

Development Opportunities of the Small Hydroenergetics in Latvia and Smart Operating System for Small-Scale Hydropower Plants

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Abstract - The possibility of usage of one of the most conventional and affordable local renewable energy resources – water resources of small and medium-sized rivers, in Latvian energy sector has been analyzed. The already known material of this issue, which has been obtained on the basis of previous studies by other authors published in different sources that vary in certainty and reliability, is presented. Actually the presence of this material to some extent was the basis of further research in this direction. Development of the algorithm of small hydropower optimization is in fact the basis of its control system and is based on dynamic programming. The approbation of algorithm is performed on the example of optimization of certain hydropower.

Keywords - Small hydroelectric power plant (SHPP), renewable sources, algorithm of operation.

I. INTRODUCTION

All energy resources on the Earth are the products of the solar activity. These resources can be divided into two main groups: those accumulated by nature (in most cases - non-renewable); and not accumulated, but constantly renewable. The first group includes biomass (renewable resource) and all reserves of fossil fuel: oil, coal, shale, peat, underground gases and thermonuclear and nuclear energy. The second group includes the majority of renewable resources: the solar radiation, wind, river (water), ocean waves and tides, as well as the internal heat of the Earth. Renewable energy sources are renewed continuously, without time limit, but the use of traditional fuels is limited with the amount of their reserves.

All of the listed explains the obvious fact that in the last decade is increased the interest of renewable energy resources development, as for untraditional - solar, geothermal, wind power, and also as for traditional, to which the first place is ascribed to the hydraulic energy of rivers. The usage of hydraulic energy of rivers is explained with the fact that complicated structure of electricity supply is increasing. The last one is caused with economic development of the territories covered by the centralized power. Those conditions cause the autonomic small capacity generators usage operating by using local energy resources, especially hydro resource of small rivers [1, 2].

Development of renewable energy technologies and small energy generation creates conditions to stimulate consumers to install personal generating capacity. In the latter case, the term "distributed generation" is used. This term is used to define different energy sources of limited size, renewable energy resources and conventional ones, that are connected directly to

the distribution network [3,4]. The main advantage of distributed generation is the reduction of operating and capital costs while providing peak loads, improvement of power quality, possibility to increase the time for the technical renovation of power systems, reducing of transmission losses, improvements of the reliability of power supply, etc. [5].

II. THE MODERN CONCEPT OF ENERGY DEVELOPMENT

The modern concept of power industry development is based on creation of smart grids, smart meters, multilevel generation control system, distribution and consumption of electricity, use of digital technologies [6-13, 17].

In Europe, the concept of Smart Grid is associated with the integration of renewable energy of power systems and the formation of active and adaptive qualities of distribution networks (e.g., self-diagnosis and self-recovery). In addition, emphasis is placed on accounting devices that are connected to a single information network and it allows optimizing energy consumption at different periods of a day.

Creation of Smart Grid concept has set itself to solve the following key objectives:

- to increase supply reliability and dependability of the EPS;
- to improve energy efficiency;
- to protect environment.

Key development segments of Smart Grid-technologies are:

- consideration of energy;
- automation of distribution networks;
- management and monitoring of electrical equipment;
- automation of the main electric networks and key substations and control of flows;
- electrical networks and acquisition of consumers;
- non-conventional and renewable energy sources.

III. SMALL HYDROPOWER ENGINEERING

Modern hydropower engineering compared to other conventional forms of electric power engineering is the most economical and environmentally friendly way to generate electricity. Small hydropower engineering goes even further in this case. Currently, there are not single worldwide criteria of adding HPPs to the category of the small ones. Moreover, in some countries these criteria are changing with time. The range of installed powers sorting out HPP to the category of small ones is quite wide in different countries - from 2 till 30 thousands kW [1,12]. In Latvia a small HPP is a HPP with power 5 MW or less.

There are many factors in the world that contribute to increased attention of the development of small hydropower

engineering, but the main factor that is necessary to admit is already the high level of the mastered part of hydropower engineering resources, which could be used for the construction of large hydroelectric power stations HPP [12].

SHPP can preserve the natural landscape and does not affect the environment, not only during the exploitation, but also in the process of construction. A negative impact on water quality does not occur; it fully retains its natural properties at the subsequent exploitation. Fish remains in rivers, water can be used to supply population.

Unlike other renewable energy sources such as sun and wind, small hydropower engineering is almost independent of weather conditions and it is able to provide stable supply of cheap electricity to consumer.

