ENERGY MARKET AND THE PERMANENT MANAGEMENT, A POSSIBLE SOLUTION FOR SMALL HYDRO-POWER PLANTS

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Abstract - The paper structured in five parts, aims to highlight the importance of an integrated management as to ensure a high efficiency and a smaller time to recovery of the investment for a small hydropower plant (SHP). In the context of sustainable development of the energy sector, due to the shortage of budgetary funds, a large amount of interests of all participants in the process must be correlated: the interests of investors - which provides funding and execution; general economic and social interests of local communities, the regulated legislature protected by state institutions. First is analyzed the importance of the study of the infrastructure energetic efficiency, in the current economic context, followed by a presentation of the optimum solutions of planning of such SHP. In third chapter are analyzed some factors that influence the optimum functioning of the SHP and in the fourth part the benefits of a real energetic management. In final chapter is presented the numerical model of the combined management and some obtained results. The paper ends with some conclusions and references.

Keywords: Small Hydropower Plant-SHP, RES-Renewable Energy Resources, modelling, energetic efficiency, energetic management, electrical network

1. INTRODUCTION

Nowadays, in the RES structure, hydropower still has the largest share. The energy provided by SHP has the installed capacity ≤ 10 MW. The potential possible to be produced is equivalent to almost 80% of the energy produced by Iron Gates I, except that they are distributed on the entire country, so their construction would lead to economic growth in all regions. On the other hand, the European Union Directive 2009/28/EC, says that hydropower, a type of renewable energy, near by wind, solar, geothermal, aero-thermal, hydrothermal etc. would avoid large emissions of carbon dioxide, as happens in the case of burning fossil fuels. SHP can solve some local problems

- such as new jobs
- electricity in various isolated villages
- the decrease in imports of primary energy resources
- the elimination of the voltage drop on the far electrical networks
- reduction of energy losses in transmission lines

Any attempt to improve the efficiency or re-technology of SHP must begin with some initial steps as mandatory works and technological operations

- Clean the vegetation, the dam and the adjacent channels
- Repair works to eliminate all cracks from the concrete structures, surfaces eroded areas, lack material
- Consolidation works upstream/downstream of the dam with the construction of reinforced concrete piers
- Construction of a fish ladder, required by the EU standards
- Rehabilitation, adaptation and modernization of all metal construction of the dam by new valves
- Sandblasting, cleaning and restoration by welding and polishing metal surfaces damaged
- Changing of all the fasteners and fastening
- Realisation of the Corrosion protection

2. THE ENERGETIC EFFICIENCY OF SHP-s

The efficiency of the electric power plant should take account primarily of the energetic infrastructure due to,

- continued growth in energy consumption closely with the economic and the industrial development

- increasing the amount of energy throughput at distances between energy systems belonging to the EU

- development of renewable, as to reduce CO2 emissions.

1. The increasing of the efficiency in the area of the energy production can be achieved by:

- reducing costs by standardizing of the equipment

- optimizing water consumption by using multiple units and smaller

- exploiting the low and very small heads of water

- implementing of the systems 'expert' of automation and the advanced adjustments as to improve the quality of energy delivered in the system (frequency and voltage)

2. The increasing of the efficiency of the transport and the distribution of the energy "Smart grids" or "Internet of Energy" by:

- introducing of the lines HV substations for reactive power compensation (sometimes losses > 12%)

- optimize consumed energy in the localities by integrating consumer in a "smart grid" - Grid Power Management

- sharing network of the consumers in smaller sub-nets (decentralized) which can connect/disconnect according to the necessary consumption or according to certain emergency local situations - Smart Distribution
- intelligent connection of small RES.

