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Micro Hydropower Station Automatic Control System: PTO Hardware and Software Implementation

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Abstract: The study deals with the variant of power return increase in Damless Micro Hydroplant (DMH) by hardware and software automatic control means. The microprocessor regulator provides the automatic electric generator load current drive in the zone of a maximum take-off needed for charging the accumulator. Additional functions of a microprocessor regulator: calculation of time and power resource to be supplied to consumers connected to a DMH outputs, automatic switching of convertors depending on power consumption, display and recording DMH operation modes and the water flow speed. The study offers a structural scheme of a microprocessor regulator and its operation flowchart.

Key words: Hardware and software implementation, PTO-power take off, extreme regulator, electric generator, microprocessor, algorithm, block diagram, flow rate/speed, load factor

INTRODUCTION

Currently many of inhabited localities experience the ever-increasing supply with modern power and electronic sources capable to provide uninterrupted power for modern equipment working in ordinary and *in situ* conditions. Any modern technology is down if there is no possibility of replacing galvanic cells or recharging batteries. This fact significantly narrows down the possibility of normal business, in-field activities and human survival under extreme conditions.

ANALYSIS OF EXISTING DMHS

Mobile and Damless Micro Hydroplants (DMH) might have largely satisfy people's demand for renewable power systems in places far away from centralized distribution grids (Dobrokhotov and Shpilrain, 1996). The DMHs can't be widely used in vast territories of Kazakhstan and Russia for their poor qualimetric parameters and cost of the equipment. The earliest sleeve-type DMH developments were mainly focused on generation of fixed water stream pressure on a hydromotor.

The structure of our sleeve-type DMH enables to create specific angular velocity of the electric generator with the help of:

- Difference in intake hose ends elevation from 5-15 m, the hose length being from 15-80 m
- A multiplier raising the angular hydromotor-rotor axis rotation from 10-40 fold

This type DMH due to its water intake hose and step-up mechanical transmission is rather large in size and weight (not mobile) (Yu and Selivakhin, 1997). Its arrangement is also costly and the field of application is restricted only in mountain streams and rivers. Moreover, the arrangement of this type DMH may inevitably effect on the landscape of protected nature reserves. The more advanced mobile DMHs designed for tourists and military personnel (DMH) refer to float type DMHs.

The upper part of a torpedo-like floating DMH corpus contains the electric generator with the rotor kinematically connected to the hydromotor axis by a two bevel drive multiplier (Perminov, 1998). The propeller type hydromotor is placed in the lower part of the corpus and oriented towards the stream.

The DMH rated capacity being 500 W, the minimum flow depth should be not <1200 mm, the water flow velocity is to be 2 m/c and above. For orienting the DMH towards the direction of water flow it is cabled on both water flow sides.

The commercial price of DMHs is rather high (2000 USD) due to its complex structure comprising a propeller hydromotor and a multiplier needed to provide several hundred revolutions per minute in the electric generator.

This DMH parameters have a limited scope of application, the water flow should be no <1200 mm deep and speed from 2 m/c and above. It means that many of small streams, ditches, culverts and rivers can not be a source of renewable energy for the said DMHs.

The widespread use of mobile DMHs is possible if there in the world market appear low speed electric

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generators that compensate magnetic rotor holding forces (Akhmetov and Kharitonov, 2012). These devices have permanent high coercive force magnets. These attraction and repulsion forces impacting on the rotor are being mutually offset in the direction of the angular rotation. The energy efficiency or power output of those generators is achieved if water flow speed is 1 m sec^{-1} and if the rotor is in line with the hydromotor. The original design of a hydromotor equipped with rotary blades enables to design a floating-type DMH that is invariant to the direction of water flow and workable in water flows 200 mm deep.

This type of DMH has a generator rotor with angular speed of 10 rev/min working at water flow speed of 5 m sec^{-1}. Consumers believe that any source of electricity should have normalized output parameters-output voltage and power. Our DMH variants discussed have normalized voltage and power stabilized by electric generator rotor speed. Since, any electric generator rotor speed stabilization variants lead to a decrease of energy flow utilization rate the researchers offer such a DMH variant that enables to extract maximum energy from the stream and convert it into electrical energy with respect to wind power plants (Muller and Kauppert, 2002). This variant radically changes the approach to using air flow energy. Researchers suggest to extract this energy from the stream by the criterion getting maximum energy output with accumulation of the obtained energy in accumulator. The normalized output voltage and power shall be provided with respective electric energy inverters accumulated in the accumulator. The positive features of this option are:

- Maximum utilization of the flow energy with its accumulation in the battery
- Supply of power to consumers that is many times greater than the rated power of the electric battery
- Uninterrupted power supply to consumers during short-term rearrangements or failure of the flow energy converter into electrical power

HARDWARE AND SOFTWARE IMPLEMENTATION OF PTO PROCESSES

Figure 1 shows the structure of a microprocessor module that implements all positive properties of the

