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Automation and Energy in Hydraulic Machinery

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1. World and Austrian energy situation

While today's world electricity production is mainly based on fossil energy-carriers, renewable sources of energy become more and more relevant in recent times (Fig. 1, Fig. 2). Especially in Austria, where up to 75% of the required electricity is produced by hydropower, this field is of special interest and content of many research-projects. The focus on renewable energy resources has also been set by new regulations of the European union, determining a percentage of energy, which has to be produced by renewable innovative energy resources. Executing these regulations, it is also necessary to have a continuously monitoring in combination with a perfect regulation of the provided energy by the energy distributor.

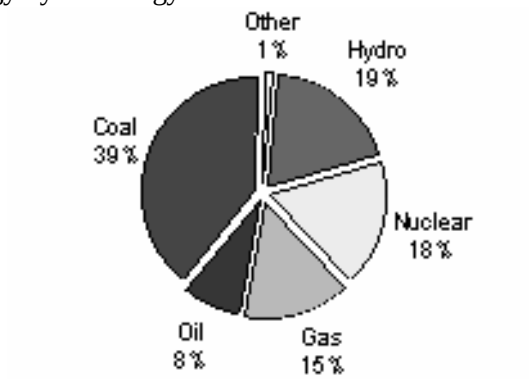

Fig. 1. Current energy sources (World)

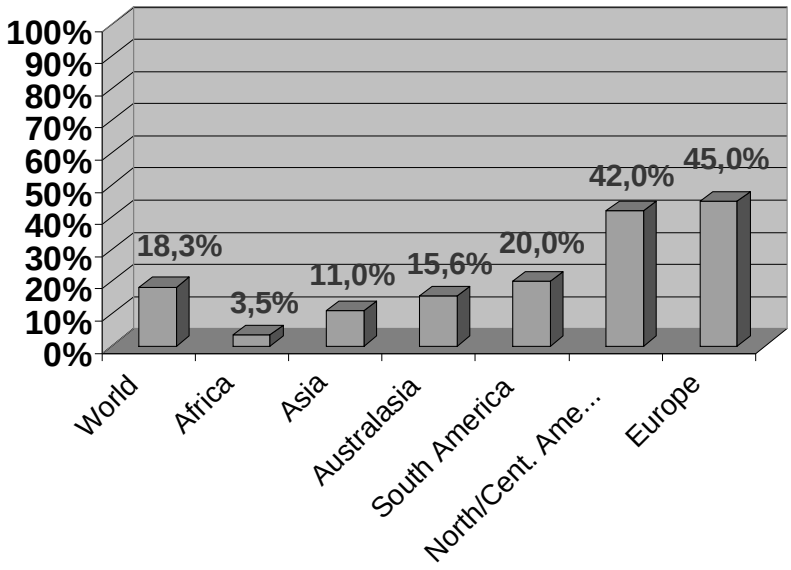

Fig. 2. Percentage of developed technologically feasible hydraulic energy (Source: Hydro Power & Dams Magazine)

Range of future energy supply and its supposed future trend:

Coal	–	Gas	– **or** =
Oil	– –	Hydro	= **or** +
Nuclear	**– or +**	Solar	+ +
Biomass	**= or +**	Other	+

2. Automation and simulation

Automation and control's roots are originally based on mechanical speed governors for waterpower plants. The important task has always been the demand for exact frequency of the turbine. Understanding the occurring problems lead to great global developments in control mechanisms for power plants and other machines.

To ensure economical and save operation, extensive tests and simulations are needed, in order to optimise automation. At the Institute for Waterpower and Pumps of the Technical University of Vienna investigations on various fields of energy production with an emphasis on hydraulic machinery have been made which will be described in the following chapters.

2.1. Automatic laboratory measurements

For high-efficient machinery-design detailed calculations and simulations are required. On the Institute for Waterpower and Pumps of the Technical University of Vienna calculations as well as state of the art measurement technologies are possible.

To give the calculations the right boundary conditions, PIV (Particle image velocimetry) and hotwire anemometry are in use (Fig. 3).

