The Effects of Renewable Energy Sources on the Structure of the Turkish Electricity Market

Canan Karatekin[1]*, Hakan Celik[2]

[1]Department of Electrical Engineering, Istanbul Technical University, Istanbul, Turkey, [2]Turkcell Energy Solutions, Istanbul, Turkey.
*Email: karatekin@itu.edu.tr

ABSTRACT

The structure of the electrical power system in Turkey has undergone rapid change and transitioned into a free market. With this development, the tendency to employ renewable energy sources (RES) has increased. In this study, both the Turkish electricity market and the renewable energy incentive structure, and the effects of RES on the electrical market have been investigated. A 10 buses power system with both traditional and renewable generator units has been considered. In this system, five different scenarios have been constructed and simulated using the PowerWorld program. Marginal prices, voltage amplitudes, voltage angles of buses and the total costs have been examined using optimal power flow. In particular, for scenarios where there was a load increase and a transmission line was disconnected, significant changes were observed in electricity prices, the voltage amplitude and the voltage angle. With the increase of RES in the electricity market, a price increase was observed in the initial stage. However, as the volume of RES gets larger, the rate of increase was observed to slow down and almost reach its previous state. Generator electricity costs have decreased and profits have increased even though retail prices have increased. The generators with increased profits have been observed to use RES.

Keywords: Turkish Electricity Market, Renewable Energy Sources, Bus Marginal Price, Voltage Amplitude, Voltage Angle
JEL Classifications: Q40, Q41, L94, C61

1. INTRODUCTION

The structure of the Turkish electrical power system has been transformed into a competitive electricity market in the same way as other examples around the globe. The electrical power system existed in a monopoly structure where the production, transmission and distribution were unified. As a result of restructuring, the production, transmission and distribution are now separated. Increasing power quality, lower prices, shared risks, decreasing government influence and increasing competition are the driving forces behind the competitive electricity market. In addition to these, the need for an independent regulatory structure that incentivizes investment, property and management has speeded up this transition.

With the Electricity Market Law (Law 4628) announced in 2001 in Turkey, the electricity market baseline was constructed, and the

competitive electricity market started to function under the Energy Market Regulatory Authority (EMRA, 2001). In the following years, the balancing power, the day-ahead and the intraday markets (IDMs) were formed. With the Electricity Market Law (Law 6446) announced in 2013, it was decided to start the Electricity Market Operations Incorporated Company (EPIAS) (EMRA, 2013). Since September 01, 2015, the day-ahead, the IDMs and the negotiation operations are managed by EPIAS, whereas the balancing power market (BPM) is governed by the Turkish Electricity Transmission Incorporated Company (TEIAS). The electricity market in Turkey is formed by the Day-Ahead Market (DAM), the IDM, the BPM, negotiation operations and bilateral agreements. The development of the electricity market structure continues with the planning of a new market model under the name future market.

With the above developments in the Turkish electricity markets, the tendency towards environmentally friendly, cheap and renewable

energy sources (RES) has increased as a result of recent climate changes, the increasing harm caused by traditional resources to nature and the scarcity of fossil resources. The two main factors encouraging energy production from RES are subsidies and carbon pricing. After the Kyoto Protocol, investments and subsidies for RES have started to increase.

Inconsistent RES production by wind and sun, susceptibility to changes in weather conditions and uncontrollability of producers causes a number of problems. There have been many studies, and technical and administrative arrangements, to analyze and solve all these problems. According to a report from the Council of European Energy Regulators, subsidies given for solar and wind power almost quadrupled and tripled from 5.885 €/MWh to 23.128€/MWh and from 4.883€/MWh to 12.44€/MWh, respectively (Ortega and Del Rio, 2016). According to the results obtained from economic panel models developed to determine the relationship between RES and electric prices, the electricity prices were observed to increase along with the increase in wind power plants between 1998 and 2009 (Moreno et al., 2012).

