Overview and feasibility study for the 300 MW Ifahsa pumped-storage project in Morocco

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1. Introduction

The Ifahsa pumped storage power station (PSPS) is planned as a reversible hydro electric plant located in the Oued Laou basin.

The Ifahsa PSPS site is situated approximately 10 km to the north-east of the Talembot dam. It is close to the confluence of the Es Sarem and the Laou wadis. The Talembot wadi passes approximately 3 km to the south west of the project and flows into the Laou wadi. The layout of the development is indicated in the figure below:

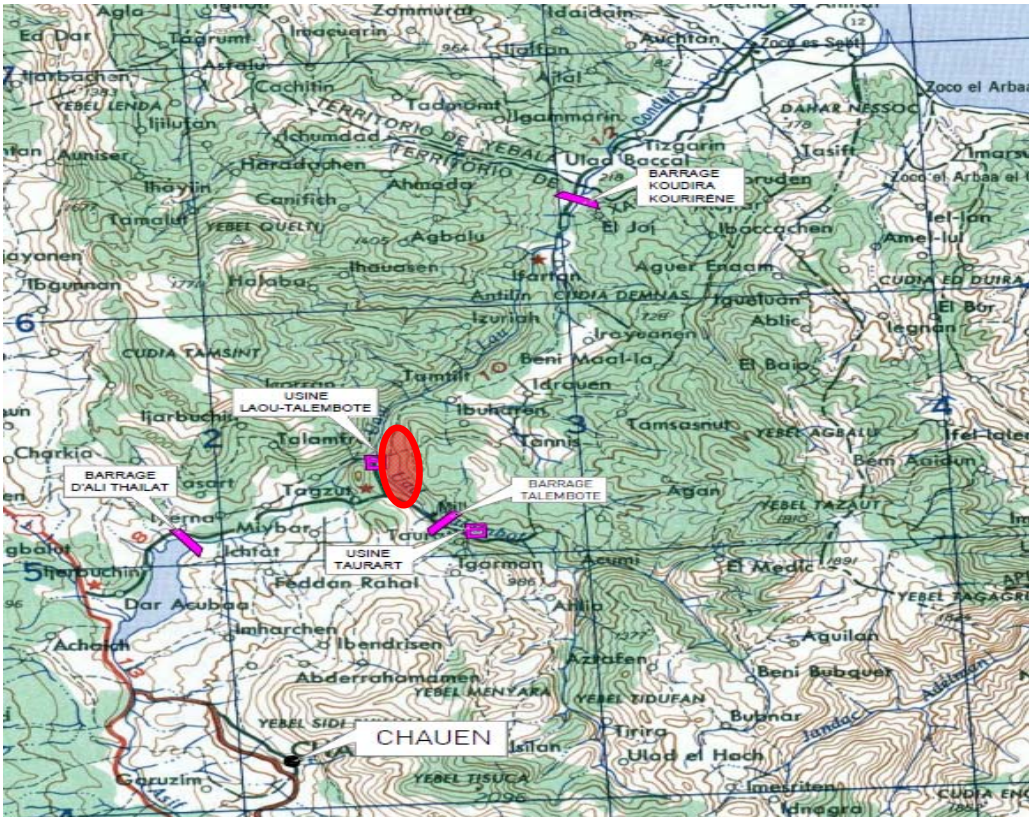

Figure 1. Location of the Ifahsa PSPS project.

The Ifahsa PSPS site is close to the P4105 road, 15 km east of the national highway (N2) linking the towns of Chefchaouene and Tétouan.

The P4105 road linking the towns of Oued Laou and Chefchaouene permits access to the lower sector of the works but access to the upper sector is difficult as the roads are steep and unsurfaced (see Fig. 2):

