



## Bidding and Operating Planning of a Virtual Power Plant in a Day-Ahead Market

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### Abstract

In this study, it is aimed to determine the optimum bidding and operating planning of a Virtual Power Plant (VPP) in the energy market to obtain maximum profit. For this purpose, the VPP containing a Wind Power Plant (WPP), a Photovoltaic Power Plant (PVPP), and an Energy Storage System (ESS) is composed on the IEEE 6-bus test system with Distributed Generators (DGs). The bidding planning and operating scheduling of the components of the VPP participating in the Day-ahead Market (DAM) are decided hourly for a day. Thus, SGS is aimed to gain maximum profit. The proposed problem has been modeled as Mixed Integer Linear Programming (MILP) in GAMS software and solved with CPLEX solver to obtain optimum results. The obtained results show that the model is applicable and the method is valid.

### Key Words

*“Virtual power plant, day-ahead market, optimization, renewable energy systems, distributed generators, energy storage system”*

## 1. Introduction

Nowadays, the need for energy is increasing with the development of the technology. Due to environmental problems, renewable energy units are preferred in many countries for electricity generation. However, uncertain and variable generation of renewable energy units is a problem for electricity market participants. Combining renewable energy units with technologies such as conventional generation units, storage systems, controllable loads, and electric vehicles can be a solution to overcome these problems. It is possible with Virtual Power Plant (VPP) to operate as a single unit with combining individually operated different distributed energy systems. VPP operator decides optimum operation and bidding planning to be offered to the market with considering the operational constraints of VPP components in the electricity market.

There are many studies that carry out research on the VPP energy management. Othman et al. (2017) have combined different optimization algorithms based on modification of big bang big crunch method for electrical energy management in an unbalanced distribution networks using VPP concept. They aim to minimize purchased energy from the grid. Abdolrasol et al. (2018) have presented a novel binary backtracking search algorithm for an optimal scheduling of VPP that consists of microgrids and distributed generation systems. Karimyan et al. (2016) have formed a VPP with the aggregation of distributed energy resources and determined the bidding strategy of it in the joint energy and reserve markets. Hannan et al. (2019) have formed a VPP in the IEEE 14-bus system including microgrids integrated with renewable energy sources and proposed a novel optimal schedule controller using binary particle swarm optimization. Wei et al. (2018) have proposed a bi-level scheduling model for virtual power plants including distributed thermostatically controlled loads and renewable energy. Vahedipour-Dahraie et al. (2020) have proposed a risk-based stochastic framework for energy and reserve scheduling of a VPP with considering demand response and uncertainties. Wozabal and Rameseder (2010) have presented a multi-stage stochastic programming approach to optimize the bidding strategy of a VPP which operates on the Spanish spot market. Gou et al. (2021) have presented a new optimal operation method for complex VPP that aggregates wind power, combined heat and power units, gas boilers and thermal and electrical loads by considering market transaction mechanism. Naval and Yusta (2020) have proposed a VPP model with the integration of water-energy management to maximize the annual operating profit of the VPP. They applied the model on a large irrigation system. Behi et al. (2020) have implemented a realistic VPP in Western Australia containing 67 dwellings to compute costs and benefits. Sadeghi et al. (2021) have studied the optimal bidding strategy of a VPP in the day-ahead energy market and frequency regulation market. They applied a deep learning-based approach for uncertainties. Vahedipour-Dahraie et al. (2020) have presented the optimal bidding strategy problem of a VPP that participates in the day-ahead, real-time, and spinning reserve markets. They also demand response programs to minimize consumption costs of the customers. Lazaroiu et al. (2015) have optimized operation of a VPP owner participating in the day-ahead market and including distributed energy resources, energy storage systems, and generating units to maximize the overall profit. Rahimi et al. (2021) have proposed a stochastic scheduling problem for a VPP model consisting of conventional generators, wind turbines, photovoltaic panels, photovoltaic-thermal panels, energy storage systems, boilers, and combined heat and power. They studied on the IEEE 33-bus distribution test system and used GAMS software/CPLEX solver.