There is a phenomenon known in literature as the merit order effect which defines the effects of RES on the market. The merit order effect describes the decrease in spot prices in the DAM following the introduction of RES. In the DAM, the supply from producers and the demand of customers are listed from the cheapest to the most expensive and from the most expensive to the cheapest, respectively. The marginal price is determined as the intersection of these two curves. Therefore, the cheapest supplies are accepted, whereas the most expensive ones are rejected. Renewable power plants enter the merit order curve at the lowest possible point since their marginal costs are low and their management costs are almost zero. This effect represents the greatest problem for the market. According to some observations made in Germany, the aggregate sales price dropped by 11% from 42.60 €/MWh in 2012 to 37.78 €/MWh in 2013 and further decreased to 33 €/MWh in 2014 (Appunn, 2015). Again, in a study conducted in Germany, although renewable electricity production varied between 4.4 and 14.7 GW, its impact on the prices was more substantial (Sensfuss et al., 2007). The actual price drop was 0 and 36 €/MWh when the system load was low and at its peak, respectively. According to the results, the merit order effect is highest at times of high demand. Acemoglu et al. 2017, demonstrated how to form an energy market where the producers have a diversified energy portfolio as a solution to the merit order effect. Producers who have a diversified energy portfolio include traditional power plants like coal and natural gas along with renewable power plants such as wind and solar. The merit order effect is neutralized by the renewable energy demand generated by these producers.

The most crucial aspect of sources like solar and wind energy is that they are uncontrollable. If the solar panels are not uniformly connected to the phases, there will be voltage imbalances. Furthermore, there will be problems of load control since the new generators will have less inertia than the old ones (Hossain and Mahmud, 2014).

In another study, the change in the voltage profile was investigated before and after introducing RES into the power system (Bayındır et al., 2016). Krishnan et al. 2014, demonstrated that there are often high spikes in the frequency when wind power plants are included in the system. In a broader study, researchers investigated six European energy markets and established a positive relationship between large changes in prices and the amount of RES (Lindström and Regland, 2012). Sometimes, the size of the price fluctuations causes sales prices to drop to negative values. Nicolosi, 2011, in work on wind power integration, determined that when wind power production is too much and the demand is low, low prices are formed in the market to prevent a drop in the production capacity to meet the phase load, and later, this causes production to be higher than predicted. In 2008, the European Energy Exchange allowed negative pricing to prevent this situation (Nicolosi, 2011). A negative price means that the consumer gets money for the electricity he/she buys.

In this study, different than the studies found in published literature, the effects of RES on the market have been investigated in a hybrid system where both traditional and renewable sources are included. Furthermore, the Turkish electricity market structure and mechanisms for incentivizing renewable energy have been taken into account. By increasing the rate of RES in the system and disconnecting one transmission line, various scenarios have been constructed to investigate bus electric prices, bus voltage amplitudes and bus voltage angle changes. In the first section, based on data for Turkey in January 2018, electricity production source distributions were prepared. In the second section, the effects of RES on the electricity market were investigated, and in the third section, analyses were conducted on five different scenarios using the PowerWorld program and a power system with 10 buses. Changes in electricity prices, bus voltage amplitudes and voltage angles have been investigated and total costs, production and losses have been calculated.

Finally, this study is intended to provide an idea about the characteristics of electricity for researchers from different disciplines (economists, lawyers etc.).

2. RES IN THE STRUCTURE OF THE TURKISH ELECTRICITY MARKET

In the Turkish electricity market, the RES Incentivizing Mechanism (RESIM) has begun to be applied (EMRA, 2014c and Gözen, 2014). According to this description, electricity production facilities based on hydroelectricity, wind, geothermal, biomass and solar energies – which are included in the RESIM portfolio – can sell the electricity they produce at specific prices for 10 years. The decreasing investment costs of RES, coupled with the RESIM subsidies, made wind and solar power plant construction much more attractive for investors. Between 2014 and 2017, a significant proportion of plants that had both previously been built and undergone a serious RES-based power increase joined RESIM (Gökçe, 2018). As a result, the 2014-2017 RESIM costs experienced a significant increase and seriously burdened the Turkish economy. This cost directly affected retail electricity companies but indirectly affected the end-user, too.

