CASE STUDIES OF SMALL PUMPED STORAGE

Pompage-Turbinage à Petite Echelle: Etude de Cas

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ABSTRACT

Energy storage through pumped-storage (PSP) hydropower plants is currently the only mature large-scale electricity storage solution with a global installed capacity of over 100 GW. The objective of this study is to evaluate the possibility of using this storage solution on a smaller scale to provide local voltage control and line congestion management to active medium voltage distribution networks. First, several potential sites were identified in the French-speaking part of Switzerland, ideally with existing reservoirs. Following a selection of the most promising sites, two are selected to pre-size the various components and estimate the investment costs. These two sites are located in the Val de Bagnes in the canton of Valais in Switzerland and offer hydraulic powers of approximately 5 and 10MW. The approximation of the investment cost is around 2 CHF /Watt. In comparison with recent large hydropower projects these prices seem quite reasonable given that the investment cost for large hydropower is of the order of 2-3 CHF/Watt. In parallel, a free software ("freeware") to evaluate the potential, to select the components and to estimate the costs was developed to facilitate future studies.

RESUME

Le stockage d'énergie grâce aux centrales hydroélectriques de pompage-turbinage (PSP) est actuellement la seule solution mature de stockage d'électricité à grande échelle avec une capacité installée mondiale de plus de 100 GW. L'objectif de cette étude est d'évaluer la possibilité d'utiliser cette solution de stockage à plus petite échelle pour assurer le contrôle local de la tension et la gestion de la congestion des lignes aux réseaux de distribution active moyenne tension. Dans un premier temps, plusieurs sites potentiels ont été identifiés en Suisse Romande idéalement avec des réservoirs existants. A la suite d'une sélection des sites les plus prometteurs, deux sont sélectionnés pour en pré-dimensionner les différents composants et estimer les coûts d'investissement. Ces deux sites se trouvent dans le Val de Bagnes dans le *canton du Valais en Suisse et offres des puissances hydrauliques de l'ordre de 5 et 10MW. L'approximation du coût d'investissement est de l'ordre de 2 CHF/Watt. En comparaison avec des projets récents dans la grande hydraulique ces prix semblent tout à fait raisonnables sachant que le coût d'investissement pour la grande hydraulique est de l'ordre de 2-3 CHF/Watt. En parallèle, un logiciel gratuit (« freeware ») pour évaluer le potentiel, sélectionner les composants et estimer les coûts a été développé pour faciliter les études futures.*

1. INTRODUCTION

Switzerland ratified in October 2017 the Paris Agreement aiming to cut greenhouse gas emissions to net zero by 2050. In January 2021 the Federal Council released its roadmap to achieve the Paris Agreement by setting ten key strategic principles that will guide and shape Switzerland's climate policy actions over the coming years [1]. This implies that most of the actual sources of energy as fuel oil, fuel gas and nuclear will need to be replaced by renewable energies as solar and wind energies. However, in 2018 these two energies represented, respectively, 2.9% and 0.2% of the annual electricity production. Therefore, a significant effort will be required to find an alternative to the non-renewable energy, which represent approximately 40% in Switzerland [2]. The expected alternative relies in solar energy with an installed capacity of 37.5 GW of photovoltaic [3].

The usage of wind and solar energies have the well-known problem of intermittency. The amount and the time of production cannot easily be predicted. Furthermore, the peak of production might not coincide with the demand making its management more complicated. Therefore, a storage solution should be used to ensure to not loose the excess of energy. A solution is to use battery as demonstrated in Australia when Tesla installed a 100 MW / 129 MWh Li-ion battery connected to a wind farm in Hornsdale in the state of South Australia [4]. However, such technology is, as of today, still under development and suffer challenges as limited cycle life, cost, and poor performance in hot and cold climate [5].

