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Automatic Control of Technological Process of Water Supply by Pumping Station of Water Lifting Systems

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ABSTRACT: This article contains a developed system of automatic control of technological process of water supply by pump station of water lifting systems, providing equality between the required schedule of water supply by pumping station and its flow by smooth frequency start and further regulation of the capacity of any of pumping units at the stages of unit by unit regulation.

KEY WORDS: pumping station, pumping unit, controlled electric drive, rotational speed, water-energy resource, setting device, power saving mode, frequency converter, starter, drive motor.

I. INTRODUCTION

In the conditions of increasing scarcity of water and energy resources, actuality of task to reduce power consumption for needs of lift (pumping) irrigation by pumping stations is at one of the first places. Therefore, ensuring energy and resource saving modes of pumping stations (PS) operation is an important task that will save significant amount of electrical energy when implementing its technological process of water supply.

Reduction of unit costs of electrical energy and rational use of water resources can be achieved mainly by using controlled electric pumping units, due to changes in speed (frequency) of their rotation [1].

It should also be noted that, in detailed development of such control systems of automated electric drives, advantages of graded unit by unit regulation of PS capacity of water lifting systems (WLS) shall be combined with regulation of rotation frequency of pump units (PU) between stages in the given range of changes of required water flow, supplied by PS on the irrigated lands of cultivated crops, thereby avoiding unnecessary electricity consumption . In addition, use of automated electric drive will also allow more rational use of water resources by reducing unproductive expenditures [2].

Therefore, automatic control of water lifting process will ensure energy-saving modes of operation of pumping units (PU) of pump irrigation systems (PIS) with higher values of units' efficiency and smaller specific energy consumption for PS water supply in the efficient use and allocation of water resources [3].

II. RELATED WORK

Works of the following authors were devoted to the development of the theory and practice of modern systems of automatic control, peculiarities of functioning of electric-mechanical and hydromechanical equipment of pumping stations as control and regulation system, as well as power saving by means of controlled electric drive: Basharin A.V., Onishchenko G.B. Yunkov M.G., Klyuchev V.I., Kamalo T.S., Ilinskiy N.F., Braslavskiy I.Ya., Moskalenko V.V., Leznov B.S., Rychagov V.V., Florinskiy M.M., Walker S., Jahns T.M., D.G. Walters and others.

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III. RESULTS AND DISCUSSION

Control systems of WLS hydro-mechanical power-consuming objects can be referred to multivariable parametric systems of automatic control.

Building of closed automatic control systems (ACS) on selected control circuits refers to the classical theory of automatic control, foundations of which were laid by I.A. Vyshnegradskiy, A. Stodola, D. C. Maxwell. Comparatively simple control circuits are characteristic for this theory: maintaining or changing of adjustable values on specified law, generation of signals on deviation etc. It uses hard control algorithm that implements basically the principle of feedback. All features of this approach are used when constructing ACS of water supply by pumping station [4], providing both smooth start and speed control of rotation frequency of drive motors of each pumping unit at the stages of unit by unit control of supply of water-lifting PS (fig. 1).

