

An Assessment of the Small Hydropower Potential of Sisakht Region of Yasuj

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Abstract—Energy generated by the force of water in hydropower can provide a more sustainable, non-polluting alternative to fossil fuels, along with other renewable sources of energy, such as wind, solar and tidal power, bio energy and geothermal energy. Small scale hydroelectricity in Iran is well suited for “off-grid” rural electricity applications, while other renewable energy sources, such as wind, solar and biomass, can be beneficially used as fuel for pumping groundwater for drinking and small scale irrigation in remote rural areas or small villages. Small Hydro Power plants in Iran have very low operating and maintenance costs because they consume no fossil or nuclear fuel and do not involve high temperature processes. The equipment is relatively simple to operate and maintain. Hydropower equipment can adjust rapidly to load changes. The extended equipment life provides significant economic advantages. Some hydroelectric plants installed 100 years ago still operate reliably. The Polkolo river is located on Karun basin at southwest of Iran. Situation and conditions of Polkolo river are evaluated for construction of small hydropower in this article. The topographical conditions and the existence of permanent water from springs provide the suitability to install hydroelectric power plants on the river Polkolo. The cascade plant consists of 9 power plants connected with each other and is having the total head as 1100m and discharge about 2.5 cubic meter per second. The annual production of energy is 105.5 million kwh.

Keywords—Hydropower potential, Iran, SHP, Yasuj.

I. INTRODUCTION

MOST hydropower systems in use today are large-scale and are unfortunately hampered by many environmental problems [1], such as, building of large dams in order to create a reservoir, mass population migration, disruption of traditional fishing practices, deposition of silt in river and deteriorating water quality due to toxic elements, methane release.

The conventional method of hydropower planning is beset with many impediments like difficult accessibility of the site, rough terrain in hilly areas etc. resulting into long gestation period extending to even 8 -10 years in some cases and cost escalation 5 - 6 times more than the original estimate [2].

Small hydropower is an important source of new renewable electricity generation capacity [3]. If developed sensitively, it has few environmental risks, and increased use will contribute to curbing CO₂ emissions thereby mitigating global warming. We expect an increased interest in small hydropower over the

coming years, as it in many cases is the most economic method of renewable power generation in Iran. In addition, Iran country have taken an interest in increased distributed generation, either as a good method in places of lacking infrastructure (places with no power lines) or just as an addition to the existing power supply. Yasuj city is located at south west of Iran. This region has many rivers for small hydropower developing. In the region around this city the topographical conditions and the existence of permanent water springs provide the suitability to install small hydroelectric power plant on the rivers. The Yasuj cascade plant consists of 9 hydropower plants on the Polkolo river connected with each other and is having the total head as 1100 m and discharge as 2.5 m³/s.

II. SMALL HYDROPOWER SYSTEMS

Amongst the renewable energy sources, small hydropower is one of the most attractive and probably the oldest environmentally began energy technology [4]. The small hydropower project can be developed economically by simple design of turbines, generators and civil works. Small hydropower systems use the energy in flowing water to produce electricity or mechanical energy. Although there are several ways to harness the moving water to produce energy, run of the river systems, which do not require large storage reservoirs, are often used for micro hydro, and sometimes for small-scale hydro, projects. For run-of-the-river hydro projects, a portion of a river's water is diverted to a channel, pipeline, or pressurized pipeline (penstock) that delivers it to a waterwheel or turbine. The moving water rotates the wheel or turbine, which spins a shaft. The motion of the shaft can be used for mechanical processes, such as pumping water, or it can be used to power an alternator or generator to generate electricity. This fact sheet will focus on how to develop a run-of-the-river project.

A. Small Hydropower Component

Small run-of-the-river hydropower systems consist of these basic components [5]:

- Small diversion dam
- Water conveyance channel
- Fore bay
- Pipeline, or pressurized pipeline (penstock)
- Turbine transforms the energy of flowing water into rotational energy
- Alternator or generator transforms the rotational energy into electricity

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- Regulator controls the generator - Wiring delivers the electricity

B. History of Hydropower

Two thousand years ago, the Greeks learned to harness the power of running water to turn the massive wheels that rotated the shafts of their wheat flour grinders. And in the hydropower heyday of the 18th century, thousands of towns and cities worldwide were located around small hydropower sites. Today, small hydropower projects offer emissions-free power solutions for many remote communities throughout the world such as those in Nepal, India, China, Iran and Peru as well as for highly industrialized countries, like the United States [6]. Small scale hydropower was already used in early 20th century. For example in 1924 in Switzerland, nearly 7000 small scale hydropower were in use. The first small hydropower plant inaugurated in 1987 in Iran. It is located in Khorasan province. It has a single unit of Banki type with 65 kw capacity generating 341640 kwh energy annually thereby fulfilling the energy requirements of the village Sarrud.

