Karadeniz Fen Bilimleri Dergisi, 12(1), 425-447, 2022. DOI: 10.31466/kfbd.1088674

KFBD

Karadeniz Fen Bilimleri Dergisi
The Black Sea Journal of Sciences
ISSN (Online): 2564-7377

Araştırma Makalesi / Research Article

Investigation and Analysis of Meteorological Factors of Energy Generation According to Feasibility in Medium Capacity Hydroelectric Power Plants

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Abstract

In this study, medium capacity hydroelectric power plant (HPP) class was investigated and Yumrutepe HPP case was studied in this power plant class. For this purpose, the effects of parameters, such as energy generation realized of Yumrutepe hydroelectric power plant, monthly average partial pressure, temperature, relative humidity, rainfall and the mass flow rate of water passing through turbines, on the efficiency and capacity factor of the Hydroelectric power plant was calculated between 2018-2019 years. The data produced by these parameters were compared with the data in the feasibility study of the Yumrutepe hydroelectric power plant and investigated. These parameters were found to be very effective, and according to these results the highest real energy generation was achieved in March with 5932 MW and the lowest actual energy generation was in September with 782 MW. When the efficiency of energy generation is analyzed, it is calculated that the most energy generation is in December, not in March in 2018. Thus, it was concluded that high energy generation in the hydroelectric power plant generally does not create much efficiency. It was found that the capacity factor, which is known to decrease the energy generation cost per KWh with the increase, has the highest value in March with 55% and the lowest in September with 7%. Thus, it has been proved that energy factor and change of capacity factor is directly proportional.

Keywords: Medium capacity Hydroelectric power plant, hydropower energy generation, energy efficiency, capacity factor, Yumrutepe HES

Orta Kapasiteli Hidroelektrik Santrallerinde Fizibiliteye Göre Verilen Enerji Üretiminde Metorolojik Faktörlerin İncelenmesi ve Analizi

Öz

Bu çalışmada, Orta kapasiteli Hidroelektrik santral (HES) sınıfında inceleme yapılmış olup bu santral sınıfında yer alan Yumrutepe HES örneği üzerinde çalışıldı. Bu amaçla, 2018-2019 yılları arasında Yumrutepe hidroelektrik santralinin gerçekleşen enerji üretimi, aylık ortalama aktüel basınç, sıcaklık, nispi nem, yağış miktarı ve türbinlerden geçen debi miktarı gibi parametrelerin bu hidroelektrik santralin üzerindeki üretimine etkileri, verimliliği ve kapasite faktörünün hesaplanması yapıldı. Kullanılan bu parametreler yardımıyla üretilen veriler Yumrutepe hidroelektrik santralin fizibilite raporundaki veriler ile karşılaştırılarak incelendi. Söz konusu parametrelerin oldukça etkili olduğu görülmüş olup ve bu sonuçlara göre en yüksek gerçekleşen enerji üretimi 5932 MWh ile Mart ayında ve en düşük 782MWh ile Eylül ayında gerçekleşti. Enerji üretiminin verimliliğine bakıldığında 2018 yılı içerisinde en fazla üretimin olduğu Mart ayında değil Aralık ayında olduğu hesaplandı. Bu sonuca göre, HES'te enerji üretiminin fazla olmasının çok verimlilik oluşturmadığı sonucuna varıldı. Artışı ile KWh başına üretim maliyetini düşürdüğü bilinen kapasite faktörünün en yüksek değeri %55 ile Mart ayında aldığı ve en düşük %7 ile Eylül ayında olduğu yapılan hesaplamalar sonucu bulundu. Böylece enerji üretimi ile kapasite faktörü değişiminin doğru orantılı olduğu ispatlandı.

Anahtar kelimeler: Orta kapasiteli hidroelektrik santral, enerji üretimi, enerji verimliliği, kapasite faktörü, Yumrutepe HES

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1. Introduction

Demand for energy has started to increase with the increase in population, developing technology and industrialization in the world. Energy is important in terms of development, development and economy of countries and researches have accelerated in order to obtain energy in a clean, cheap and easy way. In order to meet the energy deficit, it was met with the energy obtained from fossil fuels, but due to the effects such as the exhaustion of fossil-based fuels and the amount of CO_2 it increases in the atmosphere, the tendency to renewable energy has started, and it has started to grow rapidly by investing in renewable energy with the developing industry and technology. Hydroelectric power plants (HPP) are the power plants that are widely preferred especially in terms of renewable energy sources (Sims, 1991). Today, 75.5% of the current electricity generation share in the world is produced from non-renewable energy sources and 24.5% from renewable energy sources. Among renewable resources, hydroelectric energy stands out with the largest share of 16.6% (BP Statistical Review of World Energy, 2021).

As in the world, the need for energy in our country has increased in parallel with the developing industry and technology. However, although Turkey is a rich country in renewable energy resources, it imports most of the energy needs from foreign countries. In order to reduce imports and to close the energy gap to some extent, investments in energy resources have increased, and interest in renewable energy, which is less harmful to the environment and is economically viable, and this sector has started to grow. Among other countries that added new capacity in 2020, Turkey added more than 1 GW (International Hydropower Association, 2021).

Among the reasons for its preference, it is a clean energy in terms of its low installation and operating costs due to the fact that it does not need any raw materials such as fossil fuels, and also that it does not send harmful substances to the atmosphere during energy generation. Compared to other energy sources, it has a long operating life, low operating costs and high efficiency. Considering its contribution to the country, in this study, hydroelectric power plant was studied. By taking the example of Giresun province Yumrutepe HPP, which is a Medium Hydroelectric Power Plant, the data made according to feasibility report were compared with the one-year data between 2018-2019. In addition, there are a few studies about effect of methorological factors which average partial pressure, temperature, relative humidity, rainfall (Hasan at al, Huang at al,). These factors are also studied.

2. Materials and Methods

2.1. Information and Operation of Yumrutepe Hydroelectric Power Plant

Yumrutepe Hydroelectric Power Plant was established on the Aksu Stream within the borders of Giresun province in the Eastern Black Sea region and it produces and distributes the energy with the interconnected system to all of Turkey. Yumrutepe Hydroelectric Power Plant is the regulator area where water first comes and starts to accumulate for energy generation. The water accumulating at certain elevation values in the regulator area passes through the grids and passes into the transmission tunnel. This HPP regulator area is shown in Figure 1.

Figure 1. Yumrutepe HPP Regulator Area

According to the water use agreement, the amount of water to be released from the fish pass is prepared by the General Directorate of State Hydraulic Works (DSI) based on 10-year flow measurements and the values are determined monthly. Life water monitoring is confirmed by the Flow Observation Station (AGI) of the board and is periodically inspected by the General Directorate of State Hydraulic Works (DSI) and the Nature Conservation and National Parks Directorate. In case of non-compliance with the water use agreement, penalties are applied. A certain amount of life water must pass through the fish passage in order for the creatures in the stream bed to survive. In cases where the fish pass is not sufficient, the missing amount is completed from the Gravel Passage cover. The monthly life water amounts given for Yumrutepe HPP are shown in Table 1 according to the Feasibility report.