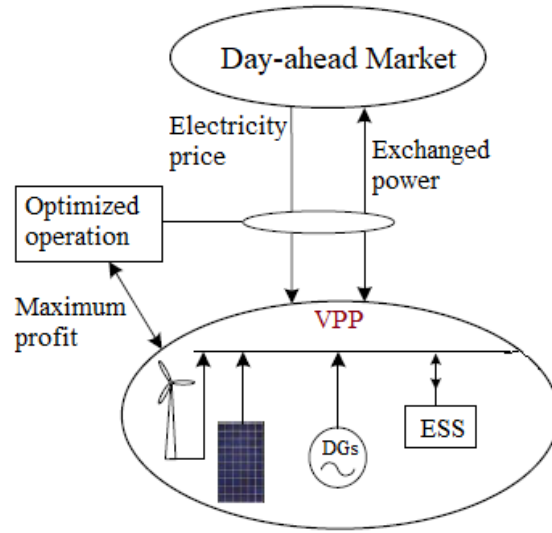
In this study, a VPP model is presented to determine optimal bidding and operation strategy of it in a Day-Ahead Market (DAM). It aims to maximize expected profit of the VPP. The VPP is applied on the IEEE 6-bus test system having Distributed Generators (DGs) by including a Wind Power Plant (WPP), a Photovoltaic Power System (PVPP), and an Energy Storage System (ESS). The problem is formulated as Mixed Integer Linear Programming (MILP) and modeled by GAMS software. The optimum results are obtained with CPLEX solver.

## 2. Model Description

The VPP increases the operational flexibility by combining different generation technologies in a single power system and provides performance improvement by combining individual distributed energy resources in the electricity market. The DAM is a system which energy transfer offers and trade are made the day before in order to balance the supply-demand and capacity energy in the electricity markets. The VPP owner participating in the DAM presents sold/purchased energy bidding and operates its components in a way that providing maximum profit. The VPP model and interaction with the electricity market is shown in Figure 1.

The VPP model consists of the WPP, the PVPP, the ESS, and the DGs. The VPP owner participates in the DAM and aims to maximize its daily profit. It decides the amount of energy to sell or purchase (exchanged power) during the electricity market and optimum operation of the DGs and ESS.

The VPP operator solves the optimal planning problem with respect to the meteorological data (wind speed, solar radiation, ambient temperature) and the data for market prices. By solving the problem, the bidding and operating scheduling of the VPP is determined to present in the electricity market.



**Figure 1.** The VPP Model in the Electricity Market

### 3. Model Formulation

In this section, the mathematical model of VPP components, objective function and power balance are explained.

#### 3.1. VPP Components

##### Wind Power Plant

Wind turbines can start to generate electrical energy at a certain wind speed known as the cut-in speed. They stop to generate electrical energy at the cut-out wind speed. At a determined wind speed for each wind turbine, the power obtained from the system reaches the highest value. This greatest power is called the nominal power and this wind speed is called the nominal speed. The output power of WPP is calculated by using Equation 1.

$$P_t^{wt}(v_t) = N^w \times \begin{cases} 0, & v_t < v_{in} \\ P_{rtd}^{wt} \times \left( \frac{v_t - v_{in}}{v_{rtd} - v_{in}} \right)^3, & v_{in} \leq v_t \leq v_{rtd} \\ P_{rtd}^{wt}, & v_{rtd} \leq v_t < v_{out} \\ 0, & v_{out} \leq v_t \end{cases} \quad (1)$$

where  $P_t^{wt}(v_t)$  is the output power of the WPP at hour  $t$  (MW),  $N^w$  is the number of wind turbines,  $v_t$  is the wind speed at hour  $t$  (m/s),  $v_{in}$ ,  $v_{rtd}$ ,  $v_{out}$  are the cut-in, rated and cut-out wind speeds, respectively (m/s),  $P_{rtd}^{wt}$  is the nominal power of the wind turbine (MW).