III. GENERAL INFORMATION OF THE POLKOLO RIVER

The Pol-koloo River is located on Karun basin at southwest of Iran. This river is abundant in, water resource, the total water head being more than 1100 m. The runoff of the river is mainly sourced from precipitation. The discharge of the river is comparatively evenly distributed in a year due to Karst development in the basin, where most of the rainfall first infiltrates into, underground and then turns to be ground water through spring openings [7]. The recorded data obtained at the Kerik gaging station for fifteen years show that the perennial average discharge is 2.67 m³/s and the max. recorded flood discharge 43 m³/s.

A. Hydrology of Basin

The basin of the PolKolo River lies to the north of Yasuj City, between east longitude 51° 24'-51° 37' and north latitude 30° 47'-30° 55'. The total catchments area is 133 km². The PolKolo River rises from the southwest of the Dena Mountain and is formed by confluence of two tributaries of Cheshmemishi and Koh-Goole. The river flows from northeast to southwest and takes in various tributaries, such as Kokh-Dan, and finally joins, in the Beshar river after the passing village of Karyak. The Pol-Koloo river is of 26.1km-long' with mean slope of 5.3% and drop of over 1200m. The tributary of Cheshmemishi is about 3km in length with catchments area of 9.56km² and rises from a spring. The tributary is steeply-sloped and torrential. The average slope of the riverbed is 18%. On the mountain slopes along both banks of the river there is almost no vegetation. On the left bank was built a simply road reaching to the upstream of Koh-Goole river, and on the right bank there is a highway connecting the river source and Sisakht city, through which Yasuj and other cities could be reached. At the river source around the spring was built a reinforced concrete protective structure to prevent the spring from blockage, some water pipes were also provided for domestic water supply. Two irrigation canals on the right bank and a small canal on the left bank were constructed for

the farmland around the Sisakht city and the terrain at the confluence of the two tributaries. The tributary of Koh-Goole river is about 10km in length, catching an area of 42.95km² with average slope of about 5%. The river is principally recharged by upstream spring water. The river bed mainly consists of sand and gravel with high permeability, which results in that the stream flow in the upstream appearing over and disappearing under the layer of sand and gravel intermittently. There are cliffy high mountains along both banks with scarce vegetation. On the right bank was built a rough road to Sisakht. On the left bank there is a diversion canal for irrigation and domestic use of the village beyond the mountain.

There is a small salt mine nearby the intake of irrigation canal in the middle part of the river. Local dwellers make salt by evaporating brine in the sun. Since brine outcrops, the river water downstream from the salt mine tastes salty. Kokh-Dan river, a relatively large tributary of PolKol River, lies on the left side of the PolKolo river and catches an area of 25.63km². Kokh-Dan rises from spring with a gentle slope of 4% in the upstream and relatively steep slope of 10% in the downstream. During dry season, when the spring flow is very small or dried up, the river is partially supplied by Koh-Goole River through its irrigation canal on the left bank. In the left side of the river there are farmlands in the upstream and cliffy high mountain in the downstream where is covered by small pieces of bushes with rock scarcely outcropped. In the right bank of the river is relatively even cultivated land, behind which on the mountain slope there are distributed some villages accessible from Sisakht by high-way. There is a relatively large orchard on the maintain slope beyond the villages. A diversion canal was provided nearby the river source to divert water to irrigate the cultivated land on the right bank near Kokh-Dan village and Aliabad village. Kokh-Dan River enters into the PolKolo River through a small water fall with a drop of about 20m. Rocks are out-cropped on both banks of the water-fall. Downstream from the water fall is a flat ground with an area of more than 100m². The main river, PolKolo River from the upstream confluence of Cheshmemishi and Koh-Goole to the confluence by Kokh-Dan is defined as middle reach with total length of 4 km and catchments area of only 4.68km². The average slope of the reach is about 6.5%, mountain slopes on both bank are quite steep rarely covered with vegetation, but bushes. There are diversion canals on both banks, where the right bank canal diverts water to Sisakht area and the left bank canal diverts water to Eqhbal Abad Village.