Inconsistent RES production from wind and sun, susceptibility to changes in weather conditions and uncontrollability of producers causes many problems. The unpredictability of the maximum power outputs coming from RES affects the market status and prices (Banshwar et al., 2017). Furthermore, unpredictable solar and wind power necessitates the use of additional resources to adjust the values in calculations to predict net power. This also necessitates restructuring the ancillary service market.

Currently, the initial setup costs of RES are quite high. However, these sources are distinguished by their almost zero management costs. Furthermore, in many electricity markets, RES is subsidized by the government. Due to this incentivization, variable costs sometimes have negative values. The meaning of a negative variable cost is that these resources can be distributed first in the market, other high-cost traditional resources will decrease their production, and the electricity prices will eventually fall. Due to the fluctuations in RES power outputs, the main goal of renewable energy producers is to provide their promised power output throughout every period. There is a need for stochastic methods to achieve this purpose.

With the increased electricity production from renewable energies and the increased variety of market resources, ancillary services has become a crucial subject. Ancillary services facilitate the system frequency, voltage control and emergency services. According to analyses conducted in Denmark, a high power wind energy intake is possible but some issues occur in terms of frequency and voltage control (Østergaard, 2006). This is why all power plants must provide supplies for ancillary services. All power plants that assume a role in active power balancing will help to solve these emerging problems.

3. ELECTRICITY MARKET SIMULATIONS

Building a safe solution, given all the problems and system instabilities caused by introducing RES into the system, is under the control of EPIAS and TEIAS in Turkey. The DAM, the IDM, and the negotiation operations are organized by EPIAS, whereas the BPM is organized by TEIAS.

In the DAM, the goal is to calculate the market clearing price (MCP) for the next day (EPIAS, 2016a). MCP is the price at the intersection of supply and demand after receiving offers from the producer and the consumer. To join the DAM, the participants must first sign the DAM Participation Agreement. After the agreement, the participants earn the right to join in the market processes. IDM, which acts as a bridge between DAM and BPM, offers the participants a chance of short-term portfolio stabilization and also contributes to the maintainability and stability of the market (EPIAS, 2015a). Problems arising from failures in power plants, instabilities caused by the integration of RES into the system, and sudden changes in consumption patterns and production areas are either minimized or completely removed by the IDM.

Real-time balancing is achieved by the BPM and ancillary services (EPIAS, 2015b). BPM provides the necessary capacity to the system operator: the National Load Dispatch Center (NLDC), that

can be taken into the circuit to stabilize it for, at most, 15 min. Ancillary services provide frequency and demand control. BPM transactions are processed hourly over a day, and participants must provide their disposable capacities. Stabilization units that can independently give or take a minimum of a 10 MW load in 15 min must join BPM. There are situations in which the system becomes unstable, such as disconnecting a power plant during the day and activating a large producer. In these cases, the NLDC evaluates offers made to BPM and attempts to maintain system stability and balance (EPIAS, 2016b).

Economic distribution in an electricity power system is the process of rationing the load demand between available production units such that the operating cost is minimized. The aim here is to keep the production costs at a minimum according to the equation below:

$$\text{Min} \sum_{i=1}^{n} C_i(P_i) = a_i(P_i^2) + b_i P_i + c_i \qquad (1)$$

Here, P_i, a_i, b_i and c_i are the power injected by the generator, the quadratic term, the linear term and the constant term, respectively.

Economic production dispatch is an optimization problem. In this problem, there are constraints in the form of equalities and inequalities. For equality, the supply–demand balance is taken into account. The power produced must meet the load and the losses.

$$\sum_{i=1}^{n} P_i = P_{load} + P_{loss} \qquad (2)$$

Furthermore, for the inequalities, the generator production limits and transmission line limits are taken into account.

$$P_i \geq P_{min} \qquad (3)$$

$$P_i \leq P_{max} \qquad (4)$$

$$P_{ij} = \frac{V_i V_j}{X} Sin\delta \leq P_{ij\,line\,limit} \qquad (5)$$

P_{min} and P_{max} are the minimum and maximum production levels, respectively. According to Equation (5), the active power transmission from the ith bus to the jth bus is directly proportional to the voltage amplitudes V_i and V_j, and the load angle δ, but is inversely proportional to the line reactance X. The active power transmitted, P_{ij}, must be below the line limit $P_{ij\,line\,limit}$.