3. To optimize or to reduce the consumption at large consumers by:

- phasing out the large consumers unprofitable and pollutants
- urban lighting intelligent (street and buildings)
- monitoring and control of all elements connected to the network as smart apparatus, smart home, voltage regulators, pre-set consumption life energy at times when the price / kW is less

4. The energetic efficiency of micro-hydro turbines:

- their design after study and analysis of real data measured at the emplacement, H and Q
- identifying of the energy and of the cavitations zones by laboratory measurements carried out on the model of hydraulic turbine
- manufacturing the equipment with modern machines in 3 and 5 axes
- developing control algorithms that automatically adapt at targeting functioning regimes, operational security and optimal exploitation
- implementing of an automation experts
- operational dispatching remote control (SCADA) and optimization of the operation in cascade system
- connecting and the automation to a specialized system for predictive maintenance and diagnostics remote process

The Expert Functions are routines implemented in software PLC and SCADA, dealing with situations with non-deterministic nature. It processes the information acquired from the process in a "holistic process" (hydro viewed as a whole. The acquired information is handled through the links established between them, in terms of phenomenological issues. All these functions are software algorithms and tend to implement the advanced expertise in holistic process.

Any information is analyzed in connection with all the interconnected elements, which may directly or indirectly affect that situation/ event. As examples:

1. Create of the patterns of the behaviour "typical" for the various parameters of the electric plant or hydro-equipment: the upstream pressure of the penstock, active power, temperature and vibrations of certain subparts of the unit. The evolution of the transient process parameters by analysis of the gradient and the steady state, by mathematical modelling of the number of "peaks" up or down over the centreline = occurrences/unit time
2. Implementation of the operation curves to the "optimum spot" (the yield curves), operating as a function of variation curves of the upstream space level
3. Self-adapting of some certain parameters that dictate the dynamics of a process, with the modification of behavioural patterns as electrical noise, the increased vibration, but falling into the range permissible, the temperature increase from baseline but kept still an admissible the beach
4. Statistical analysis (offline) of the behavioural development while imposing the policies parameters of the predictive maintenance (remote analysis and reporting to the client via the Internet or SMS)
5. Complex analysis and diagnosis of the signals from the transducers, electrical noise or vibration of the transducer support, atypical behaviour of the transducer output signal, etc.
6. Algorithms "smart" of management of the multiple units in parallel with the follow-up simultaneous targeting scenarios and estimation of the power available in each aggregate, the starting or charging power of the aggregates in which the machine turns, at better working parameters (vibration, noise, stability) etc.

3. THE FACTORS AFFECTING THE OPERATION OF SHP

1. Natural Factors

- **Geological conditions**

The rivers supply from the groundwater is determined by the geological conditions. Without a thorough geological survey, the general information collected from the specialized maps (geological, tectonic sketch, general geological profile, geo-morphological) give a first insight of the potential contribution of groundwater flow.

- **The Relief**

The relief variation with the altitude of the climate factors and of all the other physical and geographical conditions directly influences the leak. Since there is a direct link between the average height and the hydrological regime, it may be determined by estimation with simple methods as the annual average flow based on the statistical data. There is a strongly report expressed statistically between the average height and other characteristics of the leak (minimum leakage, maximum leakage, flow distribution during leaking, solid leak)

- **The micro-relief**

It has a strong influence on the volume flow, and depends on the amount of water retained on the soil surface and therefore of the size of losses through evaporation and infiltration.

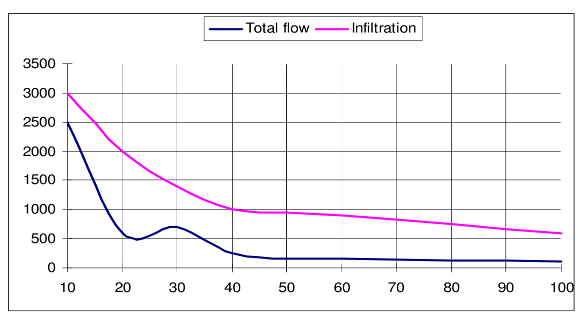

Fig. 1. Available flow rate for SHP

2. The influence of the distribution network

The demographic density can influences in the direction of the penalty indicators, of the initial investment, estimated for the preparation and execution of the investment, but can improves the financial indicators of the project, during the commercial operation. Other difficulties may appear in:

- defining the issues of land on which to place energy objectives,
- the limitations of the access directly on the site,
- the possibility of the retail of the produced electricity,
- the further future development of the activity connected with the providing of the interest distribution for the operator as to develop an integrated management of the network.