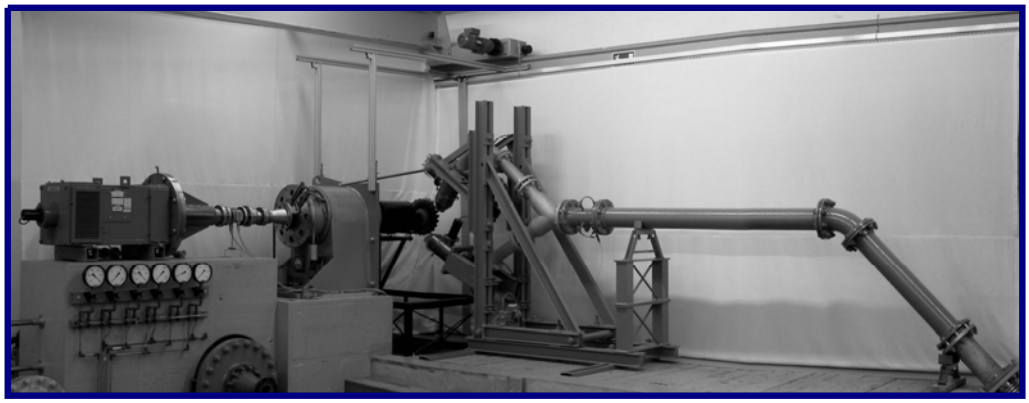

Fig. 3. 2-jet Pelton test rig at the Hydraulic Laboratory

2.2. PIV-measurements on Pelton turbines

PIV is used on Pelton turbines to acquire a complete velocity field of the turbine under various load conditions. The fluid is tracked from the nozzle outlet through the bucket to the casing, which gives interesting opportunities in design and optimisation of turbine-runner and casing.

Principles of PIV are illustrated in Figs. 4, 5, 6.

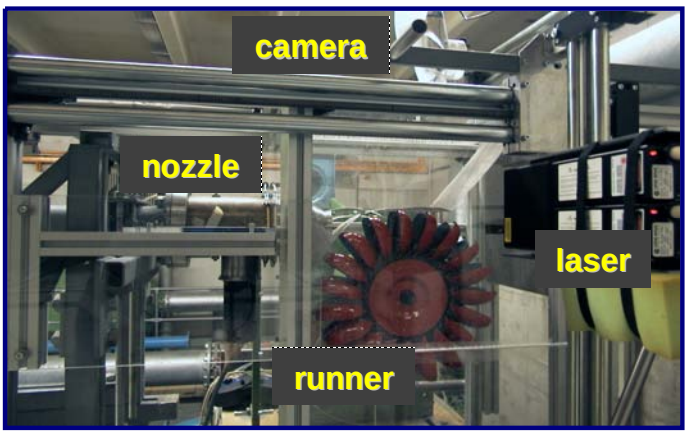

Fig. 4. Measurement – Setup

The first pulse of the laser freezes images of the initial positions of the particles onto the first frame of the camera. First frame data remains in memory, while the second frame of the camera is exposed to the light scatter by the particles from the second pulse of laser light.

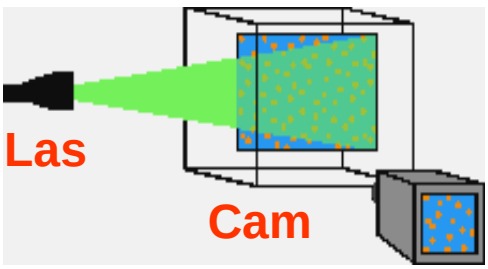

Fig. 5. PIV – setup

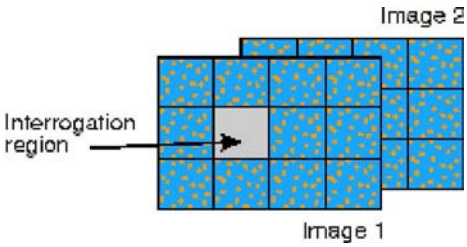

Fig. 6. Interogation area

There are thus two camera images, the first showing the initial positions of the seeding particles and the second their final positions due to the movement of the flow field. The two camera frames are then processed to find the velocity vector map of the flow field. This divides the camera frames into small areas called interrogation areas (Fig. 6). In the actual measuring an interrogation area size of 64x64 pixel is used. The time between two laser pulses varies between 8 and 20 μs. In each interrogation area, the displacement of groups of particles between frame 1 and frame 2 is measured using correlation-algorithms.

