PLANING OF SMALL HYDROPOWER PLANTS AND KEZER RIVER

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Abstract:
Investments of Hydroelectric Power Plants have been grown up and our country has become like a construction site by entering into force of the law concerning the transfer of the right of water use in Turkey since 2001. Turkey has a gross annual hydropotential of 433.000 GWh, which is almost 1% of world total potential. Its share is about 16% of the total hydropower capacity in Europe. This situation has increased the importance of planning and arousing interest of academic levels of hydroelectric power plant (HEP) and small hydropower plant (SHEP). Small-scale micro hydropower is both an efficient and reliable form of energy. The first small hydroelectric plant (SHEP) with a capacity of 88 kW was installed in Turkey in 1902. In this study, a concrete example of a not accumulated hydroelectric facility planning is discussed by aiming of consideration of Kezer River in Turkey hydroelectric energy potential. Finally Installed power and energy values of the total annual flow have been calculated using discharge, net head and turbine efficiency.

Key Words: Renewable energy, Small hydropower, Kezer river

Introduction

Energy plays a vital role in the socio-economic development and in raising the standard of living. Turkey is a rapidly growing country where both its population and economy are expanding each year, resulting in a corresponding increase in its energy demand. This increasing demand has to be met to keep a sustainable development in the economy and to raise the living conditions of the people. Although Turkey has many energy sources, it is a big energy importer. Turkey has a lot of potential to supply its own energy, which could be harnessed in order to avoid this energy dependency. Additionally, Turkey is a country with an abundance of renewable energy sources and can essentially provide all energy requirements from its own indigenous energy sources [1]. Table 1 shows Turkey's present and future energy consumption (taken from Ministry of Energy and Natural Resources of Turkey) with respect to various resources [2].

Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the entire world. This is primarily because renewable energy resources have some advantages when compared to fossil fuels. Turkey has to adopt new longterm energy strategies to reduce the share of fossil fuels in the energy consumption [3].

Turkey has a total hydropower potential of 433 TWh that accounts for almost 1.1% of the total hydropower potential of the world and for 13.75% of European hydropower potential. Only 130 TWh of the total hydroelectric potential of Turkey can be used economically. By the commissioning of new hydropower plants, which are under construction, 43% of the economically usable potential of the country would be exploited. At present the hydropower energy is an important energy source for Turkey due to its useful characteristics such as being renewable, clean, and less impactful on the environment, as well as being a cheap and domestic energy source [4].

Turkey is divided into 25 drainage basins in regard to the concept of hydrology, as given in Table 2 [5]. Annual average flows of these basins are approximately 186 km^3. The Euphrates and Tigris, among all basins, is the largest with about 185,000 km^2 of land area. Most of country's water potential lies in the southeast region (Euphrates and Tigris basin) with 28.5%, followed by Black Sea region with 13.3%, Mediterranean region with 10.8%, Marmara region with 4.5% and others.

Table 1. Turkey's final energy consumption by resources.

Type of Resources	2006	2010	2015	2020
Hard coal	14,721	17,282	26,884	48,156
Lignite	11,188	18,001	24,190	32,044
Asphaltite	259	301	301	301
Oil	32,551	41,184	50,420	60,918
Natural Gas	28,867	37,192	44,747	51,536
Nuclear	0	0	8229	8229
Wind	11	421	571	721
Solar	403	495	605	862
Fuelwood	4023	3383	3075	3075
Animal and Vegetable residues	1146	1034	926	850
Geothermal (Heat)	1081	1750	2836	4584
Geothermal (Electricity)	330	330	330	330
Hydraulic	3556	4903	7060	9419
Growth rates (%)		29	35	31

Table 2. Turkey's drainage basins [6].

