AMERICAN JOURNAL OF HYDROPOWER, WATER AND ENVIRONMENT SYSTEMS

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AMERICAN JOURNAL OF HYDROPOWER, WATER AND ENVIRONMENT SYSTEMS

Editorial

We now come to the AJHPWS's fifth edition.

This publication is one of the actions undertaken by the Latin American Working Group of IAHR's Hydraulic Machines and Systems Committee.

The fight in searching new papers and prestige from scientific community is incessant. An effective contribution for sustainable development is one of our purposes.

All our researches have the potential to promote scientific knowledge and to support new policies aiming the development of new technologies from the technical, social and economic point of view, in addition to subsidize sustainable development and the quest for a better future.

Thus, dissemination of knowledge, methodologies and procedures of physical phenomena scientific modeling and solutions to reach technological development is one of the groups' goals and consequently, of this journal.

In this case, this journal gradually becomes an eclectic vehicle within the limits of water resources and environment, if there are, and in addition it is interesting for the academy, considering that most part of papers come from research groups of several universities and research centers distributed in Brazil and Latin America.

This edition addresses several subjects such as: the project and building of a small hydropower plant aiming to become a learning tool for teaching and training of engineering students; suitability of an existing reservoir to operate as a mini hydropower plant, according to regulatory environment of not centralized micro generation in Brazil; comparative studies of methodologies for hydraulics transient calculation and finally, studies addressing management issues of water resources.

We do hope to contribute in any way in this direction. We look forward you to appreciate reading of selected papers for this edition of AJHWES.

Yours faithfully,
Geraldo Lucio Tiago Filho
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American Journal of Hydropower, Water and Environment Systems

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All papers must be submitted in English. In case the author wants to translate the article through the journal all costs for the translation will be charged on the account of the author.

1. Formatting articles

1.1. Article structure

1.1.1 Subdivision - numbered sections

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

1.1.2 Format

All text of the manuscript must be located within a 170 mm by 252 mm rectangle of a white A4 page or within 170 mm by 240 mm for the letter format. The margins are given in Table 1. An example of the page format is given in Fig. 1

[Table 1]: Page margin for manuscripts.

Margin Position	Top	Bottom	Left	Right
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All text should be single spaced, black and in 12-point type. "Times News Roman" or a similar proportional font should be used. Total length 15 pages in Word.

The terminology given in the *IEC Technical Report for the Nomenclature of Hydraulic Machinery* is recommended.

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State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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Provide sufficient details to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

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A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

References

Within the text, references should be cited in numerical order according to their order of appearance. The numbered reference citation within text should be enclosed in brackets.

After the second edition all papers must have at least one reference of the American Journal of Hydropower, Water and Environment Systems.

Example: It was shown by Prusa [1] that the width of the plume decreases under these conditions.

In the case of two citations, the numbers should be separated by a comma [1,2]. In the case of more than two references, the numbers should be separated by a dash [5-7].

List of References. References to original sources for cited material should be listed together at the end of the paper; footnotes should not be used for this purpose. References should be arranged in numerical order according to the sequence of citations within the text. Each reference should include the last name of each author followed by his initials.

(1) Reference to journal articles and papers in serial publications should include:

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Sample References

- [1] Ning, X., and Lovell, M. R., 2002, "On the Sliding Friction Characteristics of Unidirectional Continuous FRP Composites," *ASME J. Tribol.*, 124(1), pp. 5-13.
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A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and',

'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

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Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention there, as well as in the footnote. Ensure consistency of abbreviations throughout the article.

Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

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Follow internationally accepted rules and conventions: use the international system of units (SI). If other quantities are mentioned, give their equivalent in SI.

Math formulae

Present simple formulae in the line of normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text).

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FEASIBILITY ASSESSMENT FOR DEPLOYMENT OF MINI HYDROPOWER PLANT IN CONSOLIDATED RESERVOIR

¹Mendes, Thiago Augusto; ²Savas, Tuna Kan

ABSTRACT

With increasing energy demand in Brazil, preferably renewables, investment in hydroelectric generating plants has advanced. In this way presents opportunities for investment in the deployment of hydropower generating plants in reservoirs already consolidated. Given this scenario, we present an analysis of economic and environmental viability for deployment of Mini Hydropower Plant Poço da Cruz in dam engineer Francisco Saboia, Poço da Cruz, Ibimirim municipality, state of Pernambuco. This analysis will take into account the historical water reservoir in relation to energy capacity, providing investment data for Mini Hydropower Plant (MHP). At the end are three scenarios prepared based on different stages of the project. At the end are three cash flow scenarios of implementation and operation of Mini Hydropower Plant, where we determined the Internal Rate of Return (IRR) and payback on investment.

