Operating information-diagnostical system (IDS) BING-3 on the example of Andijan water reservoir

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Abstract. The article provides recommendations on the possibility of implementing an automated system of diagnostical control over the operational condition of a dam. Implementation of BING-3 allows to control the opening of cracks in concrete structures, take readings from piezometers and air temperature sensors in an automatic regime. The article gives an analysis of instruments used for diagnostics and reasons for the failure of certain devices. It has been established that further use of morally out-of-date devices reduces dam safety observation volumes.

1 Introduction

The majority of earth-fill and concrete dams in the republic were built in the middle of the last century. Correct technical solutions, implemented in the design of these dams, allowed to operate them for over fifty years [1, 2]. However, nowadays, the control over the dams is carried out by manual measurements of two or three coordinate crack measurers, pressure and non-pressure piezometers, reverse plumbs [19, 20]. Also, earth-fill and concrete structures of hydrosystems have many marks installed, whose positions are controlled relative to reference points using geodetical equipment. Such a system of control-measurement instrument management does not meet current requirements [1]. Time requires reequipping of all average and high pressure dams with modern instruments. When implementing automated systems of diagnostical control, several problems of financial origin may come out, including personnel training, etc.

In this article, we consider the issues concerning technical solutions for implementing automated systems of diagnostical control at the Andijan water reservoir (Figure 1).

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Fig. 1. Plan view and cross-section view of Andijan water reservoir

The goal of the work is to justify the practicability of implementing the system of diagnostical control over the operational condition of a concrete dam.

The task of improving the control over earth-fill and concrete dam conditions is determined with the necessity of providing the safety of operation of very important and technically complex facilities [3, 4, 10, 11, 15].

The main task of monitoring is to control the operational condition of hydrosystems. Monitoring is carried out using both inset control and measurement equipment, installed in the process of construction, geodetic, seismometric, other instrumental methods, and visual observations [21-36].

3 Methods

The research was carried out using the traditional method of conducting field research of structures.

There is a big experience accumulated throughout the world on implementing automated systems of diagnostical control over the technical condition of dams, for example, BING-3 [7,8,9,13,14].

BING-3 system operates in the automatic regime and carries out control over the opening of cracks in concrete structures, records piezometer and air temperature sensor readings. The system has successfully recommended itself at Orto-Tokoy water reservoir in Kirgizstan, being used since 2014 [13].

4 Results and Discussion

All the control and measurement equipment listed in table 1 must be replaced in Andijan water reservoir.

Table 1. Amount of instrumentation requiring reequipment. Static control and measurement equipment.

Static control-measuring instrumentation:	Amnt.
String and semiconductor transformers	1119 ea.
<i>Filtration Control Measurement Instrumentation:</i>	
Pressure piezometers	108 ea
Nonpressure piezometers	100 ea.
Including inside the dams	100 .
Measuring weirs	22 ea.
Springs at the dam tailrace	5 ea.
<i>Geodetic Control Measurement Instrumentation:</i>	
Fundamental reference marks	6 ea.
- Operation reference marks	140 ea.
- Direct plumbs	8 ea.
- Reverse plums	16 ea.
Range signs in galleries at levels 817, 845, 885	103 ea.
Hydrostatic elevation meter (level) (at 4 sections)	48 ea.
Uniaxial and triaxial crack meters	44 ea.
Seismic Control Measurement Instrumentation	
Seismic detectors	53 ea.
Hydraulic Control Measurement Instrumentation	
Concrete failure sensors, including:	39 ea.
at 1 st tier waterways	10 ea
at water outlet stilling basin	15 ea
at spillway stilling basin	14 ea.
Sensors of wearing of metal, including:	20 ea.
at section №16 waterways	10 ea
at section №21 waterways	10 ea
Pressure pulsation sensors	34 ea
Cavitation sensors	18 ea
Inserts at section №21 and cable for measurement of:	
pressure and aerations	4 ea
velocity and aeration	4 ea
Vibration sensors, including:	32 ea
in the body of sections №16, №17, №21 and №22	18 ea
at spillway stilling basin	14 ea

For measurements of deformations and temperature at the base and in concrete, openings of deformation joints and cracks, measurement of filtration pressure, string and semiconductor transformers of static control, and measurement instrumentation were installed in the dam [1]. The frequency of alternating voltage at transformer outlet or active

resistance of semiconductor thermoresistor serves as information parameter of the electrical signal [11,12]. Types of these transformers and their measuring limits are given in Table 2.