Sisakht area located on the right bank is a geographically even terrace with an area of 10km². This area together with other villages nearby the Aliabad is one of the populated areas in the basin. This reach of the River is easily accessible by simply roads on both banks connecting to main highway. From the confluence by Kokh-Dan River down to the river mouth of Pol-Koloo River is defined as down stream reach totaling 6kmlong with catchments area of about 50km². The upper part of the reach is relatively steep with an average slope of about 5.5%, cliffy mountain slopes dominate on both banks with scarce vegetation. The low part of the reach is relatively gentle with an average slope of only 4%, and the mountain slopes are well covered with vegetation. The Karyak village nearby the river mouth is again quite populated and

cultivated land concentrated. In addition to arid land, there is further 5 km² of paddy land. Diversion canals on both banks of the river reach were excavated to supply water for irrigation and domestic use. Villages on both banks are all accessible through rough roads. The construction of main highway from Yasju City to Esfahan City is under way nearby the river mouth. The construction of Karyak 1 hydropower station i.e. the previously planned No.7 hydropower station, located in the upper part of the river reach commenced in 1989.

B. Geology and Geomorphology

The Pol-koloo river basin is located at the northern edge of the Yasuj intermountain basin and is the belt of transition between the high mountains and the mountainous basin. The relief of the river basin descends gradually from northeast part to southwest part. Geomorphologically, the river basin is still in ascension and serious denudation, the river bed is still in incision. The mountain slopes and valleys are accumulated with rock blocks, debris and sands which form "skirts", surrounding the mountains. Thick Quaternary strata, which are scattered along both the main river and the tributaries, are affected by high permeability of the rocks both in slightly cemented or loose conditions. Therefore, seepage, stability of the banks and silt accumulation can never be neglected if reservoirs are to be built. The geological conditions of the places at which the hydraulic structures planned in various alternatives will be built are basically identical, the Quaternary strata in most of them. The places, alluvium and diluvial materials on the river channels and slope washes or talus and diluvial materials on the river banks. Therefore, the layouts of the hydraulic structures will be determined by the way of development of the river rather than the geological conditions.

IV. OBJECTIVE OF PROJECT

The multipurpose development of the Polkolo river should also include water supply for irrigation and domestic use. There are farmlands totaling 26 km² in area which are irrigated by the water diverted from the river. There are more than 10 irrigation canals in the basin. The required discharge of the largest canal is over 0.58 m³/s, which accounts for over 20% of the perennial average discharge of the river. It can be seen from the above said that there is a big contradiction in irrigation and power generation. In addition, the Pol kolo river should also meet the water demand for domestic use of the local people, though such demand is not big. According to the water demands as abovementioned, the most important principle in development of this river basin is to develop the hydropower with the premise of satisfying the water demand of irrigation and domestic use so as to fully utilize the rich water resources in this basin in a rational manner. The water demand for irrigation in this river basin is rather great in quantity. Since the actually recorded discharges at the Karyak gauging station are the remaining discharges after the water for irrigation has been diverted, such discharges can be regarded as developable discharge for power generation. Nevertheless, considering the prospective increment of the water demand of both irrigation and domestic use, it has been included in the water power calculation for various stations on

the D/S reach of the Polkolo river that a discharge of 0.25 m³/s is deducted from the discharge series as per the peak irrigation season starting from May to September every year. For the Cheshmemishi river a discharge of 0.15 m³/s has been applied to each existing irrigation channel on the right bank for irrigation use. But no additional discharge is considered for other reaches of the river.

V. RIVER POTENTIAL

The potential energy caused by gravity of water at an elevated level is transformed to water pressure (and some kinetic energy) as the water is lead through pipes from a water inlet down to a power station. In the power station this energy is first transformed to mechanical energy in a hydropower turbine and then to electricity in a generator. The amount of energy is decided by the flow of water and the elevation of the inlet. This principle is the basis for all kinds of hydropower stations. When constructing a hydropower plant the goal is to transform the potential energy into electrical energy as efficiently as possible, to the lowest costs possible. Finding the optimal choice is not simple. For instance, pipes with a larger diameter will cause less energy loss on account of friction than smaller ones, but they are more expensive. A turbine with a high capacity is able to utilize more water when the inflow is high, but has lower efficiency when the inflow is lower, which is the case most of the time. The water inflow through the year and from one year to another is uncertain in addition to the uncertain electricity price. The investor in a small hydropower plant will have to make an optimal investment, choosing the timing and capacity of the plant, for a project with a probable lifetime of 30 years, taking these uncertainties into account.