KEYWORDS: Viability, dams, IRR, payback.

1. INTRODUCTION

Seeking to capture alternative revenues to fund activities such as monitoring, security and maintenance of reservoirs, the National Department of Development Against Droughts in Brazil (DNOCS), promoted public bidding to explore Mini and Small Hydropower Plants in public reservoirs located in the Brazilian northeast region (DNOCS, 2009). It is defended in these reservoirs the multiple use of water, this being one of the foundations of the National Policy on Water Resources (Law 9,433/1997). Multiple use of water resources allows their preservation through streamlining and planning of its use, thereby ensuring economic and social benefits for all users.

The public bidding was performed in November, 2009. The winner of the concession contract for lots 1 and 2 that represents the totality of the contract was Rodrigo Pedrosa Engenharia, currently, JMP Energy based in the city of Goiânia, state of Goiás. In its total, National Department of Development Against Droughts in Brazil reads on the contract 36.49 MW of installed power. This potential, defined on the concession agreement by the National Department of Development Against Droughts in Brazil, can incur changes, according to further studies to be performed on each of the reservoirs. The Table 1 describes the reservoir that integrates the concession agreement.

As indicated on Table 1 the reservoir that is part of interest of this study is the Poço da Cruz, in the Moxotó river, located in the county of Ibimirim, state of Pernambuco. Initially it was planned installed capacity of 1.00 MW.

[Table 1]: Reservoirs members of the concession agreement.

RESERVOIR	CITY	STATE	POTENTIAL (MW)
Anagé	Anagé	Bahia	1.00
Armando Ribeiro	Itajá	Rio Grande do Norte	6.01
Banabuiú	Banabuiú	Ceará	3.80
Boqueirão	Boqueirão	Paraíba	1.00

RESERVOIR	CITY	STATE	POTENTIAL (MW)
Castanhão	Alto Santo	Ceará	12.30
Figueiredo	Iracema	Ceará	1.00
Flores	Joselândia	Maranhão	5.28
Jucazinho	Cumarú	Pernambuco	1.00
Orós	Orós	Ceará	3.10
Poço da Cruz	Ibimirim	Pernambuco	1.00
Taquara	Cariré	Ceará	1.00

Source: (National Department of Development Against Droughts in Brazil, 2012).

Within this context, the study seeks to analyze economic and environmental viability of Mini Hydropower Plant Poço da Cruz, seeking to optimize the principle of multiple use of water resources and even contribute for other purposes such as, per example: irrigation, cattle raising and public water supply. The preparation was based on data provided by the licensee, JMP Energy and through studies drawn from data in the region Mini Hydropower Plant (MHP). Several reservoirs in the country built with public supply, irrigation, among others, have potential for hydroelectric development was not implemented.

In the case of reservoirs already built, the analysis of hydropower potential takes into consideration the purpose of the reservoir. Other uses cannot interfere with this purpose. Therefore, to verify that the implementation of the MHP is viable, initially should be aware of the uses of upstream and downstream of the reservoir and the interested party must know whether the use was predicted in the execution of the Project of the dam (National Water Agency in Brazil, 2012).

1.1 Regulation of the sector

The Mini Hydropower Plant (MHP) is defined by the National Electric Energy Agency in Brazil (ANEEL, 2012), as the reutilization of the hydropower potential for power generation, with an installed capacity of up to 3,00 MW (Law nº 13,360/2016). The MHP independent from the concession or authorization in accordance with the Law 9,074/1995 and

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should only be registered at National Electric Energy Agency in Brazil, for its regulation.

Brazil has in total 4,724 power generation projects in operation, generating 162,950,472 kW. Among these, 617 are the MHP type, generating 558,544 kW of power. This number represents about 0.34 % of the power granted in the country.