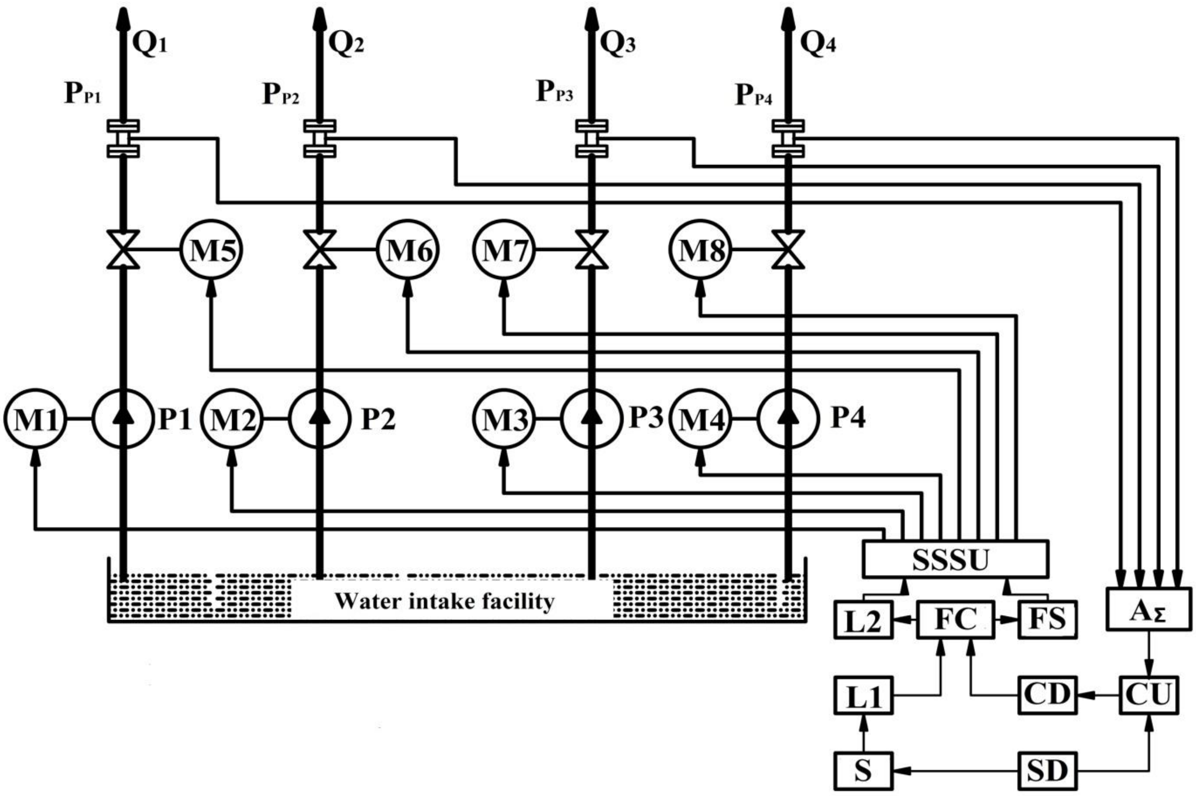

Fig. 1. Functional diagram of water-lifting pumping station

By ACS of water supply by pumping station, in which feedback signal is picked up from the flow sensors, installed on individual pressure piping (pressure system) , and by smooth start and further control of supply by the next PU , at this stage of unit control of PS capacity, both equality between the required schedule of water supply and its implementation, and energy-resource saving is provided (fig.2).