##### Photovoltaic Power Plant

The output power of PVPP is calculated by using Equations 2-6.

$$T_t^{cell} = T_t^{amb} + SR_t \times \left( \frac{NOT_{cell} - 20}{0.8} \right) \quad (2)$$

$$I_t = SR_t \times [I_{scc} + K_{ctc} \times (T_t^{cell} - 25)] \quad (3)$$

$$V_t = V_{ocv} - K_{vtc} \times T_t^{cell} \quad (4)$$

$$FL = \frac{V_{Max} \times I_{Max}}{V_{ocv} \times I_{scc}} \quad (5)$$

$$P_t^{pv}(SR_t) = N^{pv} \times FL \times V_t \times I_t \quad (6)$$

where  $T_t^{cell}$  is the temperature of solar cell at hour t (°C),  $T_t^{amb}$  is the ambient temperature at hour t (°C),  $SR_t$  is the solar radiation at hour t (kW/m<sup>2</sup>),  $NOT_{cell}$  is the PV nominal operating cell temperature (°C),  $I_{SC}$  is the short circuit current of PV panel (A),  $K_{ctc}$  is the current temperature coefficient of PV panel (A/°C),  $V_{ocv}$  is the open circuit voltage of PV panel (V),  $K_{vtc}$  is the voltage temperature coefficient of PV panel (V/°C),  $FL$  is the fill factor of PV panel,  $V_{Max}$  is the voltage at maximum power point of PV panel (V),  $I_{Max}$  is the current at maximum power point of PV panel (A),  $N^{pv}$  is the number of PV panels in PVPP,  $P_t^{pv}$  is the output power of PVPP at hour t (MW).

#### Energy Storage System

The operational constraints of the ESS are defined in Equations 7-13.

$$0 \leq P_{ch}^t \leq P_{ch}^{max} \times z_{ch}^t \quad (7)$$

$$0 \leq P_{dis}^t \leq P_{dis}^{max} \times z_{dis}^t \quad (8)$$

$$E_{bess}^{min} \leq SoC^t \leq E_{bess}^{max} \quad (9)$$

$$SoC^{(t=0)} = E_{bess}^{initial} \quad (10)$$

$$SoC^{(t=24)} = E_{bess}^{final} \quad (11)$$

$$z_{ch}^t + z_{dis}^t \leq 1 \quad (12)$$

$$SoC^t = SoC^{(t-1)} + \eta_{ch} \times P_{ch}^t - \frac{P_{dis}^t}{\eta_{dis}} \quad (13)$$

where  $P_{ch}^t$  and  $P_{dis}^t$  are the charging and discharging power of ESS (MW) at hour t,  $P_{ch}^{max}$  and  $P_{dis}^{max}$  are the maximum charging and discharging power of ESS (MW),  $z_{ch}^t$  and  $z_{dis}^t$  are the binary variables of charging and discharging status of ESS at hour t,  $E_{bess}^{min}$  and  $E_{bess}^{max}$  are the minimum and maximum energy stored in ESS (MWh),  $E_{bess}^{initial}$  and  $E_{bess}^{final}$  are the initial and final energy level of ESS (MWh),  $\eta_{ch}$  and  $\eta_{dis}$  are charging and discharging efficiency of ESS, respectively.  $SoC^t$  represents the state of charge of ESS at hour t.

#### Distributed Generators

The operational constraints of the DGs are defined in Equations 14-18. The cost of DG unit is equal to the sum of production cost, fixed cost and start-up cost.

$$y_{SU}^{j,t} - y_{SD}^{j,t} = x^{j,t} - x^{j,t-1} \quad (14)$$

$$y_{SU}^{j,t} + y_{SD}^{j,t} \leq 1 \quad (15)$$

$$P_{min}^j x^{j,t} \leq P_{DG}^{j,t} \leq P_{max}^j x^{j,t} \quad (16)$$

$$Cost_{DG}^{j,t} = (C_P^j P_{DG}^{j,t} + C_F^j x^{j,t})h + C_{SU}^j y_{SU}^{j,t} \quad (17)$$

$$Cost_{DG}^t = \sum_j Cost_{DG}^{j,t} \quad (18)$$

$$TP_{DG}^t = \sum_j P_{DG}^{j,t} \quad (19)$$

where  $y_{SU}^{j,t}$  and  $y_{SD}^{j,t}$  are the binary variables of the start-up and shut down status of the jth DG at hour t,  $x^{j,t}$  is the binary variable of the on/off state of the jth DG at hour t,  $P_{min}^j$  and  $P_{max}^j$  are the minimum and maximum possible generation of the jth DG (MW),  $P_{DG}^{j,t}$  is the generation of the jth DG at hour t (MW),  $Cost_{DG}^{j,t}$  is the cost of the jth DG at hour t (\$),  $C_P^j$  is the production cost of the jth DG (\$/MWh),  $C_F^j$  is the fixed cost of the jth DG (\$/h),  $C_{SU}^j$  is the start-up cost of the jth DG (\$),  $Cost_{DG}^t$  is the total cost of DGs at hour t (\$),  $TP_{DG}^t$  is the total amount of the generated power of the DGs at hour t (MW).