The other storage alternative is the well advanced pumped-storage technology. Two reservoirs at two different altitude will act as a battery. The excess of energy will be converted into mechanical energy via a pump and transfer the water from the lower reservoir toward the upper one. Thus, giving the water a potential energy. Then, when the energy demand exceeds the supply the water from the upper reservoir can be release to the lower one. Its potential energy will be converted to kinetic, mechanical, and finally into electrical energy. However, this highly efficient and reliable technology requires water reservoirs. Martínez-Jaramillo et al. [6] analysed the feasibility of 100% renewable generation in Switzerland. They considered hydro and photovoltaic generations combined with pumped-storage hydro. Their analysis showed that the pumping capacity should be doubled, and the reservoirs size increased up to 100% depending on the installed solar capacity. It is, therefore, necessary to find new approach to increase at reasonable cost the pump and storage capacity.

This paper focuses on the development of small scale and affordable pumped-storage powerplant. To do so, a survey was conducted to find existing reservoirs, as the ones used for artificial snow or irrigation, in the Vaud and Wallis cantons in Switzerland [7]. From this research several sites are feasible and two of them are selected. A feasibility study is carried out to evaluate the future components of the powerplant as well as the required investment cost.

2. SIG COGENER PROJECT

The SIG COGENER project led by the HES-SO Valais-Wallis and Mhylab from July 2015 to June 2017 aimed to assess the relevance of using small-scale pumped-storage powerplant as a possible solution to regulate the production of intermittent energy as solar and wind energies. This assessment focused first on the analysis of the hydraulic potential of two cantons located in the French-speaking part of Switzerland, second, on the identification of an economical model for this type of service and finally, to clarify the relevance of developing this new technology suitable to equip small to medium head sites and thus increasing the installed power and storage capacity.

The first phase of the project identified the needs in terms of storage energy, pumping and generating mode durations as well as the power of the installation. These identifications are based on interviews with Transmission System Operators (TSOs), Distribution Network Operators (DNOs), Balance Group Managers

(BGMs), BGM for renewable energy as well as with potential customers interested in this new type of technology. It resulted from these interviews that an interest exists in energy storage systems by small-scale pumped-storage. The ideal power is between 1 and 10MW with a pumping and generating mode duration from 2 to 6 hours and a powerplant usage from 1 to 2 cycles per day. This type of system could cover several services such as the mitigation of power peak at the start of industrial machines as well as for the energy adjustment. To make this technology competitive, it is necessary to integrate the future storage system into an existing structure such as the irrigation, drinking water or mechanical snowmaking networks, and thus provide them with additional flexibility.

Following the interviews, the technical, the electrical and the functional characteristics of the storage system was established. Based on these characteristics, an initial census was carried out. This initial census consists of listing the existing reservoirs with a sufficient hydraulic potential. These reservoirs considered can be natural or artificial lakes, used for turbine operation, for artificial snow, for irrigation, for drinking water or even for flood prevention [8].

The initial census was carried out in the cantons of Vaud and Wallis in Switzerland and resulted in the presence of 186 natural lakes or artificial reservoirs. The amount of reservoir might be higher as not every drinking water network were analysed. From these 186 reservoirs, 19 were identified for the installation of a small-scale pumped-storage powerplant, spread over 27 exploitable reservoirs. Thus, the total technical potential is estimated at more than 75MW, for a storage capacity of around 430 MWh. The situation of the 186 reservoirs identified is shown in Figure 1. The 27 potential reservoirs for small-scale pumped-storage are highlighted in darker blue. Among these 19 potential sites, two got attention by local authorities and were analysed in more detail. These sites are in Valais in the Bagnes valley. These sites are presented in detail in the next section.

To facilitate the study of small pumped-storage power plant, an in-house software was developed using Python 3.7 and the PySimpleGUI library (version 4.18.2). The results shown in the next section were obtained using it. The different cost models were developed based on literature or quotes obtained from suppliers.

