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Prediction of photovoltaic generation for distribution network planning

[1]Miquel Ramon-Marin, [2]Andreas Sumper, [2]Roberto Villafáfila-Robles, [2]Carlos González-de-Miguel

[1]Endesa Distribución Eléctrica S.L., Planificación y Calidad de la Red, Av. Vilanova 12, 4ª Planta, 08018 Barcelona, Spain

[2]E.U. d'Enginyeria Tècnica Industrial de Barcelona – Dept. Ingeniería Eléctrica

C/Compte Urgell, 187, 08036 Barcelona, Spain

miquel.ramon@endesa.es, andreas.sumper@citcea.upc.edu, roberto.villafafila@citcea.upc.es, carlos.gonzalez@citcea.upc.edu,

Abstract— **Nowadays utilities must optimize the utilization of their distribution networks, analyzing possibilities from technical, economic and legal point of view, and have to face several challenges. One of them is the strong presence of renewable generators [1], which are promoted by administrations and represent and answer to several social needs [2,3], as security of energy supply, the appearance of a new local industrial sector operating globally, and growing price of conventional primary sources. But this means a revolution in the way transport, and specially distribution networks are planned, developed and exploited [4]. Present paper begins an analysis of the impact of this revolution from the distributor's point of view, situating the actual boundary conditions in Spain and focusing on medium voltage network.**

Index Terms- Distribution network planning, renewable generators, electricity demand, medium voltage, prediction of photovoltaic generation.

I. INTRODUCTION

This article wants to cope with problems associated with optimization of investment, concerning planning of new and utilization of existing electrical distribution infrastructures, motivated by distributed generation (DG).

II. IMPACT OF RENEWABLE GENERATORS ON DISTRIBUTION NETWORKS PLANNING

Regarding medium voltage (MV) distribution network, utilities usually know measurements in head of MV lines, the Feeder Measure. But this measure includes distributed energy generation, and it is not possible to know the real demand from loads in the line, the Costumers Demand, or even the accumulated demand in the HV/MV substation, because actual legislation in Spain makes not mandatory for medium and small generators to install detailed registered measures that could give vital information to distributor.

This article proposes a methodology to reduce suppositions, making possible to have a simple way to estimate real generation rate of renewable generators present in an area, in one concrete moment of the past, based in historic data available, and even, based in those data, to predict future situations in the DN, with the equation:

$$\text{Feeder Measure (F)} = \text{Costumer Demand (D)} - \text{Dist. Generation (DG)} \quad (1)$$

Costumer Demand (D) can be estimated from equation (1). Feeder Measure (F) is known through measure at feeder head at substation. On the other hand, Distributed Generation (DG) can be obtained from power generation measurements or even from other source.

III. PHOTOVOLTAIC GENERATION PREDICTION

In order to have real data, it has been focused the attention in a concrete geographic area, Northeast of Spain. On this area, it have been solicited and obtained [5] the hourly solar global irradiance historical data for the period 2006-2008, data corresponding to five automatic meteorological stations that form an irregular square with 33 x 34 km sides. Data consists on solar global irradiation measured in Watts/m2 over a flat surface in station location.

A. Analisys of irradiation data

Question made here is how different irradiation is, depending on physical location of the plant, to get a better knowledge of variation of the prime mover [4] of the PV generation plant. So a Pearson's matrix correlation is done, with all data set 2006-2008. All Pearson p-values have had a result of 0,000. As said in [4], to get a better correlation, it has also been done a Spearman's ranks correlation matrix, calculating ranks for data. Results can be seen in Table I.

TABLE I. FINAL SPEARMAN CORRELATIONS BETWEEN STATIONS

Meteorological Stations				
Stations	*RANKS_MS1*	*RANKS_MS2*	*RANKS_MS3*	*RANKS_MS4*

RANKS_MS2	0,969			
RANKS_MS3	0,973	0,989		
RANKS_MS4	0,957	0,976	0,977	
RANKS_MS5	0,970	0,985	0,991	0,979

This very high correlation between irradiation measured by different stations, all over 0,95 (value of 1 would be lineal) is surprising, considering distance and different height from sea level between stations. So its possible to deduce that we can know, with a small error, the irradiation in any sunny place in the study area, if we dispose of data from any only station inside the area, in any moment of the year.

B. *Analisys of PV power generation data*

After that, it has been studied generation data. The question made in this case is how similar are generation patterns for different plants in the area of study, if they can be considered as independent random variables in a stochastic electrical load flow simulation, or as said in [4], stochastic generators with the same prime movers (sun, wind, etc.) within the same geographical area are not independent.

It has been studied four plants, three forming a small park situated on the same location, G1 (100 kW), G2 (50 kW), G3 (100 kW), and a big plant situated in another place, south from them, G4 (1.200 kW) and separated by 56 km. The study is focused on active power generation. These measures are taken every 15 minutes, but an average every four measures was done, to get hourly data that could be compared with irradiation data set. The data set analyzed is the month of July in 2008, where all data sets match.

Pearson's matrix correlation for the considered period gives high values, with all Pearson p-values with a result of 0,000. Also Spearman's correlations were done, results on Table II.

TABLE II. FINAL SPEARMAN CORRELATIONS BETWEEN GENERATORS

Photovoltaic generators			
PV	***RANK_G1***	***RANK_G2***	***RANK_G3***
RANK_G2	0,976		
RANK_G3	0,964	0,944	
RANK_G4	0,919	0,915	0,908

As we could see analyzing irradiation data, there are very high correlation factors between PV plants at the study area, so we can say that generation profile are quite similar for PV plants at the area, and is quite clear that PV generators within the same geographical area can't be simulated in a stochastic load flow as independent random values.

C. *Generation versus irradiation*

Finally, is important to analyze relation between final power generation and measured solar global irradiation in the area of study, to know if they could give the Y an X axis of a mathematical function for the area.

TABLE III. GENERATION VS IRRADIATION

Active power generation (kW) versus irradiation (W/m2)				
	RANK_G1	***RANK_G2***	***RANK_G3***	***RANK_G4***
RANKS_MS1	0,926	0,922	0,905	0,966
RANKS_MS2	0,941	0,936	0,919	0,970
RANKS_MS3	0,929	0,925	0,907	0,973
RANKS_MS4	0,950	0,944	0,927	0,951
RANKS_MS5	0,928	0,923	0,906	0,970

As it can be seen on Table III, Spearman's correlations between all PV generators and stations are all over 0,90, so solar irradiation can be used as a very good predictor of photovoltaic generation.

IV. CONCLUSIONS AND FURTHER WORK

It has been introduced how renewable stochastic generators impact in distributed network planning, and described a simple methodology to face the lack of detailed generation measures for network planning.

Later, that methodology has been applied to PV distributed generators, analyzing a real geographical area in Northeast of Spain, using historical solar global irradiation and PV generation data set from that area, and concluding that meteorological data has a high correlation in the studied area, that PV generation plants are clearly not independent random variables and have also big correlation factors, and finally, deducing that solar irradiation, even from an only meteorological station in the area, is a very good predictor for PV power production.

Further work has to be done to validate and generalize the given correlation factors with more extended data, in order to obtain a model of PV generator for stochastic power flows. It would be also interesting to know the geographical limits of the valid correlations from a station determining its boundaries.

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