Another advantage of the small hydropower engineering is economical efficiency. Under such conditions when natural sources of energy (oil, natural gas, coal) are due to be finished, constantly becoming more expensive, the use of cheap and affordable renewable energy of rivers, especially small ones allows producing cheap electricity. In addition, the construction of small hydropower engineering (compared to large hydropower facilities) is low-cost and it pays back quickly. SHPP can be put into operational within 15 - 18 months [1]. The main action to reduce the impact on water resources is the minimization of the reservoir which is not typical for SHPP. Construction of the dam is only necessary in some cases for the accumulation of resources (water) or for the creation of hydraulic pressure in areas with flat topography.

SHPP does not create significant environmental damage, even in the case when an artificial water reservoir is created in order to regulate the water level in the upper part of the river. Water in river behind the dam is filled with the air with the help of special equipment, resulting the increase of oxygen content in the water. Screens and barriers are used to control movement of fish, including acoustic screens and barriers. Special fish conductors are constructed in case of presence of migratory fish species allowing fish to move upstream. In general, the impact of small hydropower engineering on fish and aquatic ecosystems is negligible, except the cases when special protective measures are not used.

It is necessary to note that the negative impact on the environment, which is typical for large hydro power station (violation of thermal, hydraulic and climate condition of the area), is not characteristic for SHPP, which in most of the cases use natural pressure of the water without the need of large-scale construction of hydro engineering structures.

It is easy to note that the development of the previously listed key segments of the modern concept of energy is directly related to small hydropower engineering.

IV. WATER RESOURCES USE IN LATVIA

The problem of using water resources in Latvia has always been relevant, regardless of the nature of the economic system of the country [12-14]. According to data [12] the theoretical (the maximum possible capacity of energy resource) and technical (part of the theoretical potential, which can be practically used in the current level of science and technology), potentials of small hydropower engineering of

the Baltic region are respectively 6.1 and 2.4 billion KW·h. The use of technical potential volume of water resources is limited due to shortcomings of existing technologies and equipment for the production of electricity using the current water flow of rivers. Technical potential is growing with the improvement of equipment and development of new technologies.

Economic (commercial) potential (part of technical potential, the development of which is economically feasible under present conditions, at the current level of prices for equipment, materials, labor, and competing energy resources) water resources is even less. The latter is explained by various constraints: economic, environmental, social, legal, etc.

Nowadays to set overall economic potential of small hydropower engineering in Latvia is almost impossible because of the lack of reliable technical and economic indicators of all the natural and economic conditions of the structure and construction of small hydropower plants. A research for cost-effective technical solutions for SHPP is conducted and requires the development of methods of cost-effectiveness studies, almost no energy schemes using small rivers. Based on the fact that the main directions of development of small hydropower engineering in the next 10-15 years will be re-entry and recovery of decommissioned SHPP and mills, modernization and reconstruction of existing facilities, the issue of using common available resource public of small hydropower engineering is still open.

Final decision of the issue is being delayed by supporters of environmental protection ("green"), giving their arguments about inevitable environmental violations of increasing share of water potential of small rivers. In this turn, the opponents of the use of water resources potential of rivers absolutely do not consider the loss in the economy caused by the lack of electricity, which affects the social conditions of its inhabitants. It is appropriate to remind the supporters of one of the bad decisions (to halt construction of the Daugavpils HPP) that has been made by government under the pressure of "green", which had a negative impact not only on the development of hydropower engineering, but on the entire economy of the country [15]. As a promising alternative to the construction of the proposed Daugavpils HPP has been offered to use the energy of waves along the coast of the Baltic Sea. It has been over 20 years since the fateful decision, but the alternative to Daugavpils HPP did not find any practical implementation.

At present time to remedy the situation would not be able even the cancellation of the decision that was made in 1988, the decision to halt construction of the Daugavpils HPP (with the capacity of 300 MW according to project), in relation with the alleged impairment of the ecological situation in the territory of Latvia and Belarus. In connection with the acquisition of the status of independent states of Latvia and Belarus the realization of this project was quite impossible for objective reasons. Implementation of other Latvia construction projects of power plants of the same capacity on the Daugava River will lead to huge financial costs and an even greater negative impact on the environment because of the necessity to build a reservoir.

Latvian government has state support to producers of electricity using renewable energy resources, particularly

energy resources (water energy) SHPP. Latvia has more than 200 medium and small rivers with about 547 places suitable for construction of SHPP [13-14]. At the present time, the number of SHPP is more than 140. These HPP can sell their produced electricity at a price higher than the average buying cost. For example in 2011, this price was 3.7 times higher than the average buying cost.

