Developing Pumped Storage Hydro Power Plants in the North East of Iran

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Introduction

Hydropower generation in general and pump storage power plants in particular are key components of renewable Co2-free primary energies. Pumped storage projects have been available since the 1930's and differ from conventional hydroelectric projects. They normally produces electricity during high-demand periods by using the flow from an upper reservoir to drive Turbines as water passes into a lower reservoir, when demand is low. The same system pumps water from the lower reservoir back into the upper reservoir. Depending on the size of the reservoirs and electricity demand, this may be repeated daily, weekly or monthly. Pumped storage project are uniquely suited for generating power when demand for electricity is high and for supplying reserve capacity to compliant the output of other electric plants and forms of renewable resources. The ability to start generating electricity at this type of project is almost immediate, thus serving peak demand for power better than more traditional plants that require significantly more start-up time and renewable resources that have the possibility to not produce due to weather conditions. Farther more, these projects are environmentally sound because it incorporates a closed loop water system and will reduce the need for less efficient, fossil fuelled alternatives and can significantly contribute to utilities achieving their mandated renewable energy supply goals.

In the north-east of Iran, because of climate logically and hydrological conditions, rule of water for users is very important. On the other hand in this region developing of industries are more than agricultural. Therefore, it is facing the challenge of providing power to meet increasing energy demand while abiding by requirements that more of this energy be produced from renewable source and limitation using conventional hydroelectric projects in the north-east of Iran because of low run-off and seasonal rivers.

In these studies base on regional features and the main necessities of pumped storage projects, site selection process was reviewed and the main characteristics for the proper site are described.

1. Project Implementation

Khorasan region with a population of about 10,000,000 (2008) and 320,000 km2 is located in the east and north-east of Iran between 30° 55 to 38° 20 N in latitude and 55° 50 to 61° 15 E in longitude. This region is the largest and takes up more than one fifth of Iran. It is bounded on the north by Turkmenistan and on the east by Afghanistan. Figure 1 shows the location of Khorasan region. Climate of this region varies from semi-dry and locally humid in the north to dry in the southern parts. The watershed of the region includes four main watersheds; these watersheds include several sub-basins and have a combined area of 400,000 km2.

This region divided into 3 provinces, North Khorsan, Razavi Khorasan and South Khorasan. Province North Khorasan is mountainous and has area of 60,000 km2. The annual rainfall is about 350 mm.These region is the pole of agricultural and industry. Razavi Khorasan is in the middle and has an area about 90,000 km2 with annual rainfall 250 mm. south Khorasan is flat with annual rainfall about 130 mm and have an area about 170,000 km2. The climate is generally arid so that the degree of dryness increases southward. The annual mean temperatures in the north is about 13° C and increase in the southern part up to 18° C. in figure (1) topographically conditions, streams and their tributaries in the Khorasan region are showed.

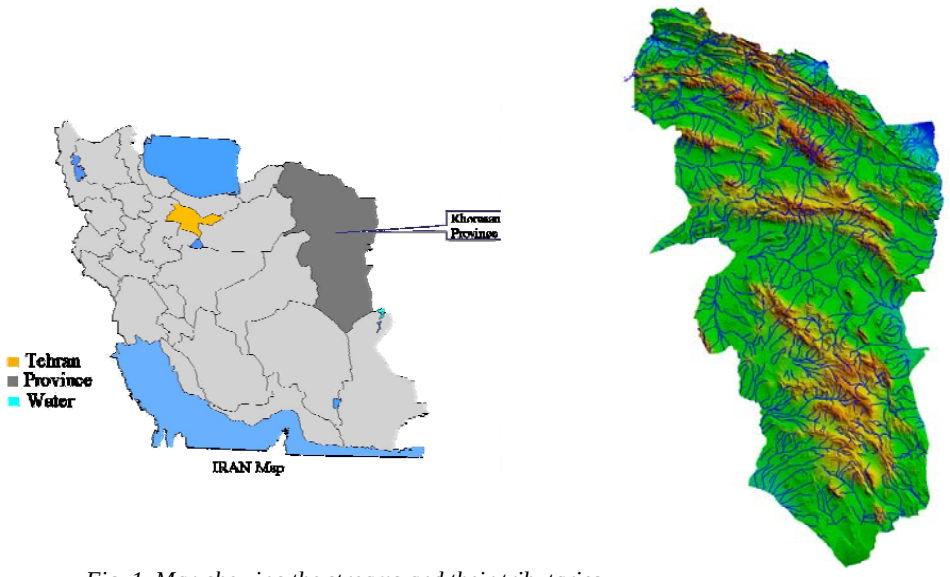

Fig. 1. Map showing the streams and their tributaries in the Khorasan region.