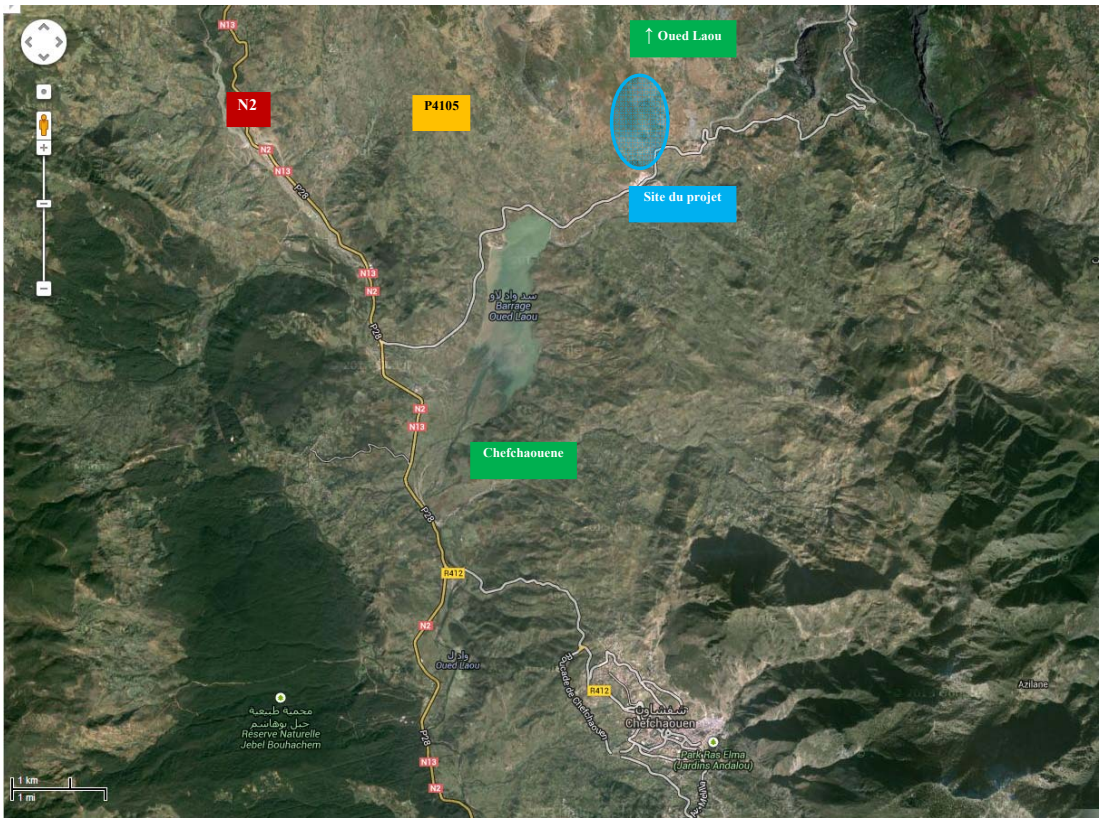

Figure 2. Access: P4105 road between the towns of Oued Laou and Chefchaouene and project site.

1.1. Description of the site

The wadi Laou basin is located in Northwest Morocco in the provinces of Tetouan and Chefchaouen. It is in the central part of the Rif Mountains also known as the High Rif. It is bordered by the peaks of Jbel Kelti (1928 m) with Soukna to the west (1800 m) and Tissouka (2180 m) to the south east, Tazoute (1800 m) is in the north east and the Mediterranean sea is to the north.

The Laou wadi´s basin is small with a surface area not exceeding 930 km² (its maximum east-west width is 28 km and it is 47 km long north-south) and its main water course, the Laou wadi, has a total length of 70 km.

The upper course of the Laou wadi follows a south-north direction in the region of Chefchaouen. It is bordered to the east by the aligned peaks of the limestone range and to the west by high numidian peaks. The medium and lower water courses are situated on the North-Rif slopes and flow in a SW-NE direction.

Despite the relatively low altitudes in this area, (varying between 300 m and 900 m) with the exception of the coastal plain, it is an extremely rugged area with steep slopes and considerable inclines.

The landscape in this area is characterised by the enclosure of the hydrographic network between narrow ridges with extremely steep slopes, which at times are like cliff edges and which are extremely steep.

1.2. General presentation of the project

The Ifahsa PSPS project concerns the construction of a Pumped Storage Power Station (PSPS) or pump turbine plant in a cavern between two reservoirs to be built in the vicinity of the villages of Ibouharane and Tifiraouine.

The plant has been designed to produce power during peak consumption times, through the flow of water from the upper to the lower reservoir by means of a turbine. The water will be repumped back into the upper reservoir when the energy needs are reduced.