The example system with 10 buses used in this study was taken from Lin and Magnago, 2017. This example system includes 8 generators, 10 buses and 10 different loads. To obtain more realistic values during the simulation, price curves, bus loads and generator types have been changed. Five different scenarios were executed in the simulation and the results have been interpreted. Marginal prices, bus voltages and bus angle changes resulting from every scenario were observed on a per-unit (p.u.) basis. Furthermore, the active and reactive powers generated by different generators and their utilizations are given in the tables. Six different generator types were used in the system. These were natural gas, coal, wind, hydroelectric, solar and geothermal plants. The Annual Energy Outlook, 2018

was used to determine the price curves for the generators to execute a simulation (EIA, 2018). Production costs are shown in Table 1. Generator production capacities were the same as the values in the given example system (Lin and Magnago, 2017).

In Table 1, the parameters *a*, *b* and *c* form the constant coefficients of the "cubic cost model." Equation 1 shows how to calculate the production costs of the generators.

3.1. Scenarios in the Power System with RES
3.1.1. Scenario 1: Operation of the electrical power system based on real Turkish production rates
In the first scenario, based on data in Turkey for January 2018, distributions for the electricity production sources were made (EMRA, 2018). Load demands on the buses are shown in Table 2. In all scenarios, bus 2 was taken as the reference.

Bus marginal prices, voltage amplitudes and voltage angles obtained after analyses – using the PowerWorld program – are given in Figures 1-3, respectively, along with comparisons against the other scenarios. Furthermore, active and reactive power values and generator utilizations after the simulation are given in Table 3. The total cost was 308,736.53 Turkish Liras/h after the simulation. The total load in the system was 8400 MW, and the total loss was 905.29 MW. According to the optimal power flow (OPF), the total electrical power produced in the system was 9270.13 MW.

According to Table 3, the issue with this simulation was disconnecting the natural gas plant. Since the load demand on the bus that was connected to the natural gas plant was low, and the production costs of the natural gas plant were high, the natural gas plant could not produce. In the electricity market, producers and consumers announce their supplies and demands, respectively. The supply and demand are matched hourly. Participants with offers that show a supply that is too high and a demand that is too low are rejected.

Table 1: Production costs

Generator type	a (kcal/MW²h)	b (kcal/MWh)	c (kcal/h)
Natural gas	0.04	5.0	0.0
Coal	0.05	10.0	0.0
Hydroelectric	0.01	5.5	0.0
Wind	0.04	4.0	0.0
Solar	0.002	6.5	0.0
Geothermal	0.001	3	0.0

Table 2: Active and reactive load demands on buses

Bus number	P (MW)	Q (MVAr)
1	490	110
2	4000	2000
3	50	10
4	850	140
5	500	140
6	210	60
7	500	90
8	450	110
9	1000	300
10	350	60

3.1.2. Scenario 2: Increasing the rate of renewable energy in the system
In this scenario, the rate of the electrical energy produced from RES was increased without changing the total load rate of the system. Wind, geothermal and solar energy inputs of the system were increased, whereas natural gas, coal and hydroelectric inputs were lowered. Again, for this scenario, bus marginal prices, voltage amplitudes and voltage angles are given in Figures 1-3, respectively, along with comparisons against the other scenarios. Furthermore, active and reactive power values and generator utilizations after the simulation are given in Table 3. The total cost was observed to drop from 308,739.53 Turkish Liras/h to 275,515 Turkish Liras/h as a result of the increase in renewable energy integration. However, bus marginal prices were observed to increase in spite of a drop in the system cost. The topic described in the literature review,

