Impact of the incorporation of photovoltaics distributed generation in electric distribution grids in Ecuador

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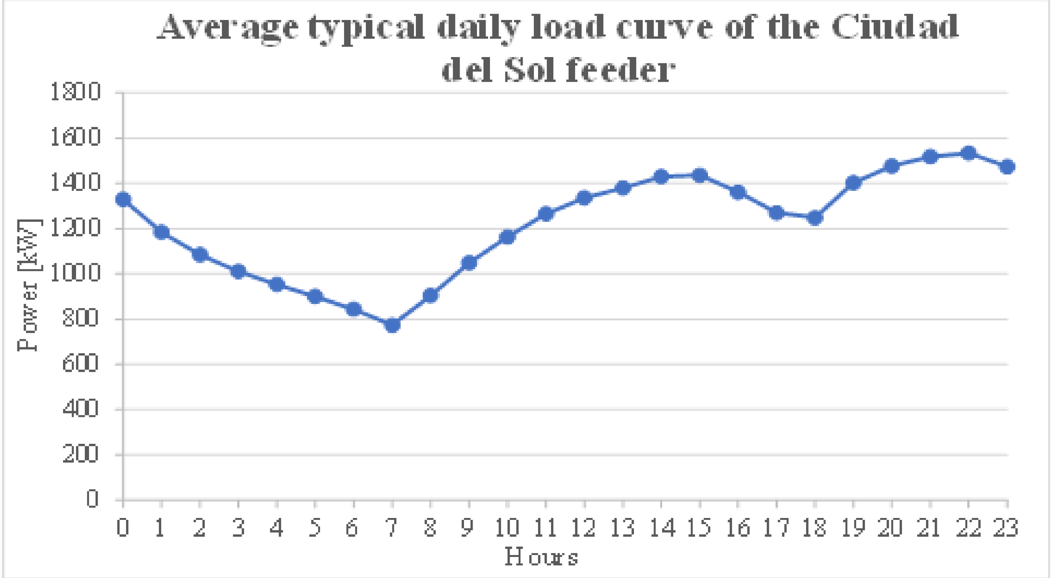
1. Introduction -

Interest in distributed generation (DG) has increased in recent years due to its close relationship with smart grids and the development of carbon-free generation technologies.

This is study evaluates the incorporation of DG in several consumers connected to the feeder Ciudad del Sol in a residential area of Machala, Ecuador. This feeder is one with the highest electricity demand. Depending on the range of energy consumption of each customer, different photovoltaics (PV) systems are proposed to meet their demands.

1. Experimental –

The study uses the feeder consumption data of the years 2019 and 2020. The month with the highest demand of the feeder was February 2020 with a 1888,97 kW.



The solar irradiation data were taken from the SOLCAST software and the solar map of Ecuador from the SCINERGY group, considering both the global horizontal component (GHI) and the direct the normal component (DNI). The data were taken from the SOLCAST software and the solar map of Ecuador from the SCINERGY group.

Month	SOLCAST		Solar map of Ecuador	
	GHI [kWh/m²]	DNI [kWh/m²]	GHI [kWh/m²]	DNI [kWh/m²]
January	4,2	2,3	4,5	2,2
February	4,1	1,8	4,4	1,8
March	4,3	2,1	4,2	2,3
April	4,6	2,8	4,2	3,2
May	3,7	1,6	4,3	2,3
June	3	1,2	3,3	2
July	3,1	1,5	3,2	2,1
August	3,1	1,7	3,5	2,5
September	4,1	2	4,1	2,7
October	3,9	1,8	4	2,5
November	3,9	1,6	4,2	2,3
December	4	1,7	4,2	2,2
Average	3,9	1,8	4	2,3

Four types of PV systems connected to the grid were designed because there are residential users with different amount of energy demands.
The loss factor (LF) is calculated using Equation 1:

$$LF = PSH.Panel\ Performance.Inverter\ performance \qquad (1)$$

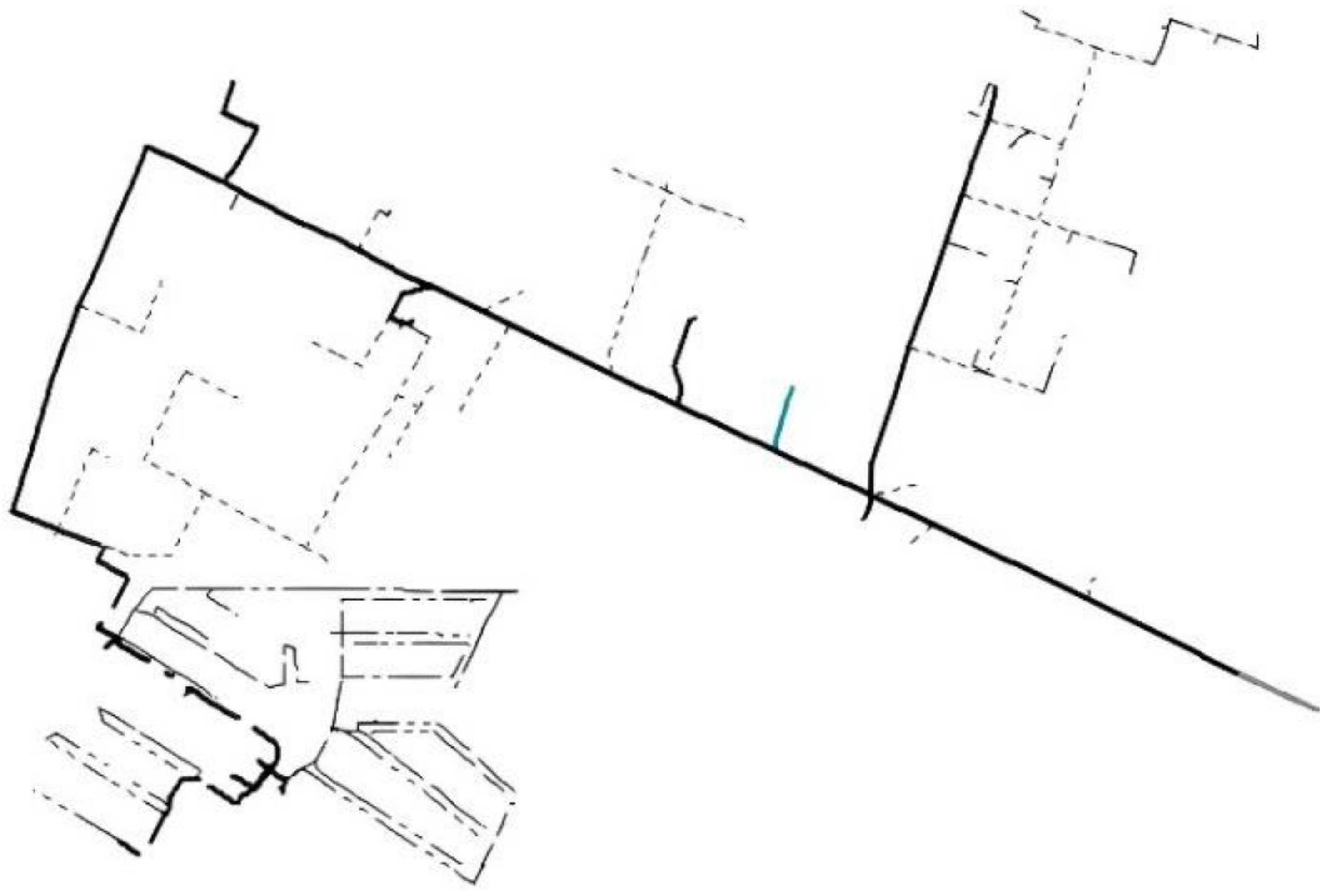
The area to install is defined by Equation 2:

$$Area\ to\ install\ [m^2] = Energy\ demand\ [kWh/day]/LF \qquad (2)$$

The design summary of the different solar PV systems proposed is shown in Table I