1.2 Feasibility Analysis

The feasibility of power generation projects is linked to some fundamental characteristics. Are important and relevant to its viability: the land, technology, workforce, customers and licenses to be obtained. When this set becomes feasible and available, and when you add all of these stakeholders you have a social, financial and environmental logic, ie, the business is viable (B-REED, 2012).

Determine the viability of a business does not guarantee that it will receive funding or will be implemented, many other factors contribute in this issue, but this will pave the way for the business that presents itself to sensible people participating technically and financially on it (B-REED, 2012).

To start the design of a Mini Hydropower Plant (MHP) is necessary to conduct an economic feasibility study and, therefore, must estimate the cost and benefit of MHP. It is important that this analysis can compare the various possibilities of arrangement and sizing of components (QUEIROZ, 2010).

Queiroz (2010) relates, in its feasibility study, power variation, energy generated, cost and benefit to define the feasibility of MHP. It is presented two developments of economic analysis, which allowed the analysis of various possibilities of arrangements, of available flow and sizing of the generating group. Based on values of cost of implementation and operation from 1998, performed the due update, the study by Queiroz (2010), was able to determine the time of return on the investment, considering an average energy price over a given time. Starting from the initial development of his study he applied this methodology in a real case and analyzed the financial return that the insertion of a MHP, in a place where they already had two potentials installed.

Investment in Mini Hydropower Plant (MHP) and Small Hydropower Plant (SHP) has attracted many entrepreneurs. This reality is linked mainly to lower investment costs compared to hydroelectric power plants and lower construction period, another important factor is linked to less bureaucracy of the regulatory system both electric and environmentally for this sized enterprise (THOMÉ, 2007).

The initial investment is the largest portion of the cost of MHP. Involve the initial development costs, project, studies, engineering, the implementation of environmental programs, acquisition of materials and equipment and execution of the work. After the operation the cost becomes only the maintenance and operation of MHP (QUEIROZ, 2010).

Gouvêa and Baggio (2012) conducted a study to define solutions that should be adopted for economic feasibility of SHP. Through the study of a real case of implementing a SHP of 4.00 MW, in 24 months, they estimated all spending and investment applied in the SHP. In general, the total budget of a SHP can be divided into four parts: land acquisition, Engineering, Procurement and Construction (EPC), administration costs and engineering and finally environmental costs.

Initially, the first solution provided by Gouvêa and Baggio (2012) to reduce costs is to use equipment usually simpler in the plant. Security and maintenance are also important points to be developed in order to seek the reduction of costs of the project. Continuing, Gouvêa and Baggio (2012) conducted financial

simulations for a total period of 30 years. With this simulation, it was possible to demonstrate the Income Statement for the project. The Internal Rate of Return (IRR) was 16.89 % p.y.

The main result of Gouvêa and Baggio's study (2012), concerns the funding held by Brazilian National Development Bank. The result of the simulations demonstrates that the increased participation of Brazilian National Development Bank to 90% in investments SHP and that keeping interest rates similar to the 70 %, significantly improves the attractiveness of the projects and, consequently, investments in the building of SHP. But it is still seen as a negative point the steady rise in prices of construction inputs, electromechanical equipment and skilled labor reconciled with the high interest rates and low sales price of the energy. These variables minimize the attractiveness of investment, which end up minimizing the rate of return on investment.

After the conducted researches, it was revealed that there is little information regarding the implementation of SHP or MHP in consolidated reservoirs. The fact that the reservoir is already built, guarantees the entrepreneur a lower cost of deployment, because as stated earlier, the main costs are related to projects and environmental programs, executive project and construction of the dam. Thus, the entrepreneur generally should only be concerned with studies of the basic design, environmental permitting (usually with few constraints), executive design of the powerhouse and finally the construction and the acquisition and installation of electromechanical equipment, all requiring verification and evaluation viability.

1.3 Hydrological Studies

The hydroelectric potential of the Mini Hydropower Plant Poço da Cruz, was not defined by study of hydropower inventory because the reservoir was not initially built for this purpose. The definition of the hydroelectric potential was performed through the hydrologic study using data from the gauged stations in the region, where it was calculated the minimum, average and maximum flow fluent reservoir. The hydropower concessionaire developed the studies from these data.