2.3. Measurements and results

Pictures below show results of the optimisation processes, which are done optically (Fig. 7) as well as by numerical analysis of the acquired velocity field data.

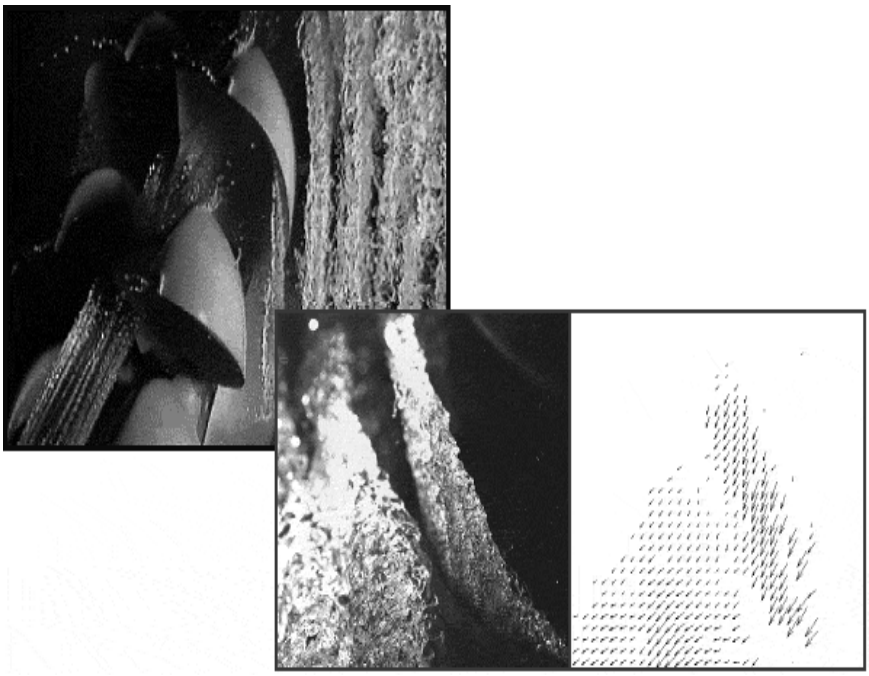

Fig. 7. PIV – results

These velocity-field measurements are based on efficiency-measurements (Fig. 8), which achieved a high degree of automation by now. The test rig can be easily applied to various runners, casings and jet-numbers. Measurement itself can be

done automatically, from the beginning till the analysis and presentation of the results.