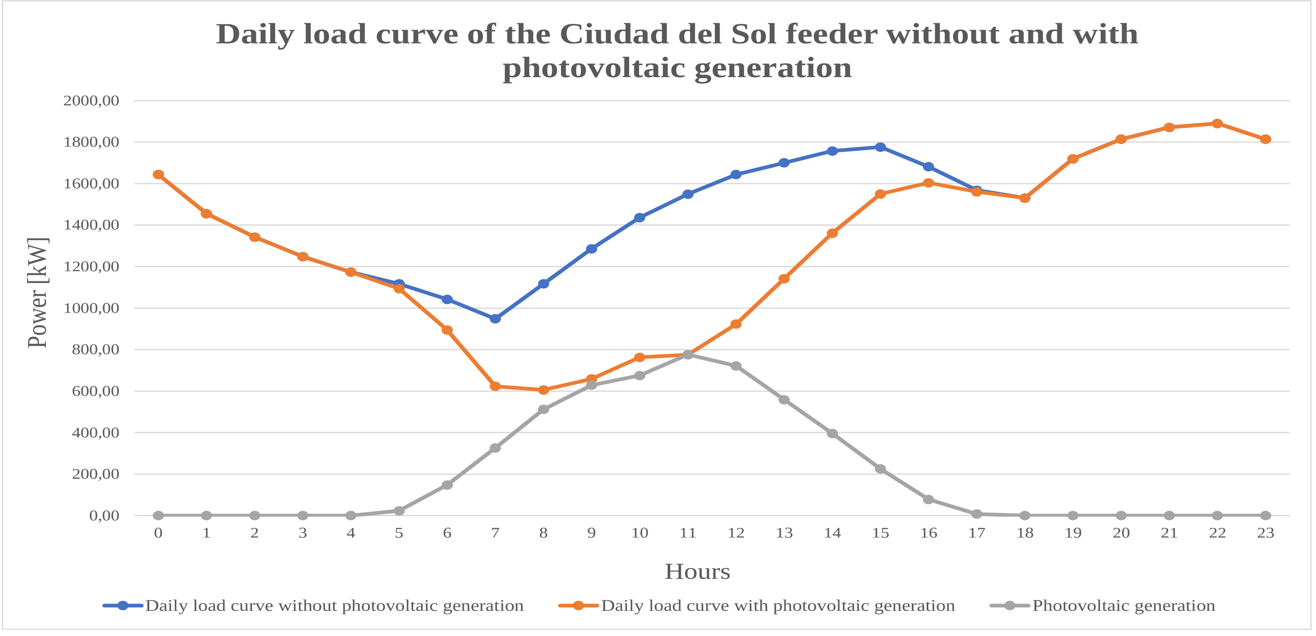
Monthly Energy Consumption per User [kWh/month]	Energy Consumption per Day [kWh/day]	Loss Factor	Area to Install [m²]	Solar Panel Power [W]	Area of the Solar Panels [m²]	Number of Solar Panels	Power Inverter Fronius Primo [kW]	Panels Layout
150 kWh < C < 300 kWh	5	0,5725	87,34	280	1,64	6	3	1 series of 6 panels
300 kWh < C < 500 kWh	10	0,5725	174,67	280	1,64	11	6	1 series of 11 panels
500 kWh < C < 760 kWh	16,66	0,5725	291,12	280	1,64	18	7,5	2 series of 9 panels
760 kWh < C < 2000 kWh	25,33	0,5725	442,50	280	1,64	28	6,1 - 11,7	2 series of 14 panels

Simulation (CYMDIST) of the PV System at Ciudad del Sol feeder
The entire feeder was parameterized and then loaded into the CYMDIST software. Fig. 2 shows its parameters, such as interconnections (2), nodes (609), source nodes (1) and sections (608).

