Using A Simple Technique To Economic Feasibility And Assess The Technical Of Micro Hydro Power Plants In Existing Watering Systems

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Abstract: A humble technique is suggested to spot turbines and pick their rule output, appraise charges and revenues and offer useful indications for Micro Hydro Power (MHP) plant project in current irrigation systems.This technique, based on simple models and demanding a reduced number of input factors cool to survey in primary project stages, has been used and confirmed in an existing irrigation system located in Calabria (Italy).The consequences have emphasized that in the case study the lowest profitable turbine would yield5 KW. A lower number of plants (with higher output) would create no particular monetary savings compared to a greater number of smaller turbines. Besides, neither was the choice of increasing pipe diameter found to provide savings. In general, a considerable potential from MHP operation has been revealed in current irrigation systems, providing a return on investment higher than that provided by the Italian monetary market.Lastly, MHP usefulness noticeably rises with total annual process time, being on average 55%higher in a wet year (eight months of electrical production/four month of irrigation) as opposed to a dry year (six months of electrical production/six months of irrigation).

Index Terms: hydro power plants, economic, period curves, peak flows,electrical energy

1. Introduction

Hydroelectric power is definitely the most advanced renewable energy employed for electricity generation, being totally inexhaustible and carbon-free [1, 4, 8, 13]. Besides, today, installation of hydroelectric power turbines permits extra economic properties for users thanks to the supports granted by the national energy rules for decreasing CO2 emissions.SHP plants (i.e. with a nominal power lower than 10 MW [4,13],have found special importance due to their low installation and management charges, short structure time, strong machinery and reliability [4,7,13]. The acceptance of SHP plants has been suggested in rural or marginal areas, because they do not need major structure works (which may contain environmental impacts),can be worked completely by remote control with limited operating workers and improve rural electrification [4, 13]. The accessibility of geodetic heads in existing water structures advises the likelihood of integrating SHP plants at bearable installation, process and repairs costs. This is the case of the existing irrigation organisms of numerous WUA, where water accessibility out of the irrigation period may allow electrical energy making by turbines, in order to exploit potential energy and integrate the revenue of the related users.

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Placement of SHP plants, calculation of the installation capacity (in particular the optimal designed discharge [7], hydraulic modifications and revenue cost approximation (to measure whether, where and how to continue with plant installation) are significant features, in order to assure the probability of electrical energy creation; These features come to be critical, especially if one considers that a SHP plant needs a high primary investment [4]. It is consequently significant to assess whether the project is worth pursuing, and if so, to plan the subsequent budget [2]. Thus, appropriate procedural and financial methods are desirable for SHP plant design. The prevailing literature describes the procedures to appraise the greatest plant formation to accept from the technical and economic facts of view. For example Voros at al. (2000) [16] advanced a suitable experiential model describing hydro turbine efficacy and the design problem was formulated as a mathematical programming problem. The study by Karlis and Papadopoulos (2000) [9] presents a computer package for classified and methodical analysis, so as to specify the factors that are vital to the financial investment feasibility of a possible SHP system project together with relevant non-financial features and socio-economic influences. A paper by Montanari (2003) [11] suggests a scientific process for planning a SHP plant, based on the formalization of the economic profitability indicators of the investment in probabilistic terms and on its connection to the typical factors of the scattering functions, which define the flow rule of the course of water. Nonetheless, these approaches are primarily pertinent for SHP combination in common water systems (e.g. aqueducts for civil and industrial uses). Furthermore, these approaches seem to be more valuable for detailed installation projects rather than for an initial likelihood assessment, because the future methods need a large number of effort variables, whose determination could be difficult and time consuming at the initial design stage. Simpler and quicker processes, easy to execute by resources of a low number of easy-to-survey input factors, may be a valuable device in determining whether or not the SHP plant is feasible; thus, they may be a support for participants, decision makers and designers to aid recognize the most appropriate practical and economic resolution for each specific circumstance. Furthermore, this simplification is mainly appropriate for design of SHP plants in current irrigation systems. Now, the current disposal of irrigation water (outdoor the dry-season irrigation cycle) creates in-depth hydrological assessments for hydroelectric construction abundant (e.g. period curves, peak flows). This paper suggests a modest process to site turbines and pick their power yield, assess costs and profits and offer valuable hints for Micro Hydro Power plant design (i.e. through a nominal power lower than 1 MW [4], in current irrigation outlines. This technique is founded on modest models accessible in the literature and needs a summary amount of input factors easy to study in initial project phases. It has been proven by way often implementation in a present irrigation outline of a WUA situated in Calabria (Italy), in order to associate three periodic MHP establishment plans.

2 Method

The technique suggested is organized by the flow chart stated in Fig. 1.

2.1 Planning of water system

Based on dependable maps (as a minimum 1:2000), joint with rapid field studies and investigate of the accessible hydraulic outlines, the water system outline can be constructed, recognizing provide and distribution lines (pipe length, physical and diameter) and nodes (environmental coordinates of supplies, confluences, pools, discharge points, etc.). Pipes should be organized by order (supply, distribution lines, etc.). The alteration in height in the nodes can be taken as the gross hydraulic heads.