Initial studies of the concessionaire predicted flow of 3.40 m³ s⁻¹ available for power generation, however this value was questioned by the National Water Agency in Brazil, as presented in the next chapter. The flow rate indicated by the concessionaire and the National Water Agency in Brazil was verified in this present study through the studies of the tank model for the Poço da Cruz's reservoir.

2. METHODOLOGY

In order to present the environmental feasibility of Mini Hydropower Plant (MHP) Poço da Cruz initially delimited the basin where the MHP is inserted, it was then collected rainfall data, historical stream flow of the reservoir of Francisco Sabóia and presented the operating regime of the MHP. The economic feasibility was based on the data provided by the company itself and the analysis was made from three simulations with the data provided, each of which addressed different phases of the project: planned scenario, scenario with environmental restrictions and current scenario.

2.1 Survey of the River Basin Moxotó

The basin of the Moxotó river is situated, mostly in the state of Pernambuco, extending in its southeastern portion to the state of Alagoas and to the São Francisco river. The basin is located between 07° 52' 21 " and 09° 19' 03" south latitude and between 36° 57' 49" and 38° 14' 41" west longitude.

The Figure 1 shows the delineation of the basin of the Moxotó river performed by Oliveira et al. (2009), in his study and assessment on land cover in the watershed.

2.2 Drainage Area

The drainage area of the reservoir Poço da Cruz was delimited using the GIS software, ArcGIS, version 9.3.

Initially we worked with planialtimetric images of the region (Miranda, 2005). They are accurate images from the satellite Shuttle Radar Topography Mission usually called SRTM images. Through initial analysis it was seen that the basin occupies 4 images in total, so it was necessary to create a mosaic of images. Images are: SC-24-XA, XB-SC-24, SB-24, SB-24.

From the image generated by ArcGIS it was possible to start the work to define the drainage area of the reservoir Poço da Cruz. The software has a tool to extract the drainage network, where at the end all possible rivers, streams, or preferential pathways of water were raised. To define the drainage area were used the images provided by National Water Agency in Brazil from Ottobacias Level 5. The Ottobacias are areas of contribution of stretches of the river coded according to the method of Otto Pfafstetter for classifying basins in Brazil. Altogether the drainage area corresponds to 4,630.84 km².

2.3 Poço da Cruz reservoir

The Poço da Cruz reservoir is located in Ibimirim, State of Pernambuco. The beginning of the construction of the Eng Francisco Sabóia, or Poço da Cruz reservoir, was in 1957, and opened in 1959. Its main purpose is to supply the Irrigated Perimeter of the Moxotó River. Table 2 presents the technical of the Poço da Cruz reservoir.

[Table 2]: Technical specifications Poço da Cruz.

reservoir engineer Francisco Sabóia	
Name	Poço da Cruz
Basin state	Moxotó river
Goal	Mainly irrigation of lands downstream of the valley, about 8,000 ha, fish farming, crop areas upstream.
State / City	Pernambuco / Ibimirim
Year beginning construction	1937
Year construction completion	1958
Capacity (m ³)	504,000,000.00
Dead volume (m ³)	75,600,000.00
Quota threshold (m)	435.00
Crest elevation (m)	437.50
Hydraulic Basin (m ²)	56,000,000.00

Source: (National Department of Development Against Droughts in Brazil, 2012).

In August 2012, the Mini Hydropower Plant of Poço da Cruz through the Resolution No. 364 of August 20, 2012, received from the National Water Agency in Brazil, a response for the request to grant the right to use water resources.

The flow rate granted by the National Water Agency in Brazil is relatively lower than the predicted by the hydrological studies conducted by the concessionaire. This is one of the factors that directly influenced in the capacity factor of generation of the Mini Hydropower Plant of Poço da Cruz. The time "idle" of the Mini Hydropower Plant of Poço da Cruz drastically reduced its ability to generate energy or also called power factor, which is currently less than 22 % of the installed capacity.

2.4 Rainfall Index

The survey of rainfall stations was based on the research in HIDROWEB. The database is provided by National Water Agency in Brazil, through its website, where data from stations scattered throughout the country, can be accessed. In many cases National Water Agency in Brazil itself operates the rainfall stations, but in others, the operation can be performed by other agencies.