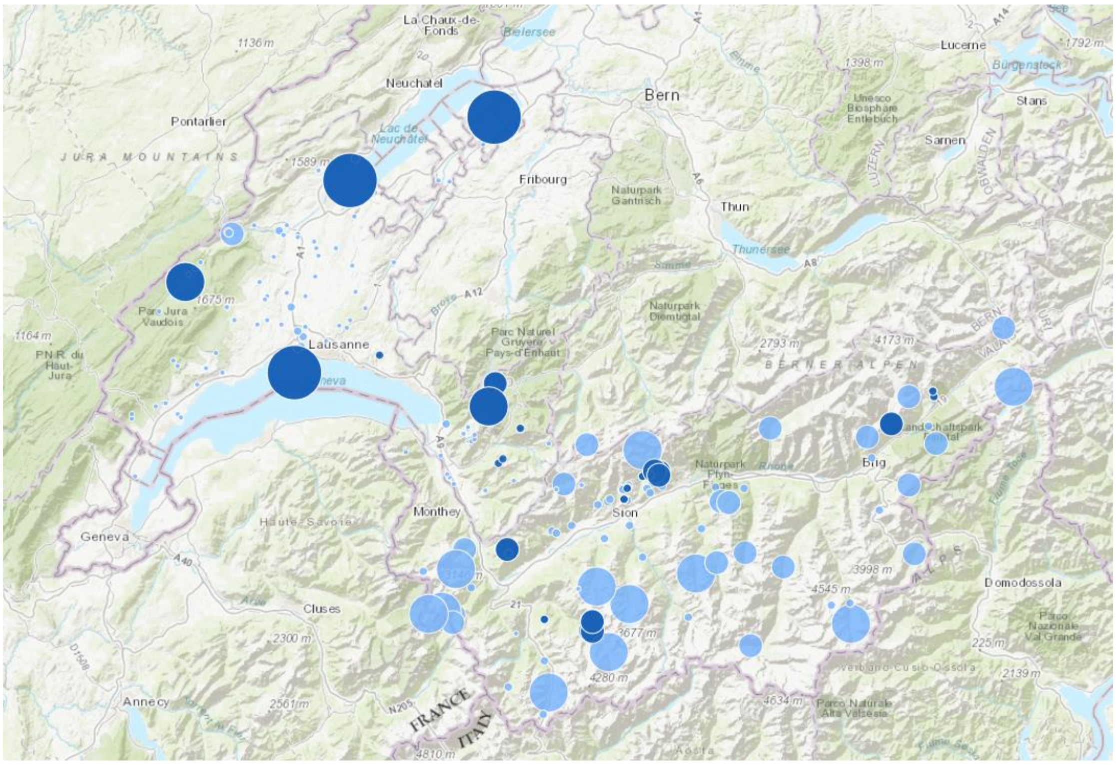

Figure 1: Potential sites to install a small-scale pumped-storage powerplant [7].

3. CASE STUDIES

3.1 Site Louvie lake – Fionnay reservoir

Site description

The site is located in Fionnay in the Wallis Canton, where two reservoirs already exist. The upper reservoir, called Louvie, is an artificial hillside catchment reservoir used for irrigation and drinkable water in the Bagnes valley. It is also used for fishing and is located at an altitude of 2’214 m. It was built in the sixties and has a water capacity of 340’000 m^3. As of today, the water exploitation is given to the company called ALTIS. The lower reservoir is a compensation basin used by the "Forces Motrices de Mauvoisin SA" (FMM) to compensate the difference of maximal turbine discharge between the powerplants located in Fionnay and Riddes. Its water capacity is 170’000 m^3 and is located at an altitude of 1’491 m. The locations of the two reservoirs are shown in Figure 2. For the present analysis, it is assumed that 10% of the water capacity of the compensation basin can be used. Based on this assumption, the energy storage *E* [kWh] can be computed as follow:

$$E = \rho g V H \cdot 2.78 \cdot 10^{-7} \left[{}^{\mathrm{kWh}}/_{\mathrm{J}}\right] \quad (1)$$

where ρ [kg m^{-3}] is the water density, g [m s^{-2}] the gravity, V [m^3] the available water volume and H [m] the head. The capacity of energy storage for this site reaches 33.4 [MWh] providing a hydraulic power of approximately 5 MW based on a cycle of approximative six hours in generating mode.

Regarding the access, all equipment can easily be brought by the road to Fionnay. The water intake at Louvie, the settling basin if necessary, and the pipes would be the more complex to install as it is located in a mountainous area. Helicopters will certainly be necessary.