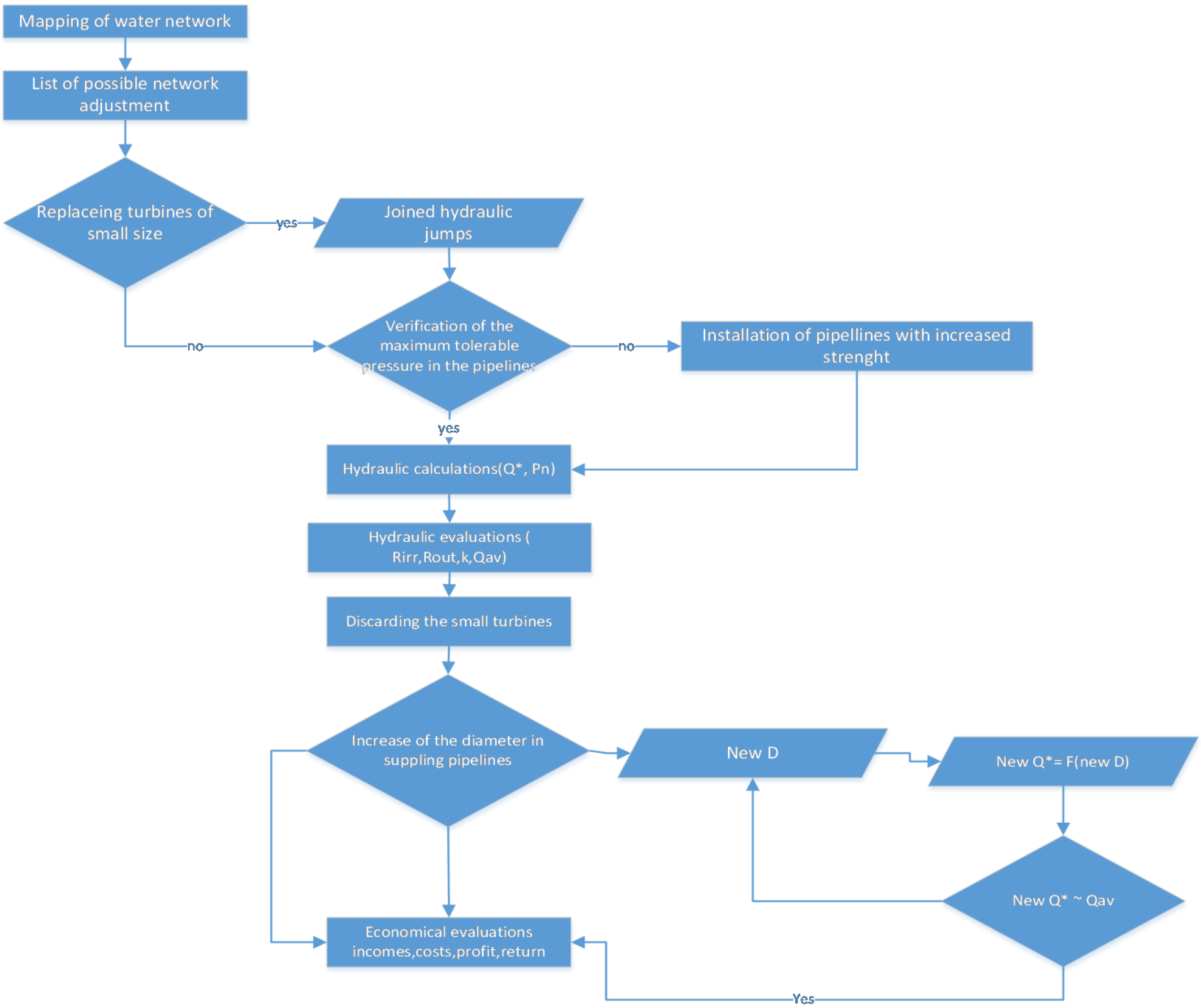

Fig. 1. *Flow chart of the method for assessing MHP feasibility in existing irrigation systems.*

2.2 Study of water system alterations

Some adjustments in the present water system could be inspected to exploit as much as potential the accessible possible energy and/or to decrease installation charges (Fig. 1). Such alterations can be classified as surveys:

- substituting turbines of small bulk (hence gaining economies of measure);
- dumping turbines of the minimum bulks;
- If necessary growing discharges and units of providing ranks.
- Substituting minor turbines can be completed:
- Through diverting the entire water discharge to the maximum hydraulic head in pipe branches, thus maximizing vigor income;
- By fixing by-passes below density in agreement to flow tanks in sequential pipes, so that evade energy losses.

These alterations necessitate the confirmation of whether the new p <pmax of the present pipe. Else, wherever p<pmax, a new pipe with greater power must be fitted.

2.3 Hydraulic controls

The suggested changes necessitate water system confirmation: toward this aim, the n equations of mass steadiness (1) (many number of the system nodes) and m motion equations (1) (many number of the network pipes) must be gratified:

$$\sum_{i=1}^{r} Q_{i,in} - \sum_{j=1}^{s} Q_{k,out} = 0 \qquad (1)$$
$$\Delta H = H_j - H_{j-1}$$

-r and s being the number of input and production pipes in the system nodes. Hydraulic controls provide Pn attainable by the plant and the similar Q*, that is the value of Q which maximizes the function (2):

$$P = \eta\gamma Q \Delta H_n = \eta\gamma Q(\Delta H - \Delta Y) = \eta\gamma Q(\Delta H - JL - \sum_{k=1}^{t} \xi_k \frac{Q^2}{2gA^2}) \qquad (2)$$