Khorasan is facing the challenge of providing power to meet increasing energy demand to its growing population and based on political reasons and main strategic program of Government for the next decades and due to environmental reasons, new technologies and increased use of reliable, renewable and clean energy such as wind, solar and certain hydropower facilities must be put in place. These requirements will reduce Khorasan's dependence on fossil fuels. On the other hand, in Khorasan region the average of annual rainfall in less than 250 mm and climatic conditions of this area is semi-arid to arid. Therefore most of rivers and waters out flows in the tributaries are seasonal or extremely reduced during the dry months, because of them; water management is the main purpose of the proposed projects. Most of projects have been planned for certain preparing of agricultural demands on dry month and flood control too.

In order to meet growing peaking demands and to significantly improve reliability of Iranian Power system, Power & Energy Ministry proposed for studying Pumped storage Hydroelectric Power in Khorasan region. Iranian Water and Power Company (IWPCO) has the mandate for providing hydroelectric power generation and TAVANIR has the mandate for Electricity in general and is a vertically integrated companies in Generating and Transmitting electricity in Iran. Iranian power demands grew at a rapid pace during the last decades, coinciding with economic growth electricity consumption. Based on TAVANIR published reports, electricity consumption has grown, on average, by 8.4 % per year and installed generation capacity increased, on average, by 7.1 % per year. While consumption has grown, the 'Load Gap' between the low and peak load has also increased. In figure (2), (3) variation of Monthly and Daily Peak demand and generation of electricity in khorasan in 2008 is shown.

