly reliable, robust, and efficient. [3] The weak and unstable nature of Iraq's national electricity grid compels us to find useful and effective alternative solutions that suit the country's conditions and climate. A model standard found in the program's examples was used, and it was considered a miniature system for the Iraqi grid as a proposed solution for adding chargers to it and studying their impact. It was then improved, developed, and implemented systematically to suit Iraq's nature and climate. A photovoltaic system is ideal for this[3] (the focus of the research), especially after the addition of heavy loads to the grid (electric vehicle charging stations).

1. PV system in ETAP.

PV systems can be generated without emissions (CO_2), which helps reduce global warming and climate change, promotes sustainability, improves air quality, and conserves vital resources. They operate without the need for cooling, so they do not require water, and they support food security by enhancing biodiversity and reducing land degradation in solar farms. "According to the International Renewable Energy Agency (IRENA), replacing fossil fuel-based energy sources with solar energy can reduce carbon dioxide (CO_2) emissions by up to 3.6 gigatons per year by 2030" (IRENA, 2021). The following table shows the different types of energy sources and their associated carbon emissions.[4], [5], [6]

Table 1: CO_2 Emissions by Energy Source (gCO_2/kWh).

Energy Source	Carbon Emissions (gCO_2/kWh)
Coal	1000
Natural Gas	450
Solar Energy	0-20
Wind Energy	10-20
Hydropower	1-30

A grid-connected photovoltaic (PV) system (IEEE 30 bus standards) is designed to better meet the system's performance needs after the addition of charging stations. The panel size is calculated based on the system's power requirements to compensate for the shortfall caused by the addition of chargers. A PV system consists of PV panels, an inverter, and a converter, all connected in series. If we rank or prioritize PV systems, the inverter is the most important because it converts power from DC to AC [7]. Additionally, it ensures compatibility between the PV system and the electrical grid. It also manages and controls the amount of active power and voltage level through the power factor (P.F.), [8] which essentially represents the amount of reactive power in the system. The ETAP Software is used for treating many problems facing electrical systems, including voltage stability.[9], [10] Therefore, this software was employed to treat voltage stability after adding chargers or charging stations for electric vehicles and loading them to the maximum possible load while maintaining the system voltage within acceptable limits (including marginal and critical). Photovoltaic systems will be added, their locations carefully selected in IEEE 30 Bus Standards, and their impact on voltage stability will be studied. As for the type of photovoltaic panel, it will be connected to a 300.1-watt polycrystalline type, the full specifications of which are shown in Figure 1 below, with the following settings:

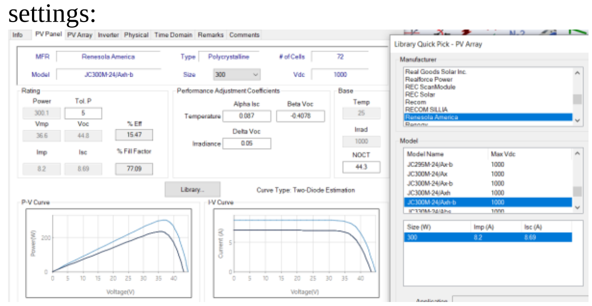

Fig.1: PV panel setting.

The model used for the photovoltaic system was designed in a simplified manner and without many details, because the main goal of using a photovoltaic energy system is enhancement, not detailed analysis or study.

No. of panels = (11 in series * 42 in parallel) = 462.

Power = Vmp * Imp = Vo.c * Is.c * derate factor (fill factor) = 300.1 W/panel.

kW.dc = V.dc * I.dc = 138.7kw.

and MPP kW = kW.dc * derate factor = 100kw.

as shown in Figure 2.

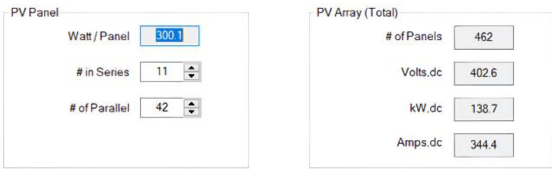

Fig.2: PV array setting.