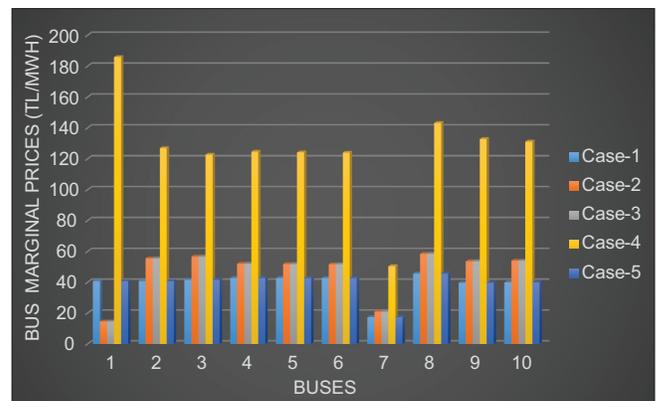**Figure 1:** Bus marginal prices obtained from the scenarios

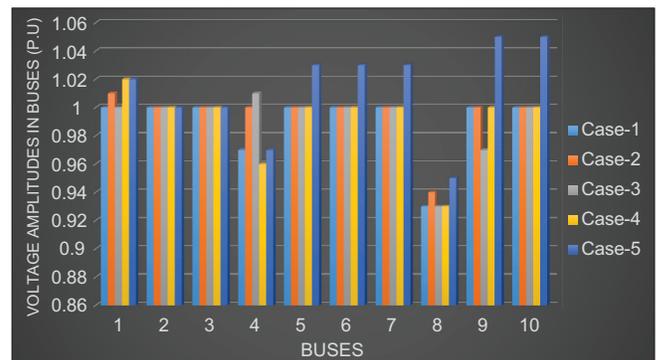**Figure 2:** Bus voltage amplitudes obtained from the scenarios
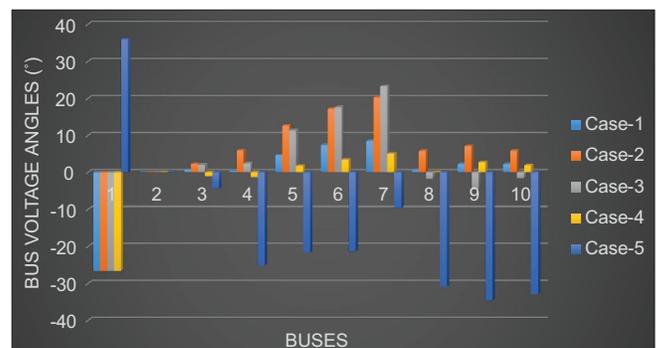

Figure 3: Bus voltage angles obtained from the scenarios

Table 3: Values for generators

Buses with generator	Power plant type	Active power (MW)	Reactive power (MVAr)	Generator utilization (%)
1	Natural gas	0	2126	0
2	Hydroelectric+Coal	4793	425	95.86
3	Coal	300	42	85.71
5	Geothermal	600	745	92.30
6	Wind	692	67	53.23
7	Hydroelectric	643	−175	64.30
9	Coal	1343	335	79.00

Table 4: Values for generators

Buses with generator	Power plant type	Active power (MW)	Reactive power (MVAr)	Generator utilization (%)
1	Hydroelectric+Coal	0	2130	0
2	Natural gas	3877	493	77.54
3	Geothermal	350	254	100
5	Geothermal	650	831	100
6	Wind	1000	83	76.92
7	Wind	800	−422	80.00
9	Coal	1700	332	100
10	Solar	950	130	100