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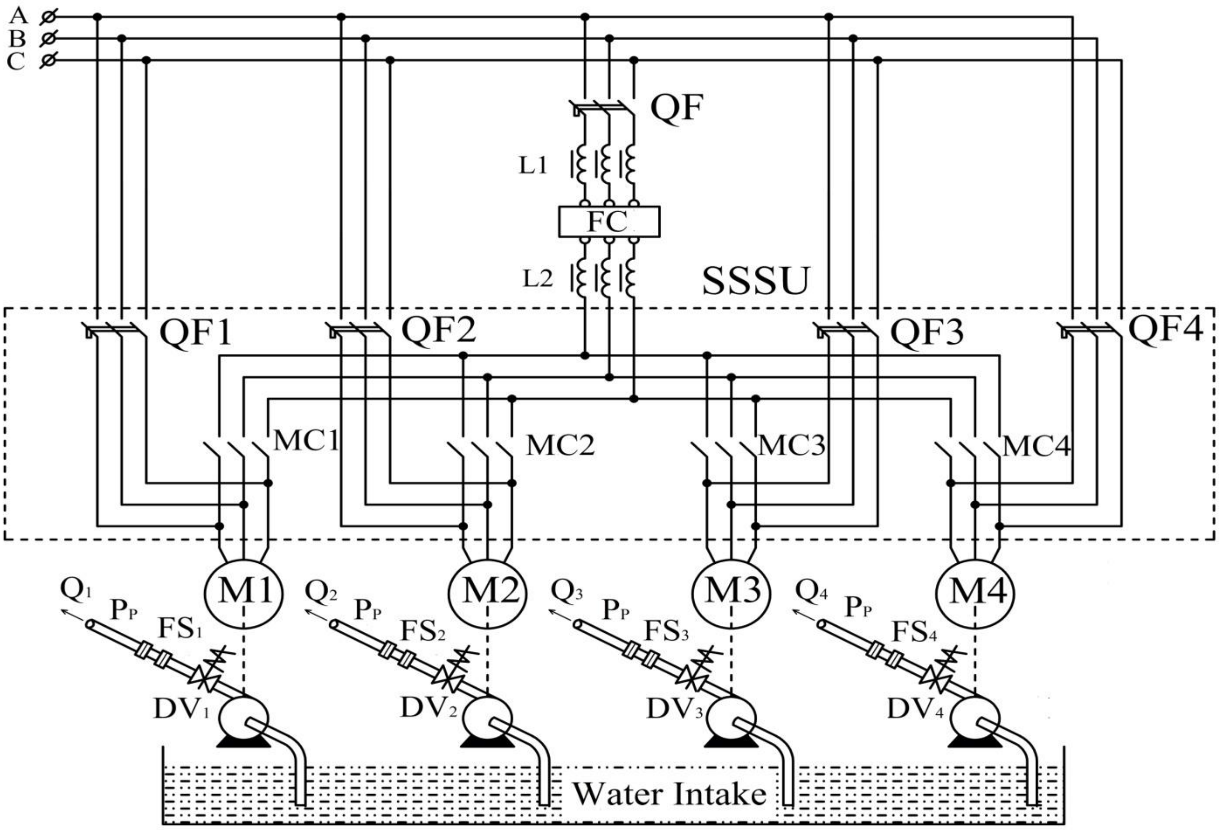

Fig. 2. Wiring diagram of power part of pumping units ACS

This ACS (fig. 3) of PU technological process functions as follows.

By setting device (SD) of water flow, desired value of PS supply is set. At the same time, commands are received by Starter (S) (automatic circuit breaker QF) of frequency converter and through comparison unit (CU) by control device (CD) of frequency converter. S (QF) through reactor L1, protecting converter from switching overcurrent, connecting frequency converter (FC), one of the outputs of which by measuring frequency sensor (FS), and the other output through output reactor L2, limiting capacitive output currents of the converter and voltage peaks on electric motors, connecting to the respective inputs of start sequence unit (SSU) of pumping units, output of which, connecting to starter S_1 of smooth frequency control (magnetic contactor MC1), initiates smooth frequency start (f = var Hz) of electric motor M1 of pumping unit P1, and then discharge valve DV_1, installed on pressure piping Pp_1, is opened by command of drive control unit of discharge valve $DCUDV_1$.