The hydraulic system and the machinery cavern are the main components of the project. It consists of the following elements (see figs 4 and 5):

1. Upper reservoir, on the Talaaf Adrhousse mountain which is an artificial lake covered with a geomembrane, the peak has an altitude of 934.5 m
2. Upper reservoir water intake
3. Upper hydraulic pipeline with a design flow of Q = 44 m^3/s, and 3.0 m diameter comprising the following elements: supply pipe installed in a trench (length 1.386 m), vertical pressure shaft (height 311 m), and a section of penstock (33 m)
4. Underground power house comprising two caverns, the machinery cavern and the transformer cavern
5. A tailrace tunnel designed for a flow of Q = 44 m^3/s, 3 m in diameter and a 417 m length
6. Surge chimney in shaft: 118 m high and 5.0 m in diameter
7. Lower reservoir water intake
8. An artificial lower reservoir which is close to the natural flow of the Es Sarem wadi (a tributary of the Laou wadi) covered with a geomembrane, height of the ridge 175.0 m

2. Background

The companies PROJEMA, ISL and EQUITER carried out a preliminary feasibility study of the Ifahsa PSPS in December 2002.

In July 2009 GAS NATURAL FENOSA Engineering (GNFe) was awarded the tender for drafting a study of the Preliminary Project Design (hereinafter the PPD study) and a Feasibility study for the Ifahsa Pumped Storage Transfer station, pursuant to the call for tenders nº SP0694MP8 issued by the National Electricity and Drinking Water Office (ONEE).

The studies were compiled in accordance with the following principal phases:

1. Award of the tender to GNF Engineering: July 2009
2. Signature of a contract between ONEE and GNF Engineering: July 2009
3. Previous preliminary studies for the project - review of the preliminary feasibility report and reference data: July 2009 to September 2009
4. First visit to the site and compilation of new data: July 2009
5. Geology: study of bibliography, aerial photography and visit to site: November 2009
6. Analysis of data and results of preliminary studies: December 2009
7. Definition by GNF Engineering of surveying work schedule leading to feasibility studies for the option chosen: January 2009
8. Surveying works: January 2009 to November 2010
9. Technical feasibility studies, studies of the different possible variants of the project and definition of the preliminary equipment outline: December 2011
10. Definition by the Consultant of geological survey schedule required to carry out the feasibility studies for the option chosen: May 2012
11. Geological and topographical surveys: June 2012 to October 2013
12. Visit to the site following the geological investigation: October 2013
13. Definition of the final solution: November 2013
14. PPD and Feasibility studies: February 2014

3. Summary of the various options

Following to the definition of the original project outline (IFAHSA PSPS pref), a number of site visits and new geological studies, several variants were put forward for comparison, in order to select the best option.

The options considered were located in an area between the towns of Tifiraouine, Tinisse, Ibouharane, Tamtile, Amellil, Ifahsa, and the J.S. Salah hill.

Three possible sites for the lower reservoir were considered from a geological perspective during the visit to the site, as well as a new site for the upper reservoir.

The waters of the Laou Wadi river were used in addition to two tributaries from the areas of Ifahsa (Oued Abïyati), and Tamrabète and Tinisse (Es Sarem) as a result of installing upper reservoirs on the hills of J.S. Salah and the Talaaf Adrhousse mountain with altitudes of 900 m NGM and 960 m NGM respectively.

Seven alternatives were studied as possible options, as follows:

1. Alternative A1. It is an improved version of the outline of the preliminary feasibility study with a dam on the hills of J.S. Salah as the upper reservoir and the IFAHSA dam (which was included in the complementary layout for the existing hydroelectric set up of the Laou wadi reservoir considered in the pre feasibility study) as the lower reservoir.
2. Alternative A2. It comprises the same reservoir on the J.S. Salah hills as in the A1 option, as the upper reservoir, and a dam on the Es Sarem tributary as the lower reservoir. The pipeline in the tunnel under the Laou wadi passes through it.
3. Alternative A3. It comprises the same reservoir on the J.S. Salah hills as in alternatives 1 and 2, as the upper reservoir, and a dam on the IFAHSA tributary as the lower reservoir.
4. Alternative A4. It comprises the same reservoir on the J.S. Salah hills as in alternatives 1, 2 and 3, as the upper reservoir, and a dam on the IFAHSA tributary as the lower reservoir, slightly downstream of the dam in alternative A3.
5. Alternative A5. It comprises an artificial reservoir on the Talaaf Adrhousse mountain as the upper reservoir, and the same dam on the Es Sarem tributary as in Alternative A2 as the lower reservoir. The pipeline is completely underground.
6. Alternative A5.1. This one has the same layout as alternative A5 but with a pipeline partially on the surface.
7. Alternative A5.2. This one has the same layout as alternative A5.1 but replacing the dam on the Es Sarem Tributary with an artificial reservoir close to that same natural water course.