### 3.2. Objective Function

The objection function of the presented model is the maximization of the expected day-ahead profit of the VPP as shown in Equation 20.

$$\text{Maximize Profit} = \sum_t P_{DAM}^t EP_t - \text{Cost}_{DG}^t \quad (20)$$

where  $P_{DAM}^t$  is the exchanged power in the DAM at hour t (MW) and  $EP_t$  is the electricity market price at hour t (\$/MWh).

The profit is equal to the exchanged cash flow between VPP and electricity market minus the cost of DGs including production, fixed and start-up costs. The total profit in one day is the sum of all profit amounts for 24 hours.

### 3.3. Power Balance

The electrical power balance is given in Equation 21. The sum of the generated power by WPP, PVPP and DGs, purchased power from the market and charged power in the ESS should be equal to the sum of the sold power to the market and discharged power in the ESS for each hour.

$$P_t^{wt} + P_t^{pv} + P_{dis}^t - P_{ch}^t + TP_{DG}^t = P_{DAM}^t \quad (21)$$

## 4. Case Study and Results

The presented model is applied on the IEEE 6-bus test system with DGs by containing the WPP, the PVPP and the ESS as shown in Figure 2. The WPP comprises 10 wind turbines and the PVPP comprises 100 PV modules. The MILP problem with equality and inequality constraints is modeled in GAMS 25.1.3 software and solved by CPLEX solver. The daily expected profit is found as 32042.695 \$.

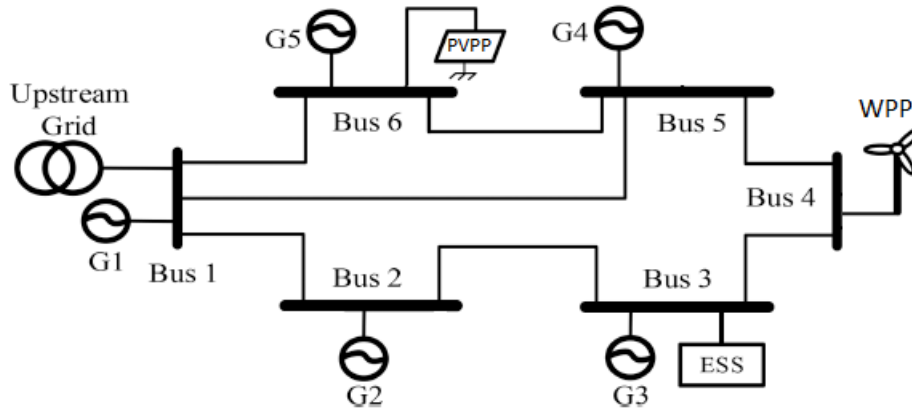


Figure 2. Schematic diagram of the modified IEEE 6-bus test system

### 4.1. Input Data

To test the model, it is considered that the WPP is in the province of Çanakkale and the PVPP is in the province of Muğla in Turkey. The data of wind speed is necessary to compute the output power of WPP and the data of solar radiation and ambient temperature are necessary to compute the output power of PVPP. Therefore, the hourly data of wind speed for the province of Çanakkale and the hourly data of solar radiation and ambient temperature for the province of Muğla for June 2018 is taken from the Turkish State Meteorological Service. The hourly average values of these data for June 2018 are used in this study. The used values in the study for wind speed, ambient temperature, and solar radiation for each hour are given in Table 1, Table 2, and Table 3, respectively.