Table 1. Yumrutepe HPP monthly life water amount

Month	Monthly Amount of Lifeblood (m^3/sn)
January	1,714 (49 cm)
February	1,714 (49 cm)
March	2,412 (57 cm)
April	3,870 (77 cm)
May	3,870 (77 cm)
June	2,412 (57 cm)
July	1,714 (49 cm)
August	1,714 (49 cm)
September	1,714 (49 cm)
October	1,714 (49 cm)
November	1,714 (49 cm)
December	1,714 (49 cm)

There are three turbines belonging to Andritz Hydro company, which produces commercially electricity at Yumrutepe HPP. These are called Unit 1, Unit 2, and Unit 3. Values such as turbine power, speed, amount of water discharged per second and generator voltage, power factors, operating frequency and current of these operating units of Yumrutepe HPP are given in Table 2.

Table 2. Yumrutepe HPP turbine and synchronous generator information

Generator	Unit 1	Unit 2	Unit 3
Power (kW)	9958 kW	3333 kW	1722 kW
Speed (rpm)	428,6 rpm	600 rpm	1000 rpm
Voltage (kV)	6,3 kV	6,3 kV	6,3 kV
Discarded Water (m^3/s)	23,25 m^3/s	7,75 m^3/s	4 m^3/s
Power Factor(Inductive)	0,85	0,85	0,85
Frequency	50 Hz	50 Hz	50 Hz
Current (A)	1074 A	359,3 A	185,7 A

2.2. Giresun Turkish State Meteorological Service (MGM) Data

The data of the monthly average actual pressure (hPa), average temperature (°C), average relative humidity (%) and average precipitation amount (kg/m²) in the atmosphere between the years

2018-2019 in the research findings section are by the MGM. Monthly data is obtained from the automatic meteorological observation station (OMGI) located in the Kümbet plateau.

The monthly average actual pressure values in the atmosphere for 2018 are shown in Table 3. The monthly average temperature change is given in Table 4 and the monthly relative humidity values in the atmosphere are shown in Table 5. Finally, the monthly average precipitation amount, which is the most important factor affecting the amount of energy generation, is given in detail in Table 6.

Table 3. Average monthly actual pressure (hPa)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2018	823,8	823,5	821,9	826,9	825,8	825,4	825,3	827,2	829,4	830,5	828,8	824,6

Table 4. Monthly average temperature (°C)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2018	-0,1	2,6	5,2	8,1	11,3	13,7	15,0	14,6	12,4	10,4	3,7	0,1

Table 5. Monthly average relative humidity (%)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2018	75,3	68,8	69,1	58,6	77,7	85,1	91,3	88,7	84,5	75,1	82,4	82,8

Table 6. Average monthly precipitation (kg/m^2)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2018	118,5	14,2	86,1	36,7	160,5	74,0	63,5	24,8	59,1	143,8	28,3	73,1

2.3. HPP Electricity Generation Efficiency

In HPP, hydraulic energy is obtained by converting the potential energy of water into kinetic energy. This hydraulic energy is first converted into mechanical energy in turbines and then into electrical energy by means of generators. The head and flow rate affecting the power to be obtained in the power plants are the most important parameters in calculating the efficiency of the power plants. While calculating efficiency, hydraulic power must be calculated first. Equation (1) shows the hydraulic power.

$$P_a = \mu\rho Q g h \quad (1)$$

Thus the efficiency;

$$\mu = P_a/\rho Q g h \quad (2)$$

P_a= Actual Energy Generation Amount (W), μ=efficiency, ρ=Density of water (kg/m^3),
Q =Flow rate of the water coming to the turbine (m^3/sec),
g =Gravity acceleration (m/s^2), h =net head (m)

Table 7. It shows the average values of the flow, which is a variable parameter, according to the months. These values were obtained from Yumrutepe power plant with Supervisory Control and Data Acquisition (SCADA) system. Here, while calculating efficiency by months, Table 8 is used. In addition, ρ, g and h values are taken as constant in the theoretical calculation.

Table 7. Monthly variation of average water flow

ρ = 1 kg/m^3, g = 9,81 m/s^2, h=48 m	
Month	**Flow (m^3/sn)**
January	8,02
February	10,97
March	18,05
April	12,55
May	15,93
June	10,85
July	4,43
August	3,01
September	2,63
October	6,35
November	7,48
December	12,97

Table 8. It shows the monthly productivity values calculated using Equation (2) for the average flow values according to the actual energy generation.

Table 8. Monthly efficiency value

Month	Actual Energy Generation(MWh)	Efficiency (μ) %
January	2706	71,65
February	3199	61,92
March	5932	69,79
April	3748	63,42
May	5385	71,79
June	3487	68,25
July	1503	72,05
August	890	62,35
September	782	63,15
October	2139	71,54
November	2464	69,96
December	4394	71,95

2.4. Capacity Factor

Capacity factor (C_F) is one of the most important parameters in the efficiency of power plants. The net capacity factor (C_F) of a power plant is the ratio of its actual energy generation to its generation at full capacity over a certain period of time. Capacity factors also vary widely depending on the type of fuel used and the design of the power plant. The importance of the capacity factor has been confirmed by the Interational Energy Agency (IEA) and it has been published that increasing the capacity factor reduces the energy cost per kWh (Interational Energy Agency Hydropower Agreement, 2000). Although the world averages are between 40-50%, the capacity factor can also take values between 0-100% according to the impact factors.

As seen in Table 9, according to the latest data of Energy Information Administration (EIA), while there was not much change in other power plant types between 2013 and 2018, the capacity factor of hydroelectric power plants showed an increasing trend (Enegry Information Administration, 2019).

Table 9. Capacity factor of different types of power plants between 2013-2018 (EIA, 2019).

YEAR	Nuclear	Hydroelectric	Photovoltaic	Wind	Biomass	Geothermal
2013	89,9%	38,9%	Veri Yok	32,4%	68,9%	73,6%
2014	91,7%	37,3%	25,9%	34,0%	68,9%	74,0%
2015	92,3%	35,8%	25,8%	32,2%	68,7%	74,3%
2016	92,3%	38,2%	25,1%	34,5%	69,7%	73,9%
2017	92,2%	43,1%	25,7%	34,6%	68,0%	74,0%
2018	92,6%	42,8%	26,1%	37,4%	73,3%	77,3%

HPP capacity factor is found by dividing the amount of energy produced by the HPP in a period to the amount of energy produced by the HPP at full capacity.

$$\% \quad C_F = \frac{MW \times Hour}{(30\ Days) \times (\frac{24\ Hours}{Day}) \times MW} \tag{3}$$

There are many reasons that affect capacity factors. The first of these is that the HPP is out of service or operating at low capacity for a while due to equipment failure or routine maintenance. This is the main reason for the unused capacity of power plants. Some power stations have the lowest cost per unit of electricity because they are designed for maximum efficiency and are constantly operated at high efficiency.