Table 5: Values for generators

Buses with generator	Power plant type	Active power (MW)	Reactive power (MVAr)	Generator utilization (%)
1	Hydroelectric+Coal	0	2122	0
2	Natural gas	5233	447	104.46
3	Geothermal	350	−4	100
5	Geothermal	650	1090	100
6	Wind	1300	109	100
7	Wind	1000	−694	100
9	Coal	0	0	0
10	Solar	950	960	100

i.e., the claim that retail prices will increase with an increase in renewable energies, was obvious here. Another reason for the price increase can be attributed to the destabilization of the system, its inability to adapt to the rapidly changing conditions and the resulting increasing costs. As a result of the simulation, these instabilities were observed to increase. In the meantime, according to the capacity utilization of the generators in Table 4, the utilization of renewable energy plants was increased to very high levels compared to the first scenario, but the production capacities of hydroelectric plants and traditional energy plants were reduced. This case becomes more likely as customers buy the electricity from producers who produce cheaper electricity. This problem may lead to the complete disconnection of the traditional energy plants in the system due to the merit order effect. The total loss in the system was slightly increased to 962.16 MW. The total electrical energy produced after the OPF was 9326.68 MW.

3.1.3. Scenario 3: Disconnecting a generator

As in all systems, there may be unexpected problems in the electricity markets. In Scenario 3, the specific problem of a generator being disconnected was investigated, and the system reaction was observed. Specifically, the disconnection of the coal plant connected to bus 9 was investigated. The load demand was not changed and kept fixed in the grid. Again, for this scenario, bus marginal prices, voltage amplitudes and voltage angles are given in Figures 1-3, respectively, along with comparisons against the other scenarios. Furthermore, active and reactive

Table 6: The old and the new values of buses where the power demand changed

Bus number	P$_{old}$ (MW)	P$_{new}$ (MW)
1	490	2490
3	50	300
4	850	1000
6	210	510
7	500	750
10	350	600

power values and generator utilizations after the simulation are given in Table 5. As shown in Table 5, the generator connected to the first bus did not produce like it did in the previous two scenarios due to the load connected to the first bus being too low, i.e., the demand being too low. The price of this bus under low demand is much lower than the other buses. In the meantime, the coal plant on bus 9 did not participate in production since it was disconnected.

Generators were observed to transition into full capacity production due to the failure in the system. Despite this, generators making excess electricity sales did not increase their profits, on the contrary, it decreased them. In the end, a failure in the grid was observed to greatly burden the producers. At a later stage, this damage might be transferred to the consumers. In our scenario, since the disconnected generator was relatively small, there was no huge disadvantage on the customer side, but large changes were observed throughout the grid.

Table 7: Values for generators

Buses with generator	Power plant type	Active power (MW)	Reactive power (MVAr)	Generator utilization (%)
1	Hydroelectric+Coal	1900	2187	32.75
2	Natural gas	5100	335	102
3	Geothermal	350	82	100
5	Geothermal	650	786	100
6	Wind	771	65	59.30
7	Wind	580	−131	58
9	Coal	1688	332	99.29
10	Solar	950	−96	100

Table 8: Values for generators

Buses with generator	Power plant type	Active power (MW)	Reactive power (MVAr)	Generator utilization (%)
1	Hydroelectric+Coa+Gas	2135	−1856	36.81
2	Wind	4243	4701	84.86
3	Solar	350	−1082	100
5	Geothermal	650	1633	100
6	Hydroelectric	260	59	20
7	Geothermal	1000	−736	100
9	Solar	615	785	47.30
10	Coal	900	800	94.73

After Scenario 3 was simulated, the total cost was observed to rise and reach 369,846.47 Turkish Liras/h. While in Scenario 2, the total cost was 275,515.97 Turkish Liras/h; in Scenario 3, this cost showed a 34.23% increase and caused an extra cost of 94,330.50 Turkish Liras/h in the system. The total system loss also increased from 962.16 MW to 1101.35 MW. After the OPF, the total electrical power produced was 9473.21 MW.

3.1.4. Scenario 4: Load increase
In Scenario 4, the system reaction was measured after significantly increasing the load values of some buses. The final values of the changed loads in the grid are shown in Table 6.

In Scenario 4, the load demand was increased by 3200 MW and became 11,600 MW. Again, for this scenario, bus marginal prices, voltage amplitudes and voltage angles are given in Figures 1-3, respectively, along with comparisons against the other scenarios. Furthermore, active and reactive power values and generator utilizations after the simulation are given in Table 7. While the load increase was 38.09%, the total cost showed a 103.83% increase compared to Scenario 2. According to Scenario 4 simulation results, the total cost was observed to be 561,607.50 Turkish Liras/h.