Table 1. The Data for Wind Speed

Hour	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8
$v_t$ (m/s)	3.927	4.100	4.063	3.820	4.407	5.560	6.007	6.563
Hour	t=9	t=10	t=11	t=12	t=13	t=14	t=15	t=16
$v_t$ (m/s)	7.013	7.717	7.893	7.863	7.810	7.847	7.443	6.993
Hour	t=17	t=18	t=19	t=20	t=21	t=22	t=23	t=24
$v_t$ (m/s)	5.987	5.110	4.203	4.137	3.900	4.013	4.003	3.787

**Table 2.** The Data for Ambient Temperature

<b>Hour</b>	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8
$T_t^{amb}$ (°C)	17.307	16.743	16.267	16.040	17.580	20.003	22.303	24.283
<b>Hour</b>	t=9	t=10	t=11	t=12	t=13	t=14	t=15	t=16
$T_t^{amb}$ (°C)	25.590	27.053	27.553	27.880	27.620	27.127	26.827	26.427
<b>Hour</b>	t=17	t=18	t=19	t=20	t=21	t=22	t=23	t=24
$T_t^{amb}$ (°C)	25.070	23.090	21.590	20.660	19.913	19.227	18.363	17.990

**Table 3.** The Data for Solar Radiation

<b>Hour</b>	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8
$SR_t$ (W/m <sup>2</sup> )	0.000	0.000	1.667	103.000	277.333	464.000	630.667	694.333
<b>Hour</b>	t=9	t=10	t=11	t=12	t=13	t=14	t=15	t=16
$SR_t$ (W/m <sup>2</sup> )	735.000	699.000	683.000	592.000	481.667	425.333	318.000	128.333
<b>Hour</b>	t=17	t=18	t=19	t=20	t=21	t=22	t=23	t=24
$SR_t$ (W/m <sup>2</sup> )	10.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The values of parameters for wind turbines in the WPP and PV modules in the PVPP, and ESS are given in Table 4, Table 5, and Table 6, respectively.

**Table 4.** Values of Parameters for Wind Turbines (Ozerdem et al., 2016)

Turbine type	$N^{wind}$	$P_{rtd}^{wt}$	$v_{in}$	$v_{rtd}$	$v_{out}$
Enercon E-66	10	1800 kW	2.5 m/s	12 m/s	28 m/s

**Table 5.** Values of Parameters for PV Modules (Hadayeghprast et al., 2019)

$N^{pv}$	$V_{ocv}$	$I_{sc}$	$K_{ctc}$	$NOT_{cell}$	$V_{Max}$	$I_{Max}$
100	21.98 V	5.32 A	0.00122 V/C°	43 C°	17.32 V	4.76 A

**Table 6.** Data of ESS (Sadeghian et al., 2019)

$P_{ch}^{max}$	$P_{dis}^{max}$	$E_{bess}^{min}$	$E_{bess}^{max}$	$E_{bess}^{initial}$	$\eta_{ch}$	$\eta_{dis}$
1.5 MW	2 MW	0 MWh	10 MWh	0 MWh	0.96	0.95

The characteristics of DGs are given in Table 7.

**Table 7.** Characteristics of DGs ((Sadeghian et al., 2019)

Units	$P_j^{min}$ (MW)	$P_j^{max}$ (MW)	$C_j^P$ (\$/MW)	$C_j^F$ (\$/h)	$C_j^{SU}$ (\$)
1	4	7	47	61	98
2	3	5	69	72	111
3	3	5	57	57	103
4	4	6	55	65	103
5	2	5	69	72	111

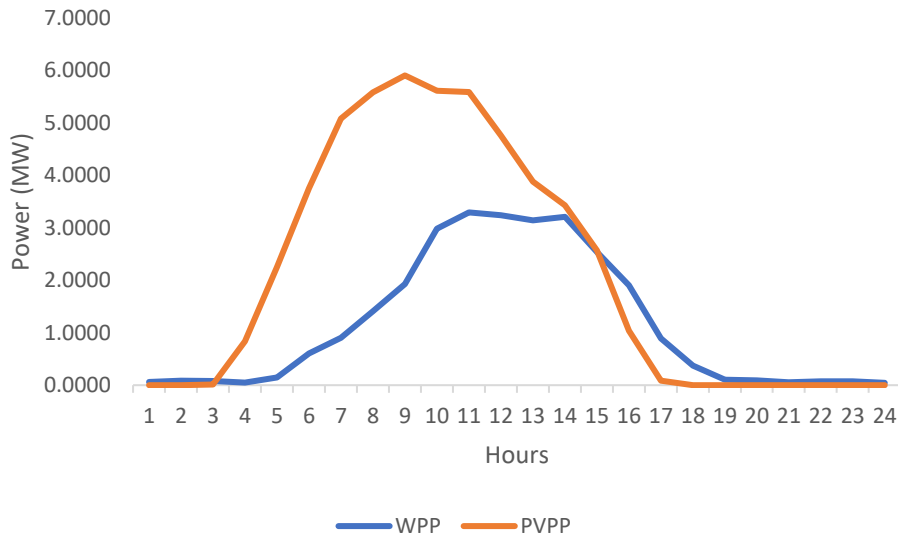
The hourly electricity market prices are taken from the study (SoltaniNeja Farsangi et al., 2018) and given in Table 8.