The second reason why a facility has a capacity factor of less than 100% is that efficiency is constrained to economize energy generation because electricity is not needed or because the price of electricity is low in the intraday market. This is the advantage of having a structure that can reduce and increase the energy generation of hydroelectric power plants according to demand. In such cases, it is not economical to operate the power plant at full capacity and causes waste of energy.

A third reason is a variant of the latter: operators of a hydroelectric power station can increase generating capacity by adding more generator units. Thus, since the water remains unchanged, a higher energy generation is achieved despite the lower capacity factor. In HPPs, it can be ensured that they sell more electricity by producing more electricity during peak hours of electricity demand and therefore at the highest spot price.

There is also a fourth reason for unused capacity. Normally, the plant can produce electricity, but there may not be enough water. For example, the energy generation of a hydroelectric power station may also be affected by requirements such as whether the water level is too high or low and to provide water for fish in the water stream.

3. Research Findings and Discussion

3.1. Energy Generation of Yumrutepe HPP 2018 Feasibility

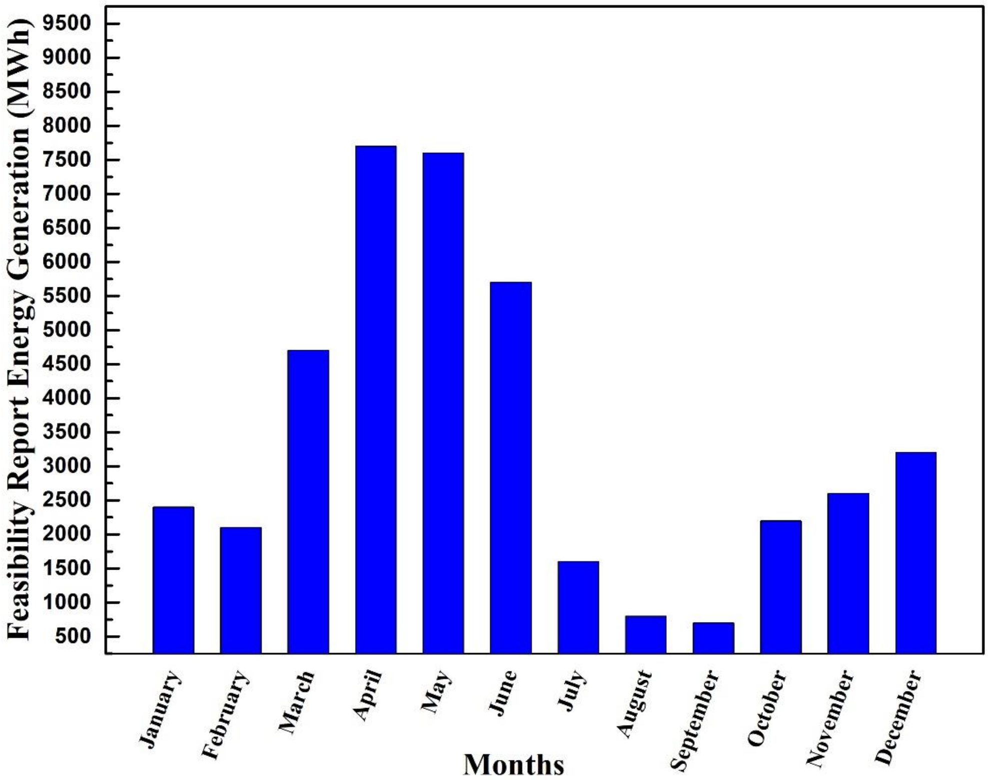

Figure 2. Yumrutepe HPP energy generation feasibility report monthly distribution chart

Figure 2 shows the monthly feasibility energy generation amounts in Yumrutepe HPP installation. The months of April and May, when the energy generation amount will reach the highest levels due to the melting of snow and the increase in precipitation in the high areas, which is called the flooding period in terms of energy generation, and the months of August and September when the energy generation is at its lowest levels due to seasonal low precipitation is calculated in the Figure 2. According to the feasibility report, the energy generation values are seen as the maximum value of 7700 MWh in April and the minimum value of 700 MWh in September.

3.2 Yumrutepe HPP 2018 Realized Energy Generation

In the Figure 3., it is seen that the energy generation realized in 2018 was 5932 MWh, which is highest energy generation, in March, although the month of May is compatible with feasibility. As a result of the melting of snow together with heavy snowfall falling on high areas, the energy generation was higher than feasibility in March. The lowest energy generation was realized in August and September as stated in the report, in accordance with the feasibility reports.

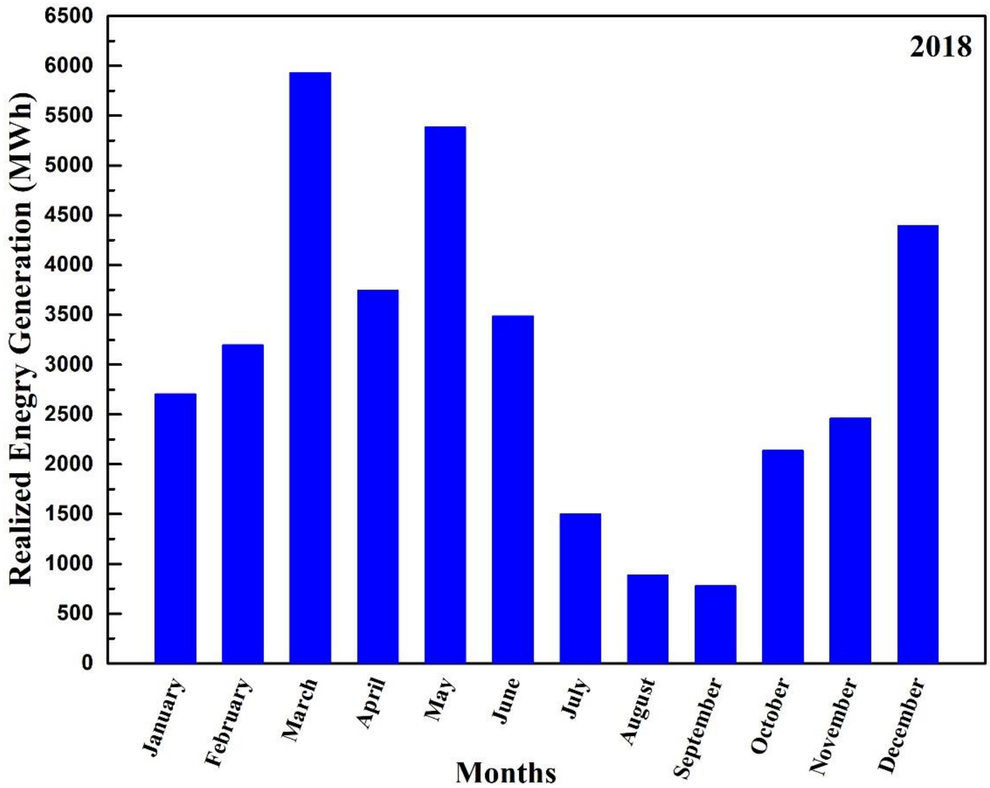

Figure 3. Distribution chart of realized energy generation by months

3.3. The Relationship of the Realized Energy Generation of Yumrutepe HPP with the Average Actual Pressure

The monthly average current pressure data is taken from Giresun Meteorology Station Directorate, showed in the Table 3. Using this data, Figure 4. was created and the monthly change was shown with the inset graph. According to these data, when the energy generation of Yumrutepe HPP in 2018 is compared, it is seen that the actual pressure was at the lowest level in March, namely 821.9 hPa, and the energy generation realized in March reached a maximum of 5932 MWh. As of

July, with the increase in the average actual pressure, a decrease is observed in the energy generation amount, and it is observed that the lowest energy generation was realized as 782 MWh in September.