The rainfall stations analyzed are presented in Table 3 and Figure 2. As indicated, the whole nine stations were selected for the study. It was not possible to access the data of the other four stations mentioned: station 837008 (Brejo do Piore), station 837030 (Poço da Cruz), station 837047 (Ibimirim) and station 837056 (Poço da Cruz).

This can occur if the operator is not linked to National Water Agency in Brazil and so the information is not passed on to the same.

[Table 3]: List of rainfall stations.

CODE	NAME	SUB-BASIN	STATE	CITY	RESPON-SIBLE	OPERA-TOR	LATITUDE	LONGI-TUDE
837006 ¹	Poço da Cruz	49	PE	IBIMIRIM	SUDENE ⁴	SUDENE ⁴	08 30 00 S	37 44 00 W
837008	Brejo do Piore	49	PE	IBIMIRIM	SUDENE ⁴	SUDENE ⁴	08 37 00 S	37 32 00 W
837025	Ibimirim (Jeritaco)	49	PE	IBIMIRIM	DNOCS ²	DNOCS ²	08 23 00 S	37 38 00 W
837028	Moxotó	49	PE	IBIMIRIM	DNOCS ²	DNOCS ²	08 43 00 S	37 32 00 W
837030	Poço da Cruz	49	PE	IBIMIRIM	DNOCS ²	DNOCS ²	08 30 00 S	37 44 00 W
837047	Ibimirim	49	PE	IBIMIRIM	EMATER	EMATER	08 32 00 S	37 42 00 W
837056	Poço da Cruz	49	PE	IBIMIRIM	ANA3	HOBECO	08 29 43 S	37 42 02 W
837010	Carualina	49	PE	SERTÂNIA	SDN	SDN	08 18 00 S	37 34 58 W
837011	Custódia	49	PE	CUSTÓDIA	DNOCS ²	DNOCS ²	08 05 60 S	37 38 60 W
837014	Fazenda Caiçara	49	PE	CUSTÓDIA	SDN	SDN	08 20 60 S	37 45 00 W
837016	Fazenda Jacaré	49	PE	FLORESTA	SDN	SDN	08 25 00 S	37 55 59 W
837032	Rio da Barra	49	PE	SERTÂNIA	SDN	SDN	08 09 00 S	37 28 59 W
837033	Sertânia (Alagoa de Baixo)	49	PE	SERTÂNIA	DNOCS ²	DNOCS ²	08 04 60 S	37 16 00 W

where: This station corresponds to 837030 station and is not shown in Figure 2; 2DNOCS - National Department of Development Against Droughts in Brazil; 3ANA - National Water Agency in Brazil; 4SUDENE - Northeast Development Superintendence in Brazil. Source: (HIDROWEB, 2013).

[Figure 2: Location of rainfall stations raised. Source: (GOOGLE EARTH, 2016).]

2.5 Tank Model

The model used to verify the monthly average of the streamflow was the Tank type. To calculate the monthly average of precipitation it was used the Multiquadric method. The Multiquadric method consists in determining the weighting coefficients that are used in interpolation, on the premise that the total area of rain over the basin may be the result of several quadric surfaces or kernel functions, each originating from a point at which the value of $f(x, y)$ is known. Adjusting a surface that passes through all points known one can find the coefficients of each position to determine the rainfall precipitation at any point (BALASCIO, 2001; BARBALHO, 2012).

The Tank model is characterized by having a simple and easy structure to implement as well as being the most suitable for analysis of longer periods as the month. The structure of the Tank model for humid regions, consists of three tanks arranged vertically in series Figure 3.

The discharge of water in the first tank, through the two lateral outlets corresponds conceptually to the flow surface and the hypodermis. The water that flows in from the second tank through the outlet side is equivalent to the intermediate flow. The flow through the outlet side of the last tank corresponds to the basic flow or underground. So the total sum of all these side exits, corresponds to the river flow in the considered section (MENDES et al., 2007). For each tank, the lateral flow Q (output) is proportional to the height h of the water stored in the tank above the outlet side and it is expressed by $Q = A.h$, where A is the coefficient of the exit side calculated by the model.

[Figure 3: Scheme Tank model. Source: (MENDES et al., 2007).]

The information on the minimum value or base flow is useful for the planning of water use in drought periods. The Tank model makes possible to consider that the discharge is a result of the amount of water stored in the basin. That way, excess and lack of flow may be associated with the condition of water storage (moisture of the hydrographic basin) (THOMÉ, 2007).