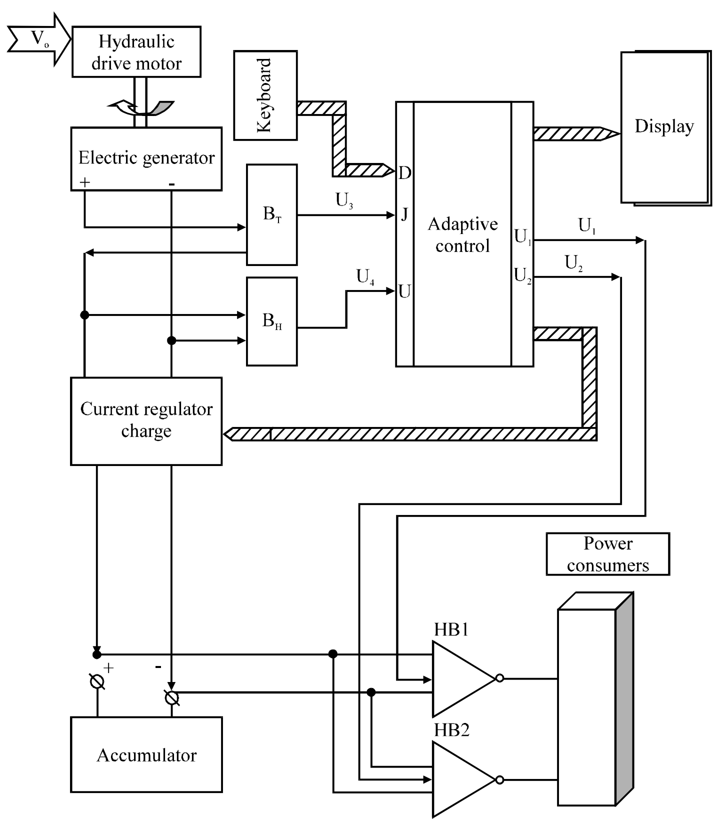

Fig. 1: Structure of microprocessor-based module of DMH end section

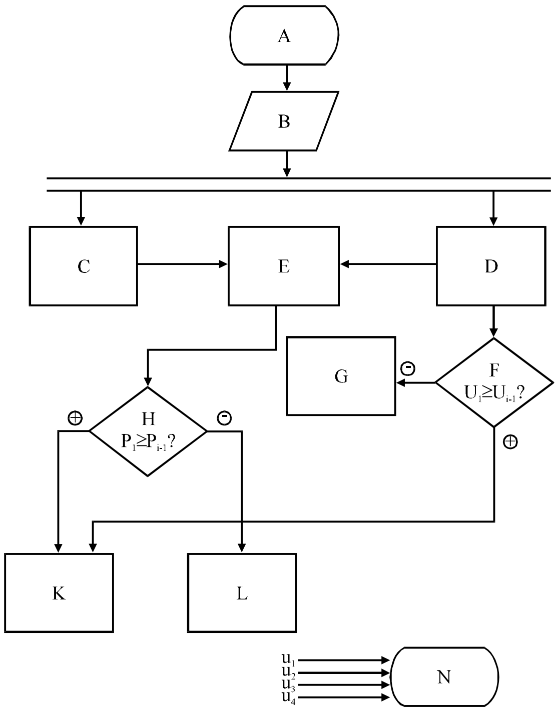

Fig. 2: Power extreme control flowchart

device with regard to a DMH. The water flow affects the hydromotor with the rate of υ_n. The hydromotor axis is connected to the generator shaft and its outputs are connected to the controlled current battery charge regulator. Current battery charge regulator control inputs are connected to adaptive microprocessor performance controller outputs. According to output current sensor B_i-output voltage sensor B_u electric generator signals, the microprocessor provides the function of extreme electric generator output power $P_O = U{\cdot}I$ regulation. The picture of DMH modes and parameters is shown on the display, a setup of power supply variant connecting to consumers is provided by control microprocessor outputs signal U_1 and U_2. Control modes and visual display can be set up by users from the module keyboard.

The structure of DMH (Fig. 1) provides the highest variant of power output from the electric generator at different values of water flow velocity υ_Π and power accumulation in the battery. At the same time, the structure regardless of power accumulation mode is capable to supply power to consumers by any variant set up from the keyboard of the module.

Flowchart of electrical power extreme control taken to be accumulated in the battery Fig. 2. A is the beginning, B is operation modes setup, C is electric generator output current measuring, D is electric generator the output voltage measuring, E is generator power output P_O calculation, H is current value P_i with previous power value P_{i-1} comparing, F is comparing output voltage U_i current value with output control range minimum value U_{min} of G is sleep mode, K is electrical generator load current I_H reduction on the quantization step, L is electrical generator load current increase I_H on the quantization step, N is DMH module operating modes and parameters indication.

A is the beginning, B is operating regime setup, C is electric generator output current measuring, D is electric generator output voltage measuring, E is power output calculation, H is comparing the current value the previous power value, F is comparing the current output voltage range value with the minimum output power control value, G is sleep mode, K is electric generator load current decrease on the quantization step, L is electric generator load current increase on the quantization step, N is DMH module of operating mode and parameter indication.

The generator rotor during its rotation through a reverse adjustment of the output load current provides the drive of extreme current output. The increase of load current I_H inevitably leads to a decrease of output voltage U_i of the electric generator but at the increase of water flow speed υ_Π there occurs the increase of the output voltage. Each time when the rate of water flow speed υ_Π is being changed due to extreme regulation there is being set up and automatically maintained individual value of the output current I_H. At this power P_H taken from the generator has the value that is maximal for this speed of water flow.

CONCLUSION

- Adaptive automatic rotated hydromotor PTO algorithm implementation and energy accumulation in the electric battery eliminates its loss that could be spent on stabilization of a generator rotary mode
- The DMH invariance with respect to water flow direction, absence of uplift transmission from a hydromotor to a generator rotor simplifies the DMH construction enabling to reduce its size, weight and cost
- The algorithm of adaptive current drive of the generator load current in the zone of a maximum extraction of power and its accumulation in the electric battery can significantly improve the DMH energy-conversion efficiency if water flow speeds are 1 m sec^{-1} and above

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