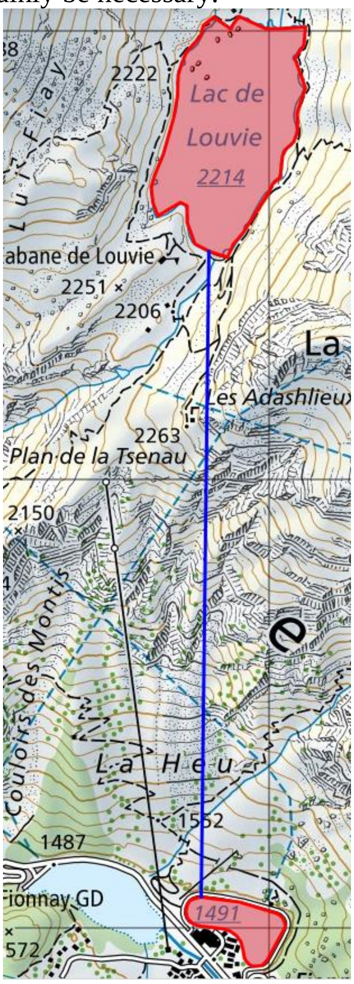

Figure 2: Geographical location of the Louvie - Fionnay reservoirs (red surfaces). The preliminary piping path connecting the two reservoirs is shown by the blue line. Source: Swisstopo

Powerplant description

The first component considered is the piping and its preliminary straight path is shown by the blue line in Figure 2. As it can be seen, the area is steep and would require significant effort to transport and install the pipes. However, there is already the know-how of such installation in the region which would make this procedure easier. The resulting pipe length reached 1’500 [m] using a 500 mm diameter to obtain an efficiency of 95.4% when operating the turbine at maximal discharge, i.e., 0.71 [m^3 s^{-1}].

Regarding the power generation, a Pelton turbine of 4.2MW would be used. With a rotation of 1’500 [rpm], about 3 injectors are needed using a vertical axis [9]. The advantage of the vertical axis is to allow to distribute the injectors to obtain a quasi-zero radial force on the turbine shaft. However, maintenances are a little bit more complicated.

To pump the water back, several scenarios should be taken into account and will depend on the owner needs. If the need is to pump back at the same generating discharge, two pumps of minimum 3.4 MW will be required. An alternative scenario would be to lower the pumping discharge to 0.5 [m^3 s^{-1}], which would require a single pump of minimum 4.3 MW. This scenario is chosen in the following description. To ensure that the pump operates cavitation free it will be located several meters below the minimum height of the lower reservoir, which has an impact on the powerhouse construction. Therefore, the quaternary set configuration will be used.

A powerhouse needs to be built near the Fionnay reservoir to accommodate the machines with their electronics. It is assumed that a building with a footprint of 150 m^2 is sufficient. However, as mentioned previously, this powerhouse will need to go several meters deeper than the minimum height of the lower reservoir to meet the requirement of the pump NPSHr and also have a part above the reservoir to evacuate the flow downstream the Pelton turbine. If it is impossible to build deep enough to install the pump another alternative is to build a second powerhouse located lower than the lower reservoir. As the lower reservoir is in a mountainous area this is feasible. However, this solution would require having both a pumping and generating pipes and both powerhouses will need to be connected to the grid, which will be more costly. Assuming that a single powerhouse is required and can be built near the lower reservoir, the connection to the grid can be done via the neighbouring cable care. The distance between the two is approximately 220 m.

Investment cost

The estimated investment cost is shown in Table 1 and its distribution shown in Figure 3. The total cost is decomposed into five main parts: reservoir cost, piping cost, civil engineering cost, hydraulic and electric costs, and the electrical connection to the grid. To these costs a percentage is taken for the study cost and miscellaneous cost. The total investment cost reached approximately 8.2 million CHF, which corresponds to approximately 1.9 CHF/Watt.