As for the inverter, it is 250 kVA at 380 volts on the AC side. As for the efficiency, it was changed with the change in the load ratio, because the solar inverter for solar panels differs from other loads, as photovoltaic energy mainly depends on electrons. Therefore, the output of these inverters is greater, and thus their efficiency is greater too. Therefore, if we want to simulate it accurately, we must enter these ratios precisely, as shown in the following Figure 3.

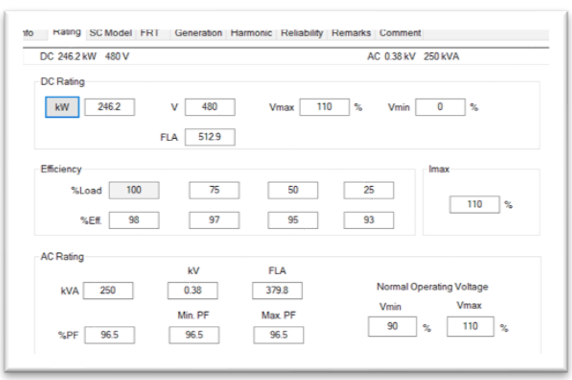

Fig.3: Solar inverter setting.

And we configured the **IP Location** system, and it was found that the longitude is 43.1155 and the latitude is 36.341 in Iraq, Nineveh Region, Mosul City. As is clear, the amount of solar radiation during the hottest month in Iraq, when the sun is directly overhead, according to the software's calculations, is equal to 799w/m^2.

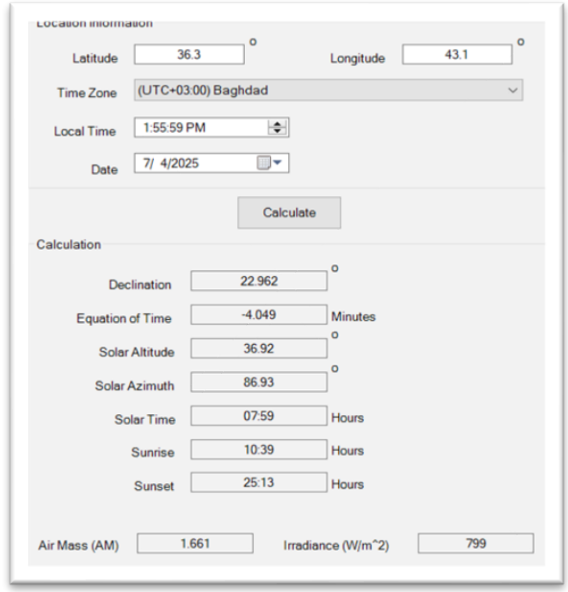

Fig.4: Calculating the amount of solar radiation.

After completing the installation of the panels and inverters, we connected a small protection circuit as shown in Figures 5 and 6, and then connected transformers to match the voltage between the photovoltaic system and the grid. A large station with many components was reduced to a small model with the same power output as shown in Figure 5.

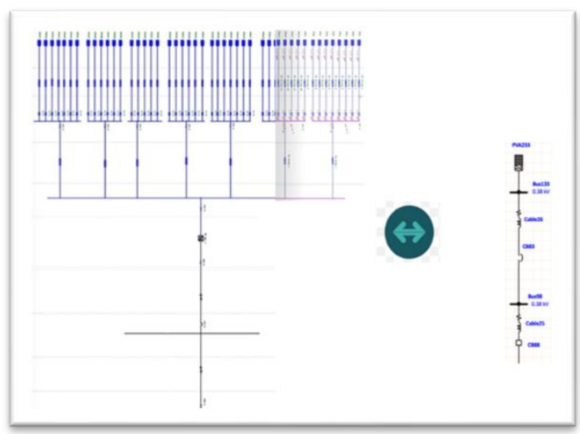

Fig.5: PV system Modeling.