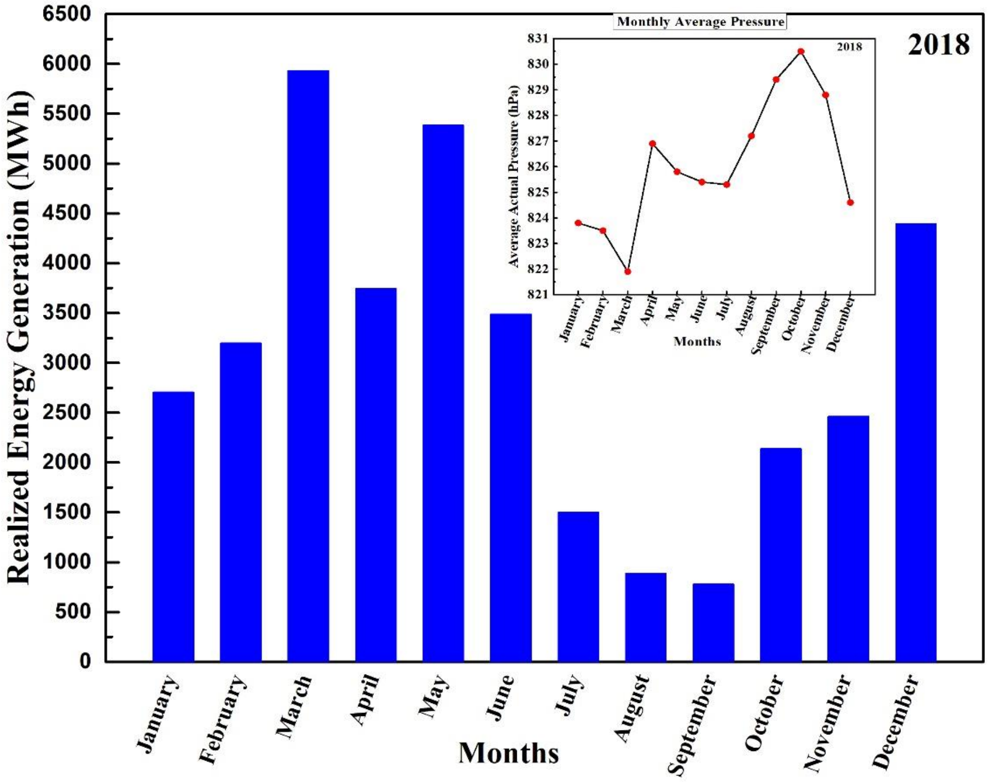

Figure 4. Distribution chart of the realized energy generation according to the average actual pressure. Inset: Variation of monthly average pressure according to months

In Figure 5, the effect of the monthly variation of the average actual pressure in 2018 on energy generation is shown. When this effect is examined, it is seen that the average current pressure was 821.9 hPa in March, the highest energy generation of this year, and the increase in the average current pressure of 826.9 hPa decreased the energy generation in April. On the other hand, in May, energy generation increased again with the decrease in the average current pressure. Even though there is a decrease in the average actual pressure since October and the increase in energy generation due to other effect parameters (temperature, precipitation amount, etc.), the monthly actual pressure of the average actual pressure appears in the monthly energy generation graph.

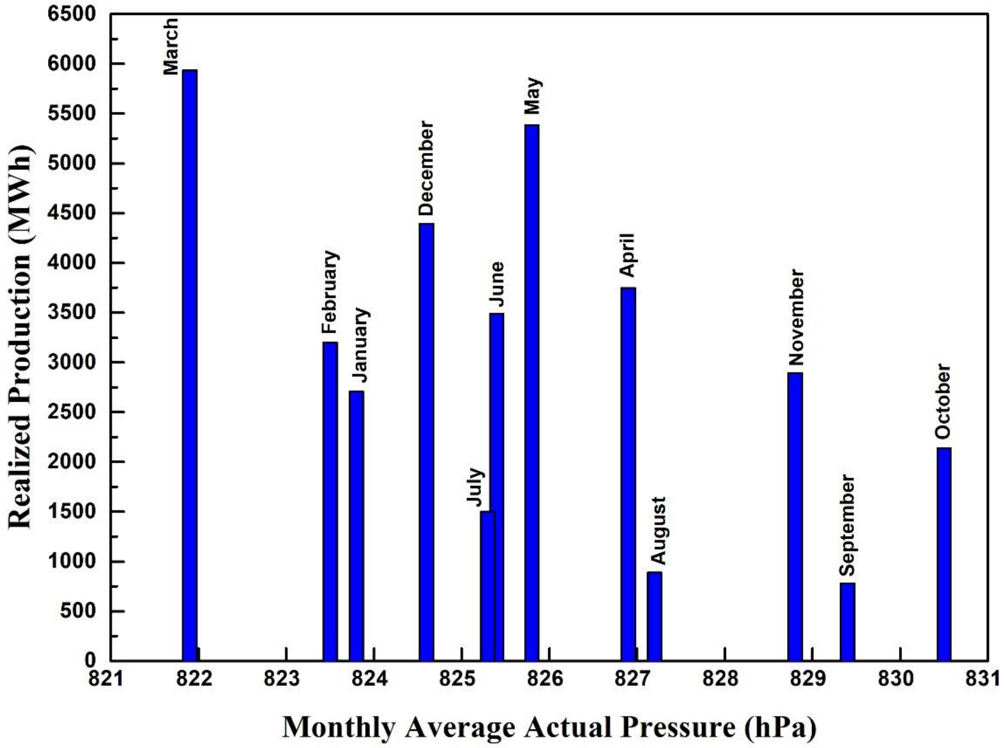

Figure 5. Yumrutepe HPP monthly realized energy generation according to average realized pressure.

3.4. Yumrutepe HPP Realized Energy Generation and Average Temperature

Figure 6, prepared with the data in Table 4., shows the monthly variation of the electricity produced in 2018 and the inset in this graph shows the monthly average temperature change. When the monthly temperature graph on the inset is examined, the energy generation was 2700 MWh and above due to low temperatures and snowfalls in January, February, and December. With the increase in temperature, the snow started to melt, and energy generation reached its maximum in March. With the more increase in temperature levels from June onwards, there are decreases in energy generation, possibly due to low precipitation. With the decreasing in temperatures in October, the amount of energy generation started to increase again.

