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The effect of Distributed Generation (Photovoltaic PV) on losses in electrical distribution network

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ABSTRACT:
Several engineering programs were used in this study for the purpose of studying and evaluating the integrated of photovoltaic systems with electrical distribution networks. The results recorded in this study represent losses in the electrical network to which photoelectric systems are connected. The main purpose of this study is to search in all matters of electrical grid losses that occur as a result of high penetration of solar energy systems and several different cases of loads. In this research we will study one case of load which is the case of loads is normal but the next study we will study the behavior of electrical losses in the case (maximum load, minimum load).

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I. INTRODUCTION:

The census is increasingly, economies and global energy consumption are increasing rapidly, especially in developed countries. It is expected that there will be an increase in the demand for electrical energy by 45% in 2035 [1]. Current electric energy is from burning of fossil fuels for example crude oil, coal, and natural gas. With all this, most of the traditional electrical energy sources are not enough to meet the large increase in the demand for electrical energy. In addition, the use of fossil fuels to generate electrical energy causes environmental problems due to the emission of greenhouse gases. The changes in the climate situation in the world, the large increase in the demand for electric energy and the significant rise in electricity prices all this led to a great concern in the world [2]. Therefore, most countries of the world are encouraging alternative renewable energy sources for the purpose of obtaining safe energy at reasonable and clean prices as well as reducing greenhouse gas emissions. These sources of renewable energy can help increase new job opportunities as well as the ability to deliver electrical energy to rural areas. Renewable energy sources such as solar, wind, hydro, and geothermal energy are likely to rank first in production in the near future [3,4,5].

With integration of solar system on distribution grids, a reversed power flow will be introduced with PV generation in addition to the loading level in every bus. This condition will reduce the real power losses, but does not in all cases.

II. METHODOLOGY

This paper begins with a literature review of the state-of-art in PV technology, relevant power system modelling standards. This paper consists of calculations completed with the aid of available computer software packages (ETAP1 and Excel2). Finally, based on the results, conclusion and recommendations are provided [6,7].

This electrical network consists of:
1. Utility Grid,
2. Bus-bar no. 22, divided as follows:
   a. Bus-bar 110 kV no. 1,
   b. Bus-bar 20 kV no. 14,
   c. Bus-bar 20 kV of the PV plant no. 1,
   d. Bus-bar 0.4 kV of residential loads no. 6.
3. Overhead transmission line and the specifications shown in the below table:

Table 1 the values of transmission lines.

Branch lines i-j	Nominal kV	Length km	Conductor type	mm^2	R-Ω	X-Ω	b-μS
Bus 1-bus 5	20	2.5	Cu	95	0.321	0.334	3.291
Bus 5-bus1	20	0.2	Cu	50	0.1	0.4	-
Bus 5-bus 10	20	1.5	Cu	95	0.321	0.334	3.291
Bus 10-bus 13	20	0.2	Cu	50	0.1	0.4	-
Bus 10-bus 15	20	1.65	Cu	95	0.321	0.334	3.291
Bus 15-bus 18	20	0.15	Cu	50	0.1	0.4	-
Bus 15-bus 21	20	1.95	Cu	95	0.321	0.334	3.291
Bus 21-bus 24	20	0.15	Cu	50	0.1	0.4	-
Bus 21-bus 26	20	1.45	Cu	95	0.321	0.334	3.291
Bus 26-bus 32	20	0.1	Cu	50	0.1	0.4	-
Bus 26-bus 34	20	1.75	Cu	95	0.321	0.334	3.291
Bus 34-bus 4	20	0.1	Cu	50	0.1	0.4	-

4. Power Transformer no. 8 and the specifications shown in the below table:

Table 2 the values of transformers.

Item of Tr.	U_n primary kV	U_n secondary kV	Capacity MVA	Z%	X/R
T25	110	20	16	10	20
T4	110	20	16	10	20
T1	20	0.4	1	5	3.5
TR2	20	0.4	1	5	3.5
TR3	20	0.4	630	4	1.5
TR4	20	0.4	1	5	3.5
TR5	20	0.4	1	5	2.5
TR8	20	0.4	400	4	1.5

5. Distributed Generation (Photovoltaic plant) no. 3, and the specifications below for each PV array:

a. Suniva ART245-60-3-1, mono-crystalline, 240 watts,

b. Design the power of inverter based on the following relation which is used in Europe:

$$0.8 < \left(P_{inverter} / P_{array}\right) < 1$$

6. Cable no. 2, XLPE, Cu, 185 mm^2, 100 m for each cable.

7. Industrial load no. 1 and residential loads no. 6, and the specifications shown in the below table:

Table 3 the values of loads at normal operating.