No	Name of basin	Rainfall area (km^2)	Annual average flow (km^3)	Share in total (%)	Annual average yield ($l/s/km^2$)
1	Meric-Ergene	14,560	1.33	0.7	2.9
2	Marmara	24,100	8.33	4.5	11
3	Susurluk	22,399	5.43	2.9	7.2
4	K. Ege	10,003	2.09	1.1	7.4
5	Gediz	18,000	1.95	1.1	3.6
6	K. Menderes	6907	1.19	0.6	5.3
7	B. Menderes	24,976	3.03	1.6	3.9
8	W.Mediterranean	20,953	8.93	4.8	12.4
9	Antalya	19,577	11.06	5.9	24.2
10	Burdur	6374	0.5	0.3	1.8
11	Akarcay	7605	0.49	0.3	1.9
12	Sakarya	58,160	6.40	3.4	3.6
13	W.Black Sea	29,598	9.93	5.3	10.6
14	Yesilirmak	36,114	5.8	3.1	5.1
15	Kizilirmak	78,180	6.48	3.5	2.6
16	Konya(closed)	53,850	4.52	2.4	2.5
17	E.Mediterranean	22,048	11.07	6	15.6
18	Seyhan	20,450	8.01	4.3	12.3
19	Asi	7796	1.17	0.6	3.4
20	Ceyhan	21,982	7.18	3.9	10.7
21	Euphrates-Tigris	184,918	52.94	28.5	21.4
22	E.Black Sea	24,077	14.90	8	19.5
23	Çoruh	19,872	6.30	3.4	10.1
24	Aras	27,548	4.63	2.5	5.3
25	Van lake	19,405	2.39	1.3	5
	Total	779,452	186.05	100	

The obvious benefits of hydropower projects in Turkey or in any other country where hydropower potential exists abundantly, is associated with the generation of electrical power, which has the ability to both assist the sustainable economical development and increase the quality of life. Furthermore, they are labor-intensive during construction, as well as providing long term employment opportunities [7]. Another benefit of exploiting water resources is about environmental concern. Because it is a renewable, clean and green energy source, it is less harmful than fossil fuel sources causing dangerous gas emissions.

Small, mini and micro-hydro plants (usually defined as plants less than 10 MW, 2 MW and 100 kW, respectively) play a key role in many countries for rural electrification. Small scale hydro is mainly ‘run of river,’ so does not involve the construction of large dams and reservoirs. Therefore there have been minimal and ignorableenvironmental problems with small scaled hydro plants in comparison with those of HEPs with large dams. In medium head (5m< head< 15 m) or high head (head >15 m) installations, water is carried to the forebay by a small canal. Low head installations (head <5m) generally involve water entering the turbine almost directly from the weir. Small hydro technology is extremely robust (systems can last for 50 years or more with little maintenance) and also has the capacity to make a more immediate impact on the replacement of fossil fuels because unlike other sources of renewable energy. It can generally produce some electricity on demand with no need for storage or backup systems [8]. Turkey has a mountainous landscape with an average elevation of 1132 m that is about three times higher than the European average. This topography favors the formation of high gradient mountain streams which are suitable locations for SHEP development [9].

It is highly sensitive to environment like other renewable energy sources. Table 3 compares potential environmental impacts of renewable energy development. These negative effects, however, can be ignored compared to those of primary energy sources such as oil, coal and gas. In addition, SHEP plants also have effects on natural environment. They cause disadvantages such as blockage of fish passages and protection, and interruption of sediment transport. For this reason, effective fish passages for all fish species in the region where SHEP was set up must be achieved. Various local SHEP projects are under investigation and the preliminary reports of some of them are either under preparation or ready. The adoption of SHEP will lead to an improved rural economy through increased employment in their construction and provision of cheaper electricity for domestic use. In addition deforestation caused by using wood for heating will decrease.

Table 3. Comparison of potential environmental impacts of renewable energy sources.