-t being the number of the focused hydraulic losses.
If J is estimate d by a communal monomial equation, as:

$$J = \lambda Q^l D^{-P} (3)$$

Whereλ,l and p are the coefficients of the assumed formula, the equation (2) becomes:

$$P = \eta\gamma Q \Delta H_n = \eta\gamma Q\left(\Delta H - \lambda Q^l D^{-P} L - \sum_{k=1}^{t} \xi_k \frac{Q^2}{2gA^2}\right) \qquad (4)$$

In hydroelectric plants integrated in common water systems (e.g. channels for civil and manufacturing usages), the variable hydrological rule of the providing aquatic course makes Q variable during the year and thus h. Nonetheless, in initial sizing of the turbines to be fitted in present irrigation systems, a constant value of h can be expected, because Q corresponds to the constant value which is drawn for irrigation resolves in the arid season and it is equal to the intended Q of the providing pipe. With L/D > 1000, local hydraulic head losses can be ignored and therefore Q* is:

$$Q^* = (\frac{\Delta H D^P}{(1+l)\lambda l})^{\frac{1}{l}} \qquad (5)$$

$Q*$maximizes the vigor making of each line; the set of Q which maximizes the vigor making in the entire system, satisfying the node stability in equation (1), has to be initiate by a "trial and error" computational process. A timesaving process could be accepted bearing in mind the DH of each line and their productivity (for instance nominal power above 5 kW). Furthermore, to Pn attainable outdoor the irrigation period, when Q brought to operators in the irrigation period is lower than Qmax of the current pipe, it is likely to exploit the extra of discharge Qen (¼Qmax _ Q) for electrical vigor making. Pn(irr) during the irrigation period is conveyed by the next equation:

$$P^{(irr)} = \eta\gamma Q_{en} \Delta H_n = \eta\gamma Q_{en}(\Delta H - J_{en} L) \qquad (6)$$

In irrigation structures with rotational transfer timetable the ejection flowing in the water system is continuously equivalent to Qmax, since the water bulks are frequently brought only by regulating irrigation period in place of discharge Q. In on-demand irrigation systems, Q conveyed to planters may be sometimes, but seldom, lower than Qmax; consequently, is the turbine competence□in general variable. Disposal pipes with Pn lesser than a definition set is commonly sensible, since of their small economic feasibility. The selection of growing D in providing lines, in order to decrease DY and/or upsurge Q, needs replacement (in the case of pipes in poor state) or fitting of a new conduit in similar. This alternative would permit the exploitation of extra power, because of amplified Q and/or ΔHn for electrical energy creation, outdoor the irrigation period and to yield extra electrical energy also through the irrigation period, because of compact head losses.

2.4 Hydrologic appraisals

The selection of growing the width of supplying pipes must consider water obtain ability. This can be passed by the rapid process suggested below, delaying more detailed hydrological calculations, if required, to future design steps. This process is wise when runoff data are not obtainable (as in many water courses of Southern Italy) and consequently the historical precipitation chain (easily obtainable) must be used. Qav can be assessed multiplying Qmax of the existing pipe, typically passed through the irrigation period, by a coefficient k, assuming a constant runoff coefficient (that is the ratio between runoff and rainfall) during the year, k could be assessed as the ratio among Rout and Rirr, as revealed by the equation:

$$k = \frac{R_{out}}{R_{irr}} = \frac{Q_{av}}{Q_{max}} \qquad (7)$$

The upsurge of D in the present network has to be estimated only when k is lesser than a definite verge (e.g. k is in the range2.4-4.4 in southern Italy, [3, 15]; if developed, it is wise to estimate also a novel water outline intentionally calculated for hydroelectric usages. The minimum Qm must be deducted from Qav, in order to guess Qs (thus Qs ¼ Qav _ Qm ¼ kQmax _ Qm). The unit charge of the pipe depend Cp on its width by considering the following monomial equation:

$$Cp = \alpha D^v \qquad (8)$$

α and v being two constants (depending on the material category of pipe), whose standards have to be appraised by a power regression based on available pairs of Cp and D. For the Italian market the exponent ϑ is in the range 1.0-1.5 [10]. The most efficient DN should maximize the ratio among energy making and the entire charges of the SHP turbine and novel pipe(this latter depending on D). Consequently, one should assess unlike DN - assumed for as many values of k in equation (7) - for the new pipe, yielding Q* ≅ Qs in equation (5). While the pipe width is increased and in the case Qs< Q*,depending on variations of movement rates in the providing watercourses, the turbine would effort at an efficacy η lower than the finest value. In following design steps (that is in the last employed plan) the investigation of period curve of the providing watercourse for an important observation period permits the approximation of Qs and the amount of days in which Qs < Q*: therefore an appraisal of decrease of energy making related to the predictable worth and the subsequent lower salary and income can be measured. Nevertheless, it is likely to accept a high-flexibility turbine for which the hypothesis of a constant η could be an accurate theory, as for sample cross-flow (with low to average heads) or Pelt on (in the situation of high heads) turbines, where η is greater than0.75-0.80 aimed at values of the proportion Q/Q* in the range 0.1-1.0 [13].

2.5 Economic assessments

Founded on the considered $P_n$formed by the water network, the economic assessment of the profits and costs will offer the feasibility of the MHP arrangement.