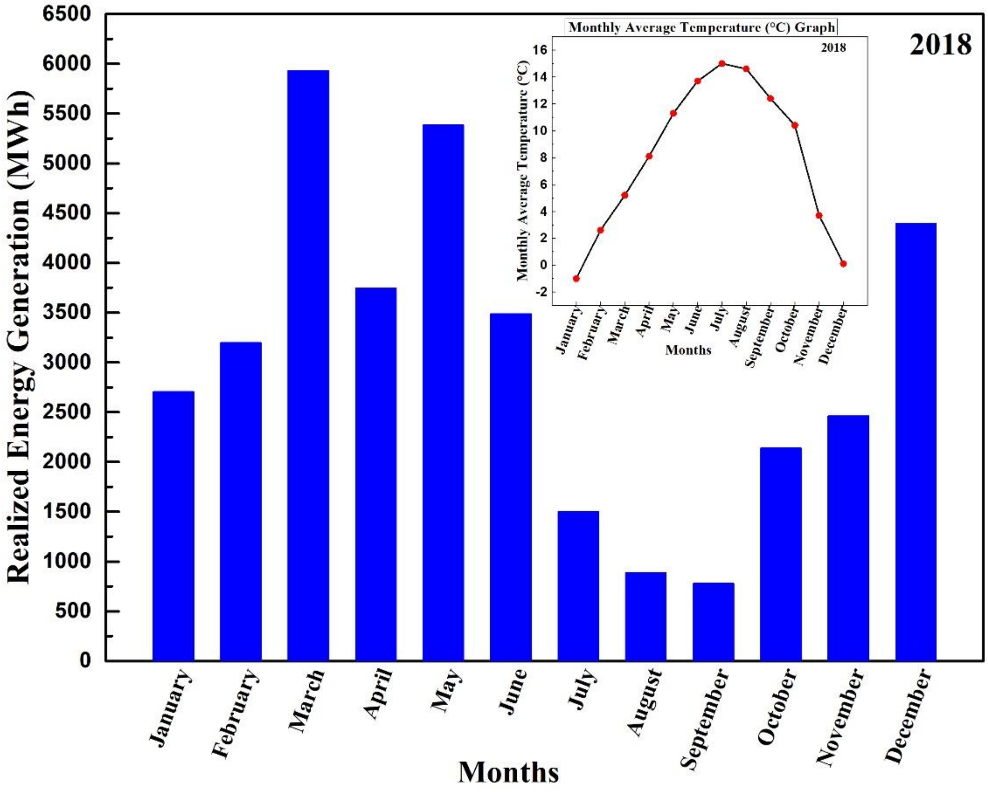

Figure 6. Yumrutepe HPP realized energy generation versus average temperature. Inset: Variation of monthly average temperature according to months

Figure 7. shows that the realized energy generation amounts against the monthly average temperature values. Here, it is seen that the lowest temperature is experienced in January with -1 °C and there is an increase in energy generation with the increase in temperature since January. Although the temperature was 8.1 °C in April, a decrease in energy generation was observed compared to March. 3748 MWh was produced in April, probably due to the low rainfall and most of the snow melted at the end of March on the higher levels. The highest average temperature is 15 °C in July, and 1503 MWh was produced this month.

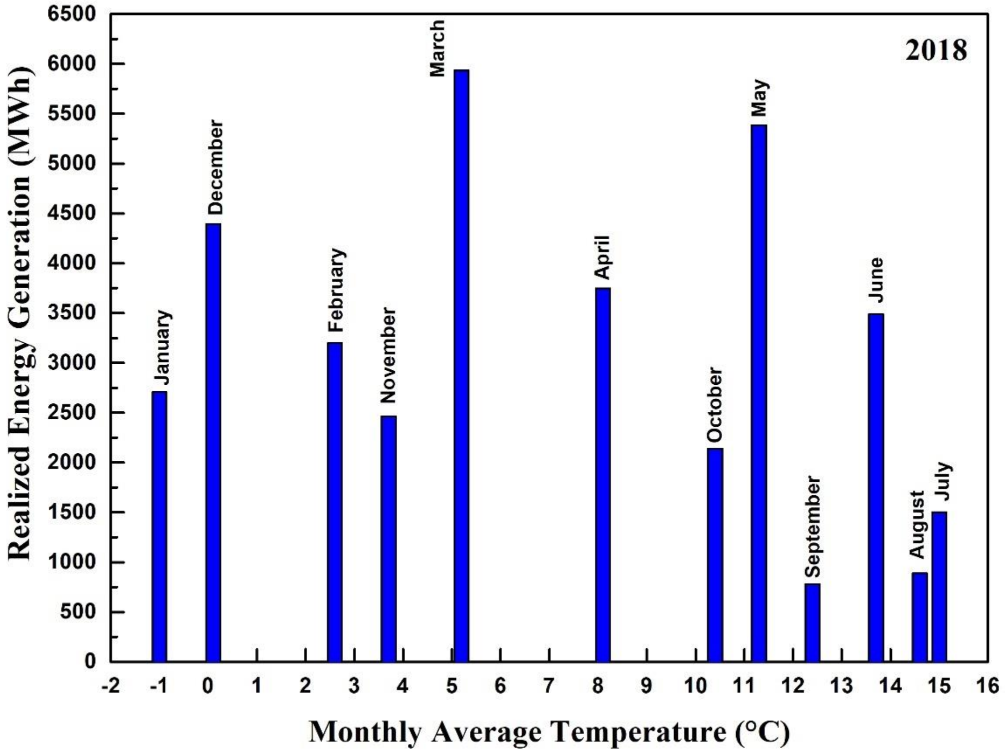

Figure 7 Yumrutepe HPP monthly realized energy generation according to monthly average temperature

3.5. Yumrutepe HPP Realized Energy Generation and Average Relative Humidity

Another often overlooked factor affecting the Energy generation of power plants is the average relative humidity. Figure 8, prepared with the data in Table 5., shows the variation of the actual energy generation with the monthly average relative humidity. When we look at the variation with the monthly average relative humidity in the inset of Figure 8, in March, the month with the highest energy generation, the relative humidity is 69.1%. The lowest energy generation is made in August and September and the average relative humidity is 88.7% and 84.5%, respectively.