A. Determining Head

Head is the vertical distance that water falls. It's usually measured in feet, meters, or units of pressure. Head also is a function of the characteristics of the channel or pipe through which it flows. Most small hydropower sites are categorized as low or high head. The higher the head the better because you'll need less water to produce a given amount of power, and you can use smaller, less expensive equipment. When determining head, you need to consider both *gross* head and *net* head. Gross head is the vertical distance between the top of the penstock that conveys the water under pressure and the point where the water discharges from the turbine. Net head equals gross head minus losses due to friction and turbulence in the piping. Gross heads of 9 stations in Yasuj cascade project are presented in Table I.

B. Determining Flow

The quantity of water falling is called flow. Stream flow is the most difficult to measure or estimate. However you should have an understanding of its sources, its fluctuations and flow measurements or estimates. Stream flow in this basin comes from either rain or melting snow, but not all the rain or melting snow immediately becomes stream flow. There are losses caused by evaporation from the ground surface, transpiration by the vegetation whose roots have absorbed moisture from the ground and from seepage or surface water into the ground to become groundwater. This groundwater can

take weeks or months to appear as stream flow, and is therefore not available for power immediately after rain or snowmelt. However, this groundwater is important, the major component of the stream flow during dry periods in the summer. Stream flow quantity of 9 stations in Yasuj cascade project are presented in Table I.

C. Estimating Power Output

There is a simple equation you can use to estimate the power output for a system [8]. The theoretical power equation (Equation 1) is:

$$P = Q \times H \times e \times 9.81 \text{ Kilowatts (kW)} \quad (1)$$

Where: P = Power at the generator terminal, in kilowatts (kW). Q = Flow in pipeline, in cubic meters per second (m³/s). H = The gross head from the pipeline intake to the tail water, in meters (m). e = The efficiency of the plant, considering head loss in the pipeline and the efficiency of the turbine and generator, expressed by a decimal (i.e. 80% efficiency 0.80) 9.81 = Constant for converting flow and head to kilowatts. Using e = 0.80 in Equation 1-1, the actual power output at the generator can be calculated from the following Equation 2:

$$P = Q \times H \times 7.84 \text{ (kW)} \quad (2)$$

The actual power output at the generators of 9 stations in Yasuj cascade project are presented in Table I.

D. Installed Capacity

Selecting the installed capacity is an important work in design of a hydropower station, it is directly in relation to the size of the station, the reasonable utilization of the state funds and water resources as well as the coordination between the long-term and short-term benefits. An unreasonable big capacity will result in squandering the state fund or letting it lie idle and causing the generating equipment not to function to full extent, while an irrational small capacity will cause unreasonable and incomplete utilization of the water resources; therefore, both the cases are in justifiable. Selection of the installed capacity is a very sophisticated issue involving quite a lot of factors to be considered. For the present planning for the Yasuj the following major factors should be considered.

1. Water resource condition: The river basin is located in a dry area with little precipitation and the water resources in the basin are precious. Therefore, the selection of the installed capacity should give due consideration to ensure the full use of the water resources in an economically reasonable manner.

2. Supplied district of Yasuj cascade stations and connection with the power system; The installed capacity of the Yasuj cascade stations will amount to more than 50% of the Yasuj power system's total before the system is merged into the national system. In such case, as soon as the river falls short of flow, the stations cannot ensure their guaranteed output and the operation of the system, hence, the industrial and agricultural production as well as the living condition in the whole supplied district, will be affected; while extra water is

available, the produced seasonal power cannot be exhausted in the power system. It is therefore considered that the integral installed capacity of the Yasuj cascade stations should not be too big. After the Yasuj power system is incorporated into the national system, the installed capacity of Yasuj stations forms a tiny part of it. When the Yasuj stations cannot operate in their full capacity, the Yasuj power system can be replenished by the national system without significant influence; however the surplus power generated by the Yasuj station in wet seasons can be absorbed by the national system. In consideration of the incorporation of the two systems incoming few years, it is deemed beneficial to appropriately enhance the installed capacity of the subject stations to make full use of the local water resources and give full play of the stations to be built.