2.5.1 Revenue

I of the MHP system derives based on the equation:

$$I = P_E E = P_E P_n T_a (9)$$

While an extra of discharge (Qen) is accessible in the irrigation period, the revenue made by exploiting Pn(irr) should be assessed. Nonetheless, this extra can be overlooked in first economic assessments and suspended to succeeding design phases, since it is important only few hours of a day or few days of a month(i.e. while there is no water request for irrigation) and not simply expectable a priori.

2.5.2 Charges

The financial investigation procedures are planned according to the rules in formed by Hosseini et al. (2005) [7]. IC are the sum of CCEME (turbines, generators, control systems besides civil works for familiarizing the current small dikes and building the tools housing, etc.), CPTL, CED and CSA (buying of land, organization, checkup and management costs). For approximating the charge of the electro-mechanical tools, there are diagrams which can roughly calculate those charges, but these diagrams have not lately been updated. Also, producers of turbines and alternators do not provide any evidence about fee, mean while each fitting is different and complex [12]. In simpler but dependable way, CCEME can be intended as a utility of hydraulic characteristics of the hydro site for example ∆H and Q or ∆Hand Pn, as conveyed in numerous revisions [2,6,14]. In this technique the equation stated by Papantonis (2001) [14] who assessed the charges of unlike works of the hydro plant based on the European data obtainable at that time, has been accepted:

$$C_{CEME} = \sum_{k=1}^{t} \beta P_{n,i}^{0.7} \Delta H_I^{-0.35} \qquad (10)$$

Actuality the total of the plants in the network system, Nonetheless, Papantonis' approximations must be used with care as they are based on out-of-date fees and the price of electro-mechanical equipment has decreased due to the increase in number of small-scale hydro power developments since his method was established[2]. Therefore, the worth of the factor β (equal to 20570∈ kW_0.7m0.35 in the source form of the Papantonis' equation) must be adjusted to existing circumstances through a assessment with the shop values of electromechanical equipments and civil works. Equation (10) highlights how element CCEME (that is charge per plant power item) reductions when Pn and ∆H increase; consequently, it is obvious that merging hydraulic heads, growing ∆H and Pn, agrees economies of measure. CPTL, CED and CSA can be implicit roughly as a portion of CCEME [8] and [7] inform a range from 4 to 8%.AC are the sum of CDE (equivalent to the yearly plant amortization),COM (comprising labour, insurance, tax, duties, landscape and expendable resources), CRR (the charges of makeover and rebuilding of equipment at year 25), FC (the passive interest ratio on the rented capital), T (the Taxes on revenue), RP (the Remaining Price at the end of the plant lifespan) and CTD (the Transportation and Discarding Costs). CDE can be an estimate expected as the percentage between the investment prices and the plant life, whereas COM are a percentage (2%) of the yearly part of IC [7].Because of the nature of the SHP plants, CRR at year 25 are about equivalent to the total value of equipment at time of buying [7] for plant lifetime shorter than 25 years, these charges can be expected null. This guess complies with findings by Kaldellis (2005) [8] who stated that the influence of different remaining values is significant for the first decade of operation and it is insignificant after this period, particularly after the 15th year of process.In the Italian bazaar circumstances RP can be measured to balance CTD.

2.5.3 Return

NPV, that is the net currency flow of the ith year (equal to the difference between income and costs for each year actualized at the first year of the investment by the coming inflation rate), and CNPV for the total plant lifetime are assessed; lastly, ROI, assumed by the proportion among the CNPV and the IC and averaged on the plant lifetime, is designed.

3 Case study: the Spilinga-Ricadi water system

3.1 Study zone

The Spilinga-Ricadi irrigation system, situated in the land of Vibo Valentia (Calabria, Southern Italy, Fig. 2) and achieved by the Water Operator Association Consorzio di BonificaTirrenoVibonese, brings and allocates irrigation water to farms which mostly develop citrus copses. In the irrigation system, high river discharge arises outer of the irrigation period (from May to September). The WUA desires to exploit the construction volume of the current geodetic heads through an MHP system.

3.2 METHODOLOGY IMPLEMENTATION

3.2 .1.MAPPING OF WATER NETWORK

The water network (Fig. 2), fitted in the 1980s and 90s,contains of eight pipes (P1 to P8), with water discharges from 34to 119 l s_1, nourished by three minor brook dams (S1, S2 and S3) and three surge tanks (R1, R2 and R3), regulating the discharge and detaching the network. The pipe network is constracted of HDPE(10.5 km) and steel (3.3 km). The plot and longitudinal profile of the water network have been schematized by 1:2000, map drawn from the last accessible midair view (2010). Field surveys, functioned on a longitudinal 100-mstep and the examination of water network enterprise have delivered the material and the diameter (from 125 to 315 mm) of the existing pipes.

3.2 .2. ANALYSIS OF WATER NETWORK MODIFICATIONS AND POLICY OF THE EXAMINED MHP OUTLINES

According to the suggested method, three thinkable MHP outlines have been recognized and analysed (Fig. 2 and Table 1).In a first consecutive (outlinen.1), with only slight water network alterations, seven turbines have been measured, each one situated in a network pipe, with a whole Pn of 106.7 kW. In this outline no turbine is fitted in the pipe P8, since its Pn would be lesser than 5 kW and therefore would not be economically feasible. In a second outline some hydraulic heads have been unified; In more features:

- ∆H of the pipe P5 has been enlarged by removing the old pipe path along a valley bottom (thus the pipe stretch is compact from 3.0 to 2.8 km);
- ∆H of the pipe P8 has been linked to ∆H in the alternative pipe P4;
- Q of the pipes P2 and P6 has been diverted to P3 and P4 and the turbines T3 and T5 have been detached;
- Two pressured detours have exchanged the surge tanks R2 andR3 and the turbines T4 and T6 have been exchanged by the superiorT10, and T2 by T9.