The following figure shows the location of the seven different possible options:

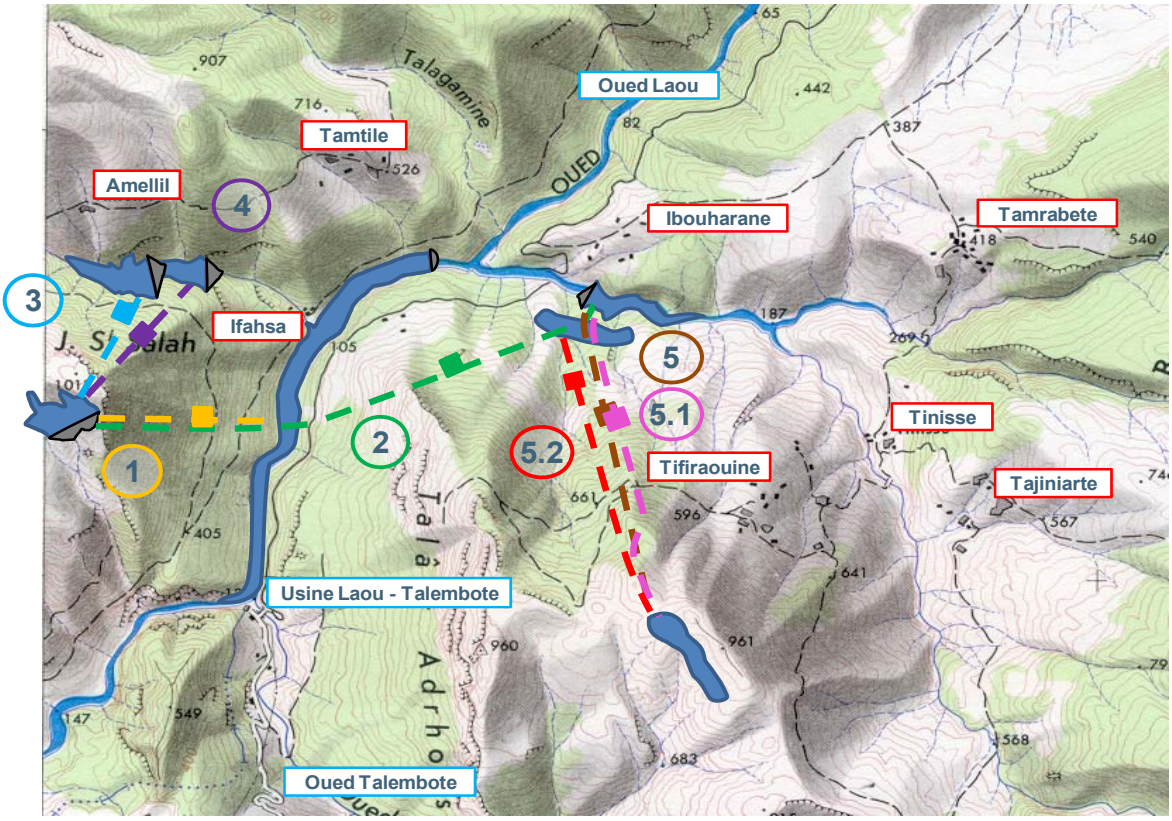

Figure 3. Location of the alternatives analysed and the original scheme

Alternative A5.2 was considered to be the best from a technical and cost-related perspective, and was chosen with a view to further development during the Feasibility Study phase.

Having selected this option, the geological-geotechnical study was carried out.

Finally, in order to perfect the chosen option, a further visit to the project site was organised in October 2013. During the visit, **the following changes were added to the A5.2 option in order to finally define the ideal solution:**

Having analysed the topographical and geological data available, it was decided that the site proposed for the lower reservoir had some disadvantages. As a result it was decided to select a more advantageous location. A site close to the original location was finally chosen, on a small plateau:

- The original location of the A5.2 option had a considerable effect on the natural flow of an important stream which it would have interrupted, and diverting the waters would have been difficult, not to mention a definite risk for the reservoir in the event of unexpected surges.

  The new set up will make it possible to divert a less significant stream and as a result it will be easier to manage.

- From a geological perspective, the conditions of the A5.2 option were not as favourable as those initially planned, and as a result the slopes of the excavation embankments had to be less pronounced than those established in the aforementioned study of alternative options, which means that the height of the clearances were more significant.