The material presented below constitutes a part of the author's studies issues of SHPP in Latvia, to improve the efficiency of their operation, operating independently and as a part of the power system.

V. GENERAL INFORMATION OF SHPP

As far as it is known, the energy of water in nature exists in three forms: mechanical, thermal and chemical. Under mechanical power the ability of water to fulfill the work while falling is meant. The amount of this work is determined by the production of mass m of the falling water of the covered distance S

$$A_p = m \cdot S, \quad \text{kgm} \cdot \quad (1)$$

Depending on water conditions (rest or motion) there are two types of energy state: potential and kinetic. Potential (or rest energy) is the characteristic for the water raised state only. Particularly in this state there is standing water (lakes, ponds, swamps) in relation to lowlands. The lowest level, in relation to which the potential energy is determined, is the average level of the mouth relatively to the sea. Raised water on high ground, due to its circuit in nature, accumulates in its mass potential energy of the sun in the form of potential energy. Once the water makes a movement or flow, it performs the job. In this case, the accumulated potential energy in the mass of water is released and converted into kinetic energy (energy of motion). An kinetic energy is determined as

$$A_k = \frac{m \cdot v^2}{2}, \quad \text{kgm} \cdot \quad (2)$$

where v - the falling speed (movement) of water, m/s.

Conversion of mechanical energy of free-flowing river water into electricity is produced in hydropower plants.

Hydropower is a type of mechanical energy of water. The amount of this energy is expressed by the well known formula

$$A_p = \gamma \cdot W \cdot H, \quad (3)$$

where A_p - potential energy, kgm ; W - the water volume, m^3 ; γ - water volume density ($\gamma = 1000 \text{ kg/m}^3$) and H - water drop height ($H = h_1 - h_2$), m .

If would be used some amount of water W in time interval t (sec.) then will get amount of water flow per second (m^3/sec .)

$$Q = \frac{W}{t} \cdot \quad (4)$$

If Q is considered in (2) expression, hydraulic energy is converted to the general form (kgm)

$$A_p = \gamma \cdot Q \cdot H \cdot t \quad (5)$$

Time unit's amount of the work done is called as capacity and it is measured (kgm/sec .)

$$P = 1000 \cdot Q \cdot H \quad (6)$$

and could be expressed in kilowatts ($1 \text{ kW} = 102 \text{ kgm}/\text{sec}$)

$$P = 9,81 \cdot Q \cdot H \quad (7)$$

The capacity of hydro unit is determined with the expression, KW:

$$P_{SHPP} = 9,81 \cdot \eta_{HA} \cdot Q \cdot H \cdot \quad (8)$$

where η_{HA} - efficiency factor of hydro unit in relative units: $\eta_{HA} = \eta_{turb} \cdot \eta_G$, where η_{turb} - turbine efficiency factor in relative units; η_G - generator efficiency factor in relative units.

In general η is the function of pressure H and used amount Q of water, i.e.

$$\eta = \eta(H, Q) \quad (9)$$

This function is formulated either in the form of a graph or a polynomial, approximating dependence (9). In the exact model it is necessary to take into account that the pressure of H (mainly due to changes in the level of the lower river level) depends on the water flow of the given interval of time and the water consumption in the preceding intervals (due to changes in the level of the upper river level).

In the calculation of any HPP regime it is a must to provide information to its hydraulic units. This information is contained in the so-called "universal" characteristics of hydraulic turbines [18-19]. Universal characteristics of hydraulic turbines are lines of efficiency η in coordinates: shaft power turbine (P) - pressure (H). Specifications are submitted by the manufacturer (based on model tests of hydraulic turbines in the laboratory) or are based on real hydraulic turbines tests at existing HPP. Figure 1 shows an example of the form of a universal characteristic for radial-axial turbine PO -211.