Table 2. Types of string transformers used for observations

№	Transformer type	Abbreviation	Unit of measurement	Range of values	Function
1	Linear displacement transformers, string type	PLPS	mm	0-1, 0-3, 0-6	Measurement of the amount of joint and crack opening
2	Linear deformation transformers	PLPS	mm	0.1; 0.22; 1	Measurement of relative linear deformations
3	Force transformers, string type	AD	kN	80	Measurement of tensile and compressive forces in rebar
4	Pressure transformers, string type	PD	MPa	3, 10	Measurement of hydrostatic pressure in concrete and joints
4	Transformers for temperature measurement, string type	PTS-60	degrees	from -20 to +60	Temperature measurement
5	Thermoresistor temperature transformers	MMT-4	degrees	from 0 to +60	Temperature measurement

Fig. 2. Location of crack meters at the axis of right buttress section 18, 24.

In 2015 observations by static control measurement instrumentation were carried out every 10 days. Monthly checks of the number of sensors, which transmitted data, showed that their amount has decreased compared to 2014.

Table 3 shows data on the number of transformers used to take measurements in 2014-2015 and the decrease of the number of transformers used for observation in December of 2015 compared to June of 2014.

Table 3. The number of transformers used for observations.

Transformer description	2010г.	2014 20 - VI	2014 30-XII	2015 30-VI	2015 20-XII	Decrease
1	2	3	4	5	6	7
SECTION 18						
Semiconductor thermometers (T)	79	79	79	78	79	0
String type thermometers (TS)	27	26	25	25	25	1
Concrete-rock contact sensors	9	6	5	6	6	0
String type crack meters (C, CS)	44	44	39	42	41	3
Rebar dynamometers (RD)	8	8	8	8	8	0
Piezometer dynamometers (PD)	12	12	11	11	11	1
Reduction of sensors used for measurement from 20.06.2014 to 20.12.2015, ea						5
SECTION 24						
Semiconductor type thermometers (T)	70	70	70	70	69	1
String type thermometers (TS)	42	40	39	39	39	1
Thermometers for determining displacement	50	49	48	48	48	1
Concrete-rock contact sensors	1	1	1	1	1	0
String type crack meters (C, CS)	52	49	48	46	48	1
Rebar dynamometers (RD)	6	6	6	6	6	0
Piezometer dynamometers (PD)	13	13	13	13	13	0
Reduction of sensors used for measurement from 20.06.2014 to 20.12.2015, ea						4

It is seen from the given data that the number of transformers used for diagnostics decreased by 9 units in 2015 compared to 2014. The main reason for the reduction of observations is the failure of generator-frequency meter IIC – 5m. This device has morally aged and taken out of production. Frequency meters and period meters produced nowadays don't have the same sensitivity as IIC – 5m. That is why it will be possible to recommence observations with a specified group of devices will be possible only after obtaining second-order devices with the required sensitivity.

The Diagnostic center receives data from Andijan water reservoir in the form of transformer string oscillation periods (microseconds) or thermoresistor resistance values (Ohm). Measurements on about 1250 transformers are taken in one cycle. 26 measurement cycles are carried out in a year. Work on these data starts with their initial processing, which lies in the conversion of transformer electrical signals into physical values [11]. Depending on the characteristics of the transformer output signal, the physical value being

measured is calculated using the following relationships:

- logarithmic relationship for thermoresistor transformers

$$Y = A/(\ln X-B) - 273.15$$

- parabolic relationship for string transformers

$$Y = A*(X^2 - C^2) + B*(X - C),$$

Where
Y is value being measured
A, B, C are graduated relationship coefficients
X is transformer output signal.