**Table 8.** Data for Electricity Market Prices

<b>Hour</b>	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8
$EP_t$ (\$/MWh)	55.911	49.592	50.047	43.933	47.752	68.417	111.56	155.334
<b>Hour</b>	t=9	t=10	t=11	t=12	t=13	t=14	t=15	t=16
$EP_t$ (\$/MWh)	128.59	99.887	93.784	89.092	87.284	81.725	79.337	82.987
<b>Hour</b>	t=17	t=18	t=19	t=20	t=21	t=22	t=23	t=24
$EP_t$ (\$/MWh)	101.716	156.565	201.701	202.224	172.936	108.075	74.69	68.505

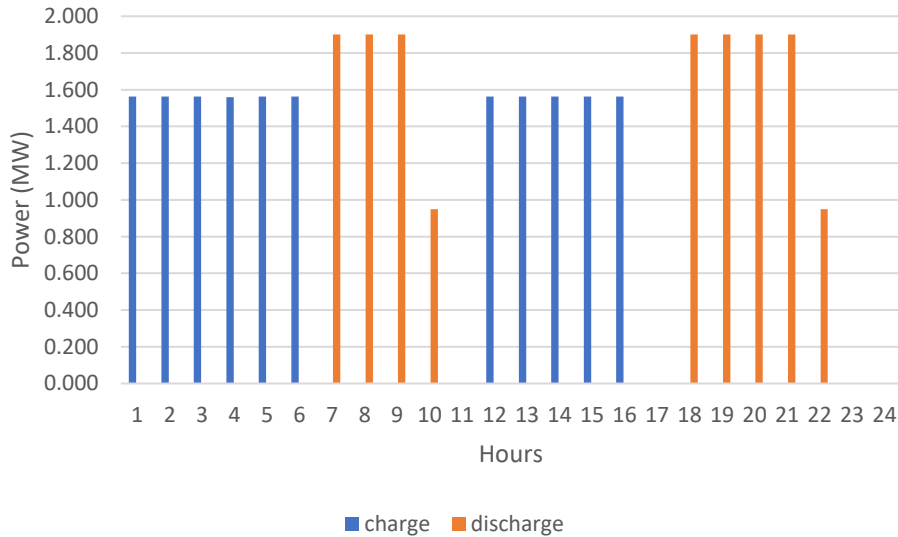
**4.2. Results**

The calculated output powers of WPP and PVPP are shown in Figure 3.



**Figure 3.** The Output Powers of WPP and PVPP

The operation planning of the ESS is given in Figure 4.



**Figure 4.** The Operation Planning of the ESS

Figure 4 shows the operation mode of the ESS for each hour. The ESS is operated in the mode of charging at 1-6 and 12-16 hours. At these hours, 1.562 MW power is charged in the ESS. It is operated in the mode of discharging at 7-10 and 18-22 hours. At 7-9 and 18-21 hours, the ESS discharges 1.900 MW. It discharges 0.950 MW at the 10 and 22 hours. The ESS is operated in the idle mode that is neither charging or discharging at the 11, 17 and 23-24 hours. It is operated in the charging mode when the electricity price is low. It stores the energy to sell when the electricity price is high. It is operated in discharging mode in high electricity prices to sell more energy to the market and increase its profit.