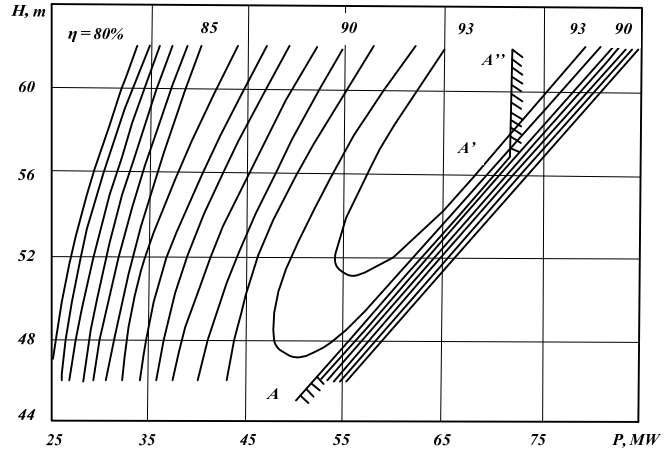


Fig.1. Operating universal characteristic of radial-axial turbine PO-211, $D1=4,1 \text{ m}$, $n=125 \text{ rot}/\text{min}$: AA' - turbine's 5% capacity reserve line, A'A'' - generator capacity limitation line.

The efficiency of the SHPP in market conditions is determined by the profit derived by HPP during the billing period. This gain can be obtained within the mode which achieves the highest possible total hydroelectric power generation and selling it to the maximum, at that time the market price for a known water inflow in the given period. The corresponding algorithm for optimal operation of the SHPP at the chosen optimality criterion allows us to solve the problem. By its nature, the optimization algorithm determines the system mode control SHPP, that does not have reservoir and running by the natural flow of water. In developing

optimization algorithm the classic monograph material was used [18], also known as an algorithm for dispatch schedule and filling the reservoir drawdown large hydropower with parallel operation of the thermal power plants in the power system [20,21]. The algorithm is based on the method of dynamic programming (DP), whose ideas and ways of its implementation is fully described in [22]. Method of dynamic programming belongs to the class of so-called multistep (multistage) processes of decision-making: for each interval the trajectory (strategy) is found, optimal (the best one) in terms of the income amount in a given interval and in all previous ones.

Method of dynamic programming provides a global solution to the optimization task. The objective function is not important at this time (linear, nonlinear etc.). It requires only the possibility to determine the value of this function at different points. The only condition to the possibility of its use is the requirement of additivity regarding the objective function (the objective function value), which optimizes the whole process and must be equal to the algebraic income sum at each stage (interval). The concrete example of the dynamic programming method implementation for solving the optimal developing tasks of current networks is the material of well-known monograph [23]. Other examples of the power industry problem solving by the DP method are provided in [19, 21, 24].

VI. SHPP MANAGEMENT SYSTEM

The variety of possible types of technological SHPP, as the sources of energy, creates some difficulties while developing its control system. The operation optimum mode implementation is required from the control system, monitoring the equipment condition, distinguishing abnormal and pre-emergency situations at HPP and preventing its development, providing the operations staff of the control centre of the distributive network and consumer with the necessary current information. The intellectual base of the modern control systems and dispatching is the software and algorithm complex that enables to ensure optimum operation conditions of a SHPP on-line under varying load of a consumer. Besides, the registration of time, daily and seasonal changes of weather and climate conditions should be mandatory. Execution of these functions by the control system of a SHPP running will provide the reliable functioning of the latter. According to some experts, all the basic functionality of the smart control systems should be provided at the program level [15, 16].

Mode of natural water flow in the river is not the same as the mode of consumption of electricity generation and other needs, and in the result there is a need for a redistribution of the natural flow, i.e. in its regulation. For SHPP working in the natural flow of water, the period of its regulatory regime is 24 hours. Consequently, one of the conditions to fulfill the proposed mode of SHPP is spending it during the period of its regulation a certain amount of water that is equal to its inflow. The change in water pressure ΔH must meet certain requirements. For example, the requirements of related fields of the economy (fishing, agriculture, water supply, etc.) must be taken into account. Consequently, the change in water level

should be restricted by limits H_{\min} to the bottom and H_{\max} above, i.e.

$$H_{\min} \leq H \leq H_{\max} \quad (10)$$

Change in water pressure of HPP is caused by water levels of upstream and downstream. This happens due to the consumption of water through the HPP turbines.

VII. ALGORITHM FOR GAINING THE MAXIMUM REVENUE OF SHPP

Mathematically the task of gaining maximum income of SHPP under the known water inflow and price forecast of electricity prices and under conditions of market relations can be formulated as the maximization of function

$$I(P_1, P_2, \dots, P_J) = \sum_{j=1}^J I_j(c_j, P_j) \rightarrow \max \quad (11)$$

under the condition (10) and the balance of water drawdown during the regulatory period for a given volume of water inflow

$$\sum_{j=1}^J Q_j \cdot \Delta t_j = W_J \quad (12)$$

where $I_j(c_j, P_j)$ - income from sale of electricity, that is produced on SHPP during the time interval Δt_j by known market price c_j , €; T - the regulation cycle duration:

$$T = \sum_{j=1}^J \Delta t_j ; Q_j - \text{the water flow through the SHPP flap}$$

during the time interval, m^3/sec ; W_J - the set amount of water that could be passed through the SHPP flap per regulation cycle (period of 24 hours).