Consequently, the outline n.2 contains of four larger turbines as an alternative of the seven lesser MHP turbines of the outline n.1 with an overall Pn of 101 kW; this worth is near to Pn of the outline n.1.The latest outline (n.3) has the equal turbine digit and outline as the outline n.2, but in a providing line (P5) a new 500-mm steel pipe has been fitted beside the current one in order to decrease ∆Y and rise Q.

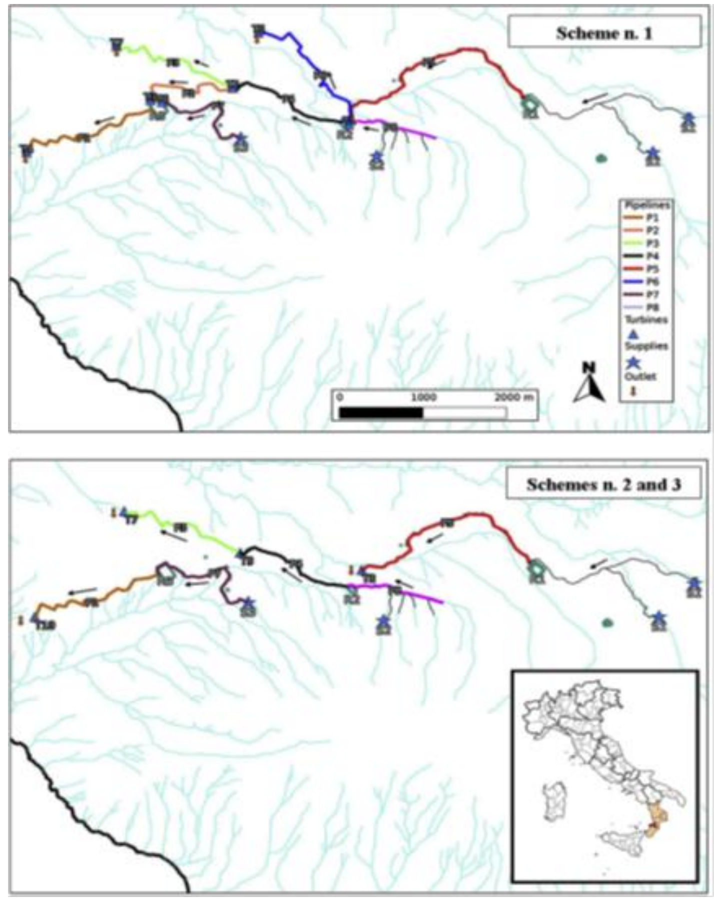

Fig. 2. *Layout of three MHP outlines in the Spilinga-Ricadi irrigation system.*

3.2.3 Hydraulic calculations

In our estimations, the rate of 0.85 has been taken for the turbine η in equation (4). It has been resulting from the ideal values proposed by Dragu et.al. (2001) [4] and Paish (2002) [13] seeing that:

- In current pipes throughout the process period the SHP plant is sized for and provided by a factor Q* (and the turbine can be selected at the ideal η);
- In the pipe P5 of the outline n.3 (where the diameter has been increased), a high-efficiency turbine has been adopted (see Segment 2.4).

Table 1 *Layout of turbines (Ti) for three MHP outlines in the Spilinga-Ricadi irrigation System*

Pipe	**Outline**		
	1	2	3
Pi	T4		
P7	T6	T10	T10
P5	Ti	T8 (D = 200 mm)	T8 (D = 500 mm)
P8	-	-	
P4	T2	T9	T9
P2	T3	-	-
P3	T7	T7	T7
Pe	T5		

D of the new pipe has been sized according to equation (5) with Q* ≅ Qs.

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- In the pipe P5 of the outline n.3 (where the diameter has been increased), a high-efficiency turbine has been adopted (see Segment 2.4).

Hazene Williams' equivalence has been selected as monomial formula (3) for calculating J. Actuality L/D > 1000, focused head losses have been overlooked; therefore, ∆Hn=∆H-JL. All ∆H are above50 m (Table 2); consequently the plants can be categorized as medium-to high-head, agreeing to Smalls Hydro Suggestion organization [5], although these varieties are not rigid, but are only funds of classifying sites: it funds that the physical scope of turbines needed for a lucrative energy profit can be even lesser than 5 kW [1]. As stated above, after a initial submission of the procedure this charge has been taken as a threshold, so that classify the minimum turbine Pn compromising an annual medium revenue higher than 6% (equivalent to the existing arrival of Italian bonds) over a 25-year period.

3.2.4 Hydrologic appraisals

A factor k equal to 4.0 has been considered, utilizing the rain data of the last 90 years collected at the weather station of Mileto (inside the watershed nourishing the providing river dams). Qs has been calculated in line with the Italian law (L.D. 152/2006), which offers the technique to estimate Qm. The optimal DN of the new pipe has been calculated as 500 mm.