3.1.5. Scenario 5: Disconnecting a transmission line
In this scenario, the transmission line between the second and tenth buses was disconnected. Again, for this scenario, bus marginal prices, voltage amplitudes and voltage angles are given in Figures 1-3, respectively, along with comparisons against the other scenarios. Furthermore, active and reactive power values and generator utilizations after the simulation are given in Table 8. The total cost went up compared to the first scenario (the reference scenario). The total cost was calculated to be 435,437.94 Turkish Liras/h. The total electricity production was observed to be 10,153.28 MW. The most crucial result was high losses. The total loss was 2453 MW due to the overloads in the other transmission lines because one line was disconnected. As

seen in the simulation, a problem in one line greatly affects the others and damages the whole system in the long run.

As shown in Figure 1, the largest price increases were experienced in the fourth scenario where there was a serious load increase. In terms of prices, there are no differences in the other scenarios. Despite the large spike in prices in scenario 4, the voltage amplitudes and angles were observed to be nominal in Figures 2 and 3, respectively. According to Figure 1, the lowest prices were obtained in the first scenario (the reference scenario) and in the fifth scenario where one transmission line was disconected. Again, in terms of voltage amplitudes and angles, the most serious change was obtained in the fifth scenario where one transmission line was disconnected.

4. CONCLUSIONS

In this study, the effects of RES on the electricity market were investigated, and to this end, bus marginal prices, bus voltage amplitudes and bus voltage angle changes were observed. By increasing the rate of RES in the system, disconnecting a generator, increasing the system load and disconnecting a transmission line, various scenarios were constructed and their outcomes were interpreted.

The most crucial of the results obtained was that while at the first stage an increase in retail prices was observed after RES were increased, later the increase in retail prices slowed down and almost reached its previous level as the RES volume increased. Though the retail prices increased, the electricity costs of generators dropped down and profits increased. Generators using RES were the generators with increasing profits. Furthermore, generators using primary energy sources (fossil fuels) were observed to be unable to compete in the market due to high-cost electricity production. The most crucial divergence in the prices happened when there was a load increase. In case of unexpected and sudden load increases, if the market cannot, or is just be

barely able to meet the demand, prices were observed to increase due to the high increase in electricity demand. The remaining changes to the market were observed at bus voltage amplitudes and bus voltage angles. In cases where there was a load increase and a transmission line was disconnected, divergences from the optimal bus voltage values were observed. Particularly in the case where the transmission line was disconnected, the high divergence occurring in voltage amplitude and angle may prevent the electricity grid to function in a safe and stable way. With the transmission line disconnected, any congestion in other transmission lines also caused other issues.

As RES spread in the electricity market, the reliability and stability of the system is affected. The market environment must be structured according to RES. Otherwise, a market may form where the prices do not fall even though the electricity production costs decrease. This will result in a system that benefits the producer more than the consumer.

REFERENCES

Acemoglu, D., Kakhbod, A., Ozdaglar, A. (2017), Competition in electricity markets with renewable energy sources. The Energy Journal, 38(1), 137-155.

Annual Energy Outlook. (2018), U.S Energy Information Administration. Available from: https://www.eia.gov/outlooks/aeo18. [Last accessed on 2019 Mar 20].

Appunn, K. (2015), Setting the Power Price: the Merit Order Effect. Available from: https://www.cleanenergywire.org/factsheets/setting-power-price-merit-order-effect. [Last accessed on 2018 Nov 05].

Banshwar, A., Sharma, N.K., Sood, Y.R., Shrivastava, R. (2017), Renewable energy sources as a new participant in ancillary service markets. Energy Strategy Reviews, 18, 106-120.

Bayındır, R., Demirbaş, S., Irmak, E., Çetinkaya, E., Ova, E., Yesil, M. (2016), Effects on Renewable Energy Sources on the Power System. IEEE International Power Electronics and Motion Control Conference. p388-393.