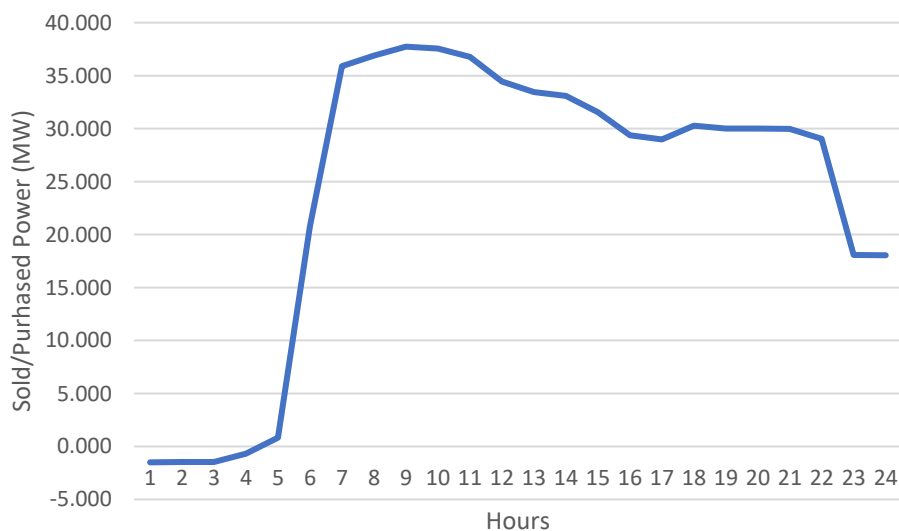
The operation planning of the DGs is given in Table 9.

**Table 9.** The Operation Planning of the DGs

Hours	Generated Power (MW)				
	DG1	DG2	DG3	DG4	DG5
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	7	0	5	6	0
7	7	5	5	6	5
8	7	5	5	6	5
9	7	5	5	6	5
10	7	5	5	6	5
11	7	5	5	6	5
12	7	5	5	6	5
13	7	5	5	6	5
14	7	5	5	6	5
15	7	5	5	6	5
16	7	5	5	6	5
17	7	5	5	6	5
18	7	5	5	6	5
19	7	5	5	6	5
20	7	5	5	6	5
21	7	5	5	6	5
22	7	5	5	6	5
23	7	0	5	6	0
24	7	0	5	6	0

Table 10 shows the amount of generated power of each DG for each hour. In general, DGs are operated at maximum capacity in order to sell more energy to the market when electricity prices are high. DG2 and DG5, which cost more than other DGs, are operated less hours than others. When electricity prices are low (at 1-5 hours), all of the DGs are not operated.

The bidding scheduling of the VPP model is given in Figure 5.



**Figure 5.** The Bidding Scheduling of the VPP Model



Figure 5 shows the amount of sold/purchased power in the market. The negative values indicate the amount of purchased power, and positive values indicate the sold power in the market. The VPP owner purchases power from the market at 1-4 hours due to low electricity prices. It sells power to the market by increasing generation of DGs when electricity prices are high.

## 5. Conclusion

In this study, the optimum bidding and operating planning has been established in order to obtain maximum daily profit for the VPP participating in the day ahead electricity market. The VPP model is formed on the IEEE 6-bus test system with DGs by including the WPP, the PVPP and the ESS. The real data of wind speed to calculate the WPP's output power and the real data of solar radiation and ambient temperature to calculate the PVP's output power are obtained from Turkish State Meteorological Service. The problem is modeled as MILP in GAMS software and solved by CPLEX solver. The optimum operating planning of VPP components and bidding planning that VPP owner presents in the energy market are determined. The numerical results demonstrate the effectiveness of the proposed methodology. It helps VPP owners to make profitable decisions in the electricity market.

## Referanslar

Abdolrasol, M. G. M., Hannan, M. A., Mohamed, A., Amiruldin, U. A. U., Abidin, I. B. Z. & Uddin, M. N. (2018). An Optimal Scheduling Controller for Virtual Power Plant and Microgrid Integration Using the Binary Backtracking Search Algorithm. *IEEE Transactions on Industry Applications*, 54(3), 2834-2844. doi: 10.1109/TIA.2018.2797121

Behi, B., Baniasadi, A., Arefi, A., Gorjy, A., Jennings, P. & Pivrikas, A. (2020). Cost–Benefit Analysis of a Virtual Power Plant Including Solar PV, Flow Battery, Heat Pump, and Demand Management: A Western Australian Case Study. *Energies*, 13, 2614. doi: 10.3390/en13102614

Guo, W., Liu, P. & Shu, X. (2021). Optimal dispatching of electric-thermal interconnected virtual power plant considering market trading mechanism. *Journal of Cleaner Production*, 279, 123446. doi: 10.1016/j.jclepro.2020.123446