Table 1: Global investment cost for the Louvie – Fionnay site

Reservoirs	0
Piping	2’237’000
Civil engineering	2’020’000
H&E equipment	2’227’000
Electrical connection	126’000
Study	697’000
Miscellaneous	488’000
Total [CHF]	**8’158’000**
Total [CHF/W]	**1.9**

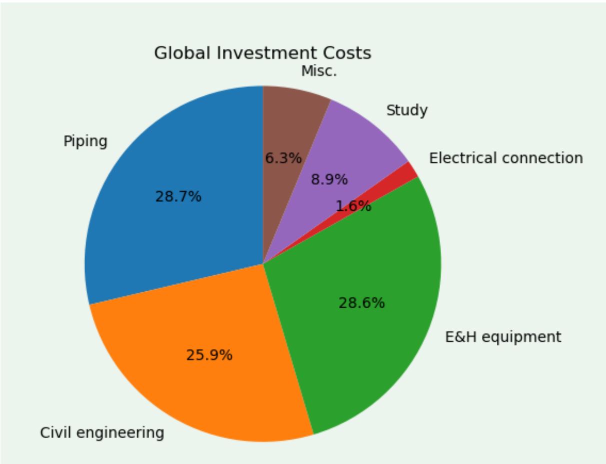

Figure 3: Pie chart showing the investment cost distribution.

3.2 Site Moneyeu reservoir – Les Vernays pond

Site description

The second site is located near Bruson also in the Wallis Canton, where two reservoirs already exist. The upper reservoir is an artificial hillside catchment reservoir built in 2013-2014 to supply the ski resort in artificial snow. This reservoir is located near Moneyeu and is at an altitude of 1’940 m with a water capacity of 14’000 m^3. To ensure the full capacity of the reservoir before the ski season, this reservoir is connected by a pipe of 200 mm to a pumping station (elevation: 1’650 m, location: St.-Tarpe) with a pumping capacity of 80 l/s. The lower reservoir, called "La Gouille des Vernays", is located near Le Châble. Its elevation is 792 m and has an approximated water capacity of 170’000 m^3. It is assumed at this phase of the analysis, that a volume of water of 15’000 m^3 can be used even though no interaction with the local industry using the lower reservoir has been carried out. The capacity of energy storage for this site reaches 47.0 [MWh] providing a generating power of approximately 8.3 MW based on a cycle of approximative five hours in generating mode. Regarding the access of the construction site, no particular difficulty is expected. The upper reservoir is located in the subalpine region where there are already roads to allow trucks to reach easily the construction site.

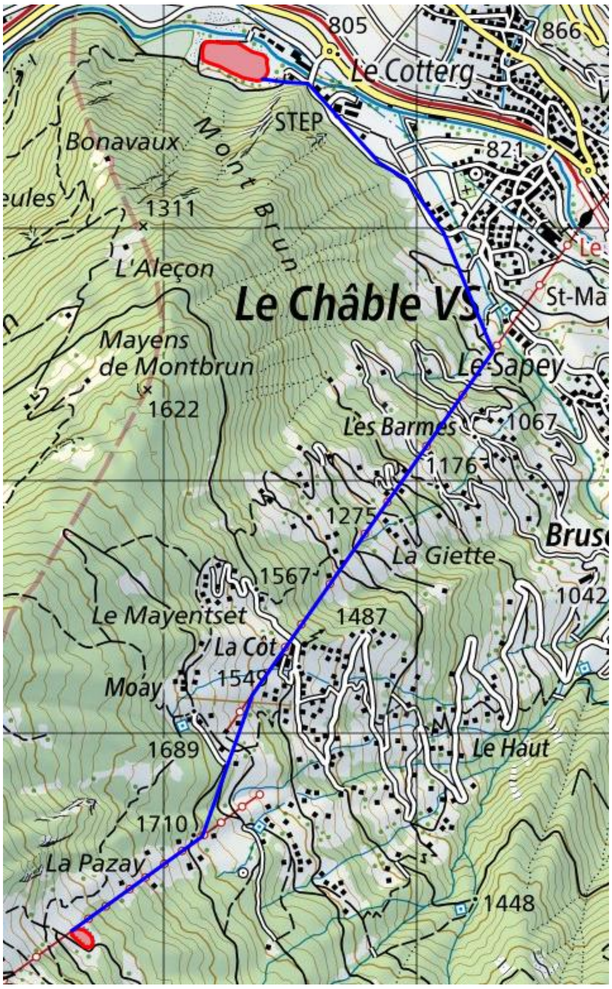

Figure 4: Geographical location of the Moneyeu - Vernays reservoirs (red surfaces). The preliminary piping path connecting the two reservoirs is shown by the blue line. Source: Swisstopo