3. Choosing of the turbine type

The selection of the turbine type is essential. It is pre-determined according to the analysis parameters of the site (Q, H) and to direct the information, in longitudinal profile and the arrangement in plane, the quality of the processed water, like the turbidity, of the operating conditions imposed in time of the flow (daily, seasonal, annual)on the distribution, and finally the socio - economic local conditions.

4. THE ADVANTAGES OF THE ENERGETIC MANAGEMENT

First, must be assured a Management of the energy demand DSM-Demand - Side Management.

DMS assume to identify and implement initiatives that improve utilization of the production capacity of the provider by altering with the characteristics of the energy demand. Modern tracking in real time of the behaviour of the electricity network, with automatic SHP may be realised with programs, providing an energy management. They allow the optimal leadership of the local/regional energy systems with higher energetic efficiency by ensuring the demands of the power quality electricity, supplied to consumers.

Intelligent monitoring systems ensures

- a remote reading of energy meters
- a centralized load control consumer by changing the load curve of the system
- a control of the disturbances introduced by the consumer network
- a centralized control for changing tariffs / prices
- an automated billing.

Table 1. The advantages of the energetic management

Producing	Consuming
Ensuring adequate energy production	Quantities accepted Control required
Flexibility of the offer in planning/production in the medium and long term	Knowledge / estimation of the consumption trends
Optimizing the production planning and supply	- demand forecast - daily load curves, week timetables -flattening, filling gaps, transfer the load from peak hours in the hours of low demand
Compliance with quality indicators correlated with consumer input frequency disturbances, temporary and transient surges, supply disruptions	Secondary indicators - rapid fluctuations of voltage unbalance, non-sinusoidal regimes
Dispatching and common commercial offer	monitoring of the tender request

As to determine the annual average flow Q in the natural conditions, are used for correlating, at least three simplified method.

1. Utilization of the graph curves

Connect the multi-layer average flow (mm) and the average altitude.

- it is determined from the statistic data from the catchments area F (Km^2) connected with the average elevation of the basin H_m (m).
- from the local map is determined the water courses A with a multi-annual average flow, calculated:

$$Q_m\left(m^3/s\right)=\frac{F\left(km^2\right)\times H_m(mm)\times 10^{-3}}{T(s)} \qquad (1)$$

T – Time reference in seconds

2. The Method of the water balance

Notation: the Annual average of river leakage Y_0, The surface Leakage S_0, the Groundwater flow U_0, the Wetting annual average of soil W_0, the Feed rate underground river K_{u0}.

$$K_{u0}=\frac{U_0(1)}{W_0}\Rightarrow Y_0=S_0+K_{u0}\times W_0 \qquad (2)$$

$$Y_0=S_0+U_0(2)$$

By using of the schematic map, of the territorial distribution of the component of the hydraulic balance, are obtained the corresponding values of the geographical position of the surface stream. As it follows: From the full surface runoff layer it was extracted the value S_0 (mm). From the map of the geographical spread of the total soil, the moisture, it is extracted the value W_0 (mm). From the map of the power, the underground distribution coefficient is extracted the K_{u0} value. By substituting, the values extracted from the above point Y_0 may be estimated the average annual average flow.

3. Method of hydrologic balance

Notation: X0 - average annual rainfall, Y0 - average annual flow, Z0 - the annual average evaporation from land, surface evaporate-transpiration

$$X_0=Y_0+Z_0(1)\Rightarrow Y_0=X_0-Z_0 \qquad (3)$$

From the precipitations map corresponding to the receiving containers is extracted the value X_0. From the map distribution, of the total average of evaporate-transpiration, it is extracted the value Z_0. By introducing the extracted values in (3) is obtained the average annual runoff value Y_0 (mm) and determined the annual average flow rate.