Generation of electricity by HPP for the j - (number) interval Δt_j is defined as: $P_j \cdot \Delta t_j$. Knowing domestic inflow (natural usage of river flow) W_j domestic, water usage of HPP in each interval of the regulatory period is determined by the change in pressure ΔH in a predetermined range and the known mirror surface of the river.

Taking into account relatively small change in water pressure (in the range a few centimeters) in the observed HPP it is possible to restrict it with a small step h change in pressure H . Levels (mark) of the pressure may be labeled as H_j^i , where

the subscript indicates the number j ($j = \overline{1, 24}$) of time interval of the consideration of the regulatory cycle, and the upper i - variant number of its size, which depends on the chosen discretization step of the pressure.

Transition from point H_0 to point H_j^i corresponds to a specific pressure change ΔH , leading to a change of SHPP power. Corresponding to this power income I of selling it (at the currently known market price [26]) may be the efficiency indicator of SHPP within the given reservoir storage use of SHPP. So, each point H_j^i is characterized with two value - income and water usage.

Transition from any point H_j^i at the end of the first interval to the end of the second interval H_2^i is available by several paths (trajectories). At the end of the second interval the

optimal transition trajectory from a point H_0 can be determined for each point H_2^i . The maximum income in the first I_1 and in the second intervals I_2 corresponds to this trajectory, i.e.

$$\text{MAX} (I_1 + I_2).$$

Income I_2 is determined by a simple comparison of possible proceeds for pressure H at all possible pressures, which could be at the end of the first time interval.

In the issue of this modeling, to each possible pressure level H_2^i at the end of the second interval the maximum total income from an individual variant of use of the SHPP's reservoir storage from the beginning of regulatory cycle at H_0 will correspond. This income is characterized by the efficiency index for the first two intervals for the given pressure. Therefore, when observing the third interval, the previous two intervals may be combined into one and the optimal trajectory's choice procedure of the reservoir storage use can be repeated. The efficiency indices at the end of the third interval will be initial points for examination the fourth period of time etc. Attaching one interval after another, it is possible to reach the last one, at the end of which the trajectory should pass the set point $H_0 = H_{end}$ (H_0 - began of the optimization period; H_{end} - the end of optimization cycle), corresponding to the reservoir storage level at the end of the regulatory cycle. So as for this point the optimal trajectory can be found, then it corresponds to a certain point H_{J-1}^i at the end of the $(J-1)$ -st interval, through which passes the optimal trajectory. In its turn, to this point H_{J-1}^i of the end of the $(J-1)$ -st interval corresponds the optimal trajectory passing through the similar point of the end of the $(J-2)$ -nd interval etc. As a result of this „reverse” the optimal trajectory will be found defining the path from initial point H_0 to the end point $H_{end} = H_0$. This path (strategy) will correspond to the most advantageous variant of use of the SHPP's reservoir storage in terms of getting the maximum income. In this case a few options with the same maximum income are possible. In this case, choosing the option (strategy) of the use of water resources some concerns can be taken into account, caused by operational need and a known schedule of HPP.

VIII. APPROBATION OF AN OPTIMIZATION ALGORITHM

Let us illustrate the efficiency of the developed algorithm with the example of optimization mode of a certain SHPP in the Berzes river in Latvia. Initial data are the following [27, 28]: installed capacity of SHPP is 300 kW, efficiency is 0.85 rel. units; a maximum water level prior to the dam - 8.2 m, the minimum acceptable level of the SHPP pool - 7.9 m (in accordance with the regulations of the environment protection of Latvia); the average annual flow of the river - 2.4 m³/sec, river surface basin is 274000 m². Microcontrollers are used to control the level of water used in standby and control the water flow to find the value of the water pressure in a specified range. In addition to the initial data on SHPP graphs are used of market prices change for a considered period [26].

The accuracy of modelling by the DP method depends on the number of possible discrete marks of pressure marks made

at the end of each interval - the more points H , the better the result. To assess the influence character of magnitude of the step change in the pressure of the water produced results were calculated for the considered SHPP for steps in water pressure change equal respectively 0.025 m, 0.0125 m and 0.01 m. The values of these steps need to be considered at the end of time interval (from first till 23rd), respectively 13, 25 and 30 discrete marks of water level. Fig. 2 – Fig. 4 shows changes in water levels in the river in the implementation of the method of DP for different values of steps.