Powerplant description

The preliminary piping path is shown by the blue line in Figure 4 and can be decomposed into two sections. The first section is located on the ski resort and the second section in the urban area. On the first section, the piping path follows first the path of a chair lift and second of a cable car. On the second section, the pipe path will go through a field and along a road to reach the lower reservoir. The total length of the path is approximately 4’600 m. To ensure about 95% efficiency, the pipe diameter is 600 mm resulting in a head loss of 64 m at the considered generating discharge, i.e., 0.89 [m^3 s^{-1}].

The difference of altitude between the two reservoirs is high, i.e., 1'148 m. Therefore, the turbine type selected is a Pelton turbine rotating at 1'500 rpm with two to three injectors. If two injectors are chosen a horizontal axis can be selected otherwise a vertical axis is preferred.

The height of the site makes challenging to get a pumping discharge similar to the generating one. In order to use only two pumps, the pumping discharge is lowered by 50% in comparison with the generating discharge resulting in a pumping discharge of 0.42 [m^3 s^{-1}].

Similar to the previous site, the powerhouse will need to go sufficiently deep to allow an installation of cavitation free pumps. Also, the use of a Pelton turbine requires to have it installed above the maximum height of the lower reservoir. Therefore, quaternary set configuration will be used.

For this site, a powerhouse needs to be built. It is estimated that a footprint of 150 m^2 is sufficient to accommodate all the machines and their electrical equipment. The powerhouse can be connected to the grid via the neighbouring industry. The distance needed is less than 250 m.

Investment cost

The estimated investment cost is shown in Table 2 and its distribution shown in Figure 5. The total investment cost reached approximately 15.5 million CHF, which corresponds to approximately 1.9 CHF/Watt. This price per Watt is closed to the one obtained with the first investigated site.

Table 2: Global investment cost for the Moneyeu – Vernays site

Reservoirs	0
Piping	4'556'000
Civil engineering	2'032'000
H&E equipment	5'299'000
Electrical connection	482'000
Study	1'322'000
Miscellaneous	926'000
Total [CHF]	**15'471'000**
Total [CHF/W]	**1.9**

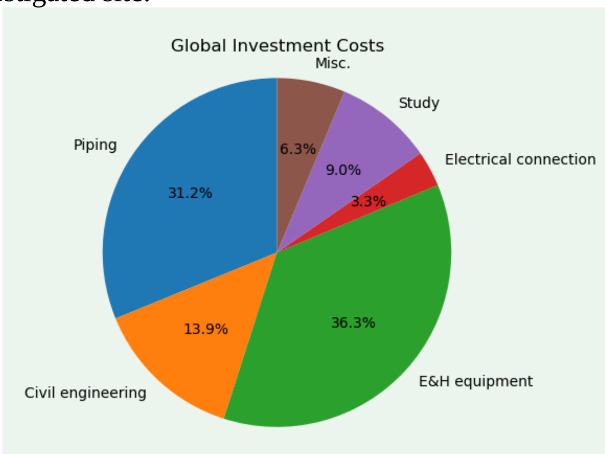

Figure 5: Pie chart showing the investment cost distribution for the second site.

3.3 Comparison with large hydro projects

The Limmern pumped storage powerplant

The Limmern pumped storage powerplant (LPSP) is one of Axpo's most important expansion projects in recent years with investments amounting to CHF 2.1 billion [10]. LPSP was commissioned in 2016/2017 after 10 years of construction and planning period. It is located in the Glaris canton and features two artificial reservoirs. The upper one called Muttsee dam is at an altitude of 2'474 m and can contain up to 23 million m^3 of water. The lower one called Limmernsee dam is at an altitude of 1'885 and can contain up to 92 million m^3 of water. The expansion project increased the output power from approximately 520 MW to 1'520 MW with four GE 250 MW variable speed pump-turbines [11]. Therefore, the expansion cost is about 2.1 CHF/Watt.