3.2.4 Economic appraisals

According to period of irrigation durations studied above the past20 years, Ta has stable to be about 5040 h, identical to 24 h per day in the seven months beyond a 5-month irrigation cycle. Utilization ofenergy extra in the irrigation duration has not been preventive estimated. The economic feasibility of the investment has been assessed seeing a plant lifetime of 25 years [7]. For PE the standards of0.22 є kWh-1 for the first 20 years (including the unit aids providing by the Italian government, based on the actual M.D. 6/7/2012) and of 0.07 є kWh-1 (with no public aids) for the lasting five years of the plant lifetime have been expected. For approximating CCEME of turbines with electrical power lesser than 100 kW, the worth of the factor β has been adjusted for Italian bazaar situations. To this end, the bazaar values of electromechanical equipment and the charges of the public works have been measured for altered size of turbines (below100 kW) and compared with the production of (11), based on data collected for MHP plants lately fitted in southern Italy; a charge of 25635 є kW-0.7 m0.35has been calculated and assumed for b (Fig. 3).

For the major turbine (T8, with Pn= 250 kW) in the pipe P5(outlinen.3), the bazaar fee has been taken (about 310 kV). The charge of pipe substitution has been appraised on the basis of an analytical calculation of the public works (700 kV).

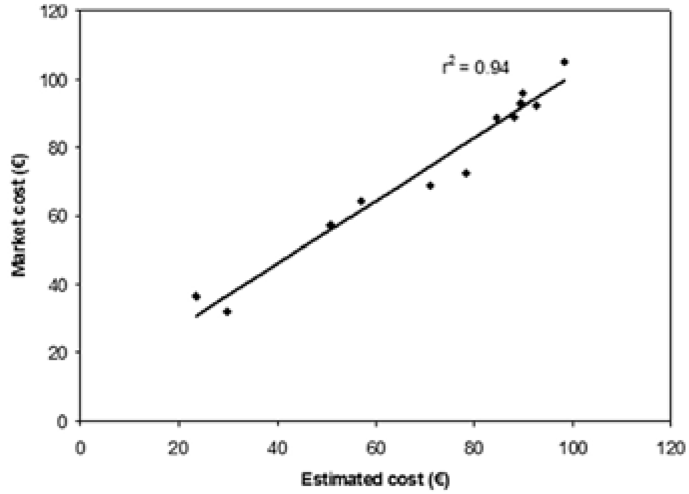

Fig. 3. *Regression equation of CCEME of SHP plants in the Italian market versus those appraised by Equation (10) (b ¼25635 V kW_0.7 m0.35).*

A percentage of 5% of CCEME has been expected for CPTL, CED and of4% for CSA. COM and CDE were calculated as informed in the Segment 2.5.2. The accepted inflation rate (2.5%) has been prediction on the basis of the average charges over the last five years. The leaders of WUA Consorzio di BonificaTirrenoVibonese have scheduled that 20% of IC is providing by its own assets, while the residual 80% is providing by a 15-year loan. Consequently, the annual FC prices have been assessed seeing

Table 2 *Hydraulic parameters and Pn calculated for three MHP schemes in the Spilinga-Ricadi irrigation system*

MHP turbine	Pipe	ΔH [ml	L [m]	Q* [L s^{-1}]	Q[Ls^{-1}l	J[m^3km^{-1}l	ΔY = JL [m]	ΔHn [m]	Pn [kW]
Outlinen.1									
T1	P5	60-9	3043	27	27	7.01	21.3	39.5	
T2	P4	118.5	1545	57	57	26.9		76.9	36.3
T3	P2	59.9	1363	33.67	33.67	0.22—4.14		56.0	
T4	P1		1882	42	42	5.48	10.3		
T5	P6	117.0	1941	50	50	2.52		112.1	
T6	P7	80.0	1529	19.22	19.22	4.14—5.61		72.6	
T7	P3	82.4	1696	44	44	17.04	28.9	53.5	19.8
Total outline n.1		600.4	12998				118.4	482.0	106.7
Outline n.2									
T7	P3	82.4	1696	44	44	17.56	29.8		19.8
Ts	P5	134.1	2800	44	44	16.79	47.0		31.9
T9	P4 + P8	178.7	2349	27.57	27.57	17.56—67.16		97.6	36.6
T10	P11P7	161.7	3411	22.42	22.42	1.08-5.61		152.2	
Total outline n.2		556.9	10256				167.4	389.6	101.0
Outline n.3									
T7	P3	82.4	1696	44	44	17.56	29.8		19.8
Ts	P5	134.1	2800	57	57	3.29		124.9	243.7
T9	P4 + P8	178.7	2349	27.57	27.57	17.56—67.16		97.6	36.6
T10	P11P7	161.7	3411	22.42	22.42	1.08—5.61		152.2	
Total outline n.3		556.9	10256				129.6	427.4	312.8

an interest ratio on the borrowed capital equivalent to 6% (recent average value for the Italian investment bazaar). Prices for T have been planned by the law defined tax-coefficient of 33% of the variance between the revenue and the sum of CDE and AC, if positive; else, T has been expected as zero. Lastly, the mediocre RUE (the ratio among the CNPV and the overall energy income) for the three examined MHP outlines has been calculated distinctly for years 1-20 and years 21-25 by deducting CDE and AC from the annual I.