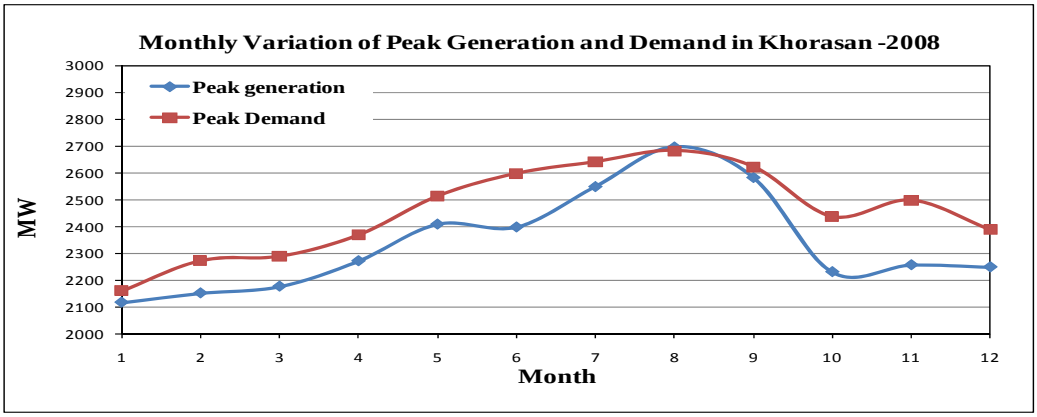

Fig. 2. Monthly Variation of Peak Generation and Demand in Khorasan-2008

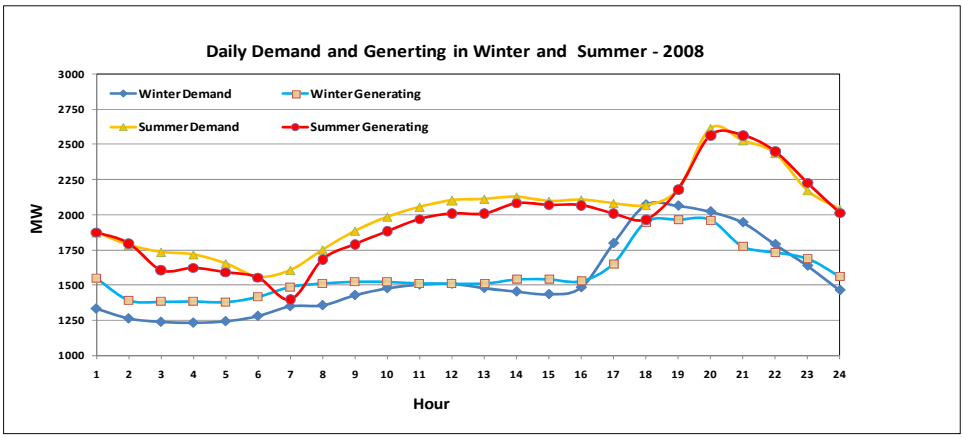

Fig 3. Daily Variation of Generation and Demand in Khorasan-2008

The current peak load in Iranian network is being met by Combined Cycle or Gas Thermal Power Plants. However such fuel supply is not economical due to the high fuel price, and because of the inefficient intermittent operation of the thermal power plants. Therefore, to cape with the increasing 'Load Gap' in an affordable and efficient manner, an adjustable power sources, due to the importance rule of water and related social and environmental impacts in khorasan, is pumped storage hydropower scheme. These schemes require smaller reservoirs and catchment areas and require less construction costs in similar generation mode than conventional hydropower schemes.

In this study first based on hydrological data, outflow of tributaries with minimum stream flow of 200 litre/sec were selected and data bank of physiological and topographical condition of any sites were performed. Based on these information 70 sites in initial studies were defined. These sites had minimum features of a suitable site for pumped storage project including: minimum 200 meters head between two assumed reservoirs with the maximum distance of 5 km from lower reservoirs, and Minimum base discharge that should be more than 200 litre/sec, finding natural reservoirs or dams as a lower and upper reservoirs. Then for more investigations, site visits for initial selected sites were performed in these process existing reservoir and dams mixed with pumped storage hydropower plant and pure pumped storage project were studied.

At during of sites visit, Some effective aspects were considered which the most important of them were included: geology, construction material, distance and head between reservoirs, upper and lower reservoirs in view of sediments, landslide and the other geotechnical hazard, social and environmental impact, access roads, adjacent population centres, land use and downstream demands, power transmitting line and the other electrical Plants near to the sites. In this stage after completion data gathering, all main features and characteristics of any site were weighted. Then with the normal methods of screening all sites were sorted and 20 proper sites were selected for continuing studies. In this process, some initial layouts of upper and lower dams and hydraulic structures beside underground power house and water conveyance tunnels were initially designed. Then the cost of any project was estimated and with the other qualitative features, all selected site were sorted. One of the main parameters in this step was determining price of one kilowatt. After cost estimation, five proper sites for complementary design process were selected. In table (1) the main parameters of them are shown. Engineering studies revealed that these five proposed sites could have approximately 2600 MW potential of generating capacity at cost ranging from $720. To $1000 per kilowatt. Two sites are located in the north of khorasan near to Bojnoord city and three sites are near to Mashhad and Naishaboor city. In the following, the main features of Mirabad pumped Storage hydropower plant as the most proper site in these studies are presented.

Tab. 1. Main Features of Properties in Khorasan Region

Main Features	Final ProperSites				
	Mirabad	Frizi	Kalat	Firooze	Darkesh
Near Big City	Nayshaboor	Mashhad	Mashhad	Bojnoord	Bojnoord
Rate Installed Generation Capacity(MW)	850	585	580	540	310
Maximum Tubine Discharge (m^3/S)	132	153	174	174	132
Rated Net Head-Generation (m)	780	435	380	350	265
Chachment Area(km^2)	144	118	218	230	90
Total Volum oflower reservior(mcm)	29	23	27	28	20
Active Volume (mcm)	1.9	2.2	2.5	2.5	2
Height of Lower Dam(m)	95	103	80	85	100
Crest Length(m)	340	310	395	250	495
Length of Headrace Tunnels(m)	3130	780	1650	1950	830
Length of Tailrace Tunnels(m)	490	550	440	260	200
Cost/Kilowatts	720	790	770	815	1000

1.1 Mirabad Pumped Storage Hydro Power

Mirabad proposed pumped storage project is located in the 20 km north- east from Neishaboor City that is located in 130km from Mashhad city. The lower reservoir and dam is located on the Faroob-Rooman River which is on the south hillside of Binalood Mountain Range. Binalood mountain range catchments have an important effect on economy of the Mashhad and Neishaboor cities which are respectively placed on the northern and southern sides of the mountain range. Neishaboor is the nearest metropolitan area with a population of about 600000 people. Mashhad city with a population of approximately 2,500,000 people is located in the north-east of the site.