Type of renewable	Potential environmental impact
SHEP	Blockage of fish passage and interruption of sediment transport
Wind	Noise, visual impacts, avian and bat mortality
Geothermal	Thermal pollution, damage to natural geothermalfeatures, subsidence
Solar PV	PV panel disposal

There is a clear growth trend for SHEP plants, as can be seen in Table 4. Since 1990, number of SHEPS and their capacity has more than doubled. Installed capacity and power generation of SHEP plants are expected to be 260 MW and 968GWh/year by 2010 and 335 MW and 1250GWh/year by 2015. Table 4 gives the growth trend of SHEPs during the period 1996-2002 and short term and long term forecast of SHEP development [10].

Table 4. Small hydropower development in Turkey during 1996-2002 [11].

	1996	1997	1998	1999	2000	2001	2002	Forecast	
								2010	2015
Total number of SHEP	55	56	59	61	67	70	71	100	130
Capacity (MWh)	124.9	137.7	138.6	144.1	146.3	170.2	175.5	260	335
Generation (GWh)	499	500	524	533	636	664	673	968	1250

Material And Method

Introduction of the project area

The province of Siirt is located in the northeast of Southeastern Anatolia Region, 41^{o}-57i-north latitude and 37^{o}-55i east longitude and located on the Sirnak and Van, east, north and Bitlis, Batman from the west, south, surrounded by the provinces of Mardin and Sirnak. From north to south Mus Mountains, east of the province of Siirt area surrounded by the East of the Mountains, the Tigris River, is one of the major water catchment areas. All of the territory of the province fall into the Tigris river basin. Siirt’s largest river, the Botan, is a major tributary of the Tigris. One of the deepest and narrowest valleys in the country, the Botan river valley opens onto the Bitlis river valley and the Tigris valley. Siirt’s other major rivers are the Bitlis, Kezer and Zorava. Boasting over 350 km of rivers and beautiful countryside. Siirt abounds in plateaus and high mountains. The city is backed by steep, high mountains to the north, which form part of the Southeastern Taurus range. Large plateaus such as the Cemirakı, Ceman, Herekol and Bacavan are used as pasturage. Siirt ongoing terrestrial climate and the most prominent features of the four seasons are experienced. Eastern and northern parts of the more hard and rainy winters, warmer summers in southern and southwestern regions. Summers are hot and dry. Surface water source of project is Kezer river and its side branches. Drainage area of kezer river is 1077 km^2 at 577 m elevation. Drainage area and water branches map is given in Fig 1.

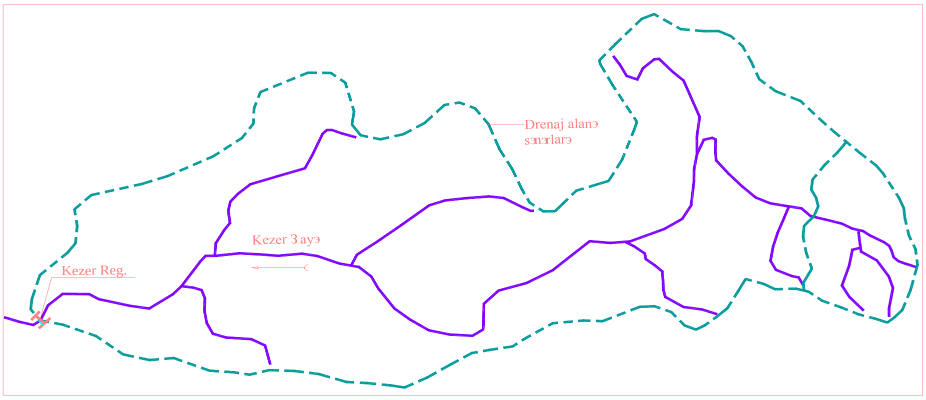

Fig 1. Kezer river drainage area and water brances map

Determining the project formulations

In order to determine project formulation we have used topographic map and google earth program and we have also done the investigations about land's geomorphological state, topographic state, impact of agricultural area, historical and cultural entities. Satellite images about project area are shown in Fig 2 and land pictures are shown in Fig 3. It is thought as not accumulated HEP after investigation mentioned above. It is much more suitable to put regulator location to 569 m. Free surface trapeze is used in order to transmit translated by regulator. Total lenght of transmission channel is 8200 m. Installation pool is made for providig connection with penstock made by transmission channel open to the atmosphere. Installing pool is made in order to perform pipe with pressure to store the water requirement at least for one minute for the turbine and to meet rebound in case of water entrance to turbine or water cut.