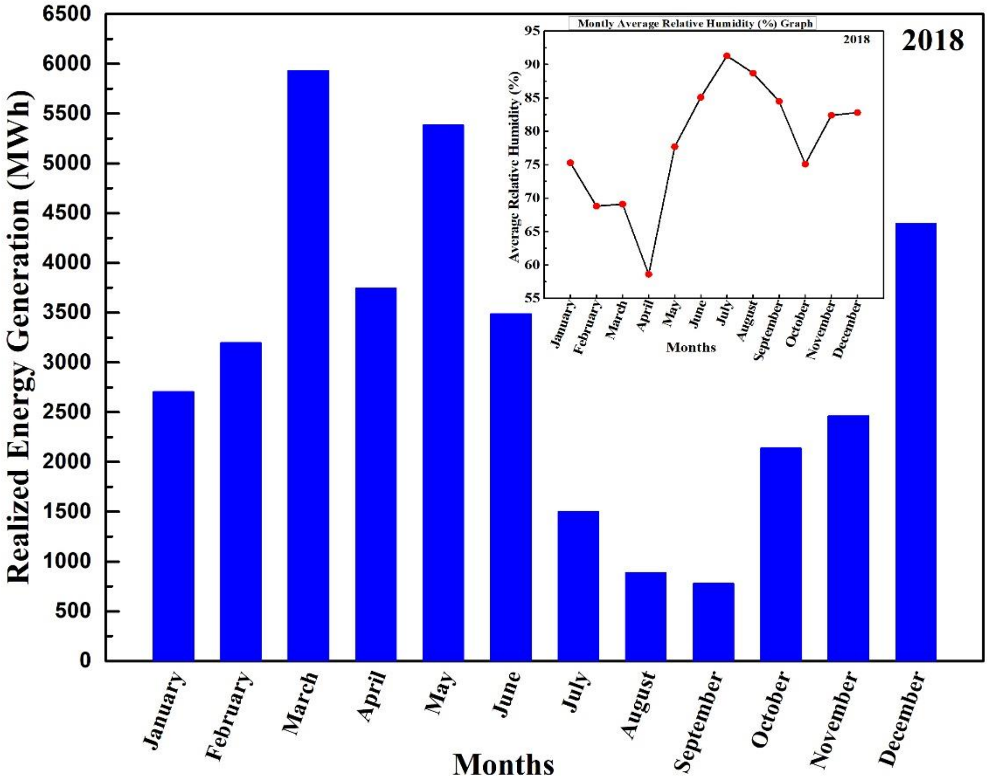

Figure 8. Yumrutepe HPP monthly realized energy generation versus average relative humidity. Inset: Variation of monthly relative humudity according to months

In Figure 9., It shows the energy generation realized against the monthly average relative humidity. Monthly Average Relative humidity was 58.6% in April and energy generation was 3748 MWh in that month. The highest Average Relative Humidity for 2018 is 91.3% in July, and 1503 MWh of energy was produced this month. With 782 MWh energy generation, the relative humidity average remained as 84.5% in September when the energy generation was the lowest.

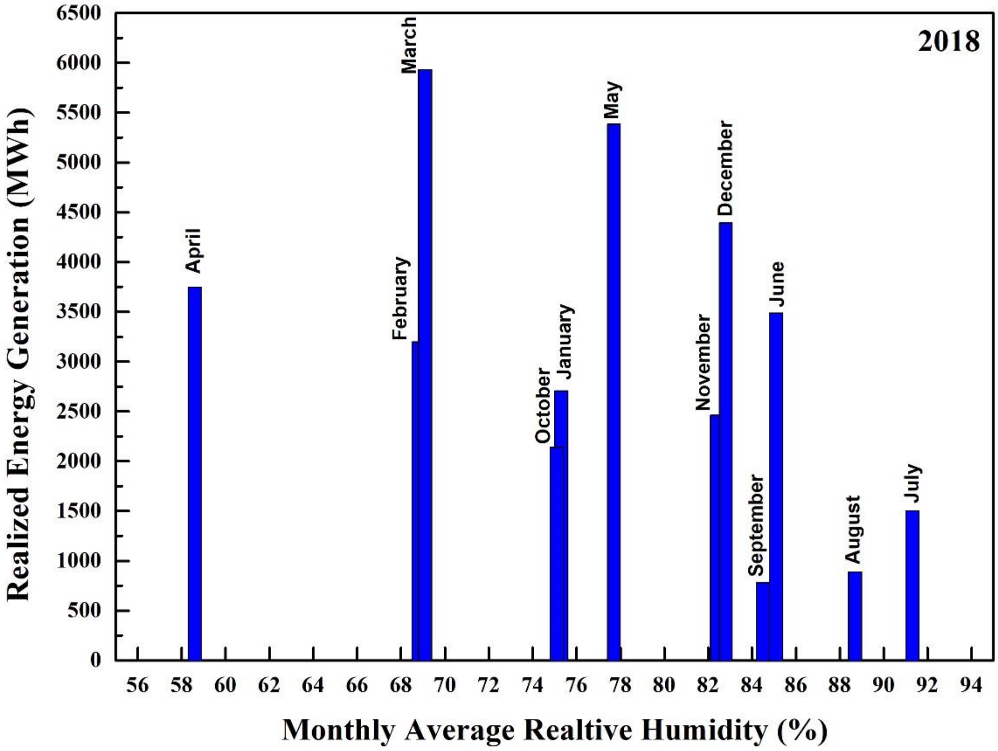

Figure 9. Yumrutepe HPP realized energy generation according to Monthly average relative humidity

3.6. Yumrutepe HPP Realized Energy Generation and Average Precipitation

The effect of the monthly average precipitation amount prepared with the data taken from Table 6. on the actual energy generation is seen in Figure 10. The average precipitation amount in September, which is the minimum energy generation, is 59.1 kg/m^2. When the second highest energy generation is observed, the amount of precipitation is high compability with the feasibility in May.

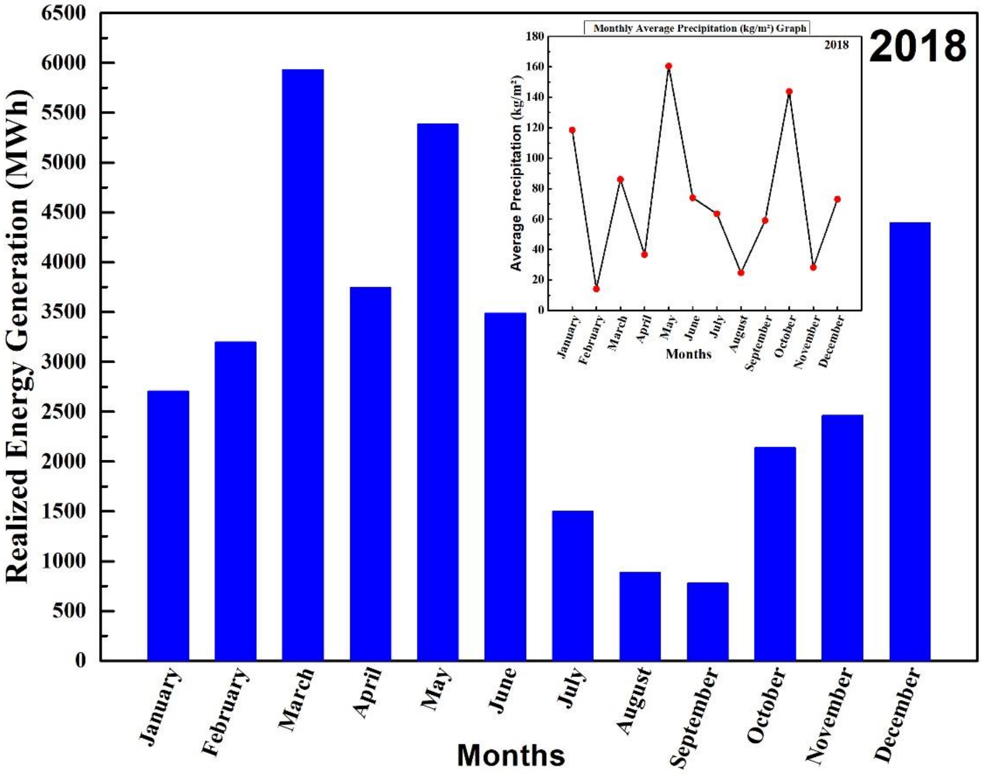

Figure 10. Yumrutepe HPP monthly energy generation versus average precipitation. Inset: Variation of monthly average precipitation according to months

Figure 11. It shows the variation of the actual energy generation to the monthly precipitation amount. The highest average precipitation amount was 160.5 kg/m^2 in May, and energy generation was 5385 MWh. The lowest average rainfall occurred in February and was 14.2 kg/m^2. In accordance with the rainfall amounting to 24.8 kg/m^2 and 59.1 kg/m^2, respectively, in August and September. The generation realized as 890 MWh and 782 MWh, the lowest levels in these months. At the end of the low rainy summer season, the amount of precipitation increased suddenly in October and realized energy generation is reached the value of 2139 MWh.