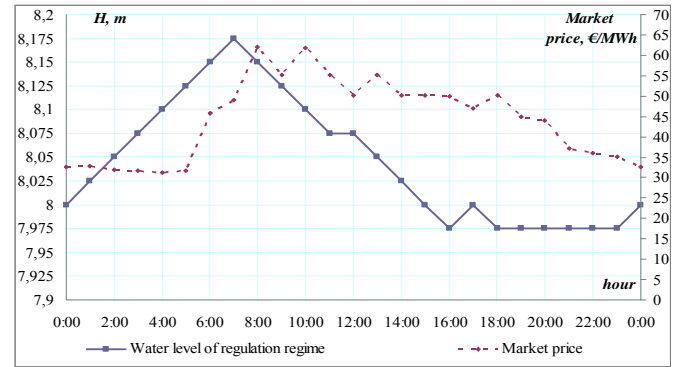


Fig.2. Water level in reservoir by optimizing with dynamic programming method with water level step 0.025m.

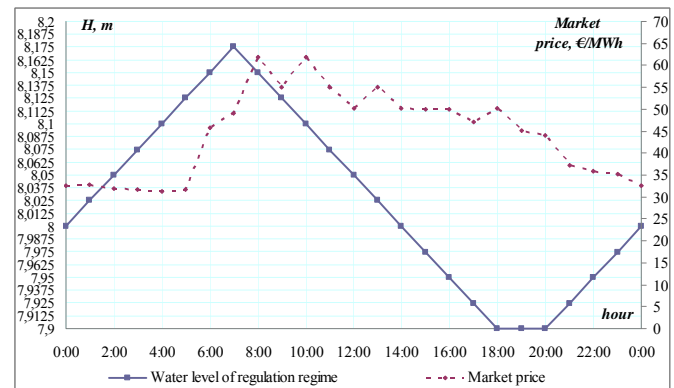


Fig.3. Water level in reservoir by optimizing with dynamic programming method with water level step 0.0125m.

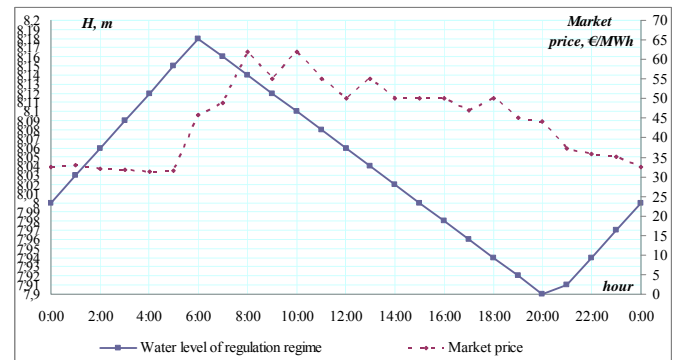


Fig.4. Water level in reservoir by optimizing with dynamic programming method with water level step 0.01m.

Fig. 5-7 illustrates the power changes results of algorithm of work control of SHPP depending on pressure change at the end of each hour of the 24-hour period. SHPP income from optimization by DP with the selected step 0.025 m constituted

192.23 €, by selecting step 0.0125 m income constitutes 196.26 €. By selecting step 0.01 m SHPP mode is more optimal and income constitutes 196.86 €.

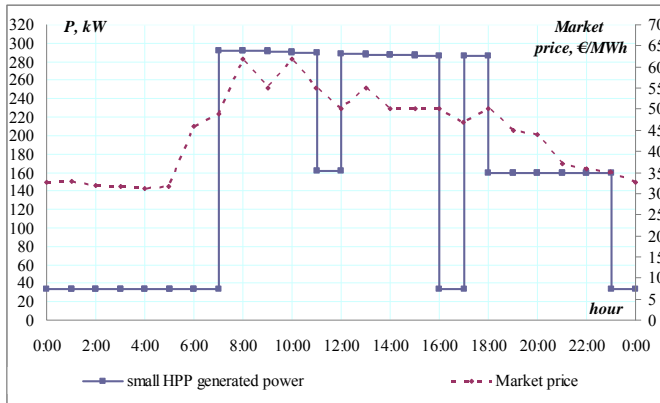


Fig.5. The market price and generated power graphs by optimizing with dynamic programming method with water level step 0.025m.