2.6 Economic Viability Analysis

The early assessment of the implementation of the project is the evaluation of the costs until the current time. The data was provided by JMP Energy Ltda, through spreadsheets, showing actual expenses with MHP and payments for the purchase and sales of energy. For being a reservoir that is consolidated, in other words, the work of the dam has been done and the reservoir is in operation, the project for the hydroelectric exploitation follows a less bureaucratic way on environmental issues and also in relation to other regulatory companies, such as National Electric Energy Agency in Brazil (ANEEL). Because of such factors, many expenses common to the implementation of hydropower plants do not need to be performed, for example, studies of hydroelectric inventory, land acquisition, environmental activities in the reservoir and engineering costs (executive project and construction of dam).

The costs that were analyzed refer to stranded costs (basic design, topographic studies, permits, hydrological studies, among others), investment (management, consolidation of the basics on the project, civil executive project, electromechanical executive project, insurance and warranty, the civil works, equipment: electrical/automation/mechanical, turbine/generator, hydro-mechanical equipment, substation/adaptor, assembly, unexpected expenses) and finally costs with operation/maintenance of the plant (actual data submitted by the company).

The company also allowed the access to revenue relating to energy sales. The sales began in the month of January of 2012. That same year, the sales did not occur in a steadily for, as some electromechanical problems happened and the data were nor consolidated. From the beginning of 2013 the operation of the plant was normalized, and every month since then, there is energy available for sale in the free market. The months in which the generation data were not consolidated, the company bought energy in the free market to meet its commitment to the trader. These data were also presented by the company, and at the end were assessed.

2.6.1. Viability Analysis

For economic viability analysis it was used spreadsheets in MS Excel provided by JMP Energy Ltda. It was used projections of cash flow of the company over a 35 years period of projection of the company awarded by DNOCS. The analysis took into account the scenario originally planned by the company, a scenario with environmental restrictions (factor of capacity reduced) and the real scenario of operation of the MHP.

In the first scenario the data and initial parameters were those used for the viability analysis prior to construction of the project, which means, the project data. In the second scenario presents data and parameters considering environmental constraints for the operation and functioning; at this moment the capacity factor of power generation is drastically reduced. Finally, the third scenario presents actual data and parameters of operation of the MHP considering losses with no power generation, maintenance expenses, among others. It was adopted averages in order to present the actual generation capacity of Mini Hydropower Plant from December 2011 to February 2016 (Table 4).

[Table 4]: Basic dates.

POWER AND ENERGY	1° SCENARIO		2° SCENARIO		3° SCENARIO	
Power Installed	840	kW	840	kW	798	kW
Capacity factor	94.0%		22.0%		22.0%	
Average energy	789.60	kW medium	185	kW medium médios	176	kW medium
Energy firm	764.60	kW medium	160	kW medium	151	kW medium

Source: Data provided by the JMP Energy, adapting it to the author.

3. RESULTS AND DISCUSSIONS

The data collected for economic viability study that were presented, refer to the operation of Mini Hydropower Plant (MHP), between December, 2011 to February , 2016, and all the information were given by the Financial Department of JMP Energy Ltda. Based on data provided by the company, three different scenarios were simulated in order to present the cash flow of each one.

3.1 Calculated Flow Rates from Tank Model

Once all the input data were obtained (average of monthly rainfall – Multiquadratic method, monthly average streamflow – Provided by the company and evapotranspiration – measured by Thorwaite method) it can apply the method of rainfall-runoff Tank model and, from several simulations, obtain data of calibration model and a possible answer to the question of data discharges into the reservoir.

Figure 4 shows the annual average of rainfall calculated by Multiquadratic method in the basin of the reservoir Poço da Cruz. The method allows to acquire monthly average of rainfall, which were used in the Tank model.

In the Tank model the data of rainfall stations that were used were from January 1963 to December 1984 (about 21 years). The parameters for the characterization of the basin found in the calibration process for the period of January 1963 to December 1984, were obtained from the Excel Solver tool, and are presented in Table 5. Figure 5 shows the visual comparison between observed and calculated values in this process.