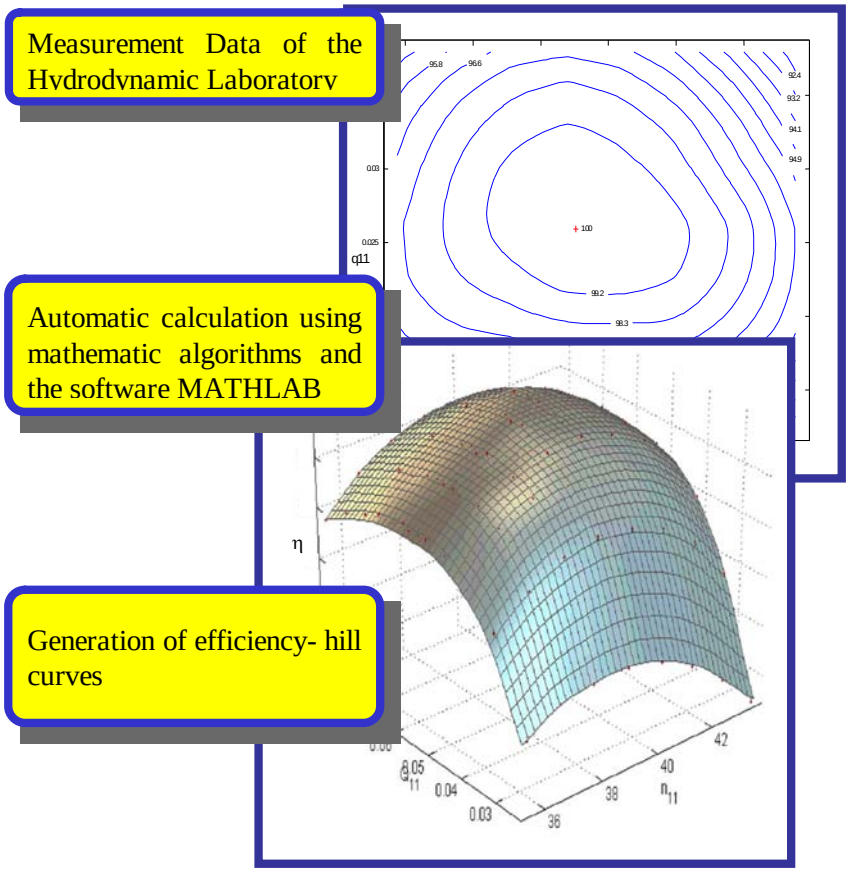

Fig. 8. Efficiency hill curve

2.4. Automation and simulation for uprating and refurbishing

Besides the operation of Hydro Power Plants, where it is necessary to optimise the turbine settings in order to maximise the electricity output depending on the water flow, the constant evaluation of the components is an important part. Based on this component evaluation, several strategies for uprating and refurbishing of existing Hydropower Plants can be figured out.

To simplify this task, a knowledge based system, called REVEX©, has been developed by the Institute for Waterpower and Pumps (Vienna University of Technology). This system supports engineers during stock taking and evaluating of several components and will automatically advise during working out strategies for uprating and refurbishing (Fig. 9).