This project has several unique attributes that make its development for pumped storage very attractive in comparison to other potential projects in the region. In this part some of main features of Mirabad site were explained.

Catchment area of Faroob-Rooman River is about 144 km^2 and the main portion of precipitation in the study area occurs in the cold seasons and average annual rainfall amount is about 340 mm. Minimum, Maximum and average monthly value for the number of wet days are around 1.4, 58, 20 mm ,respectively. Minimum, Maximum and mean temperature in this site are 1.3, 27, 15 C°. The average annual stream flow in the dam location is 1.35 m^3/sec and it ranges between 0.25 and 4.3 m^3/sec. In figure (4) location of Mirabad proposed pumped storage is shown.

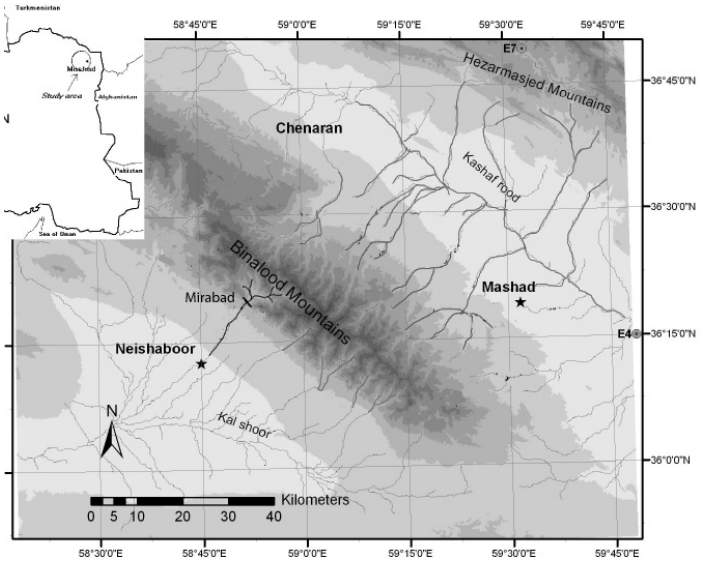

Fig 4. Location of Mirabad pumped Storage site

As agricultural is the largest water user in downstream of Mirabad site, therefore effect on downstream water needs is unacceptable and because of water scarcity, social problems in this region will be predictable. Nevertheless lots of advantages of pumped storage Hydro powers and using a closed water system, demands of consumptive water users should be allocated fully. This subject should be considered on estimation lower reservoir capacity and it was caused total volume of lower reservoir in this project is extremely more than active volume and the other related volumes to the function of pumped storage hydro power. Based on water management and hydro-energy studies, lower dam and reservoir can allocate downstream water needs and water rights with less than 15% uncertainty at the during of hydropower operation. On the other hands, because of climate conditions and regional temperature, evaporative losses, with the minimum and maximum monthly evaporation amounts 12, 185 mm, 7 mcm of reservoir was considered for evaporative and other water losses.

Geology of this project area owes many of its features to its location with adjacent to the Binalood mountain range and north Neishaboor and Bojan faults. These information aid in the preliminary design of major project features and used to confirm the site, such as upper and lower dams, tunnels and power house.

Binalood Mountains are composed of carboniferous slightly metamorphic sand store and Devonian lime stone. Reservoirs are underlain with the calcareous and black shale formation. Shape of proposed valley was formed by morpho-tectonic activities and is V-shape with side slope about 35 to 40 degrees. Wide of valley in the lower dam Axis is about 40 meters because of morphologic conditions of catchment area processes of erosion and depositions are considerable. Depth of deposition and transported material by running water in the bed river is about 30 meters and most of them are included coarse grain with boulders. The main fault in this region is the north Neishaboor fault