[Table 5]: Parameters used in the Tank model (Figure 3) for reservoir Poço da Cruz in the period Jan/63 - Dec/84.

h1 (mm)	h2 (mm)	h3 (mm)	a1 (mm)	a2 (mm)	a3 (mm)	b1 (mm)	b2 (mm)
607.64266	306.237	0.0	0.472707	0.583322	0.080961	0.318973	0.889312

Source: Developed by the authors.

The flow rate calculated by the Tank model did not adjust well to the observed discharge (provided by the company) using the objective functions commonly used (module and square of the difference). This can be explained by the unreliability of the observed discharged that was provided.

3.2 Analysis of Costs and Investments

Like was mentioned earlier, the JMP Energia Ltda provided all the data related to costs and investments for the implementation/refurbishment and operation of the MHP. The data were provided through spreadsheets, which contains all payments made by the company.

The information given in Table 6 consist primarily of the cost with civil structures, improvements (such as improved access and reform of the penstock) the purchase and electromechanical installation (turbines, generators, automation systems, among others), and the costs of the projects.

[Table 5]: Parameters used in the Tank model (Figure 3) for reservoir Poço da Cruz in the period Jan/63 - Dec/84.

DEPLOYMENT	SPECIFICATION	TOTAL (R\$)
PROJECT	Basic Project	97,047.06
CIVIL	Retirement of Facilities	240,000.00
ELECTROMECHANICAL	Equipment	275,965.30
TOTAL		2,544,769.45

Source: Developed by the authors.

Table 7 shows the relationship of costs with the operation and maintenance of the MHP. The vendor data were not presented for confidentiality reasons, so, the table presents just the sum of the amounts paid and the purpose of payment.

[Table 7]: General costs of maintenance and operation of MHP.

MAINTENANCE AND OPERATION	TOTAL (R\$)
Class Association	R\$ 11,230.50
Purchase Of Materials And Other Electromechanical	R\$ 61,116.14
Energy Consumption And Network Access Transmission	R\$ 83,876.16
Administrative Costs / Office	R\$ 76,306.49
Procedural Costs	R\$ 14,301.87
Expenses Related To Maintenance / Operation	R\$ 213,874.23
Attorneys Fees	R\$ 1,995.30
Accounting Fees	R\$ 35,258.77
Renewal Of Operating License	R\$ 10,811.34
Salary And Wages Operator	R\$ 55,728.00
Guarantee Insurance	R\$ 217,087.67
Outsourced Corporate	R\$ 75,497.51
Fees, Taxes And Contributions	R\$ 109,406.70
Contribution /Payment NATIONAL DEPARTAMENT OF DEVELOPMENT AGAINST DROUGHTS IN BRAZIL	R\$ 54,144.02
TOTAL	R\$ 1,020,634.70

Source: Data provided by the JMP Energy, adapting it to the author.

Since it was a MHP already in operation, it was possible to gain access to revenue relating to sale of energy generated. The data are presented in Table 8. It can be observed that the sale started to occur from January 2012, with the energy generated in December 2011.

[Table 8]: Sale of energy.

RECEIVING (YEAR)	TOTAL (R\$)
2012	86,558.00
2013	266,040.00
2014	628,056.00
2015	436,076.00
2016	31,848.00
TOTAL	1,448,580.00

Source: Data provided by the JMP Energy, adapting it to the author.

In some months of 2012, there was no power generation due to mechanical problems, so there was no energy generated for sale. To meet the energy supply contract with the trader, the Mini Hydropower Plant Poço da Cruz had the need to buy electricity on the open market and provide the trader. The amounts referring to this purchase are described in Table 9.

[Table 9]: Purchase Energy.

TRADERS	PURCHASE DATA	DATE OF PURCHASE	TOTAL (R\$)
Trader A	October/2012	11/14/2012	88,908
Trader B	November/2012	12/12/2012	124,135
Trader B	December/2012	01/14/2013	92,795
TOTAL			305,839

Source: Data provided by the JMP Energy, adapting it to the author.

3.3. Initial Considerations for Viability Analysis

For Mini Hydropower Plant Poço da Cruz the following parameters were considered in the elaboration of Cash Flow:

- investment for the construction of the MHP in the amount approximate R\$ 2,500,000.00;
- construction term of MHP in 11 months, starting in January of 2011;
- annual maintenance cost, R\$ 7.00/MWh, resulting in approximately R\$ 50,602.50, adjusted 4.5 % in 2013;
- the selling price of energy was adjusted by 4.5 % per year;
- operation started December 2011;
- concession period of 35 years.