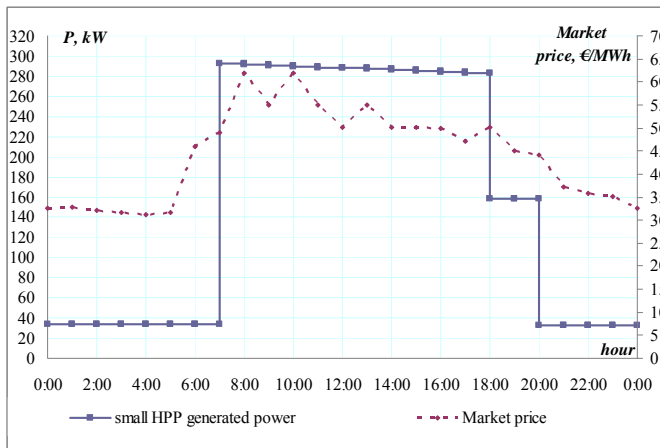


Fig.6. The market price and generated power graphs by optimizing with dynamic programming method with water level step 0.0125m.

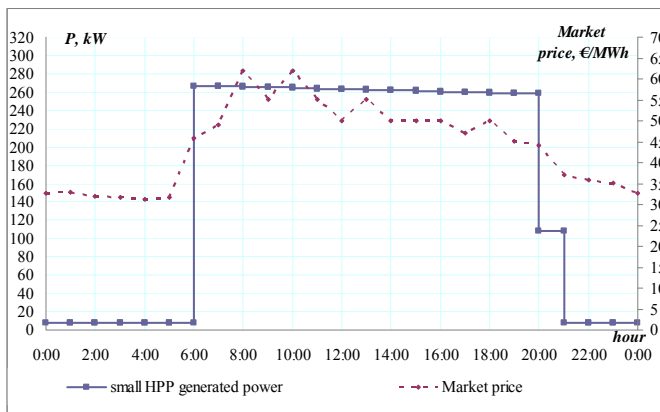


Fig.7. The market price and generated power graphs by optimizing with dynamic programming method with water level step 0.01m.

The obtained results suggest the influence of the features of developed control algorithms intellectualization of system control of SHPP to optimize their operating modes. Calculation of SHPP capacity and water flow usage in each interval must be based on the water flow usage depending on the specific amount of change of the water pressure but not the

average value of pressure. In this regard the authors of this article have serious doubts in the adequacy of the power calculation of SHPP in each time interval of the regulatory period according to formula [25].

This is easily verified by simple calculation. To show by reasoning, we assume that at the end of each interval of the regulation cycle (except the last, where the final pressure of level set H_{end}) there are three states of pressure that are considered - H_0 , H_{min} and H_{max} , equal respectively to 3, 2 and 4. We consider only the last interval. It is easy to see, the formula P [25] is valid only for the case at the end of the penultimate interval of pressure in optimal schedule of SHPP was equal to the initial pressure H_0 , that determines the final incorrect result of optimizations and not allowing us to assume that by the beginning of the next period, the mode control of SHPP water pressure is equal to the initial value H_0 . As a result, the volume of sold electricity that is determined on the basis of the above formula of capacity for SHPP is not true. It is clear that this fact does not meet one of the main components of the concept of Smart Grid of energy resources counting. In addition to the facts already mentioned it is necessary to note the inconsistency of the illustration in [25] the essence of dynamic programming, from Fig. 2 and further, that only testifies that the calculation scheme is not the implementation of this method.

IX. CONCLUSION

1. Latvia territory has more than 200 small and medium-sized rivers because of its geographical position and its water resources have considerable theoretical potential for electricity production. With the improvement and development of new technologies, Latvia energetics can significantly increase national energy supply and increase the level of energy independence by generating the electricity with the use of water resources.

2. Consideration of the objective circumstances that requires the use of local renewable energy, Latvia sooner or later will have to discuss seriously the issue of the usage of potential energy of water resources of small and medium-sized rivers.

3. The smart basis of the control system of small HPS work should have corresponding complex of algorithms and programs, fulfilled in different control devices (controllers and sensors). On the electricity market with the participation of small HPS the appropriate devices are used to control the mode of it, with the limited inflow of water allows reaching maximum power generation and income from the sale of it at the highest price.

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Anatolijs Mahnitko, Jānis Gerhards, Oļegs Linkevičs, Renāta Varfolomejeva, Inga Umbrasko. Par mazās hidroenerģētikas attīstības iespējām Latvijā un mazo hidroelektrostaciju vadības sistēmas intelektuālizāciju.