  The conditions of the terrain are more favourable to the new layout as it will allow more vertical excavation embankments and will reduce the total clearance elevations and the resulting visual impact.

4. Description of the main characteristics of the solution adopted

The plan for installing the IFAHSA PSPS comprises the following works (Fig..4&5):

- Upper reservoir, on the Talaaf Adrhousse mountain forming an artificial lake covered with a geomembrane and with an altitude of 934.5 NGM, and a useful volume of 793,000 m3.

- Upper reservoir water intake

- Upper hydraulic circuit designed for a control flow of t Q = 44 m^3/s, with a diameter of 3.0 m comprising the following:

  - An air inlet pipeline installed in a trench (1,700 m length)
  - A vertical well (205 m high)
  - A section of penstock (33m)

- Underground power house comprising two caverns, the machinery cavern (turbine hall) and the electrical equipment cavern

- Cable outlet shaft 204 m high with external transformer post platform 225 kV with a surface area of 1,900 m^2

- A lower hydraulic circuit comprising the tailrace tunnel designed for a flow of Q = 44 m^3/s, 3.0 m in diameter and 161.5 m long

- A surge chimney in a vertical shaft: 137 m total high and a diameter varying from 3.0 m to 5,0 m

- Lower reservoir water intake
- An artificial lower reservoir, on the right bank of the natural flow of the Es Sarem wadi (a tributary of the Laou wadi) covered with a geomembrane, height of the ridge 175.0 m NGM, with a volume of 793,000 m3
- Pumping station for the first fill of water of the lower reservoir, and refilling of PSPS evaporation losses with water from the Laou wadi.
- Access to the works namely:
- An access tunnel to the underground power house with a length of 615 m and 7.5 m high.
- The access routes to the works (upper and lower reservoirs, transformer post and surge chimney).

Features of the IFAHSA PSPS	
Number of groups	2
Net average turbine head	753.45 m
Maximum turbine flow	2 x 22 m^3/s
Maximum pumping flow	2 x 18.5 m^3/s
Turbine power	2 x 150 MW
Pumping power	2 x 150 MW
Synchronous speed	750 rev/min