5. NUMERICAL MODELLING

As a study case were selected three rivers from the Ialomita river hydrologic catchments. In Table 2 are mentioned the main values used for modelling.

Table 2. The selected data-base as input for modelling

Entrance data	Measured values			Calculated values			Errors 9%)		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
Annual average flow Q_m, [m^3/s]	0,24	0,42	0,45	0,24	0,39	0,45	1,25	-6,3	0
Minimal flow Q_{min} [m^3/s]	0,06	0,09	0,08	0,05	0,09	0,08	-19,7	-6,4	0
Maxim flow $Q_{max,1\%}$ [m^3/s]	66	96	103	71	113	127	7,57	17,7	23

For numerical modelling was selected the Ialomita river basin. Here it was applied the software Vapidro- ASTE, which generates hydro-graphic network of the area of interest, as in Figure 2, using the terrain implemented as input, based on the field maps. It is able to locate the best position of the water supply and for the hydropower plant, optimized in technically and economic.

Fig. 2. The basin of Ialomita River

In this stage, the entered data values necessary to perform the hydrological analysis are the average multi-flow rate, the captured flow and the returned flow.

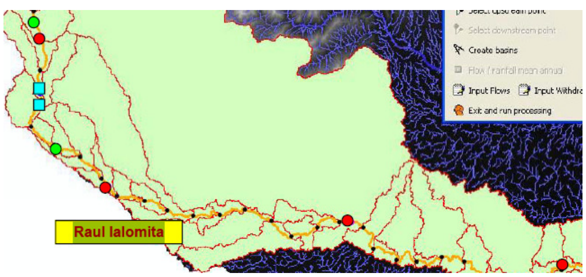

Fig. 3. The necessary data of the Ialomita river: red-measured, blue-captured, green-returned flow rate

Consequently, the necessary data are introduced for the financial analysis: the equipment costs, the maintenance costs, the costs of execution and to perform the cost-benefit analysis. In Figure 4 is presented the utile water fall along the riverbed, determined by numerical modelling and the realized SHP.

By numerical modelling, it is estimated the installed capacity for possible SHP plants, the total annual energy able to be produced, the total costs for realization, the benefits, the cost-benefit analysis and finally the amortization period.

All the economical optimizations are performed and the results are transposed in a graphic form. Technical and economic optimization results consist of the most favourable locations for positioning of the hydroelectric power plant and of the water intakes for the new SHPs, as mentioned in Figure 5.

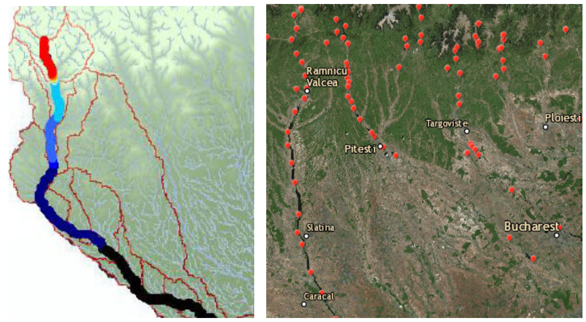

Fig. 4. The real and the modelled utile fall

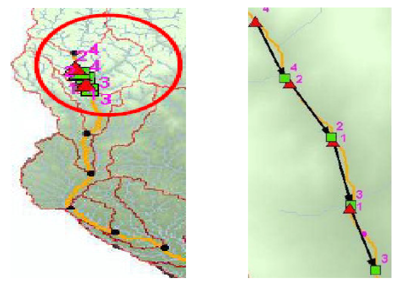

Fig. 5. The Possible developments, green-hydropower power plant, red-water intakes

The others two rivers selected for analyze are Teleajen River and Prahova River. For each one were made the same calculations as for Ialomita River. In Table 3 and Table 4 are presented some obtained results.