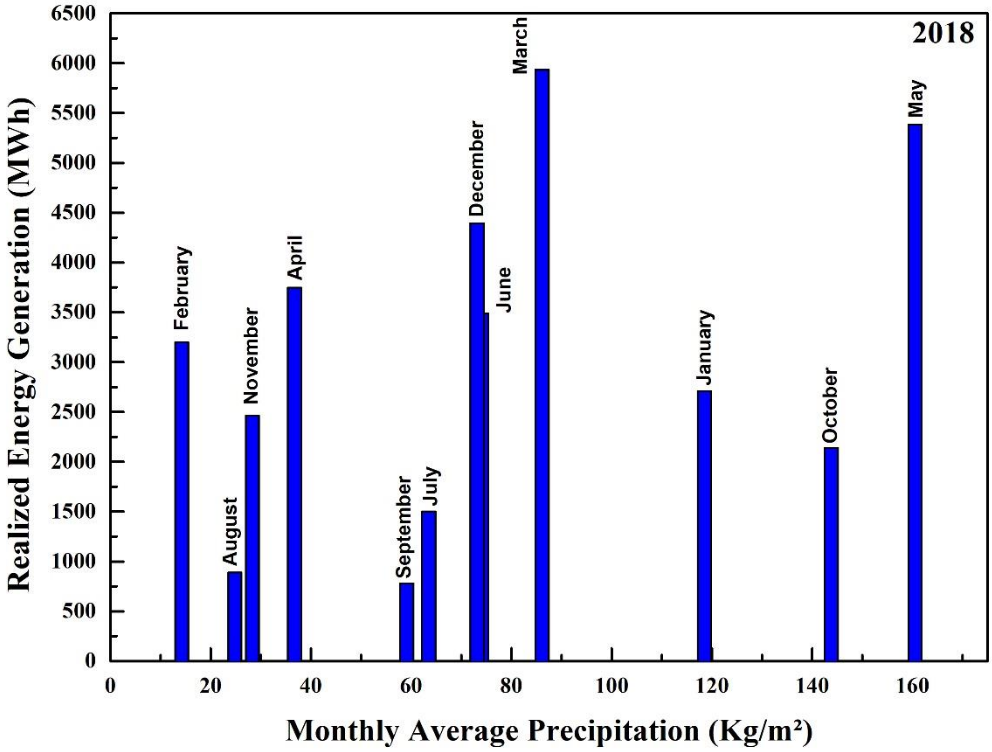

Figure 11. Yumrutepe HPP monthly realized energy generation according to Average monthly precipitation

Table 7. and according to the data in Table 8. Energy generation efficiency of Yumrutepe HEPP between 2018-2019 was calculated and it is shown in Figure 12. Efficiency, which was 71.65% in January, decreased by 61.92%, 69.79% and 63.42% in February, March and April, respectively, but increased again in May, when the second rank energy generation was 71.78%, respectively. reached level. Looking at Figure 12, it is seen that the productivity in 2018 was 72.05% in July. With the decrease in the amount of precipitation after July, the productivity decreases and it reaches the value of 71.53% by increasing as of October when the precipitation amount starts to increase again.

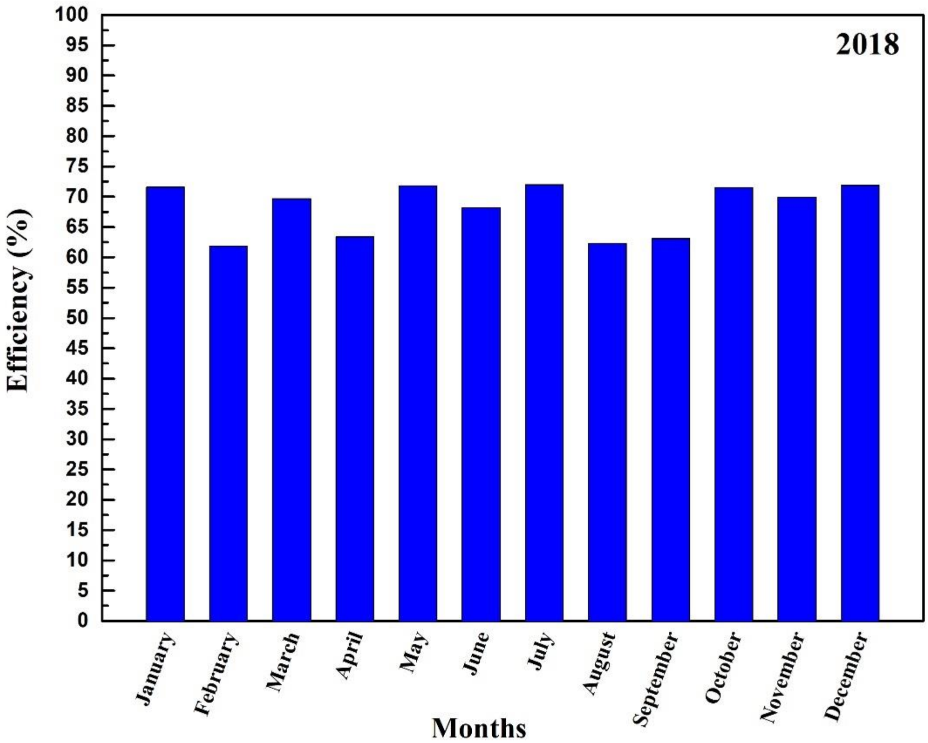

Figure 12. 2018 Yumrutepe hydroelectric energy plant efficiency graph

3.7. Yumrutepe HPP Capacity Factor

Figure 13. It shows the capacity factor values of Yumrutepe HPP between the years 2018-2019, calculated according to Equation 3. While calculating the capacity factor, theoretically, the maximum amount of energy that Yumrutepe HPP can produce monthly if it operates with 3 units for 24 hours is used. Yumrutepe HPP, with an installed capacity of 15 MWh, achieved a maximum energy generation capacity of 55% in March. In May, when the highest amount of precipitation is observed, energy was produced with 50% capacity. The months with the lowest capacity were in August and September with 7% and 8%.

