

# Integration of distributed energy resources in the distribution system expansion planning considering a method of forecasting EV charging demand: Study data

Table I shows the operational scenarios, while the data for the substations is shown in Table II. The demand data for each node is shown in Table III. The parameters related to DG units are shown in Table IV– Table VI. Also, energy storage systems were considered to have a capacity of 1000 kW, an investment cost of US\$ 1000/kW, and a life cycle of 15 years.

TABLE I  
OPERATIONAL SCENARIOS.

Scenario	Time blocks	Sub-block	Demand factor (pu)	Wind speed (m/s)	Solar irradiation (W/m <sup>2</sup> )	Charging demand (kW)	Hours
1	1	1	0.9482	8.550	836.10	1671.39	147
2	1	1	0.5776	6.774	445.80	421.052	90
3	1	1	0.8381	7.315	28.900	3653.15	255
4	1	1	0.6305	4.135	580.20	1967.42	192
5	1	1	0.9054	7.911	354.70	3107.77	271
6	1	1	0.8041	5.731	163.40	146.112	204
7	1	1	0.7638	6.250	661.50	821.600	207
8	1	1	0.7240	10.37	939.40	2683.42	252
9	1	1	0.8706	9.352	773.00	1350.23	332
10	1	1	0.6774	5.029	220.70	2296.06	234
11	1	2	0.6924	6.757	0.0000	508.750	239
12	1	2	0.8500	5.229	0.0000	3370.71	256
13	1	2	0.6345	5.812	0.0000	1461.93	201
14	1	2	0.7823	8.946	0.0000	2942.19	263
15	1	2	0.8160	7.798	0.0000	3842.10	352
16	1	2	0.7463	7.279	0.0000	1039.07	220
17	1	2	0.5965	6.262	0.0000	169.300	107
18	1	2	0.8901	9.841	0.0000	2114.84	98
19	1	2	0.7174	4.444	0.0000	1761.82	213
20	1	2	0.6643	8.313	0.0000	2528.26	235
21	2	1	0.8672	7.398	101.90	2069.87	150
22	2	1	0.5219	4.972	737.80	267.150	84
23	2	1	0.7122	8.046	465.00	3571.66	217
24	2	1	0.7909	10.89	847.40	2434.93	214
25	2	1	0.6241	9.502	638.70	3046.04	187
26	2	1	0.7895	6.285	282.50	1087.61	212
27	2	1	0.8239	3.997	546.90	1633.58	349
28	2	1	0.7606	6.825	5.1000	3956.66	286
29	2	1	0.6715	5.689	153.60	2783.77	300
30	2	1	0.5832	8.745	359.70	3300.00	197
31	2	2	0.7551	5.547	0.0000	2913.38	231
32	2	2	0.5791	9.192	0.0000	202.631	263
33	2	2	0.8362	7.579	0.0000	3263.47	272
34	2	2	0.6691	4.205	0.0000	627.560	182
35	2	2	0.6328	7.105	0.0000	1326.29	252
36	2	2	0.7999	8.310	0.0000	3731.72	315
37	2	2	0.7099	6.334	0.0000	2364.33	198
38	2	2	0.6034	5.959	0.0000	2658.33	280
39	2	2	0.5257	6.699	0.0000	1724.57	79.0
40	2	2	0.5554	4.923	0.0000	2077.29	124

TABLE II  
SUBSTATION DATA.

$s$	$SI_i^S$ (kVA)	$SF_i^S$ (kVA)	$C_i^S$ (kUS\$)	$\zeta_i^S$ (ton/MWh)
21	10000	5000	750	0.5600
22	10000	8000	1200	0.5600
23	10000	8000	1200	0.5600
24	8000	7000	1050	0.5600

TABLE III  
DEMAND DATA.

Node	Period 1	Period 2	Node	Period 1	Period 2
1	4000	10402	13	850	2063
2	500	1429	14	1990	2488
3	2761	3701	15	1020	1275
4	463	1578	16	0	1960
5	444	1555	17	1512	2890
6	860	1701	18	0	2653
7	2120	4150	19	0	1425
8	888	1110	20	0	1984
9	1672	2090	21	0	0
10	1268	2835	22	0	0
11	1764	2205	23	0	0
12	812	2015	24	0	0

TABLE IV  
GAS TURBINE DATA.