Tiek analizēta viena no tradicionālākajiem un pieejamākajiem vietējiem atjaunojamajiem energoresursiem – mazo un vidējo upju hidroresursa, izmantošanas iespējas Latvijas enerģētikā. Tiek sniegts faktiskais materiāls šajā jautājumā, kas iegūts balstoties uz oficiālos avotos publicētiem citu autoru iepriekš veiktajiem pētījumiem. Tiek atzīmēts, ka teritoriju, kas atrodas mazo upju tuvumā un nav ietvertas centralizētās elektroapgādes sistēmā, saimnieciskā apgūšana rada apstākļus patērētāju stimulēšanai izmantot autonomas vietējos energoresursus, ieskaitot hidroenerģiju, izmantojošas mazas jaudas energoiekārtas. Atjaunojamās enerģijas tehnoloģiju un iekārtu pastāvīga attīstība un pilnveidošanās veicinās mazo upju plūsmas izmantošanas elektroenerģijas ražošanas efektivitātes paaugstināšanos.

Enerģētikas mūsdienu attīstības koncepcija, kas balstīta uz viedo tīklu (*smart grids*) izveidi, ļauj paaugstināt mazās hidroenerģētikas darbības efektivitāti, integrējot to elektroenerģētiskajā sistēmā. Mazo hidroelektrostaciju (MHES) darbības vadības sistēmas intelektuālizācijas pamatā jābūt kompleksam algoritmam

un programmām, kas ļauj tiešsaistes (*on-line*) režīmā nodrošināt izdevīgu MHES darbības grafiku (režīmu) maksimālā ienākuma gūšanai, balstoties uz zināmu elektroenerģijas cenas prognozi attiecīgajam laika periodam (diennaktij).

MHES darbības optimizācijas algoritma, kas pēc būtības ir tās vadības pamats, izstrāde tiek veikta balstoties uz dinamiskās programmēšanas metodi.

Izstrādājot programmu kodus, kas realizē autonomā režīmā strādājošas MHES optimizācijas algoritmu, nepieciešams izmantot speciālas aprēķinu procedūras, kas ir adaptīvas pret konkrētiem MHES ūdens spiediena ierobežojumiem. Algoritma aprobācija veikta uz konkrētas MHES režīma optimizācijas piemēra.

Анатолий Махнитко, Янис Герхардс, Олег Линкевич, Рената Варфоломеева, Инга Умбрашко. О возможностях развития малой гидроэнергетики в Латвии и интеллектуализации систем управления малыми гидроэлектростанциями.

Анализируется возможность использования в энергетике Латвии в качестве энергоресурса одного из наиболее традиционных и доступных местных возобновляемых энергоресурсов – гидроресурсов малых и средних рек. Приводится фактический материал по данному вопросу, полученный на основании ранее выполненных исследований другими авторами. Эти материалы опубликованы в официальных источниках. Отмечается, что хозяйственное освоение территорий, находящихся вблизи малых рек и, не охваченных централизованным электроснабжением, создает условия для стимулирования потребителей использовать автономные энергоустановки малой мощности, работающих с использованием местных энергоресурсов и, в частности, энергии воды рек. Постоянное совершенствование и развитие технологий и оборудования возобновляемых источников энергии будут способствовать повышению эффективности использования свободного течения воды в малых реках для производства электроэнергии.

Учет современной концепции развития энергетики, основанной на создании активно-адаптивных сетей (*smart grids*) позволяет повысить энергетическую эффективность работы малой гидроэнергетики при ее интеграции с электроэнергетической системой. Интеллектуальной основой системы управления работой малых ГЭС (МГЭС) должен быть комплекс алгоритмов и программ, позволяющих в режиме реального времени обеспечить выгодный график (режим) работы (МГЭС) с точки зрения обеспечения максимального дохода при наличии известного прогноза цены на электроэнергию для соответствующего периода времени (суток).

Разработка алгоритма оптимизации работы малой гидроэлектростанции, являющегося, по сути, основой ее системы управления, производится на базе метода динамического программирования.

При разработке программных кодов, реализующих алгоритм оптимизации для МГЭС, работающей в автономном режиме, приходится использовать специальные вычислительные процедуры, адаптивные к конкретным ограничениям по напору воды на МГЭС. Аprobация алгоритма произведена на примере оптимизации режима конкретной гидроэлектростанции.