Table 3. The main parameters

Nr	Data parameters	Method	R1	R2	R3
1	Area F_{BH} [km^2]	Plane map	10	16	18
2	Average Altitude H_m [m]	Direct read	1000	1200	1500
3	Average Length L_m [m]	Direct measurement	5100	3800	4400
4	Cote upstream C_{am} [mdM]	Direct read	810	850	800
5	Cote upstream C_{av} [mdM]	Direct read	608	700	600
6	Crude fall H_{br}[m]	Calculation	-	-	-
7	Annual average flow layer Y_0[mm]	Direct read[1]	800	840	820
8	Surface leakage S_0[mm]	Direct read[2]	400 500	440 510	420 500
9	Evapor –transpiration Z_0[mm]	Direct read[3]	280 340	280 300	280 320
10	The total wet soil W_0[mm]	Direct read[4]	710 700	700 700	700 700
11	Underground alimentation coefficient K_{u0}[mm]	Direct read[5]	0,36 0,4	0,4 0,4	0,38 0,42
12	Average annual rainfall X_0 [mm]	Direct resd	1000	1100	1200
13	Minimum leakage q_{min} [l/sxkm^2]	Direct read[5]	4,8	5,5	4,2
14	Minimum flow Q_{min}[m^3/s]	Calculation	0,04	0,08	0,08

Where: ^{1}=Y_0=f(H_m), ^{2}=S_0=f(H_m), ^{3}=Z_0=f(H_m), ^{3}=W_0=f(H_m)

^{4}= K_{u0}=f(H_m), ^{5}=q_{min}=f(H_m),

Table 4. The Calculated values

Nr	Data parameters		R1	R2	R3	Formula
1	F_{BH} [km^2]		10	16	18	Confirmed by statistic data
2	H_{med} [m]		1300	1400	1350	Confirmed by statistic data
3	L_m [m]		4700	3500	400	Correlated with decreasing altitude
4	C_{am} [mdM]		790	820	802	Confirmed GPS
5	C_{av} [mdM]		580	670	610	Confirmed GPS
6	H_{br}[m]		210	150	192	$H_{br}=C_{am}-C_{av}$
7	Y_0[mm]		800	780	790	Adopted minimum value
8	S_0[mm]		450	470	450	Adopted average value
9	Z_0[mm]		290	280	280	Adopted average value
10	W_0[mm]		700	704	706	Confirmed value
11	K_{u0}[mm]		0,38	0,4	0,39	Adopted average value
12	X_0[mm]		1100	1050	1100	Consider arithmetic mean
13	Annual average flow Q_m[m^3/s]	[1])	0,253	0,405	0,456	[1])
		[2])	0,220	0,380	0,418	[2])
		[3])	0,256	0,410	0,462	[3])
14	Q_{min}[m^3/s]		0,049	0,088	0,0756	Calculation
15	Max. specific flow rate insurance of 1%		71	113	27	Extrapolation Q_{max}=7100 l/s x km^2

[1]) Direct Method

T_s = (8760 x 3600)[s] and

$$\frac{F\left(km^2\right)\times Y_0\left(mm\right)\times 10^3}{T_s\left(s\right)} \tag{4}$$

[2]) Water balance method-Variant I

$$\frac{F\left(km^2\right)\times\left(S_0+K_{u0}\times W_0\right)\times 10^3}{T_s\left(s\right)} \tag{5}$$

[3]) Water balance method-Variant II

$$\frac{F\left(km^2\right)\times\left(X_0-Z_0\right)\times 10^3}{T_s\left(s\right)} \tag{6}$$

$$q_{\min}\left(l/s\times km^2\right)\times F\left(km^2\right)\times 10^{-3} \tag{7}$$