3.3 Consequences and thoughts

3.3.1 Hydraulic features

Hydraulic calculations have been providing Q up to 68% (outline n.1)lower than Q* (Table 2), because of the mass equilibrium in each network knot; total Pn is up to 68% (outlinen.1) less evaluated with the theoretical worth calculated by input of Q*. In the MHP systems, ΔHn is conditioned by the small D of the network pipes (seldom over200 mm) and the age of the steel pipes (about 30 years, with enlarged internal roughness), which regulates obvious years(with civic aids) CNPV of 964, 985 and 2200 kϵ are grasped for the MHP outlines n.1,2 and 3 correspondingly (Table 3). If the MHP plant is exploited after the 20th year, the average NPV is 13%(Outline n.3) to 20% (Outline n.2) than in the first 20 years(Table 3). Fig. 4 emphasizes that the outlines n.1 and 2 yield a revenue(that is CNPV befits positive) after four years from fitting and the outlinen.3 after six years. The assessment of the outlines n.1 and 2, soft comparable total energy and CNPV after 25 years (Table 3 and Fig. 4), displays that a lesser number of plants (with higher production) yields no definite budgetary savings associated to a greater number of smaller turbines in the examined case. Fig. 4 also element energy losses (shown by J). According to the hydraulic calculations (tried to maximize the total electrical income of every outline), Q* is in the range19-67 L s-1; Pn differs from 6.1 to 36.3 kW for the outlinen.1 and12.7 to 36.6 for the outline n.2. Consequently, total Pn of the outlines n.1 and 2 is 107 and 101 kW correspondingly, which provides E of 538 and 509 MWh correspondingly. In outline n.3 the turbine T8, located in pipe P5 with the new DN with a 5-fold Q, produces a 8-fold Pn (244 kW against 31.9 kW) associated to T1 in outline n.2 (Table 2). E of the outline n.3 is only three times advanced associated to the outline n.2 (1577 in contradiction of 509 MWh correspondingly).

3.3.2 Economic appraisals

As clarified above, 5 kW has been recognized as the minimum turbine Pn to support an annual average profit higher than 6% of the investment above25-year duration. This is the cause why, as stated above, turbines with a Pn under this threshold have been disqualified from this reading. IC for the installation of the MHP outlines n.1, 2 and 3 are 275,198 and 1249 kV correspondingly; AC signifies 6% of IC. After 20 emphasizes that the growth of CNPV in time (revealed by the inclines of the three curves):

- is upper for outlinen.3 associated to the other examined outlines regarding to the higher Pn installed;
- is upper, as anticipated, in the first 20 years (with a higher PE) than in the last five years of the plant lifetime (without civic aids).

This is also exposed by the mediocre RUE during the first 20 years (0.07-0.09 ϵ kWh-1); these values are 4-7 times more associated to the period (years 21-25) deprived of general aids (0.01-0.02 V kWh-1) (Table 4). This approves that RUE relays on markedly on the general aids for renewable energy, mainly for MHP turbines of greater size (as for outlinen.3). ROI of 14.0%, 19.9% and 7.0% (this final negatively affected by public workings desirable for pipe substitution) have been accomplished, which are in outlines n.1 and 2 markedly superior to the productivity of the capital providing by the WUA. In specific, in outline n.3, where the segment of an existing pipe (P5) has been amplified2.5 times against a growth of the CCEME by about 20 times, E of turbine T8growths only 8 times associated to outlinen.2.The technique also permits the assessments of the economic feasibility of the turbines with Pn slightly greater than 5 kW, whose productivity for the entire MHP outline is peripheral. For example, inoutlinen.1 the removal of the turbines T1, T3 and T6 (with Pn of 9.0, 6.1 and 6.5 kW correspondingly) reduces CNPV from 964 to 798 kє after25 years, but growths the ROI starting 14.0 to 16.4%.

Table 3 *IC and AC as well as average NPV and CNPV estimated for three MHP schemes in the Spilinga-Ricadi irrigation system*

MHP outline	IC [k€]	AC [k€]	Average *NPV*[k€]		*CNPV*[k€]	
			Years 1—20	Years 21—25	Years 1—20	Years 21—25
1	275	16.5	46.2	8.2	923	41.1
2	198	11.9	47.0	9.2	939	46.2
3	1249	74.9	106.5	13.8	2131	69.0