Table 1. Features of the IFAHSA PSPS

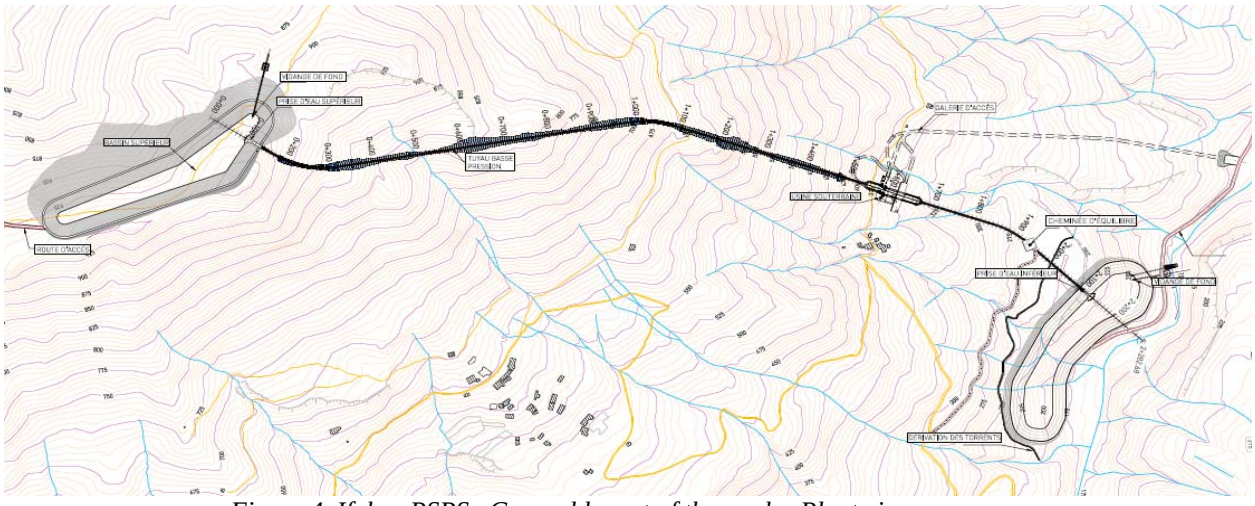

Figure 4. Ifahsa PSPS. General layout of the works. Plant view

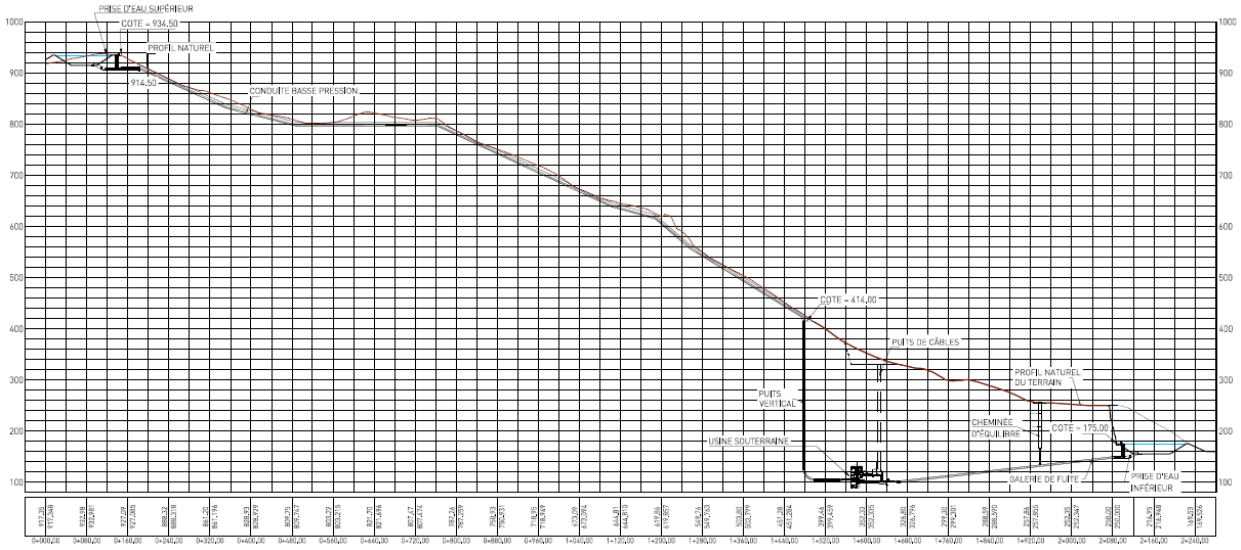

Figure 5. Ifahsa PSPS. General layout of the works. Profile

5. PSPS energy performance

The IFAHSA PSPS project will function on the basis of a daily cycle. Every week, the daily cycle will generate approximately 1500 MWh over 5 hours with peaks in the morning and in the afternoon. The pumping operates for periods of approximately 6.5 hours during which all the water passing through the turbines during the day will be pumped to the upstream reservoir.

During this slow period, the PSPS regulates the system and acts as a spinning reserve.

5.1. Volumes and levels of the upper and lower reservoirs in the PSPS

As indicated previously, the characteristic operating heights of the reservoirs will be as follows:

Ifahsa PSPS	**Normal hold height [m]**	**Minimum operating height [m]**
Upper reservoir	933.70	914.50
Lower reservoir	174.10	155.00

Table 2. Operating levels of the IFAHSA PSPS

The maximum gross head will occur at normal holding levels in the upper reservoir and the minimum operating level will occur in the lower reservoir. It reaches a value of 778.70 m.

Conversely, the minimum gross head will occur at minimum holding level in the upper reservoir and the normal holding height in the lower reservoir. It reaches a value of 740.40 m.

5.2. Design flow for pumping and turbines

The maximum turbine power will be 150.0 MW for each unit (300.0 MW total). This power is obtained for the 2 units in operation at a maximum flow and gross head of (44,0 m^3/s - 778,70 m).

The maximum pumping power will be 150.0 MW for each unit, the same value as for the turbine. The maximum flow will vary according to the gross head at any given time between 32 m^3/s (maximum head) and 3.7 m^3/s (minimum head).

The details of the operation of the equipment may be consulted in the sub dossier 2/3. Set up concept.

5.3. Energy produced

The pumping-turbine cycle of the PSPS lasts 24 hours. This is indicated in the following table:

Hour	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
Operation	P	P	P	P	P	P	P											T	T	T	T	T		

With turbines operating, the PSPS power is 300 MW which will allow a production of 1.5 GWh per day (hypothetical operation of 5 hours daily)

The 5 hour turbine cycle will complete the 793,000 m^3 of useful volume of the reservoirs. With the variable pumping flow between 32 and 37m^3/s, this volume will be repumped in approximately 6.5 hours.

The Authors

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