Item	Rated kV	App. Power MVA	PF %
Lump1	20	8	85
Lump2	0.4	0.4	91
Lump3	0.4	0.48	91
Lump4	0.4	0.25	90
Lump5	0.4	0.49	90
Lump6	0.4	0.51	89
Lump7	0.4	0.2	89

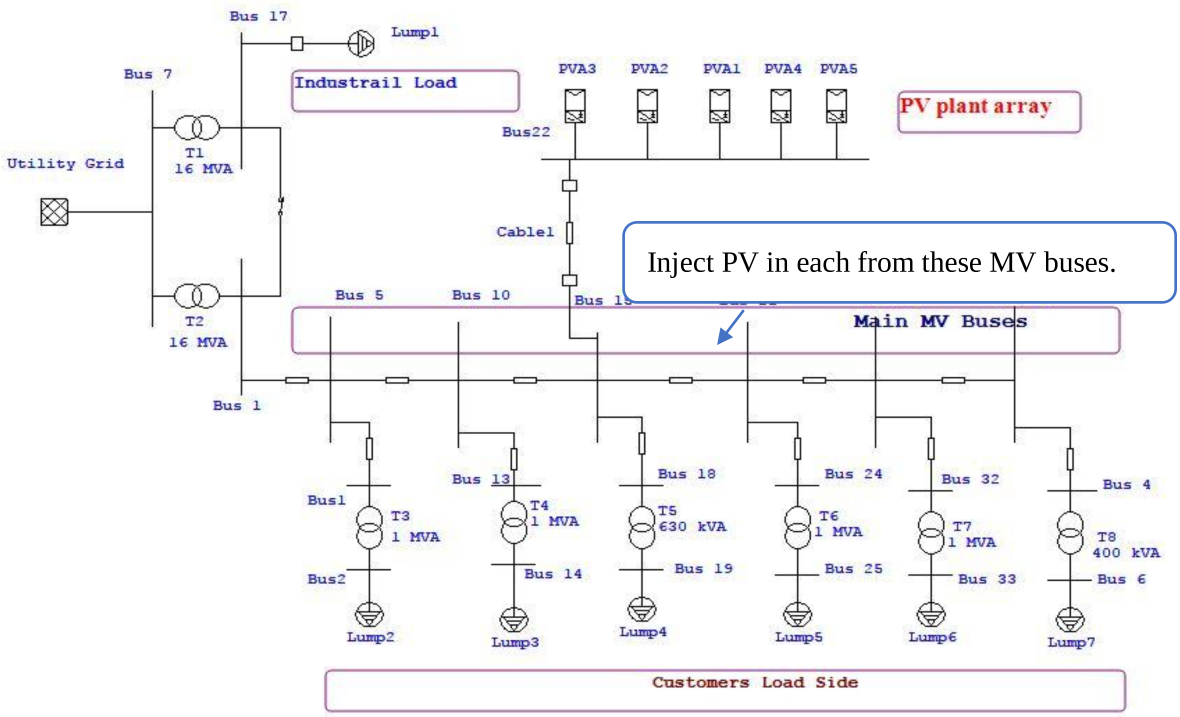

Figure 1 Single line diagram for electrical grid that I will study.

III. RESULTS AND DISCUSSION:

Effect of PV on losses in the distribution grid:

We will study effect of photovoltaic on losses in several different penetration level. The purpose of these values is to determineimpact of PV on medium voltage and low voltage buses.

The power losses in the distribution networks which supported with PV can be minimum due to reduce power flow in the feeder. Therefore, in this study different scenarios have been considered by ETAP program to analyze the losses effect on 7-buses distribution grid.