Further, some numerical results in Figures 6, 7, 8, 9, 10

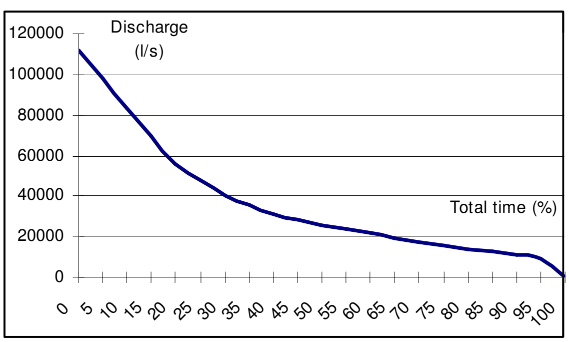

Fig. 6. The Flow duration curve

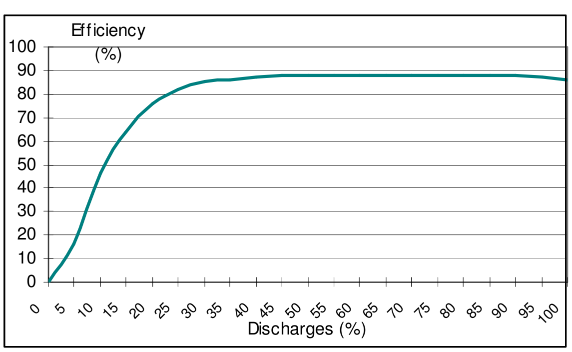

Fig. 7. The Efficiency curve

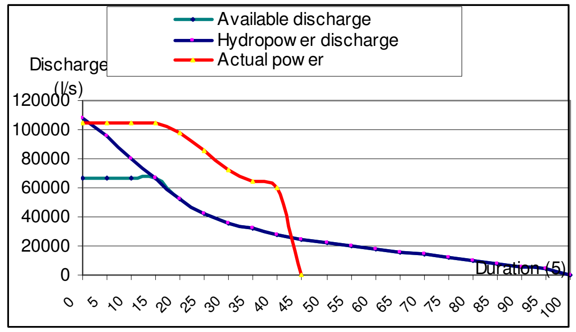

Fig. 8. Flow and Power duration curves

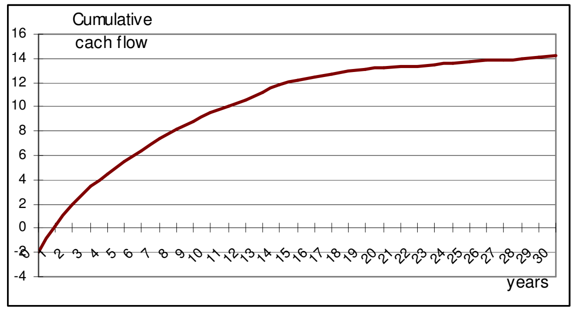

Fig. 9. Cumulative cash flow

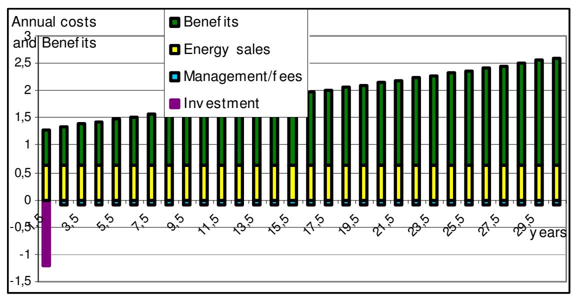

Fig. 10. Benefits and Cost breakdown

5. CONCLUSION

SHP-s, represent a distinct category, both in terms of technical and financial as to use the relatively small hydraulic energy resources. They are ideal for promoting the interests of the local communities/industry by small and medium/self-producers/entrepreneurs. They respond to the requirements of a sustainable development and of the optimization of the geographical areas, both in socio-economic and to the environment domains. Consequently, may be included, the financial and the economic aspects of competitiveness, now included into open market energy. SHP-s can be the basis for reliability, suitability, regional electricity, and systems security. In terms of establishing the criteria of efficiency of water utilisation, considered as a limited resource, the energy recovery by building an optimum SHP represent a social cost-benefit ratio.