And now I will do load flow analysis for PV system modeling as shown in Figure 6:

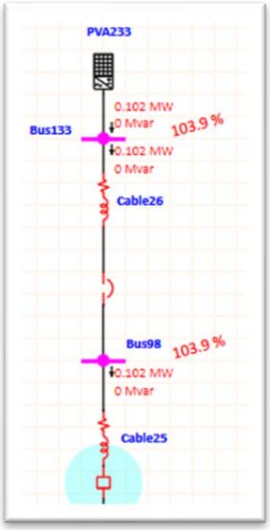

Fig.6: PV system Load flow.

2. Voltage stability analysis

Voltage Stability analysis shown in Figure 7, IEEE 30 Bus Standards in the ETAP software [11], [12]

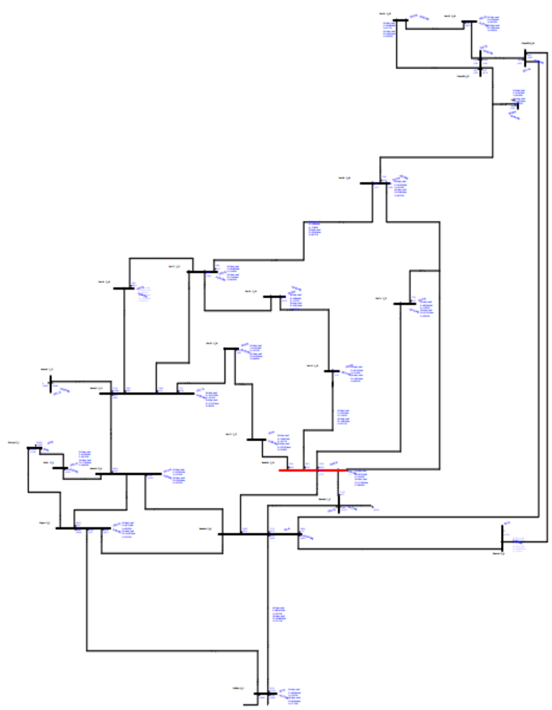

Fig. 7: Voltage Stability analysis in ETAP.

Figure 8 shows the chargers in a microgrid after they have been added to the system.

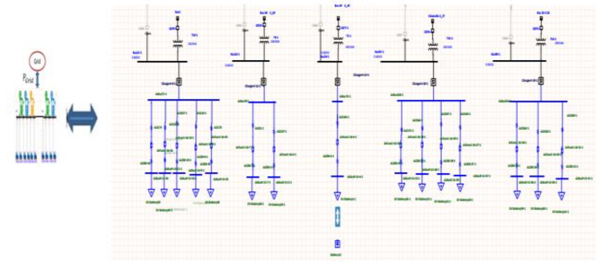

Fig.8: Chargers in IEEE 30 Bus.

After adding chargers to the weakest buses in the system, a hybrid system was developed. The same weakest buses were used to install PV panels[13], [14]. This helps transfer energy more efficiently along their paths. The following Figure 9 shows the buses equipped with a photovoltaic power station, their voltage, load flow analysis voltage ratio, their ranks, and the voltage index before installing the photovoltaic power station, as shown in the subsequent images and figures.

Fig. 9: Picture of the Hybrid station system.

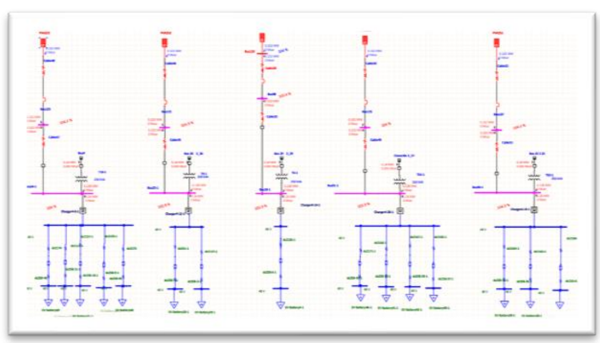

Fig.10: Load flow for the Hybrid system.