Water entrance from installation pool to tribunes in central is done with penstock. Penstock working with pressure is made with reinforced concrete and polietilen pipe or mainly steel pipe. Penstock's diameter can be changeable according to the discharge rate. Average speed in penstock is required as 3-6 m/s but maximum speed is required as 10 m/s [12] . Penstock is determined as 100 m in Kezer regulator and HEP project.

Fig 2. Kezer regulator, HEP regulator location and route of the transmission channel

Fig 3. Kezer regulator and HEP route of the transmission channel

Power house is the plant transforming water to energy and water comes from penstock. Water passed through turbines transform into mechanic energy. Energy made up of with water passed through turbines decreases with its productivity and energy transferred to generator is transformed to electrical energy. But, there can be seen decreases in the quantities of energy according to the productivity of generator. Voltage of the electricity is increased from medium to high and it is transferred to the switcyard. Operation of the water leaving the turbine again into the river bed is done by tail water channel. Elevation of the tail water channel of this project is 532 m.

Determining water discharge

There are records of observation station (AGİ) numbered as EİE 2624 from 1972 to 2010 and this AGİ is located on Pınarca village site 530 m on Kezer stream in the downstream of project working border around 577 m and 532 m. There is no need to investigate another stations or statistical analysis among stations and this AGİ has got enough time of period (39 years) and perfect information for represantation of the project. Discharge and flow rates should be determined for regulator place in order to move this discharge and flow rates to regulator place. For this reason, field calculation should be made for the regulator place on 569 meters and records should be moved to regulator place with areas ratio method. Discharge results should be used to discharge continuity curve and then water discharge (in the 95 % of time) and quantity of firm (reliable) energy would be determined.

Installed capacity calculation

To calculate the installed power required to account for the net head. For this, first head losses to be calculated and calculation will be based on the difference between the gross head.

Flood calculation

Regulator to determine the capacity of the spillway flood accounts is required. For this purpose, regional flood frequency analysis method will be used.

Findings And Discussion

Climate and water resource of the region

Kezer rainfall area completely have features of climate of east anatolia. Regions parameters of rain, humidity, heat, evaporation, relative humid, wind and snow are determined by stations used by DSI (state water affairs) and DMI (state meteorological service). kezer regulator at the thalweg elevation of around 569.00 m is planned to turn water comes from rainfall area which is on this elevation. In Fig 4, rainfall area of Kezer regulator is determined on the map with the scale of 1/ 25000, rainfall area for regulator place is 1077.60 km^2 and rainfall area for power house is 1169.60 km^2. Meteorology observations stations near the project rainfall area were drawn using the thiessen poligons. Project rainfall area's observation stations are Baykan, Siirt, Sirvan, Bitlis, Hizan, Resadiye, Sarikonak, Tatvan. These stations represantation rates are respectively 2.11%, 4.43%, 36,08% 19.67%, 13.79%,4.23%, 15.86%, and 3.82%.

Surface water source of project is Kezer river and its side branches. In the northeast of project rainfall area, Sapur river sprang from about 2700.00 m elevation, then named as Guzeldere with joining of large and small side branches from right or left shore. Guzeldere is then renamed as Baykan river and its name is changed as Cobansuyu with joining of Ceviz river around 1050.00 m elevation. It is named as Koca river with joining of Harmanyeri river and then it is named as Kezer river with joining of side branches at 569.00 m elevation where it is reached to regulator place. Branches from right and left shores joined to Kezer river which flows in the South direction and it is reached to central place as Pınarca river at 532.00 m elevation.