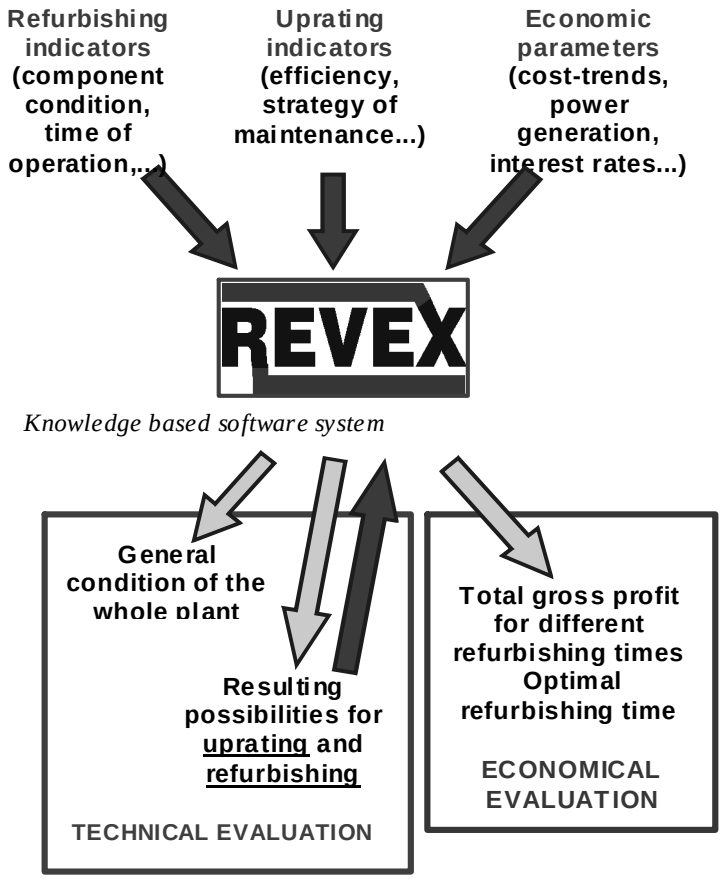

Fig. 9. Knowledge based software system

The system is divided into two parts. The first part includes a technical evaluation, where the present condition of the components and the whole plant will be evaluated via an expert system based on weighted points between 1 to 10, resulting in statements about the modernisation potential of the components and the whole plant. Additionally possible weak points will be pointed out leading to statements about the technical urgency for refurbishing measurements. Based on these statements, the second part of this system analyses the economic effects of uprating and refurbishing several components of the Hydro Power Plant. The program automatically simulates different time points, when refurbishing measurements regarding to the components will take place, and depending on several economic influence parameters as well as the component conditions, the optimum time point for refurbishing and uprating measurements will be calculated (Fig. 10).

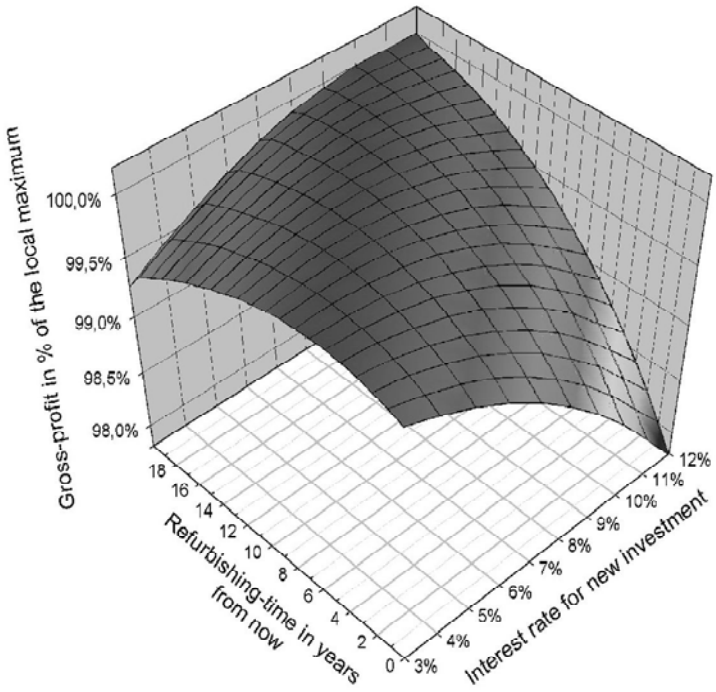

Fig. 10. Result of the simulation process

3. Optimisation of the construction-site including the ecological impact

The construction of new or the reconstruction of existing hydro power plants is always paired with the question of its ecological impact. Therefore already in the planning stage, all the relevant impacts have to be figured out, optimised and improved.

Some important points, which have to be considered are (Figs. 11, 12):

- Conservation of the typical river landscape,
- Regulating the drinking water level as well as the flood protection,
- Revitalisation and construction of the ecological parts of the HPP (fish ladder, headwater & tailwater channel, etc.),
- Ecologically friendly civil engineering work,
- Improvement of the possibly inaccurate control of existing HPP,
- Increasing the reliability,
- Better exploitation of the existing water management.