Nant de Drance pumped storage powerplant

The Nant de Drance project started in 2008 and will be fully completed in 2021 [12]. It consisted in the construction of a new underground powerplant in the Wallis canton. It features six GE 150 MW variable-speed pump-turbine [13] and connects two existing reservoirs: Émosson dam and Vieux-Émosson dam. The Émosson dam is at an altitude of 1'931 m and can contain up to 225 million m^3 of water. The Vieux-Émosson dam got its height increased by 20 m to double its water capacity. Its altitude is 2'225 m and can contain up to 25 million m^3 of water. This new project costed about CHF 2.1 billion [14], i.e., 2.3 CHF/Watt.

FMHL+

The FMHL+ project consisted in an expansion of the former Forces Motrices Hongrin-Léman SA (FMHL) pumped-storage powerplant. The first powerplant was commissioned in 1971 and connects the Léman lake (372 m) to the Hongrin dam located in the Vaud canton at an altitude of 1'255 m and can accumulate up to 52 million m^3 of water. The FMHL powerplant accommodates four horizontal ternary set composed each of one pump and a turbine composed of two Pelton wheels for a total installed capacity of 240 MW. The expansion, commissioned in 2017, consisted in building a new powerhouse cavern and connect it to the existing head race and tail race. It accommodates two vertical ternary set composed of one pump and one Pelton turbine of 120 MW [15], [16]. Therefore, the extension allowed to double the installation capacity for a cost of CHF 0.331 billion [17], i.e., 2.8 CHF/Watt.

4. CONCLUSION

An initial study showed locations where natural or artificial reservoirs are located in the French part of Switzerland. From these sites, two promising sites were selected, and a pre-sizing was carried out to build a new small pumped-storage powerplants with their investment cost.

The first site is connecting Louvie lake to the Fionnay reservoir and has a usable volume of water of approximative 17'000 m^3 with a head reaching 722 m. The capacity of energy storage for this site reaches 33.4 MWh providing a hydraulic power of 5 MW based on a cycle of approximately six hours in generating mode. To fulfil this requirement one pump and one turbine in a configuration of quaternary set is selected. The preliminary investment cost reached 8.2 million CHF corresponding to 1.9 CHF/Watt.

The second site is connecting the Moneyeu reservoir to the Vernays pond. The volume of usable water is approximately 15'000 m^3 and the head reached 1'148 m. The capacity of energy storage for this site reaches 47 MWh providing a generating power of approximately 8.3 MW based on a cycle of less than five hours in generating mode. Because of the high head the pumping discharge is reduced by 50% in order to limit the installation to use only two pumps. The resulting installation is composed of quaternary set type which connect the motor to its pump. The estimated investment cost reached 15.5 million CHF corresponding to 1.9 CHF/Watt.

In the present analysis, the estimated cost of the two small hydro projects is lower than recent large hydro projects. One reason is that only sites with already existing reservoirs were considered. Furthermore, these large projects implied for example the construction of cavern powerhouses or the heightening of dams, which are much more complex than the construction considered in the present analysis. As an order of magnitude, it can be estimated that the cost of reservoirs is representing 33% of the total cost. For this reason, the evaluation of the potential of small PSP was focused on sites with one or two existing reservoirs (Figure 1) with the required water volume. It is not surprising that the two most promising sites are sites with two existing reservoirs in close proximity to each other, as well as high heads, which reduces the size and cost of the Hydraulic and Electromechanical (H&E) equipment. However, high head requires high performance pumps, especially in terms of cavitation. It should also be noted that the cost estimation is based on literature or quotes obtained from suppliers. It does not take into account the constructive specificities of each site. The requirement of the pump NPSHr imposes to implant the pump room at a great depth, whose cost is strongly dependent on the geological nature of the soil and the methods of construction used. In addition, the present software is focused mostly on the technical part, whereas some additional cost should be included as the administrative ones. An example would be to get a study assessing the environmental impact of the project or to deal with objection against the project that could significantly impact the cost.