Table 4 Illustrate the Losses at Various PV Locations at normal load.

location PV connection	losses kW
without PV	56.441
bus 1	47.011
bus 5	41.623
bus 10	42.081
bus 15	47.279
bus 21	56.213
bus 26	72.642
bus 34	90.32

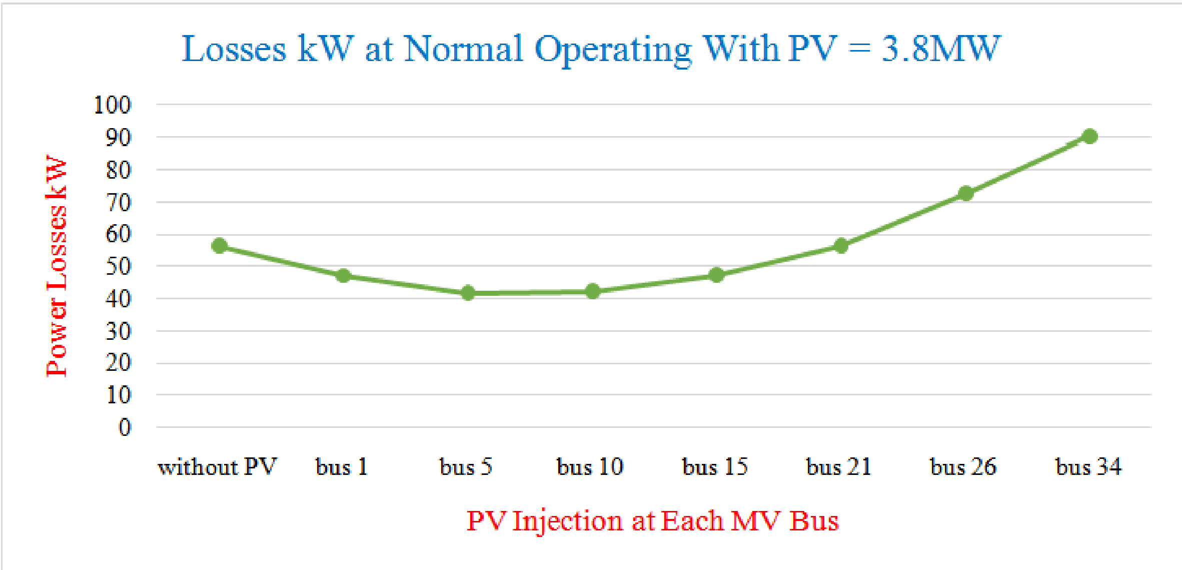

Figure 2 Illustrate the Losses at Various PV Locations at normal load.

From the table (4), we note that the lowest losses were obtained at the (bus 5) at PV power 3.8 MW, and it is value 41.623kW.
Hold on to the generator at the ideal node that was selected from the above cases, which owns less losses and then start injecting Power values for PV (located in the bus 5) from 0.5 MW to 6 MW and then choose the value of the injected Power that achieved less losses, and in the same time we take the minimum and maximum value of voltage in any bus for the grid, as shown in the table (5) and figure (3).

Table 5 Illustrate the Losses at Various value of active power at PV connected in Bus 5.

P_{PV}[MW]	losses[kW]	U_{min} kV	U_{max} kV
0.5	50.775	19.698	20.004
1	46.375	19.729	20.013
1.5	42.905	19.76	20.02
2	40.491	19.793	20.028
2.5	39.356	19.824	20.036
3	39.329	19.854	20.054
3.5	40.475	19.884	20.084
4	42.679	19.914	20.114
4.5	46.282	19.822	20.022
5	50.711	19.852	20.052
5.5	56.241	19.883	20.083
6	62.875	19.915	20.114

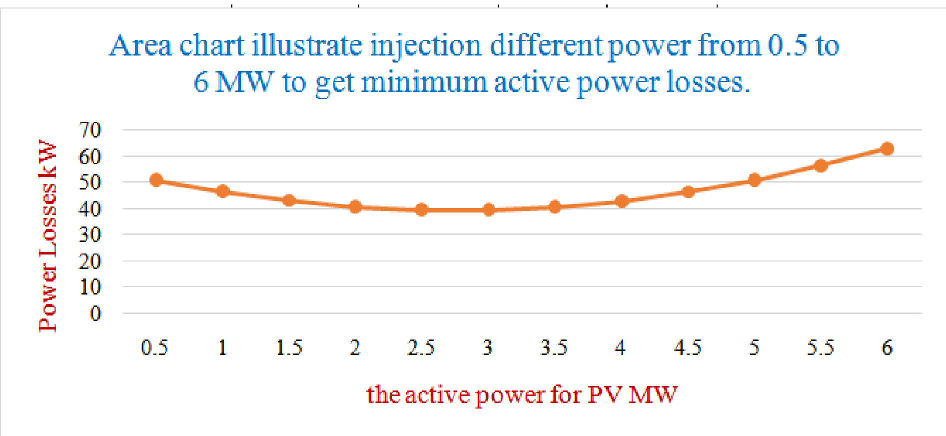

Figure 3 Curve between P_{PV}& losses illustrate the Losses at Various value of active power at PV connected in Bus 5.