These calculations are carried out for each of 1250 transformers of static control measurement instrumentation. Table 4 with measurement data, carried out in March of 2015 and the results of their initial processing, is given as an example of information obtained from the water reservoir.

Table 4. Measurement data

Device number	Data, transmitted from water reservoirs for processing			Transformers	Results of conversion of electrical signals into physical values		
	Date of measurement				Measurement dates		
	10/01/15	20/01/15	10/01/15		10/01/15	20/01/15	10/01/15
	Readings from devices (microsecond, Ohm)				Physical values (mm, grad, kg/cm ²)		
0	6423	6424	6423	BT-7	-4.194	-4.2535	-4.1943
1	5908	5909	5909	BT-8	-2.198	-2.2828	-2.2828
2	6246	6243	6243	BT-9	-1.834	-1.6322	-1.6322
3	6282	6282	6282	BT-10	3.0462	3.0462	3.0462
4	6466	6467	6468	BT-12	-0.1084	-0.1661	-0.2239
5				BT-13			
6	6248	6249	6250	BT-14	-3.2085	-3.2741	-3.3396
7	6565	6585	6564	BT-15	-2.0848	-2.0848	-2.0298
8	6380	6380	6381	BT-7	4.2659	4.2659	4.2017
9	7033	7033	7032	BT-16	9.9307	9.9307	9.9531
10	6086	6083	6084	TC-31	1.3304	1.5415	1.4711
11	6083	6085	6082	BT-11	1.7619	1.6241	1.8308
12	6240	6241	6241	BT-17	-0.3769	-0.4443	-0.4443
13	6632	6626	6631	BT-18	-8.9753	-8.6583	-8.9225
14	6337	6338	6339	BT-19	-3.7545	-3.8166	-3.8788
15	6267	6281	6268	BT-20	-5.7628	-6.6733	-5.8280
16	6355	6354	6355	BT-21	5.3308	5.3925	5.3308
17	6415	6413	6412	BT-22	-9.4542	-9.3352	-9.2757
18	6220	6219	6219	BT-24	-7.5873	-7.5210	-7.5210
19	77892	7788	7787	BT-25	-1.7655	-1.6312	-1.5976
20	6543	6543	6543	BT-26	-1.1296	-1.1296	-1.1296
21	7145	7149	7157	BT-27	9.5034	9.4291	9.2809
22	6016	6015	6015	TC-38	0.5907	0.6638	0.6638
23	6064	6064	6063	BT-28	-3.6407	-3.6407	-3.5699
24	6232	6231	6231	BT-31	-5.1491	-5.0811	-5.0811
25	6236	6235	6232	BT-32	-0.6328	-0.5653	-0.3625
26	6132	6132	6133	BT-33	-4.0200	-4.0200	-4.0899

Table 4. Measurement data (continuation)