SHP, a solution to recovery of a body of water and has many advantages:

- small and medium unit <10 MW and can be controlled, constructed and operated in less than two years, with the immediate production of the income
- Reduced environmental impact
- Suited to industrial, commercial and residential area of the network
- The investment project can be develop modular as to cover the increased consumption
- Complexity and simple maintenance
- The cost of a unit of electricity can be determined with certain accuracy.
- Ideal for application of control technology systems, smart meters at customers premises, points of connection in the main nodes, as to determine the flow value
- real-time charging and billing

By modelling with the this software Valpidro- Aste it can be achieved

- Identify optimal locations to determine the optimal number as to be built on the river

- The Yearly analysis of the cost-benefit

- Determination of some specifications extremely utile in the SHP construction

- A Hydropower Implementation, instrument as to inform the local communities in the preliminary stages

- The Model is very adaptive at local topography

- Finally, it estimates the technical and economic feasibility of the power-plant

REFERENCES

[1]. http://www.asociatiamhc.ro/

[2]. http://www.british-hydro.org/development V3.pdf

[3]. Popa, B., Hidroenergetica, Cap. 6- Microhidrocentrale, curs Hidroenergetica, UPB

[4]. Seteanu, I., Radulescu V., Numerical models in Hydraulics and Power Engineering, Seria Cursuri Universitare, Editura Bren, Bucuresti, 2004, ISBN 973-99604-4-8

[5]. Vasiliu N., Radulescu V., Sisteme hidraulice, Fundamente si Aplicatii, 1998, Editura Tehnica, Bucuresti, ISBN 973-31-1412-X

[6]. Radulescu, V., Nistreanu, V., Sisteme hidraulice de Aductiune. Fundamente, Calcul, Exemple, Seria Hidraulica, Editura Bren, Bucuresti, 2006, ISBN 973-648-255-3

[7]. Seteanu, I., Radulescu V., Identification, calibration of the hydraulic parameters-linear optimization, Romanian Journal of Hydrology & Water Resources, vol. 2, No 1-2, pag.33-37, 2005, ISSN1223-1126

[8]. Radulescu, V., Estimarea randamentului turbinelor hidraulice prin analiza curgerii fluidului real prin rotoarele axiale, Revue Roumaine Sciences Techniques: Série Mecanique Appliquee, No 1-2, T 55, pag.61-68, Jan-April, 1994, ISBN: 0035-4074

[9]. Radulescu, V., Seteanu, I., The drag Force Estimation for Hydro-Impellers, Scientific Bulletin, University Polytechnic of Bucharest, Series D: Mechanical Engineering, vol. 58-59, No.1-4, pag.115-120, 1996, ISSN 1220-3041

[10]. Radulescu V., Radulescu, A., Utilisation of Renewable Resources in Rehabilitation of existent Micro-Hydro Power Plants, Hydro 2009-Progress-Potential-Plans, Session 12-Special Hydro Presentation, pag.156-163, 26-28 Oct. 2009, Lyon, France

[11]. Radulescu V., A Complex Pilot Station using Renewable Resources: Small hydropower, Wind turbine and Photovoltaic systems, Annals of the Oradea University, Fascicula de Energetica, vol.15, mai 2009, Issue II, Renewable Sources of Energy& Sustainable energy technologies, Part II, 2.25, pag. 295-300, Editura Universitatii Oradea, ISSN: 1583-0691

[12]. Turbatu, A., Radulescu V., Abrudan, T., Eficientizarea conducerii operative a centralelor hidroelectrice prin urmarirea on-line a parametrilor de functionare. Aplicatie la SH-Curtea de Arges, Revista Energetica, An.49, nr.8-9, pag. 432-436, aug.-sept. 2004, ISSN 1220-5133

[13]. Seteanu, I., Pasoi, I., Radulescu V., Consideratii privind aplicarea metodei "Cost-Precizie" în proiectarea unei retele hidrometrice pentru o acumulare, Revista Hidrotehnica, vol. 43, nr.7, pag. 235- 237, 2008, ISSN: 0439-0962

[14]. Radulescu, V., Managementul integrat al amenajarilor de mica si medie capacitate, Conferinta Internationala Energie, Oradea mai 2008