EIA. (2018), U.S. Energy Information Administration, Annual Energy Outlook 2018, Available from: http://www.eia.gov/outlooks/archive/aeo18/pdf/AEO2018.pdf. [Last accessed on 2019 Mar 20].

EMRA. (2001), Elektrik Piyasası Kanunu, Turkish. Available from: https://www.epdk.org.tr/Detay/Icerik/3-0-0-2256/kanunlar. [Last accessed on 2019 Jun 05].

EMRA. (2013), Elektrik Piyasası Kanunu. Available from: http://www.epdk.org.tr/english/regulations/electric/law/EML.doc. [Last accessed on 2019 Jun 20].

EMRA. (2014), Yenilenebilir Enerji Kaynaklarının Belgelendirilmesi ve Desteklenmesine İlişkin Yönetmelik, in Turkish. Available from: http://www.epdk.org.tr/index.php/elektrik-piyasasi. [Last accessed on 2019 Jul 10].

EMRA. (2018), Elektrik Piyasası Sektör Raporu, Turkish. Available from: http://www.epdk.org.tr. [Last accessed on 2019 Apr 20].

EPIAS. (2015a), Gün içi Piyasası Kullanıcı Kılavuzu, Turkish. Available from: https://www.epias.com.tr/gun-ici-piyasasi/gip-kullanici-kilavuzu. [Last accessed on 2019 Jun 16].

EPIAS. (2015b), Elektrik Piyasası Dengeleme ve Uzlaştırma Yönetmeliği, Turkish. Available from: https://www.epias.com.tr/mevzuat/dengeleme-ve-uzlastirma-yonetmeligi. [Last accessed on 2019 Jun 15].

EPIAS. (2016a), Dengeleme Güç Piyasası Genel Esaslar, Turkish. Available from: https://www.epias.com.tr/dengeleme-guc-piyasasi/genel-esaslar. [Last accessed on 2019 Jul 05].

EPIAS. (2016b), Yeni Gün Öncesi Piyasası Kullanıcı Kılavuzu, Turkish. Available from: https://www.epias.com.tr/wp-content/uploads/2016/03/G%C3%96P-KULLANICI-KILAVUZU_V.1.6.pdf. [Last accessed on 2019 Jun 20].

Gökçe, B. (2018), Impact of Renewable Energy on the Power Market, Master Thesis. Turkey: Istanbul Technical University, Energy Institute.

Gözen, M. (2014), Renewable energy support mechanism in Turkey: Financial analysis and recommendations to policymakers. International Journal of Energy Economics and Policy, 4(2), 274-287.

Hossain, J., Mahmud, A. (2014), Renewable Energy İntegration in Green Energy and Technology. Singapore: Springer. p203.

Krishnan, V., Das, T., McCalley, J.D. (2014), Impact of short-term storage on frequency response under increasing wind penetration. Journal of Power Sources, 257, 111-119.

Lin, J., Magnago, F. (2017), Electricity Markets: Theories and Applications. New York: John Wiley and Sons, IEEE Press.

Lindström, E., Regland, F. (2012), Modeling extreme dependence between European electricity markets. Energy Economics, 34(4), 899-904.

Moreno, B., López, A., García-Alvarez, M.T.(2012), The electricity prices in the European Union. The role of renewable energies and regulatory electric market reforms. Energy, 48(1), 307-313.

Nicolosi, M. (2011), Fundamentals of RES-E Market İntegration. The Economics of Renewable Electricity Market Integration. Nicolosi: Marco. p15-21.

Ortega, M., Del Río, P. (2016), Benefits and costs of renewable electricity in Europe. Renewable and Sustainable Energy Reviews, 61, 372-383.

Østergaard, P.A. (2006), Ancillary services and the integration of substantial quantities of wind power. Applied Energy, 83(5), 451-463.

Sensfuss, F., Ragwitz, M., Genoese, M. (2007), The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. Fraunhofer Institute Systems and Innovation Research, 7, 5-6.