Hadayeghparast, S., Farsangi, A. S. & Shayanfar H. (2019). Day-ahead stochastic multi-objective economic/emission operational scheduling of a large scale virtual power plant. *Energy*, 172(2019), 630-646. doi: 10.1016/j.energy.2019.01.143

Hannan, M. A., Abdolrasol, M. G. M., Faisal, M., Ker, P. J., Begum, R. A. & Hussain, A. (2019). Binary Particle Swarm Optimization for Scheduling MG Integrated Virtual Power Plant Toward Energy Saving. *IEEE Access*, 7, 107937-107951. doi: 10.1109/ACCESS.2019.2933010

Karimyan, P., Abedi, M., Hosseini, S. H. & Khatami, R. (2016). Stochastic approach to represent distributed energy resources in the form of a virtual power plant in energy and reserve markets. *IET Generation, Transmission & Distribution*, 10(8), 1792-1804. doi: 10.1049/iet-gtd.2015.0715

Lazaroiu, G. C., Dumbrava, V., Roscia, M. & Zaninelli, D. (2015). Energy trading optimization of a Virtual Power Plant on electricity market. The 9<sup>th</sup> International Symposium on Advanced Topics in Electrical Engineering, May 7-9, 2015, Bucharest, Romania.

Naval, N. & Yusta, J. M. (2020). Water-Energy Management for Demand Charges and Energy Cost Optimization of a Pumping Stations System under a Renewable Virtual Power Plant Model. *Energies*, 13, 2900. doi: 10.3390/en13112900

Othman, M. M., Hegazy, Y. G. & Abdelaziz, A. Y. (2017). Electrical energy management in unbalanced distribution networks using virtual power plant concept. *Electric Power Systems Research*, 145, 157-165. doi: 10.1016/j.eprsr.2017.01.004

Ozdem, B., Ozer, S. & Tosun, M. (2006). Feasibility study of wind farms: A case study for Izmir, Turkey. *Journal of Wind Engineering and Industrial Aerodynamics*, 94 (2006), 725–743. doi: 10.1016/j.jweia.2006.02.004

Rahimi, M., Ardakani, F. J. & Ardakani, A. J. (2021). Optimal stochastic scheduling of electrical and thermal renewable and non-renewable resources in virtual power plant. *International Journal of Electrical Power & Energy Systems*, 127, 106658. doi: 10.1016/j.ijepes.2020.106658

Sadeghi, S., Jahangir, H., Vatandoust, B., Golkar, M. A., Ahmadian, A. & Elkamel, A. (2021). Optimal bidding strategy of a virtual power plant in day-ahead energy and frequency regulation markets: A deep learning-based approach. *International Journal of Electrical Power & Energy Systems*, 127, 106646. doi: 10.1016/j.ijepes.2020.106646

Sadeghian, O., Shotorbani A. M. & Mohammadi-Ivatloo, B. (2019). Generation maintenance scheduling in virtual power plants. *IET Generation, Transmission & Distribution*, 13(12), 2584-2596. doi: 10.1049/iet-gtd.2018.6751

Vahedipour-Dahraie, M., Rashidizadeh-Kermani, H., Anvari-Moghaddam, A., & Siano, P. (2020). Risk-averse probabilistic framework for scheduling of virtual power plants considering demand response and uncertainties. *Electrical Power and Energy Systems*, 121 (2020), 106126.

Vahedipour-Dahraie, M., Rashidizade-Kermani, H., Shafie-khah, M. & Catalão, J. P. S. (2020). Risk-Averse Optimal Energy and Reserve Scheduling for Virtual Power Plants Incorporating Demand Response Programs. *IEEE Transactions on Smart Grid*, doi: 10.1109/TSG.2020.3026971

Wei, C., Xu, J., Liao, S., Sun, Y., Jiang, Y., Ke, D., Zhang, Z. & Wang, J. (2018). A bi-level scheduling model for virtual power plants with aggregated thermostatically controlled loads and renewable energy. *Applied Energy*, 224, 659-670. doi: 10.1016/j.apenergy.2018.05.032

Wozabal, D. & Rameseder, G. (2020). Optimal bidding of a virtual power plant on the Spanish day-ahead and intraday market for electricity. *European Journal of Operational Research*, 280(2), 639-655.