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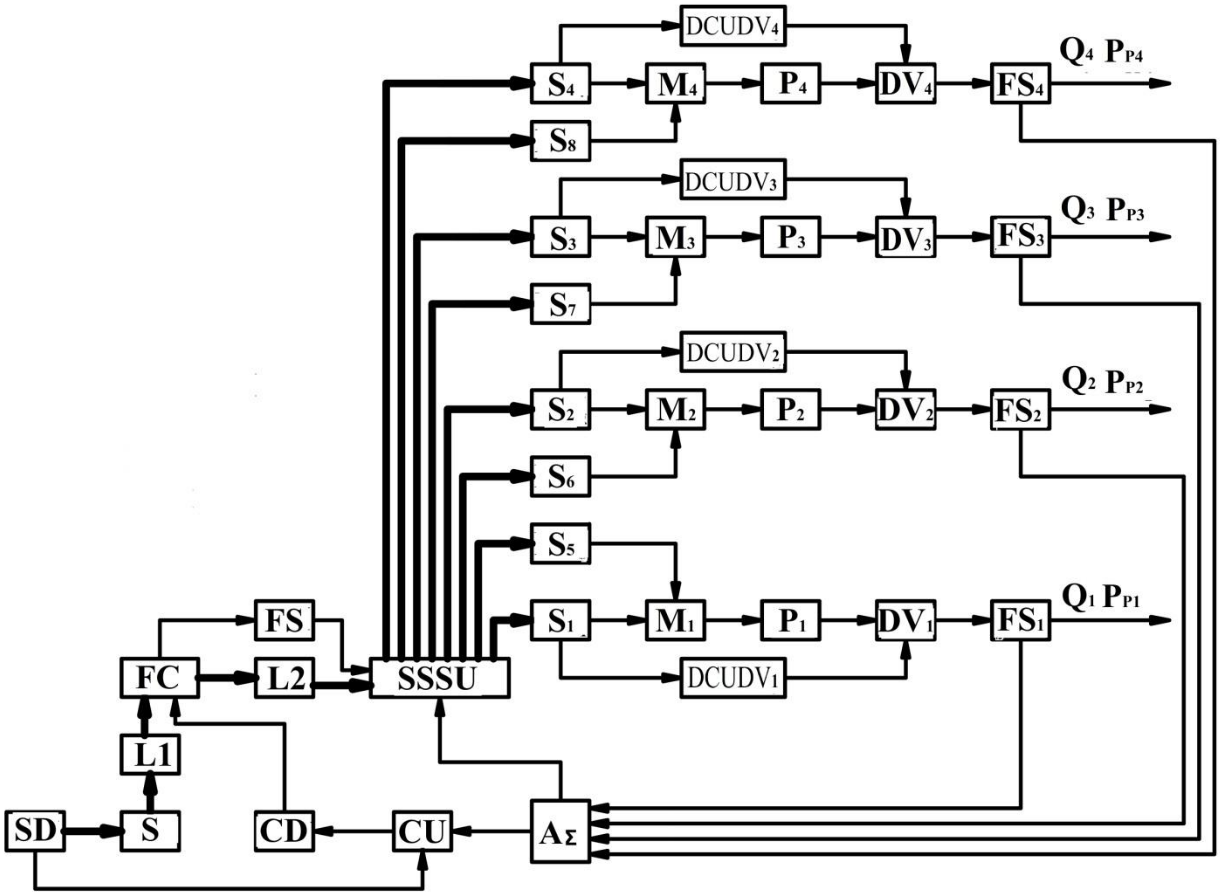

Fig. 3. Block diagram of automatic control system of pump station

Signal, proportional to the value of water flow, supplied by pump P1, from flow sensor FS_1 comes through Adder A_Σ in the comparison unit CU and then from it to the inlet of Control device of frequency converter, which continues changing frequency (f) and, as a consequence, rotation speed of electric motor M1 of pump unit P1, providing the required compliance of water flow with the schedule of water supply at this stage of capacity regulation of water lifting pumping station.

In the case, when set by setting device (SD) of water flow, required value of PS water supply exceeds the nominal value of pump unit P1 supply, generated by flow sensor Fs_1 signal, reaching its maximum value, through adder A_Σ, coming in block of start sequence selection SSSU of one of the pumping units P2 – P4, and at the same time signal from the frequency sensor FS, fixing achievement of value of converter frequency, equal to frequency of power mains (f = 50 Hz), leads to triggering of pumping units CUDV, which, bypassing frequency converter , facilitates start of mains starter S_5 (automatic circuit breaker QF1), directly connecting electric motor M1 to the mains. At that, at the same time, from adder output, through comparison unit, corresponding signal, equal to difference of signals of setting device SD и adder A_Σ , coming in CD, brings converter FC to readiness to smooth start of the next pump unit.