$\bar{P}_f^{gt}$ (kW)	2000	$Q_{f,1}^{gt}$ (kVAr)	-857
$P_{f,1}^{gt}$ (kW)	1807	$Q_{f,2}^{gt}$ (kVAr)	0
$P_{f,2}^{gt}$ (kW)	2000	$Q_{f,3}^{gt}$ (kVAr)	857
$P_{f,3}^{gt}$ (kW)	1807	$Q_{f,4}^{gt}$ (kVAr)	1428
$P_{f,4}^{gt}$ (kW)	1400	$\zeta^{wt}$ (ton/MWh)	0.5600

TABLE V  
PHOTOVOLTAIC MODULE DATA.

$\bar{P}_u^{pv}$ (kW)	100	NOCT (°C)	45
$\zeta^{pv}$	0.0584	$\delta$	-0.004
$C_u^{pv}$ (US\$/kW)	700	$c^{opv}$ (US\$/kWh)	0.0004

TABLE VI  
WIND TURBINE DATA.

$\bar{P}_k^{wt}$ (kW)	2000	$Q_{k,1}^{wt}$ (kVAr)	-1605
$P_{k,1}^{wt}$ (kW)	1194	$Q_{k,2}^{wt}$ (kVAr)	-575
$P_{k,2}^{wt}$ (kW)	1915	$Q_{k,3}^{wt}$ (kVAr)	0
$P_{k,3}^{wt}$ (kW)	1877	$Q_{k,4}^{wt}$ (kVAr)	1085
$P_{k,4}^{wt}$ (kW)	1205	$\zeta^{wt}$ (ton/MWh)	0.0276
$C_k^{wt}$ (US\$/kW)	1000	$c^{owt}$ (US\$/kWh)	0.001

The candidate nodes for the installation of wind turbines, photovoltaic modules, non-renewable generators, EV charging stations, and energy storage systems, are respectively:  $\Omega_{wt} = \{4, 5, 9, 11, 16, 19\}$ ,  $\Omega_{pv} = \{3, 4, 7, 8, 10, 13, 14, 15, 19\}$ ,  $\Omega_{gt} = \{3, 5, 9, 11, 14\}$ ,  $\Omega_R = \{3, 4, 6, 8, 13\}$ , e  $\Omega_b = \{4, 7, 8, 12\}$ . The PV units have a nominal power capacity of 100 kW and are composed by 40 modules with 2.5 kW each. A maximum of 40 generators of this type can be installed throughout the system. The power factors for

PV and WT/GT units are defined as 0.98 and 0.90, respectively. Table VII presents the data for the two alternative EV charging stations. Finally, Fig.1 shows the initial system topology.

TABLE VII  
EV CHARGING STATION DATA.

$c$	$P_c^{PR}$ (kW)	$C_c^{PR}$ (kUS\$)
1	330	3000
2	110	1000

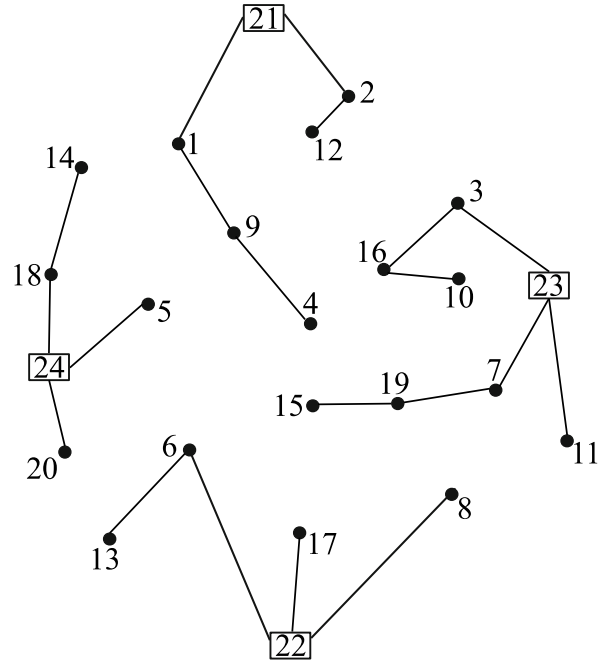


Fig. 1. Initial topology of the 24-node system.