At increasing the value of the power of the distributed generation we note that losses decrease reaching to 3MW and then back to increase. As shown in figure (3).
After selecting the (bus 5) as the best location for less losses now we will remain the PV at this node and calculate the penetration level that represents the ratio between the PV capacity to the total load of the distribution network, we find losses in all cases as shown in the table and figure (6,4), the relation for penetration level is:

$$penetration\ level\ \% = \frac{installed\ PV\ power}{total\ load\ demand};\ P_{PV} = 3.8MW\ \&P_{total\ load} = 8.9MW$$

Table 6 Illustrate losses in each penetration level, and minimum losses in PV capacity certain.

penetration level	PV capacity MW	Losses kW
without PV 0%	0	56.441
10%	0.89	47.031
20%	1.78	41.311
30%	2.67	39.116
40%	3.56	40.713
50%	4.45	45.703
60%	5.34	54.07
70%	6.23	66.062
80%	7.12	81.787
90%	8.01	104.772
100%	8.9	125.396

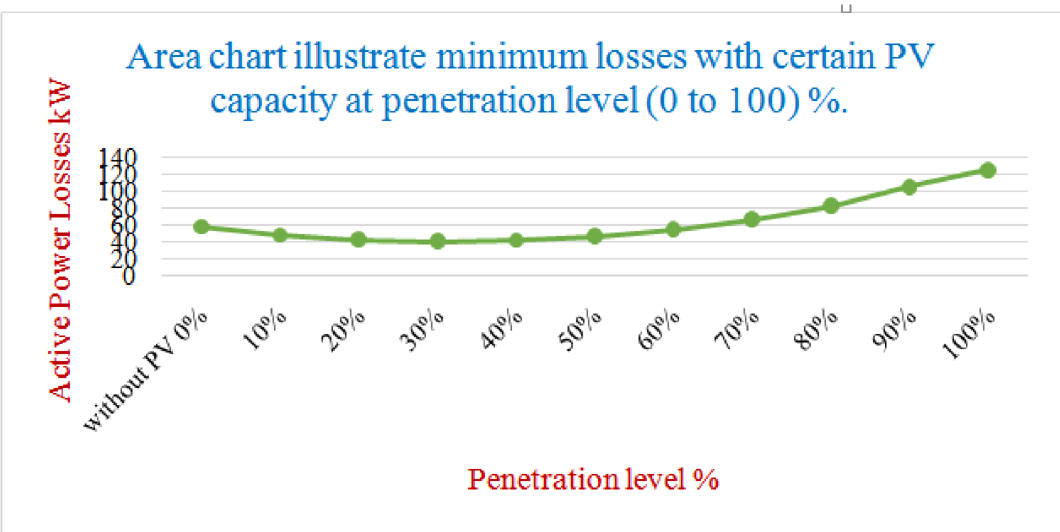

Figure 4 Illustrate losses in each penetration level, and minimum losses in PV capacity certain.

The Excel program showed that the U-shape route has been acquired, where the behavior of losses dropped until less at 30% and 40% penetration. After 30% and 40%, the losses start to increase again due to the reverse power from the bus connected to the PV. Figure 4shown that the advantage of the PV system connection is until 65% of the penetration level, where the losses after that will be more than before the installation of PV. The system losses up to that level of penetration would be more than those losses before PV integration. In this case, economic issues would be taken in concern.

IV. CONCLUSIONS:

The most important result from this study, in this network with a certain penetration level that is permitted to reduce the electrical network losses.For the purpose of overcoming the overload demand by placing a photovoltaic system, which in turn reduces the power flow on the associated line. The results showed that the location of the photovoltaic plant is in a place that has more high loads than others and this location leads to reduced losses. Because the losses depend on the amount of loads, the losses are reduced when the PV penetration level increases to a certain limit.

Therefore, higher power loss reduction in distribution networks in the presence of PV depends on the optimal size, location.

The state of the photovoltaic system, which contributes to reducing losses, is similar to that of the capacitor banks. But the difference between the two cases is that in the case of the photovoltaic plant it contributes and supports the network with the active power (P) and the reactive power (Q). As for the capacitor banks, it shares the network with a reactive power (Q) only.

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