Kezer river numbered as EİE 2624- Pınarca flow observation station (AGİ) is on the same stream with the project. Rainfall area of this sation is 1169.60 km^2 and its approximate elevation is 530 m. Flow records of this station are decided to be used in water supply of Kezer regulator and HEP Project. The flow records of EİE 2624 AGİ is used in the calculations of average daily flow of Kezer regulator place planned to set up at 569.00 m elevation. 1972 - 2010 years of recorded daily average flows for the period covering the 39-year, monthly and annual average flow rates (Fig 5), monthly and annual total flow is used. This AGİ's average daily records of discharge for 39 years, average monthly and yearly dicharge (Fig 5) and total monthly and yearly total flow rates are used. Accordingly, EİE 2624 AGİ's yearly average discharge is 19.78 m^3/s and yearly average flow is 622.73 hm^3.

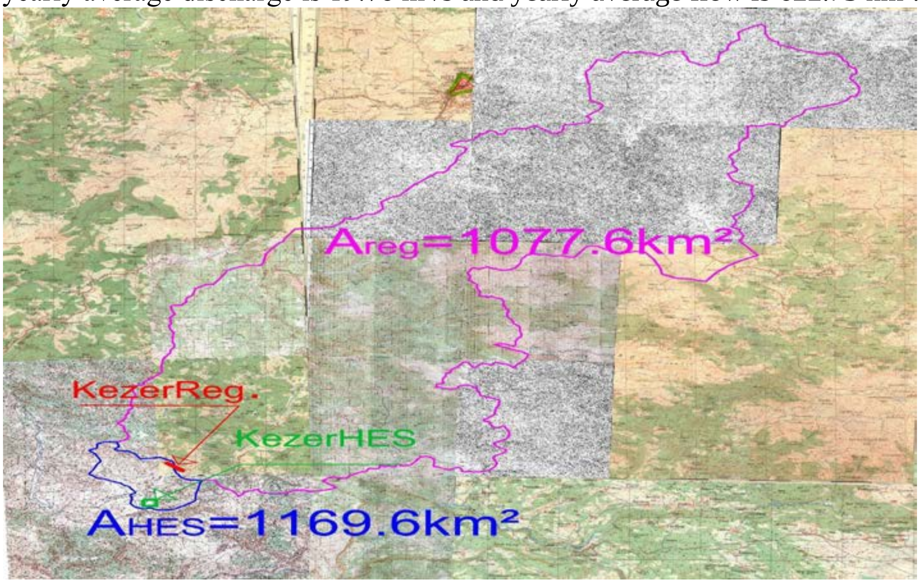

Fig 4. Regulator place and drainage area of the central place

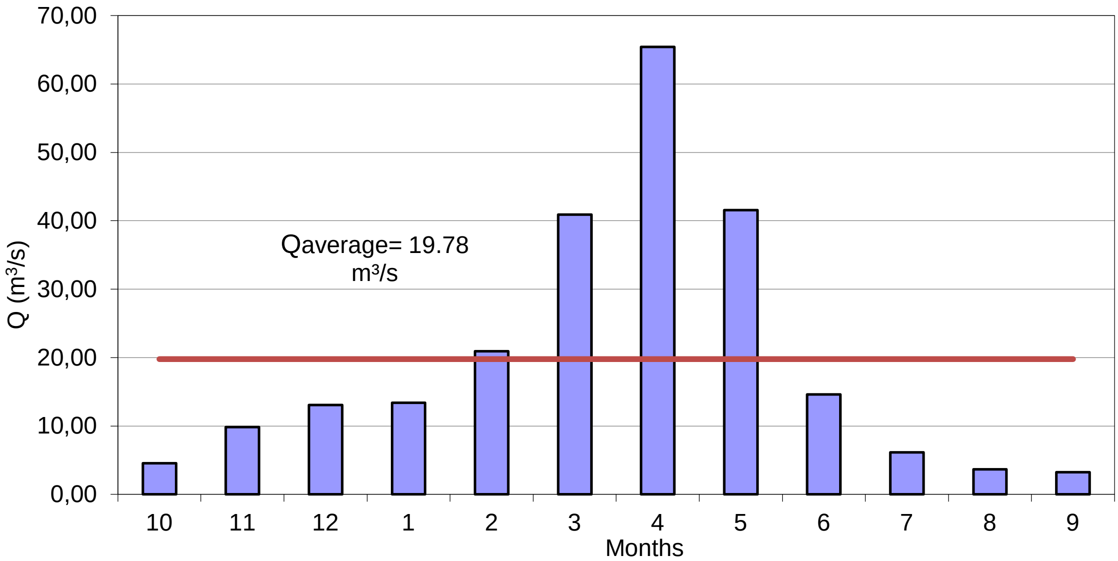