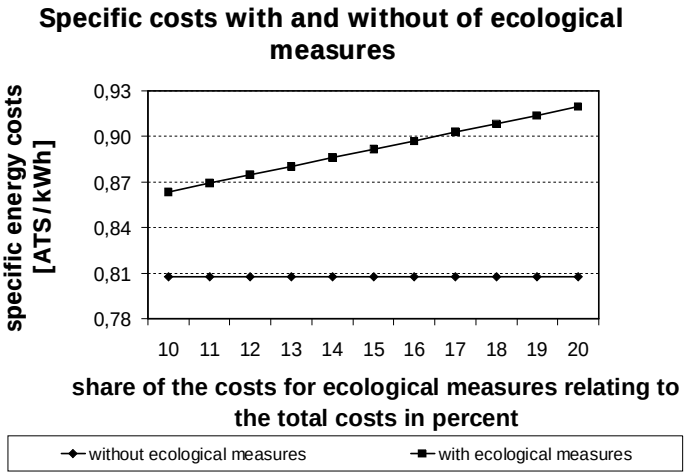

Fig. 11. Result of the optimisation process

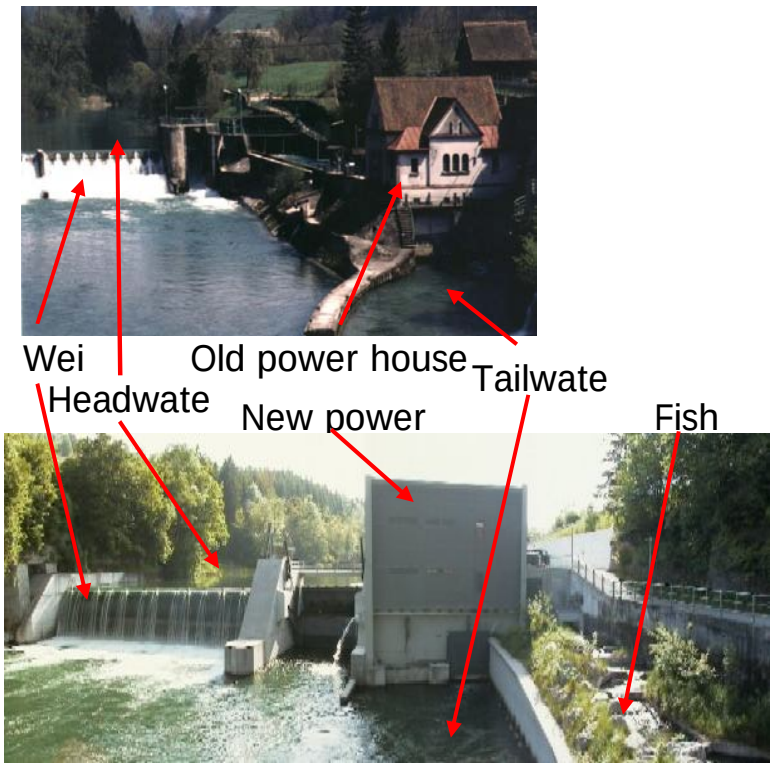

Fig. 12. Revitalisation and automation of an existing Hydro Power Plant including ecological improvements

4. Latest research activities of the Institute for Waterpower and Pumps

Cavitation Monitoring in Hydraulic Machines Sponsored by the the European Community
(in cooperation with **Turboinstitut**, **Darmstadt Univ. of Technology** and **Soske Elektrarne Nova Gorica**)

Investigation of the Splash Water Velocity Field in the Casing of a Pelton Turbine with PIV
Sponsored by FWF (**Austrian research fund**), 1999–2000

Estimating the Downstream Flow of a Sliding Gate Valve
Sponsored by the **Chamber of Commerce**, 1999

Evaluation of Old Hydro Power Schemes – Documentation of the Scheme Condition
Sponsored by the **City of Vienna**, 1999

Small Hydro Market Study in the Czech Republic
Sponsored by the **THERMIE-program of the European Community** cooperation: ETSU, Hyder Ind. & Orgrez, 1998

Influence of the Casing to the Efficiency of Pelton Turbines
Sponsored by **Verbund** (Austrian electricity supp.), 1997–1998

Investigation of Economical Parameters on the Right Moment for Refurbishing Kaplan Turbine
Sponsored by **Verbund** (Austrian electricity supp.), 1997

Analysis of Export Constraints and Opport-Unities for European Small Scale Hydro Equipment Manufacturers
Sponsored by the THERMIE-program of the **European Community**, in cooperation with ETSU, GB, 1996–1997

Possibilities for the Use of Ultrasonic Flow-Meter
Sponsored by the **City of Vienna**, 1996

Analysis of the Influence of the Guide Vane Interstices to the Flow in Front of the Runner
Sponsored by **Verbund** (Austrian electricity supp.), 1996