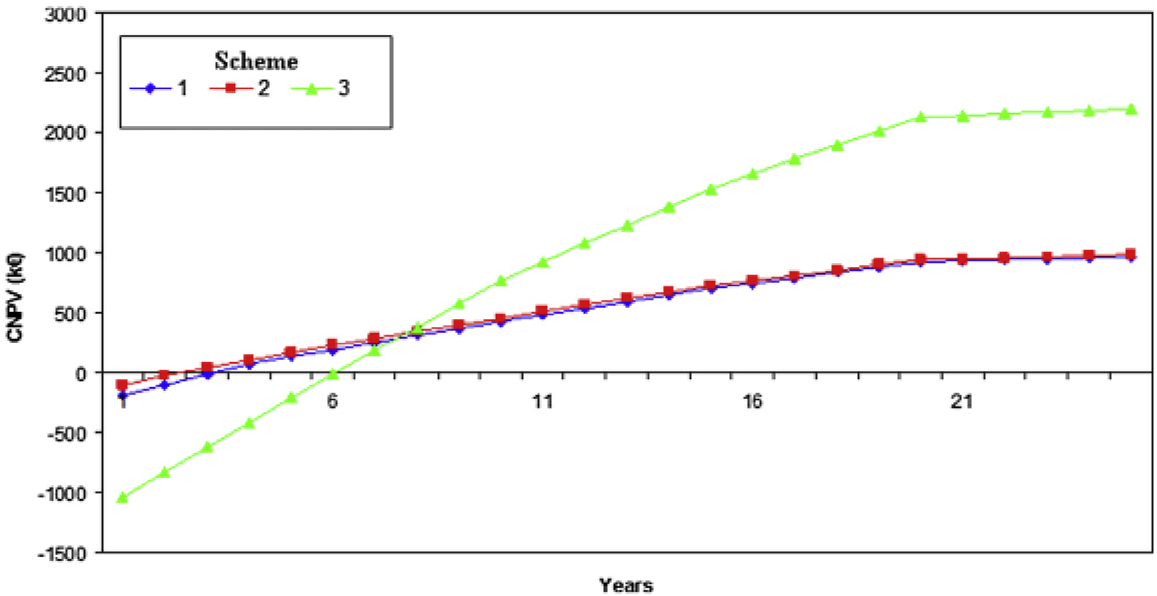

Fig.4. *CNPV of three MHP outlines in the Spilinga-Ricadiirrigationstructure.*

Additional issue which markedly affects the financial feasibility of MHP systems is Ta. In our revision it was initial invented that the MHP turbines work for as a minimum seven months per year outer the 5-month irrigation duration, which can be measured as a faithful value for the Mediterranean climatic circumstances. Additional simulations were carried out by hypothesizing a Ta of 4320 and 5760 h per year (conforming respectively to a 6-month or 4-month irrigation duration, classic standards for a dry or wet year). As revealed in Fig. 5, after 25 years from the investment, CNPV of the analyzed outlines rises appreciably with Ta. Furthermore, the variance of CNPV between a wet year (Ta= 5760 h, consistent to an operating time of eight months) and a thirsty year(Ta = 4320 h, irrigation period lifelong six months) quantities to 55%on average for the three analysed outlines.

Table4 *Total E, CNPV and RUE of three MHP schemes in the Spilinga-Ricadi irrigation system.*

MHP **outline Years *1—20***	**Total *E*[MWh]**	**CNPV [k€]**	**RUE [€/kWh]**
1	10755	923	0.09
2	10181	939	0.09
3	3 31530	2131	0.07
Years 21-25			
1	2689	41	0.02
2	2545	46	0.02
3	7883	69	0.01
Years 1-25			
1	13444	964	0.07
2	12726	985	0.08
3	39413	2200	0.06

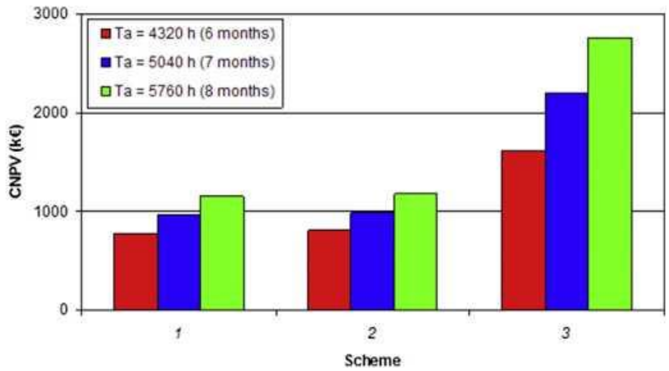

Fig. 5. *CNPV after 25 years for dissimilar T_a for three MHP outlines in the Spilinga-Ricadiirrigation system.*

4. Conclusions

A simple technique is planned for placement turbines, selecting their power production and assessing charges and profits for MHP plant design in current irrigation structures. Besides, valuable signs for MHP installation are also informed (e.g. linking small hydraulic heads in repeated pipes, by-passing surge tanks, growing pipe segment). This technique has been confirmed by assessing the practical viability and the financial presentation of three dissimilar MHP outlines in an irrigation organism of a WUA in Calabria (Southern Italy). In the analyzed case study, the smallest turbine power supporting a medium income of as a minimum 6% of the investment was shown to be5 kW. A lower number of plants (with higher output) yields no particular financial savings associated with a greater number of smaller turbines. Additionally, growing the width of a supplying line by a coefficient of 6.25 (from 200 to 500 mm) is not mainly desirable, since the pipe replacement charge is not stable by a rise of revenue from electrical energy fabrication. As a whole, it can be realized that MHP installation in the current irrigation schemes offers a return higher than the existing earning presentation in the Italian investment bazaar. The monetary viability of MHP organizations markedly growths with the annual process time: over 25 years the variance of CNPV between a wet and thirsty year quantities on average to 55% in the three analysed outlines. Generally, the technique planned, easy to execute by resources of a low number of easy-to-survey input factors, may characterize a valuable provision for investors, decision makers and designers to recognize the most appropriate procedural and monetary resolution for every definite case of small hydroelectric plant project.

7.2 Acknowledgments

The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks ... ." Sponsor and financial support acknowledgments are included in the acknowledgment section. For example: This work was supported in part by the US Department of Commerce under Grant BS123456 (sponsor and financial support acknowledgment goes here). Researchers that contributed information or assistance to the article should also be acknowledged in this section.

7.3 References

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