Fig 5. EİE 2624 AGİ, for many years monthly average flow rates

Discharge continuity curve darwn by using flow rates btween the years of 1972 and 2010 is shown in Fig 6. Accordingly, yearly average discharge of Kezer regulator area is 17.16 m^3/s and its yearly total flow is 540.08 hm^3. Firm discharge available at least 95% of not accumulated HEP project is described as discharge on the source of river [13]. For this reason, discharge continuity curve is used. Firm power is described as power obtained by this discharge and firm energy. Energy which is not firm is named as secondary energy.

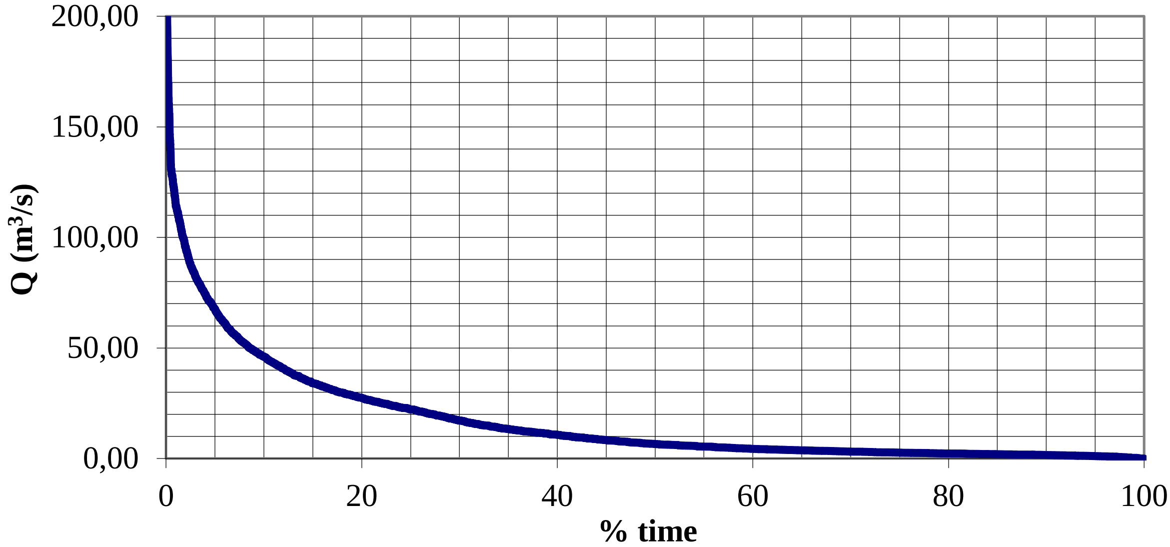

Fig 6. Regulator place discharge continuity curve

Discharge continuity curve drawn by discharge and temporal percentages is shown in Fig 6 [14]. According to discharge results obtained by discharge flow curve in the time of 95 % is 1.64 m^3. The turbine power plant, set up with this discharge, is accepted as firm power and energy can be generated is accepted as firm energy.