From the moment of triggering of the unit of start sequence selection SSSU of pump unit, converter FC, changing frequency (f = var Hz), initiates smooth frequency start (f = var Hz) of electric motor M2 of pumping unit P2, from corresponding starter of smooth frequency control FC_2 (magnetic contactor MC2) and (DCUDV2) drive control unit of discharge valve DV_2 , which opens it on pressure piping Pp_2. Rising signal from the water flow sensor FS_2 comes to Adder A_Σ , where upon implementation of adding operation of the adder, with the signal, coming from the flow sensor FS_1, their resulting signal comes to input of comparison unit CU, in which signal, obtained as a result of comparison, setting required value of supply of water-lifting pump station from setting device SD with the signal, proportional to the actual value of supply , delivered by pumping units P1 and P2, picked up from $A_{\sum}$, comes to input of CD и continues to change frequency (f) of the converter FC and thus the rotational speed of the electric motor M2 of pump P2 until bringing water flow, pumped by PS, in compliance with the schedule of its supply.

If the defined by setting device SD required value of pump station supply is higher than nominal performance values of both operating pumping units P1 and P2, signal, produced by flow sensor $FS_{2,}$ reaching its maximum value, is summarized with maximum value of the signal, coming from the flow sensor FS_1 in the Adder, and then it comes to start sequence unit of one of the pumping units P3 – P4, as well as simultaneously signal from frequency sensor FS, fixing achievement of frequency value of the converter, equal to frequency of the mains (f = 50 Hz), leads to subsequent triggering of start sequence unit of pumping units, which, bypassing the frequency converter, facilitates start of mains starter S_6 (automatic circuit breaker QF2), directly connecting electric motor M2 to the mains. At the same time, from Adder output through comparison unit corresponding signal, equal to the difference of signals of setting device SD and adder $A_{\sum}$, coming to control device, brings converter FC to readiness to smooth start of the next pump unit.

From the moment of triggering of the unit of start sequence selection SSSU of pump unit, converter FC, changing frequency (f = var Hz) initiates smooth start of electric motor M3 of pump unit P3, from corresponding starter of smooth frequency control FC_3 (magnetic contactor MC2) and DCUDV3 drive control unit of discharge valve $DV_{3,}$ which opens it on pressure piping P_{p3}. Rising signal from the corresponding water flow sensor Fs_3 comes to Adder $A_{\sum}$, where upon implementation of adding operation of the adder with the signals, coming from the flow sensors FS_1, FS_2 their resulting signal comes to input of comparison unit CU, in which signal, obtained as a result of comparison, setting required value of supply of water-lifting pump station from setting device SD, with the resulting signal, proportional to the actual value of supply of pumping units P1, P2 and P3, picked up from adder, comes to input of CD и continues to change frequency (f) of the converter FC and thus the rotational speed of the electric motor M3 of pump P3 until bringing water flow, pumped by PS, in compliance with the schedule of its supply.

Process control system of PS water supply can work both in automatic and manual modes, where switching of modes is carried out from the control panel. Choice of PS operating mode is carried out by duty staff from operator’s post. For start or stop of electric drive control system of pumping units in automatic mode or their egress from standby mode, buttons "start" or "stop" are used.

At the considered pumping station, one, two or three pumping units may work permanently, where the fourth unit is a reserve pump unit. Reserve pump unit is selected by the switch position at the operator’s post, where at the selected PU the corresponding discharge valve, located in the discharge part of pressure pipeline, closes, in automatic mode.

IV. CONCLUSIONS

Thus, the developed system of automatic control of technological process of water supply by pump station of water lifting systems by smooth change in capacity of any of its operating pumping units as a result of implementation of their smooth start and speed control of pumps drive electric motors will allow rational use of hydropower resources by irrigation water saving at each of the stages of unit regulation and allow reduction of specific consumption of electrical energy per volume unit of pumped water.

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