2.1 V-Q Sensitivity Analysis

a. **After adding chargers before the Enhancement**.

Below is a sensitivity analysis of voltage stability when adding chargers to the system:[15]

Table 2: Sensitivity Analysis before Enhancement.

V-Q Sensitivity Analysis Report			
Bus ID	**kV**	**Rank #**	**V-Q Sensitivity**
Bus23	0.38	1	1.000
Bus24	0.38	2	0.990
Bus18	0.38	3	0.983
Bus91	0.38	4	0.950
Bus90	0.38	5	0.944
Bus4	33	6	0.014
Bus 30 3_30	33	7	0.014
Bus 29 3_29	33	8	0.013
Bus 25 3 25	33	9	0.007
Cloverdle 3_27	33	10	0.006
Bus 19 3_19	33	11	0.005
Bus 18 3_18	33	12	0.005

The following figure represents a flowchart of a sensitivity analysis table. It will appear as shown below:

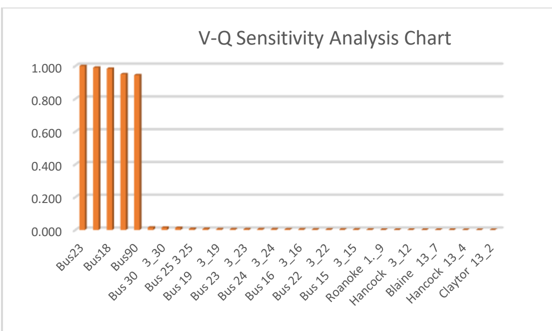

Fig.11: Chart of Sensitivity Analysis in ETAP.

b. After adding chargers and enhancements:

The same previous table will be repeated with the addition of PV stations, and the difference will be noted in Table 3 and Figure 12.

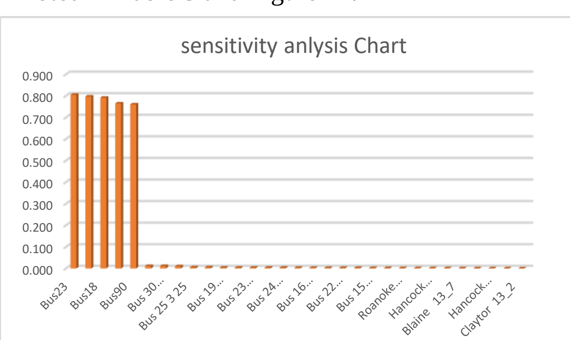

Fig12: Chart of Sensitivity Analysis in ETAP.

Table 3: Sensitivity analysis after adding PV system

V-Q Sensitivity Analysis Report			
Bus ID	**kV**	**Rank #**	**V-Q Sensitivity**
Bus23	0.38	16	0.805
Bus24	0.38	17	0.797
Bus18	0.38	18	0.791
Bus91	0.38	19	0.765
Bus90	0.38	20	0.760
Bus4	33	42	0.012
Bus 30 3_30	33	43	0.011
Bus 29 3_29	33	44	0.010
Bus 25 3 25	33	45	0.005
Cloverdle 3_27	33	46	0.005
Bus 19 3_19	33	47	0.004
Bus 18 3_18	33	48	0.004

As shown in the two tables and the Charts above, the rank of the same buses increased significantly after adding the PV station to them, and this is evidence of their increased stability. All of the above was in terms of the sensitivity of the system or its weakest Regions, and we were able to improve the stability of these Regions and strengthen[16]

2.2 P-V and Q-V Analysis.

a. After adding chargers before Enhancement.

After adding the chargers to the IEEE 30 Bus Standard system in the ETAP software, we conducted a second-type voltage stability analysis (P-V and Q-V Analysis) and found the following:

Table 4: P-V and Q-V Analysis.