Device number	Data, transmitted from water reservoirs for processing			Transformers	Results of conversion of electrical signals into physical values		
	Date of measurement				Measurement dates		
	10/01/15	20/01/15	10/01/15		10/01/15	20/01/15	10/01/15
	Readings from devices (microsecond, Ohm)				Physical values (mm, grad, kg/cm ²)		
27	6794	6802	6811	BT-34	10.7634	10.5881	10.3916
28	6619	6620	6618	TC-40	1.3645	1.3107	1.4183
29	6513	6511	6510	BT-29	-1.8129	-1.7008	-1.6448
30	6265	6265	6262	BT-35	-5.3377	-5.3377	-5.1431
31	6524	6518	6514	BT-36	-2.5699	-2.2154	-1.9785
32	6145	6145	6146	BT-37	-8.4079	-8.4079	-8.4797
33	7448	7461	7476	BT-38	9.7693	-.5632	9.3267
34	6329	6330	6329	TC-41	0.5039	0.4418	0.5039
35	6450	6448	6442	BT-30	1.8371	1.9570	2.3174
36	6317	6318	6317	BT-39	-12.8882	-12.9505	-12.8882
37	6787	6798	6825	BT-40	11.0533	10.8209	10.2553
38	6218	6214	6212	TC-44	0.5597	0.8193	0.9493
39	6423	6422	6423	BT-41	-5.5869	-5.5260	-5.5869
40	6062	6059	6056	BT-42	1.2151	1.4303	1.6458
41	5961	5960	5961	BT-43	-6.5667	-6.4917	-6.5667
42	6974	6990	7011	BT-44	11.5932	11.2696	10.8480
43	6250	6248	6247	TC-45	1.7839	1.9147	1.9802
44	6931	6928	6926	BT-51	4.9359	5.0786	5.1739
45	6267	6266	6267	BT-45	-10.5833	-10.4975	-10.5633

4 Discussion

Principles of building the automated system of diagnostical control over the condition of hydraulic structures (ASDC HS) [13] is in the following (Figure 3):

- ASDC system includes in itself an automated system of sensor query (ASQ CMI) and information-diagnostical system (IDS) BING-3, operating in a common computer network (local or corporate) and integrated at the software level.
 - ASQ CMI carries out open-end transfer of data from initial sensors to central data collection server. At the data collection server outlet ASQ SMI is integrated with IDS BING-3. Besides, overall ASDC HS is an “open” type AS, which provides stage-by-stage system development, interchangeability of hardware and software means, and compatibility with ASM of other levels.
 - ASQ CMI is a distributed system of remote control, which is built according to “industrial network” technology, which provides reliable protection from interferences, reduction in price, and simplification of works in mounting and operation of automated systems.
- ASDC HS structurally includes the following elements:
- lower level – control-measurement instrumentation (CMI): sensors, measuring devices;
 - medium level – the system of telecommunication, transformation, and transmitting of information in digital code to central data collection block ASQ CMI;
 - higher level - program-technical complex, including in itself central automated query block ASQ CMI and information-diagnostic system of control over structure safety (IDS) with corresponding computer hardware and software.

Fig. 3. Simplified structural scheme for data collection system network CMI “BING-3”.

At the lower level ASDC directly uses measuring devices with sensors, registering physical processes and impacts on the structure. This automatization system uses water level sensors, sensors of excess pressure in pressure and nonpressure piezometers, discharge meters at drainage wells and measuring weirs, displacement sensors in crack meters, plumbs, string ranges, temperature sensors. The general requirement to sensors is their unified analogue, a digital or radiofrequency outlet of standard type, and interchangeability.

Medium level of ASDC HS includes in itself sensor communication means, transformations of the analogue signal into digital codes, and communication lines for signal transmission from sensors to the central block of automated query system ASQ. Data collection modules, located in the maximum concentration of measuring devices, are used to connect sensors to a communication line with an industrial interface.

Higher level of ASDC HS system is a program-technical complex, including data input-output controller, central block based on data collection industrial server, base specialized software for management of automated query of sensors and automated work areas with the complex of programs as part of IDS safety control of HS.

4 Conclusions

- The main results of the work consist of the following:
1. Collected and analyzed field observation data from Andijan water reservoir concrete dam indicate of their safe operation at its long operation state.
 2. Based on the analysis of available data, the main requirements to hydraulic structure operational control systems were determined, i.e., composition and types of field observations, device control means, observation periodicity, and initial data processing seismic monitoring and registering of earthquakes.
 3. Permanent control over CMI operational efficiency in the process of monitoring HS

condition is provided.

4. Use of IDS BING-3 at Andijan hydrosystem allows for automatization of monitoring the condition of all structures at water level, piezometer pressures, discharge measurements, displacement, and temperature.

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