References

1. L i s t, B., P. A n g e r e r, J. P r o s t, H. -B. M a t t h i a s. PIV-Measurements on Pelton turbines. – In: Proceedings of PSFVIP-3 (3rd Pacific Symposium on Flow Visualization and Image Processing), May, 2001, PSFVIP (CD-Rom), p. F3117.
2. P r o s t, J., B. L i s t, K. K a f e r. Velocity measurement at the outlet of a pelton runner with PIV. – In: Tagungsband 11.Internationales Seminar Wasserkraftanlagen, Wien, Institut fur Wasserkraftmaschinen und Pumpen, 2000, 189-194.
3. P. A n g e r e r, E. D o u j a k, H.-B. M a t t h i a s. Economic analysis for uprating and refurbishment. – In: Tagungsband 11.Internationales Seminar Wasserkraftanlagen, Wien, Institut fur Wasserkraftmaschinen und Pumpen, 2000, 45-58.
4. L i s t, B., P. A n g e r e r, H. -B. M a t t h i a s. Velocity field measurements on pelton-turbines with PIV. (particle image velocimetry). – In: Proceedings Hydroforum 2000, Gdansk, Instytut Maszyn Przeplywowych, 475-482.
5. A n g e r e r, P., E. D o u j a k, H. -B. M a t t h i a s. A new possibility for planning and modelling the economies of uprating and fefurbishing projects. – In: Conference Proceedings “Hydro 2000 – Making Hydro more Competitive”. Aqua-Media International Ltd., 2000, 565-574.
6. P r o s t, J., K. K a f e r. Estimation of the downstream flow of valves. – In: IMEKO 2000, Proceedings Volume VI, Vienna, Austrian Society for Measurement and Automation, 2000, 97-101.
7. L i s t, B., J. P r o s t, H. -B. M a t t h i a s. Using PIV on the splash water in a Pelton turbine. – In: IMEKO 2000, Proceedings Volume VI, Vienna, Austrian Society for Measurement and Automation, 79-83.
8. K a f e r, K., H. -B. M a t t h i a s. Efficiency measurement, control and evaluation. – In: IMEKO 2000, Proceedings Volume VI, Vienna, Austrian Society for Measurement and Automation, .39-42.
9. M a t t h i a s, H. -B., K. K a f e r, J. P r o s t. Control system for a turbine test rig. – In: IFAC Symposium on Power Plants & Power Systems Control 2000 – Preprints, Brussels, IFAC, 2000, 443-448.
10. A n g e r e r, P., E. D o u j a k, J. P r o s t. Uprating and refurbishing strategies through software tools. – In: Conference Proceedings “Small Hydro 2000”, International Water Power & Dam Construction, 143-154.
11. P r o s t, J., B. L i s t, H. -B. M a t t h i a s, K. K a f e r. Investigation of the splash water velocity field in the casing of a Pelton turbine with PIV. – In: Proceedings of the 8th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, Honolulu, Volume I, 2000, 134-138.
12. E l i a s s o n, J.; G. L u d v i g s s o n, E. D o u j a k. Global optimisation of hydropower plants. – Conference Proceedings “Hydropower into the next century”. Aqua-Media International (CD-Rom), 1999.
13. D o u j a k, E., J. P r o s t. Uprating and refurbishing of small hydro in the Czech Republic. – In: Conference Proceedings “Hidroenergia 99” – Session A: Exploitation Research, OVFK (CD-Rom), 1999.
14. E l i a s s o n, J., G. L u d v i g s s o n, E. D o u j a k, A. O l s e n. A proposal to exploit optimally the hydropower potential of Fljotsdalur Iceland. – In: Conference Proceedings “Waterpower 99”, ASCE (CD-Rom), 1999.
15. P r o s t, J.; G. C a t t o, E. D o u j a k, J. C r a i g. Export constraints and opportunities for european small hydro equipment manufacturers – a barometer of opinion. – In: Conference Proceedings “Small Hydro 98”, International Water Power & Dam Construction, 1998, 113-120.

Автоматизация и энергия в гидравлических машинах

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(Р е з ю м е)

Для создания современных систем автоматизации, необходимо иметь устойчивые и дешевые энергийные системы. Энергийное потребление непрерывно увеличивается и его проблемы являются одной из главных задач проектирования. В статье анализируются способы построения надежные и экономичные источники энергии, которые проверяются в лабораторных и полевых экспериментах.