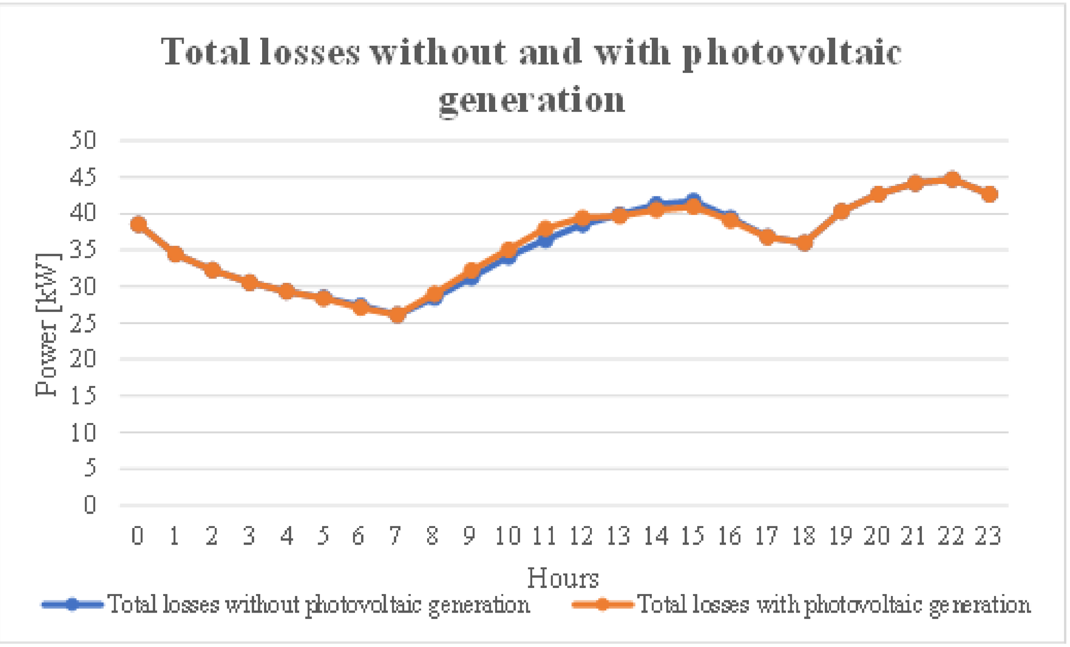


3. Results and Discussion -

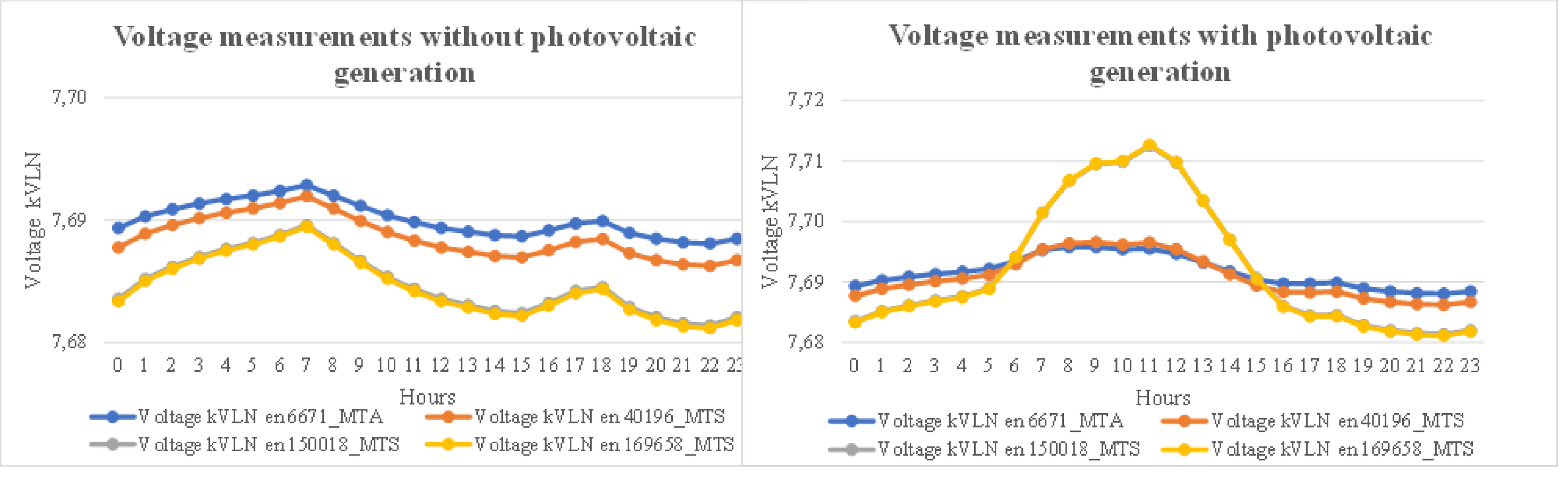
The PV system is expected to start operation at 06:00 and finished it at 18:00 hours. The figure shows the load profile of the feeder without and with PV DG, where, the section without DG shows very high demands especially at peak hours. The DG system supplies approximately 50% of the energy demand of the feeder.



The feeder has power **losses** in the conductors, transformers, and in other components. In this context, the PV systems reduce this losses up to 2,5% in periods of high radiation, however, overall losses are reduced slightly (1%).



The introduction of PV generation causes a slight voltage increase from 07:00 to 12:00 hours, which could represent a change in the feeder operation, but it is observed that from 13:00 hours it returns to the conventional operating state.



4. Conclusions –

The PV systems sized supply up to 50% of the demand of the Ciudad del Sol feeder, and are a profitable option for consumers. System losses, in conductors and transformers, have a reduction up to 2,5% in periods of high radiation, however, overall losses are reduced slightly (1%). Voltages increase slightly between 07:00 and 12:00 hours, but after 13:00 they return to previous values.

The peak demand (between 20:00 and 23:00 hours) of the feeder is not affected by the incorporation of PV systems. In this sense, the conventional electricity system must support the same peak demand. Therefore, no savings are reflected in the electrical infrastructure, unless energy storage systems are added, which at the moment is expensive.