Calculations of installed power

The installed power of project is calculated by the discharge and head, the equation is as follows:

$$P = 9.81 \times Q \times H \times \eta \quad (1)$$

where, P: installed power (Kwh), Q: discharge (m^3/s), H: Net head, η: productivity of the turbine.

In this equation, we must find firstly head loss in order to find net head. Total head loss is calculated as 4.22 m. Gross head is 45 m (577-532) and net head is obtained as 40.78 m (45-4.22).

Design discharge is accepted as 36 m^3/s by choosing discharge in 15% of time in the discharge continuity curve. In the literature calculation of firm power, installed power is Q_{50} and maximum design discharge is Q_{15}. Initial design discharge is described as the value of the time in the 15% and 30 % . Installed power P is calculated as 1325 kwh or mechanically 13.25MW (9.81x36x40.78x0.92). 0.98 which is the coefficient generator is multiplied by this energy and we find the electrical power. In this case installed power is 13.00 MW electric.

Energy production calculations

The amount of energy that can be produced in a year is calculated based on annual water volume and head. The annual volume of water taken as the average of all years removed tailrace,

$$E = 2.32.10 \times V \times H_{net} \times \eta \quad (2)$$

where, E: annual amount of net energy generated (kwh), V: annual amount of water (m^3), H:amount of net head (m), η: turbine efficiency. Total energy is calculated as 42,57 GWh/year ($2.32.10^{-3}$x$489.12.10^6$x40.78x0.92). Firm energy is calculated as 4.44 GWh/year ($2.32.10^{-3}$ x $50.96.10^6$x40.78x0.92). Secondary energy is calculated as 38.13 GWh/year (42,57-4,44).

Choosing of turbines

According to the calculated discharge and head, It is chosen as Francis turbine. The productivity of turbine's exit power is determined as 0.92. The number of turbine is two because project design discharge is above the average discharge. Discharge of water is divided in to two named as branch in the central entrance after penstock and it will be passed through each turbine as 18.00 m^3/s. Each turbine power is 6635 kwh. Horizantally Francis turbine is used.

Flood Accounts

Regional flood frequency analysis is chosen in this project because the numbers of records are enough and flow data exactly represents the area. In these calculations annual recurrence flood discharge found by AGİ's frequency analysis and this discharges moved to regulator and central by using formulations given below;

$$Q_{Reg}=(A_{Reg}/A_{AGİ})^{2/3}\ xQ_{AGİ} \quad (3)$$

$$Q_{Santral}=(A_{Santral}/A_{AGİ})^{2/3}\ xQ_{AGİ} \quad (4)$$

Given the recurrent times for AGİ flood values calculated for regulator and central place is given in Table 5.

Table 5. Flood values

Recurrence year	Station place (m^3/s)	Regulator place(m^3/s)
2	328.98	307.84
2.33	345.68	323.47
5	480.81	449.91
10	574.64	537.71
25	687.98	643.77
50	769.24	719.8
100	848.13	793.62
500	1022.31	956.61

Conclusion

In this paper the evaluation of hidroelectrical potential of Kezer river (the branch of Botan river on Dicle basin) between the elevation of 532 m and 577 m is done. For this reason firstly, regulator which is thought as convert structure for plant is seen suitable to place it at the 569 m elevation. Water taken from the regulator is thought to transmit to central by transmission channel with a free surface flow which is 8200 m long. Installing pool is designed for controlling water entrance to central with penstock at the end of the transmission channel. Water discharge in the time of 95 % is found as 1.64 m^3/s with drawing discharge continuity curve. Total of continuous and local head loss is calculated as 4.22 m (In the sedimentation pool, transmission channel and penstock) and it is substracted from gross head (45 m) and real head is found as 40.78 m. Discharge, real head and the productivity of turbine are used to find the value of installed power as 13.25 Mwh and the value of total energy as 42.57 Gwh.

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