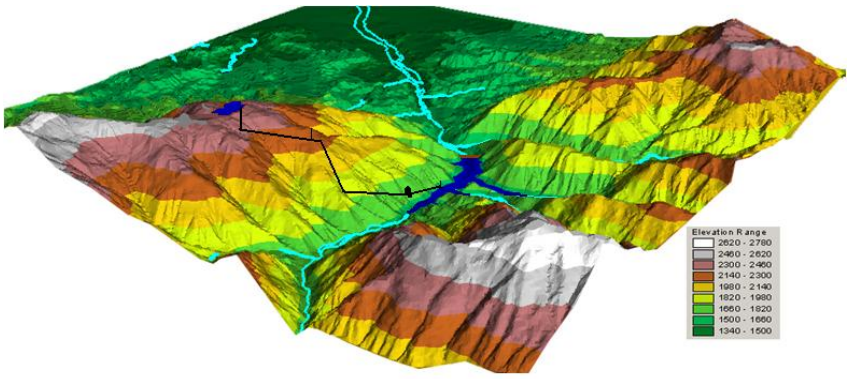

Fig 5. Schematic showing of Mirabad pumped Storage site

That is located on the South hillsides of Binalood mountain range with distance about 1.5 km from dam axis to downstream. Figure 5 illustrates the Schematic showing of Mirabad Project.

The proposed site will consist of an upper and lower reservoir, underground tunnel system and power house complex with a potential generation capacity of approximately 850 MW. The Upper reservoir is located in the flat area on the left side of lower reservoirs in the height of 780 meter from maximum Operation Level. Mirabad lower reservoir was created by building a rock-filled dam with a central impervious core across the Faroob-Roman River with distance approximately 300 meters from inlet of powerhouse. The main dam embankment is 340 meter and has a maximum height of 95 meter from river bed. It has upstream and downstream slope of 2.5 H: 1V and 2.2 H: 1 V respectively.

Upper reservoir located in the flat area about 2500 meter on the left bank. Reservoir will be created by excavation on the rock and then will be covered by geo-membranes liner to control seepage. Maximum depth of reservoir is about 30 meter. Total volume of reservoir is about 2.0 mcm and active volume was considered about 1.9 mcm.

The intakes which admit water for power generation consist of Intake Tower with 5 cylinder gates and trash racks that were connected to the side of reservoir by a bridge. Spillway has been seized to accommodate a discharge that can be created by over pumping and has 15 meters wide.

System of water conductor tunnels will convey the water from upper reservoir to the underground power house and lower reservoir. It is include the vertical shaft with 59 meter deep and 6.5 meter diameter that is extended to the first headrace tunnel with length of 730 meter and extended to a 580 meter deep inclined shaft and then to the 1760 meter pressured tunnel up to the power house. All tunnels and shafts are concrete lined with diameter of 6.5 meter wide except inclined shaft and pressured tunnel that are steel penstocks. The tailrace tunnel will extend approximately 490 meters that will be concrete lined and finished diameter of 9 meters. The cavern of power house will be approximately 200 meter long, and 27 meters high, and 40 meters wide that will be seized to accommodate four 215 MW units.

The transmission lines of 400 kv between Toos thermal power plant in Mashhad city and Neishaboor combined cycle power plant is passed from the lower reservoir that is very important point for this site.

The water level of the Mirabad reservoir at any particular time is a function of the demand for power and ability of the facility to generate electricity. The maximum range of water level fluctuation in lower reservoir is 20meter. The actual magnitude and rate of drawdown and pumping varies daily. In figure (6, 7) general layout and longitudinal section of Mirabad Pumped Storage Hydropower are shown.