P-V Analysis Summary						
Load Variation Pattern:	Constant PF			**Load Variation Location:**		Study Bus Only
Bus		**Load**	**Operating Load**		**Maximum Load**	
ID	**kV**	**Variation**	**%V**	**P (MW)**	**%V**	**P (MW)**
Bus 18 3_18	33	Yes	102.7	3.200	63.4	72.172
Bus 25 3_25	33	Yes	101.1	9.500	62.9	74.105
Bus 29 3_29	33	Yes	99.54	2.400	59.0	36.001
Bus 30 3_30	33	Yes	98.36	10.600	61.5	43.296
Bus18	0.38	Yes	91.22	0.126	50.9	0.460
Bus23	0.38	Yes	89.92	0.126	50.9	0.449
Bus24	0.38	Yes	90.84	0.126	52.5	0.456
Bus4	33	Yes	99.2	3.500	56.1	26.508
Bus90	0.38	Yes	93.04	0.126	53.0	0.487
Bus91	0.38	Yes	95.5	0.126	54.1	0.483
Cloverdle 3_27	33	Yes	101.7	0.000	63.9	64.483

b. After adding chargers and Enhancement.

Adding PV stations to the system enhances the active power in the system, thus covering the increased demand resulting from adding additional loads to electric vehicle charging stations. The following table 4 shows the voltage stability analysis (p-v analysis) after improvement by adding PV energy to the system.

The following table 5 shows the voltage stability index. This is done by adding the PV system gradually, each time 0.1 MW is added.[17], [18]

Table 5: P-V Analysis Summary after Enhancement.

Addition PV (Mw)	**Voltage stability index%**									
	Charging Station Buses					Weakest System Buses				
	Bus 23	Bus 24	Bus 18	Bus 90	Bus 91	bus 4	bus 30 3 30	bus 29 3 29	Bus 25 3 25	Cloverdle 3_27
zero	89.92	90.84	91.22	93.04	93.61	99.2	98.36	99.54	101.1	101.7
0.1Mw	91.45	92.35	92.72	94.31	95.02	99.32	98.48	99.66	101.2	101.8
0.2Mw	92.82	93.71	94.07	95.45	96.3	99.42	98.58	99.75	101.3	101.9
0.3Mw	94.06	94.94	95.28	96.46	97.46	99.5	98.67	99.83	101.3	101.9
0.4Mw	95.17	96.04	96.38	97.35	98.51	99.57	98.74	99.9	101.4	101.9

Results

Adding electric vehicle charging stations to the studied system will cause numerous disturbances to the network, particularly in voltage stability, given that the model under study is in an overvoltage state. [8] However, the voltage stability index will be particularly affected, even exceeding the marginal region (95%), as shown in Tables 5 and 4, where the voltage reached 89.92% in P-V analysis. By conducting a sensitivity analysis, we found that the areas to which the chargers were added represent the weakest areas of the system, with the highest ranks. Therefore, we sought to improve this system and make it more stable by adding photovoltaic power stations. After the Enhancement, it has been noticed that the voltage stability index has improved in the system, as is evident from Tables 5 and 4. The sensitivity analysis shows that the ranks of all buses, especially the weakest, have improved significantly, as shown in Tables 2 and 3 and Figures 11 and 12.

Conclusions

This research paper concludes that adding renewable energy plants, especially photovoltaic (which are ideal for exploitation in our country due to their proximity to the equator), would add active power to the system, enhancing voltage stability and improving voltage stability index, especially after expanding the electrical system or adding new loads (electric vehicle charging stations). The addition of enhancement using PV stations and gradually increasing from 0 to 0.4 MW in 0.1 MW steps significantly improved the system due to the increased active power. Regarding the system sensitivity analysis, it was found that this enhancement led to an increase in the weakest buses ratings from rank #1 to rank #16, which also led to an increase in the voltage stability index in the p analysis from 89.92% to 95.17%.

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