3. System load level and characteristics: The installed capacity of a power station should be compatible to the system load level and characteristics. The irrational big installed capacity designed for a new power station will result in wasting of power and keeping funds lying idle if the growth of load in the system is slow, with a power demand not too big, and contrarily, the installed capacity should be enhanced to a possible extent to satisfy the demand of the system. In addition, the system load characteristics will also impose effect on the installed capacity. In the case that the daily load curve is fairly even without prominent peak and as a result the system requires mainly electric energy from the station, then the installed capacity should be in smaller side. On the other hand, if the daily load, curve is rather steep with high, peak, the system will require from the station not only energy but also capacity so as to meet the demand of the system peaking. As previously mentioned, both the Yasuj system and the national system have an evening peaking on the load Curves, which amounts to 30% - 50% of the capacity therefore, it is deemed necessary to enhance the installed capacity of the Yasuj cascades stations to provide them with peak regulation capacity and serve the peak load.

4. Multipurpose, utilization in this respect, the Yasuj stations encounter the problem of water demand of irrigation. In most cases, the irrigation and power generation are in contradiction to each other in that the increasing water supply for irrigation will result in reducing the water for power generation, hence, the installed capacity.

5. Interactions between the cascade stations: In selecting the installed capacity, attention should be drawn to the coordination of the discharging capacity of the cascade stations to avoid unnecessary surplus water.

The cascade plant consists of 9 power plants connected with each other and is having the total head as 1200m and discharge about 2.5 cubic meter per second. The annual production of energy is 105.5 million kwh.

E. Type and Number of Turbines

Because it is rather difficult to find suitable mix-flow turbine for the first station on the Cheshmemishi river and the station in one-cascade scheme for the pol-koloo upstream reach, which have high head(300m), but small discharge, therefore, impulse turbines are selected for these two stations. For the other stations, the mix-flow turbines suitable for the

water head ranges of the Yasuj stations, which can be available in the market, will be selected. Number of units except for the Kokh-Dan station and the Cheshmemishi 2 station, which are respectively planned to equip with one unit due to their small capacity and well-distributed discharge, all the other stations will be equipped with two units to increase the flexibility in operation but without too much additional investment.

TABLE I
GENERAL INFORMATION OF YASUJ CASCADE PROJECT

Station no	1	2	3	4	5	6	7	8	9
Grass head (m)	147.5	17 6	116 .8	145 .5	145 .5	97	95	97. 5	117 .3
Flow (m3/s)	1.05	0.6 6	2.5 4	3.1	3.1	1.0	3.3	3.3	3.3
Capacity (kw)	1200	90 0	230 0	350 0	350 0	75 0	25 00	250 0	300 0
Annual energy (10 ⁶ kwh)	7.15	5.0 4	11. 89	16. 19	16. 19	4.7 9	15. 1	13. 14	16. 03

F. Volume of the Daily Regulating Pond

Since the Yasuj cascade stations should undertake a certain amount of peak load, it is necessary to build a reservoir or regulating pond. As mentioned before it will be much more economical to build a daily regulating pond than a reservoir for this river basin. Less troubles will be encountered in operation if a pond, is built. During comparison of the alternatives, the volume of the pond was set at 30000 m3 by empirical formula.

VI. CONCLUSION

The Polkolo river is located on Karun basin at southwest of Iran. Situation and conditions of Polkolo river are evaluated for construction of small hydropower in this article. The topographical conditions and the existence of permanent water from springs provide the suitability to install hydroelectric power plants on the river Polkolo. The cascade plant consists of 9 power plants connected with each other and is having the total head as 1100m and discharge about 2.5 cubic meter per second. The annual production of energy is 105.5 million kwh. The Yasuj cascade plant on Polkolo River are free from many of the environmental problems associated with their large-scale relatives because they use the natural flow of the river, and thus produce relatively little change in the stream channel and flow. The diversion dams built for some run of the river projects are very small and impound little water and many projects do not require a dam at all. Thus, effects such as oxygen depletion, increased temperature, decreased flow, and rejection of upstream migration aids like fish ladders are not problems for many run of the river projects. Construction of the Yasuj cascade plant of small hydropower on Polkolo and other river in Iran country can reduce exposure to future fuel shortages and price increases, and help reduce air pollution. Small hydropower systems can provide you a clean, reliable source of power for years to come.

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