Finally, the cost shown in the analysis are an estimation to provide future customers an order of magnitude of the investment cost which is crucial to validate the choice of site and allow customers to pre-evaluate the type of services they could offer, as energy storage or frequency containment reserve.

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REFERENCES

[1] The Federal Council (2021). *Switzerland's Long-Term Climate Strategy*. https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/reduction-targets/2050-target/climate-strategy-2050.html

[2] OFEN. (2020) *Statistique Suisse de l'électricité 2019*. https://www.bfe.admin.ch/bfe/fr/home/approvisionnement/statistiques-et-geodonnees/statistiques-de-lenergie/statistique-de-l-electricite.html

[3] Swissolar. (2020). *L'OFEN confirme : la Suisse a besoin d'un développement rapide et massif du photovoltaïque*. https://www.swissolar.ch/fr/services/medias/news/detail/n-n/bfe-bestaetigt-die-schweiz-braucht-einen-raschen-und-massiven-photovoltaik-ausbau/

[4] IRENA (2020). *Battery Storage Paves Way for a Renewable-powered Future*. https://irena.org/newsroom/articles/2020/Mar/Battery-storage-paves-way-for-a-renewable-powered-future

[5] Kabir, M. M., & Demirocak, D. E. (2017). *Degradation mechanisms in Li-ion batteries: a state-of-the-art review*. International Journal of Energy Research, 41(14), 1963-1986.

[6] Martínez-Jaramillo, J. E., van Ackere, A., & Larsen, E. R. (2020). *Towards a solar-hydro based generation: The case of Switzerland*. Energy Policy, 138, 111197.

[7] Martignoni, S., Smati, L., Denis, V., & Münch, C. (2018). *Un stockage local et compétitif de l'énergie, le pompage-turbinage à petite échelle recèle de nombreux avantages*. Bulletin ElectroSuisse, No 2, pp. 27-31.

[8] Crettenand, N. (2012). *The facilitation of mini and small hydropower in Switzerland shaping the institutional framework (with a particular focus on storage and pumped-storage schemes)*, EPFL thesis. http://infoscience.epfl.ch/record/176337

[9] Zhang, Z. (2016). *Pelton Turbines*. Springer International Publishing. doi:10.1007/978-3-319-31909-4.

[10] Axpo. (2020). *Limmern pumped storage plant: Battery in the mountains*. https://www.axpo.com/ch/en/about-us/energy-knowledge.detail.html/energy-knowledge/limmern-pumped-storage-power-plant.html

[11] Tomas Kellner (2016). *Could This Be The Most Extreme Power Plant In The World?* GE. https://www.ge.com/news/reports/how-the-swiss-turned-an-alpine-peak-into-a-battery-the-size-of-a-nuclear-plant

[12] Nant de Drance. (2020). *A one-of-a-kind construction project*. https://www.nant-de-drance.ch/en/construction

[13] Peter C. Beller. (2020) *Pump it up: How an alpine lake became a massive battery ready to feed the grid on a moment's notice*, GE. https://www.ge.com/news/reports/pump-it-how-alpine-lake-became-massive-battery-ready-feed-grid-moment%E2%80%99s-notice

[14] ATS (2019). *Dernière étape pour la centrale du Nant de Drance*. 24 heures. https://www.24heures.ch/suisse/derniere-etape-centrale-nant-drance/story/22181776

[15] N. Rouge, A. Jaccard, G. Micoulet, (2016) *FMHL+: de l'idée à la mise en service - Doublement réussi de la puissance de pompage-turbinage de la centrale FMHL*. Bulletin SEV/VSE 11

[16] N. Rouge, A. Jaccard, G. Micoulet, (2017) *FMHL+: défis et experiences Construction d'une nouvelle centrale de pompage-turbinage de 240 MW (2e partie)*. Bulletin SEV/VSE 1

[17] Alpiq. (2017). *New FMHL+ power station is fully operational*. https://www.alpiq.com/alpiq-group/media-relations/media-releases/media-release-detail/new-fmhl-power-station-is-fully-operational