Other data used to calculate the cash flow suffer change based on the simulation model, as follow:

- The average net of energy production:
 - o 1º. Scenario: 6,697.896 MWh annual trading
 - o 2º. Scenario: 1,401.600 MWh annual trading
 - o 3º. Scenario: 1,322.760 MWh annual trading
- Initial sale price of energy:
 - o 1º. Scenario: R\$ 140.00/MWh
 - o 2º. Scenario: R\$ 200.00/MWh
 - o 3º. Scenario: R\$ 225.70/MWh

3.4. TIR and Investor's Payback

As presented on Table 10 the 1º. scenario, the internal rate of return to the shareholders was 29.14 % per year. The simple payback (return on capital invested) was calculated over 4.79 years. The 2º. scenario shows that the internal rate of return to the shareholders was 9.04 % per year. The simple payback (return on capital invested) was calculated over 12.11 years. The 3º. scenario shows that the internal rate of return to the shareholders was 8.72 % per year. The simple payback (return on capital invested) was calculated over 12.43 years.

[Table 8]: Sale of energy.

PROJECT: POÇO DA CRUZ						
SIMULATION	1º SCENARIO		2º SCENARIO		3º SCENARIO	
POWERS AND ENERGIES						
Installed capacity:	840	kW	840	kW	798	kW
Capacity factor:	94.00	%	22.00	%	22.00	%
Energy firm:	764.6	kW medium	160.0	kW medium	151.0	kW medium
EXPENSES AND TAXES IN OPERATION						
Operation and maintenance:	51,700.00	R\$/year	51,700.00	R\$/year	50,602.50	R\$/year
Amount of grant:	4.00	%	4.00	%	4.00	%
Total tax burden (no ir):	4.30	%	4.30	%	4.30	%
Income tax:	25.00	%	25.00	%	25.00	%
EXPENSES IN DEPLOYMENT						
Depreciable cost:	2,634,509.90	R\$	2,634,509.90	R\$	2,634,509.00	R\$
RELEVANT DATA						
Investment average:	3,136.32	R\$/kW	3,136.32	R\$/kW	3,301.39	R\$/kW
Participation of the entrepreneur	100.00	%	100.00	%	100.00	%
Value of disbursements (equity):	2,500,000.00	R\$	2,500,000.00	R\$	2,500,000.00	R\$

PROJECT: POÇO DA CRUZ						
SIMULATION	1º SCENARIO		2º SCENARIO		3º SCENARIO	
Rate of energy firm:	140.00	R\$/MW	200.00	R\$/MW	250.00	R\$/MWh
Period of exploration:	35	year	35	year	35	year
Period return:	4.79	year	12.11	year	12.43	year
Internal rate of return:	29.14%		9.04%		8.72%	

Source: Data provided by the JMP Energy, adapting it to the author.

4. CONCLUSIONS

The purpose of this study was clearly satisfied after the data presented in Table 10. The difference, at least troubling that occurs with what is designed to happen and what usually happens over the operation of the Mini Hydropower Plant (MHP) is a decisive factor in the viability of the activity.

The importance of developing a good and serious study on hydropower, is very clear considering these results. Studies of the outflow available for power generation should be well structured to continue the viability study for the constructions of hydroelectric projects in consolidated reservoirs. This fact is evidenced by the results of the outflow calculated and adjusted by the model of Tank Model, that indicated low pick flow rates that were observed and average flow rates higher than observed.

As mentioned in the beginning of our study, perceiving the multiple uses that already occur in the reservoir is not an option, it is a decisive factor for the decision making and even allow the evaluation of real capacity for power generation in the reservoir. With the participation of the community combined with public management the outcome can be positive because it is no easy task reconciling all uses of the reservoir.

It is not possible to reverse the situation of Mini Hydropower Plant Poço da Cruz, the accumulated loss in the operation can be used as learning experience by the entrepreneur for other projects that are being developed through the Concession Agreement with the National Department of Development Against Droughts in Brazil (DNOCS). Possible errors can be assessed and avoided. The expected profit and the return time can be compensated after the implementation of others already planned.

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