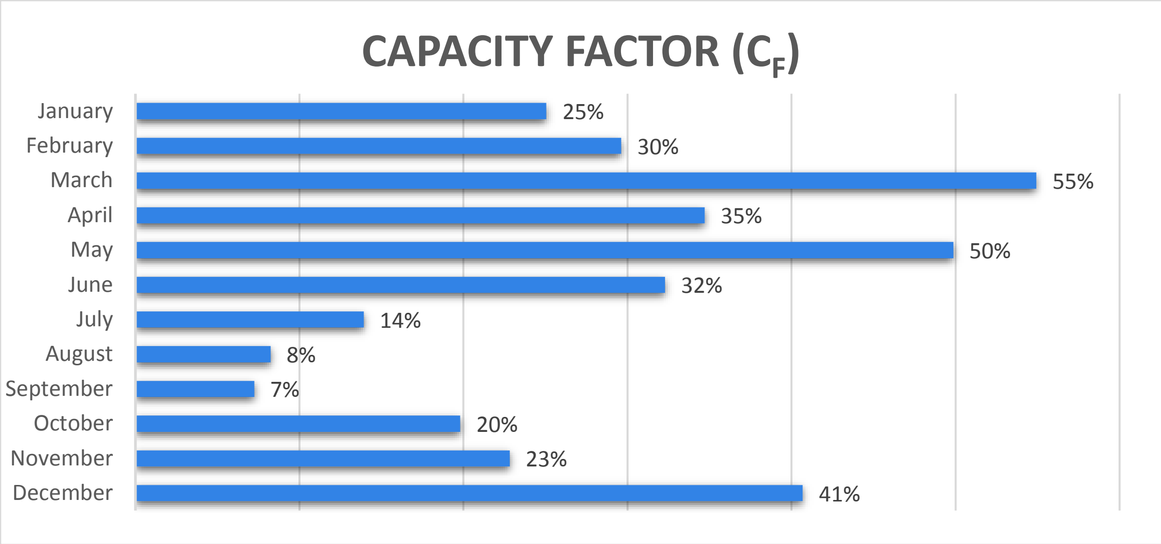

Figure 13. 2018 Yumrutepe HPP monthly capacity factor values

4. Conclusion

Since the most ideal situation was considered in the feasibility report, the energy generation amount was shown as the highest 7700 MWh in April and the lowest 700 MWh in September. The energy generation realized in 2018 showed that the energy generation were approximate in accordance with the feasibility report in the months. For example, the actual value of May, which is calculated as 7600 MWh in the ideal case, is 5385 MWh per month. In March, it reached the maximum energy generation amount and became 5932 MWh. In this month, a energy generation value very different from feasibility was achieved due to the early start of the 2018 flooding period and the low snowfall.

When we investigated the relationship between the monthly average actual pressure in the atmosphere as a general behavior, an increase in energy generation is observed with a decrease in partial pressure, and a decrease in generation with a decrease in pressure. In other words, the current pressure and the energy generation in the HPP are inversely proportional. This is especially true after July, with the actual pressure value rising from 825.3 hPa to the last peak of 830.5 hPa, and there is an obvious decrease in the generation till October. Then, towards the end of the year, there was an increase in energy generation again as the pressure decreased.

The effect of the monthly average temperature on the actual energy generation were analyzed for two period intervals. The first period was divided into the first six months of 2018 and the second period as the last six months of 2018. Here, an increase in energy generation is directly proportional to the average temperature, due to the melting of the snow left over from the winter of 2017 in the first period, which is the exception due to the extra-failure situation in March. In the second period, which is after July, the average temperature is started to decrease, and the energy generation decreased until October by the effects of temperature in the summer, and then increased again due to atmospheric parameters effects such as the actual pressure in the air, partial humidity, and the amount of precipitation. The energy generation amount was 2706 MWh in January, when the average temperature was minimum with -0.1 ^{o}C throughout the year, and it was 1503 MWh in July, when it reached the maximum average value of 15 ^{o}C.

When the effect of monthly average relative humidity on energy generation is examined, it is seen that relative humidity has less effect on the energy generation compared to other parameters. it has been determined that relative humidity has a similar effect as partial pressure. In other words, it is observed that an increase in energy generation by decrease in relative humidity and a decrease in energy generation by increase relative humidity. Contrary to popular belief, excess relative humidity in the atmosphere does not provide more energy generation. the maximum value of relative humidity is in July with a value of 91.3%., this is is the month with the highest monthly average temperature in this year. In addition to this, in March, which stands out with its maximum energy generation. The partial humidity naturally remained at a low value and reached the minimum value of 58.6% in April, while the maximum energy generation was supposed to be according to the feasibility report. This is a clear proof that monthly average relative humidity and energy generation are inversely proportional.

The average precipitation amount is the other parameter for energy generation. In May and October, precipitation amounts have their highest values with 160.5 m^3/s and 143.8 m^3/s, respectively. Although there were fluctuations in the amount of precipitation throughout the year, while the regular increase and decrease in seasonal energy generation continued with the predominance of other parameters, it was observed that the amount of precipitation was not very effective on the productivity in energy generation.

The energy generation efficiency of Yumrutepe HPP is the lowest in February with 61.9% and the highest is in December with 71.9%. Considering the productivity calculation, the highest productivity was not achieved in March, which the month with the highest energy generation or in September, although energy generation is the lowest, it is not the worst month in terms of productivity. Considering the reasons for the lowest productivity in February, it was seen that the monthly precipitation amount in January decreased by 8.34 times in February. In December, productivity increased by 2.58 times compared to the previous month and reached its highest value. One of the main variables used in the calculation of efficiency is the amount of water flow. An increase was observed in terms of efficiency by the increase in water flow due to rains and it caused increase in energy generation since October. The reason for the maximum efficiency in December was interpreted as the flow rate of the water coming to the turbines was more stable compared to other months in that the flow fluctuation in December was very low. Since there was a lot of fluctuation in January, the lowest productivity was achieved this month. We concluded that the month, which amount of realized energy generation is high, does not mean that the Hydroelectric energy plant is more efficient for that month. It was understood that other parameters examined in this study should also be taken into account.

Considering the monthly capacity factor changes of the Yumrutepe hydroelectric energy plant between 2018 and 2019, it was seen that March and May, the months with the highest energy generation, is the best in terms of capacity. Looking at the feasibility report, Altough the highest energy generation and the highest capacity factor were expected in April, it is calculated 3748 MWh with 35% capacity in April as a result of atmospheric and other factors.

The capacity is 30% in February, which the least precipitation was experienced. However, although there is more precipitation in August and September than in February, the capacity factors are 8% and 7%, respectively, these are far behind February. There are many different factors that affect the generation capacity of hydroelectric power plants. Among these, the most prominent factors are electrical and mechanical failures, energy generation losses in annual maintenance, losses in transmission lines, environmental waste and sediments in the water accumulating on the grids through which the water taken for energy generation, clogging the grids and the decrease in the amount of flow taken into the turbine. These are negatively affects energy generation related to the capacity factor.

Authors' Contributions

All authors contributed equally to the study

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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