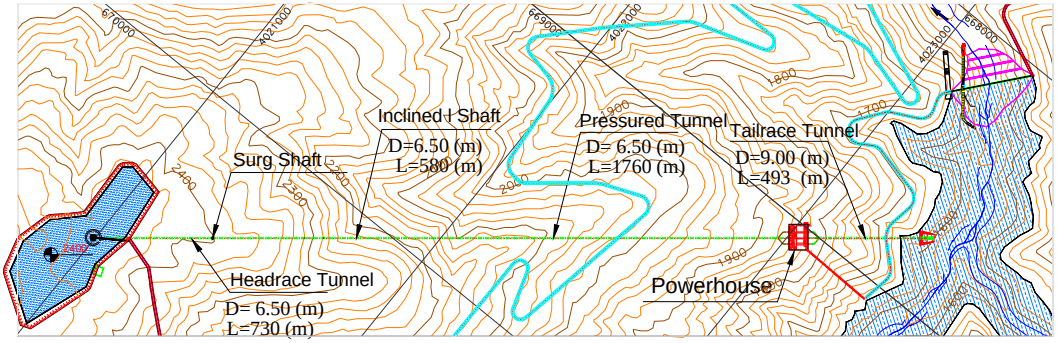

Fig 6. General Layout of Mirabad pumped Storage site

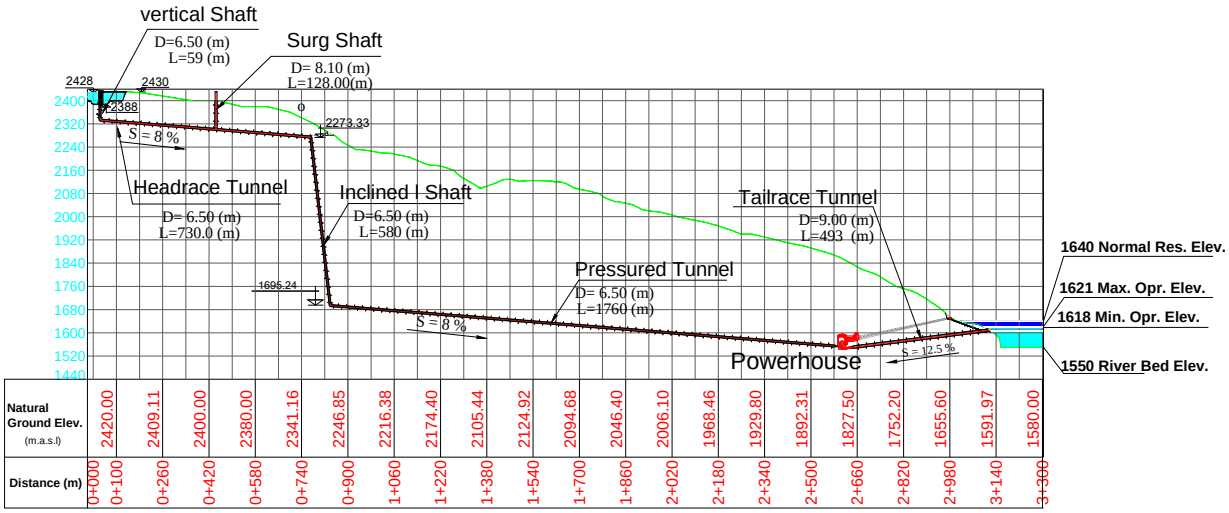

Fig 7. Longitudinal Section of Mirabad pumped Storage Hydro Power

2. Conclusion

Hydropower schemes are very important from an operational standpoint as it needs no" ramp-up" time, many combustion technologies do. Hydropower can increase or decrease the amount of power. It is supplying to the system almost instantly to meet shifting demand. With this important Load-following capability, peaking capacity and voltage stability attributes and a significant way to store electricity, pumped storage hydro power schemes plays a significant part in ensuring reliable electricity service and in meeting customer needs in a market driven industry. In the north-east of Iran, because of climate logically and hydrological conditions, rule of water for users is very important. On the other hand in this region developing of industries are more than agricultural. Therefore, it is facing the challenge of providing power to meet increasing energy demand while abiding by requirements that more of this energy be produced from renewable source and because of importance rule of water and related social and environmental impacts in khorasan, an adjustable power sources is pumped storage hydropower scheme. Mirabad project has several unique attributes that make its development for pumped storage very attractive in comparison to other potential projects in the region which some of main features of site explained.

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Massoud Daliry: I was born at 1967 in Iran. I graduated in Structural Engineering from University of Mashhad. I am in charge of Toossab consultant Engineers Company as a Manager of Dams & Hydro Power Division. I was rather experienced for Structural designing Hydraulic Structures & Hydropower and Concrete Dams including: Doosti Dam (Iran-Turkmenistan), Shirin Dareh Dam (Iran), Esfrayen Dam (Iran), Daroongar Dam (Iran), Komayestan Concrete Gravity Dam (Iran), Gambiri Hydropower & Irrigation Project (Afghanistan) and Structural Safety Evaluation of Torogh, Kardeh and Shirvan Arch Dams (Iran) and Rehabilitation of Mashhad Water System for Earthquake. I have a lot of experience as a project manager for Daroongar Dam, Khayrabad III Dam, Gezel Ozan Dam & Hydropower Project and Development of Pumped Storage Project in Khorasan region of Iran. I am member of IRCOLD (Analysis & Design Committee) in Iran.