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Centralized Downstream PI Controllers for the West Canal of Aghili Irrigation District

A. Montazar[1*], and S. Isapoor[2]

ABSTRACT

In the face of limited water resources, better utilization and operation of irrigation networks is essential. Use of control systems is considered as one of the most assured ways to achieve the aim. In the course of the present study, two centralized controllers are applied to the west canal of Aghili irrigation district in I. R. Iran. The proposed control algorithms consist of a distant Downstream PI Feedback control (DPIF), and a distant Downstream PI Feedback along with Feedforward control (DPIFF). In the controllers, each water-level regulator is adjusted as based on water levels in all the pools of the canal. The test case canal and flow scenarios are simulated using SOBEK. The controllers are evaluated using the simulation results. The results indicated that both of the proposed controllers possess the considerable needed potential to closely match the discharge (at the cross regulators) with those ordered by water users while properly maintaining the water level throughout the length of the canals of the irrigation system. It is apparent that the DPIFF controller is more effective than DPIF controller in providing a desirable performance. Use of these algorithms makes demand oriented water distribution as well as a better performance of the system possible. The DPIFF controller as the main control system accompanied by a local controller as a backup system can be recommended to present an efficient robust control system for the canal.

Keywords: Aghili irrigation system, Centralized control, Control systems, Downstream control, PI controller.

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INTRODUCTION

Water management improvement in irrigation canal systems is widely recognized as an important step in attaining better management at the farm level. Improved operation of irrigation canal systems will improve service to water users, conserve water through increased efficiency, increase delivery flexibility, and provide more prompt responsive reactions to emergencies. Application of control systems is considered as one of the most assured ways to achieve the aim. The demand-oriented operational concept, which bases operations on downstream conditions (Bureau of Reclamation, 1995), provides the needed flexibility in terms of water quantity and timing to achieve improved crop yields as well as water-use efficiency. In the downstream control, water is released in response to the actual water withdrawal demand from the system, and the adjustment of each gate is based on the information downstream from it. Hence, a target water level is immediately maintained at the upstream end of each pool.

A wide variety of algorithms for automatic control of water levels in irrigation canals have been proposed (Malaterre *et al.,* 1998). These control algorithms range from the classic Proportional-Integral (PI) controllers,

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[1] Department of Irrigation and Drainage Engineering, Campus of Aburaihan, University of Tehran, Islamic Republic of Iran.

[*] Corresponding author, e-mail: almontaz@ut.ac.ir

[2] Yekom Consolation Engineers, Tehran, Islamic Republic of Iran.

which are extensively employed in the process-control industry, to heuristic controllers, and to optimal controllers. A number of such more sophisticated controllers as linear quadratic and model predictive controllers have also been proposed.

Two main control techniques can be considered, feedback and feedforward. With a feedback control algorithm, the controlled variable is measured and any deviation from the corresponding set-point value -error- is fed into the control algorithm to provide for a corrective action. External disturbances are indirectly taken into account through their effects on the output of the system. Using the error as input, the feedback control algorithm calculates gate openings or flow rates in real time to maintain the target values for the controlled water depth. Examples of feedback control in water level are Amil, Avis, and Avio gates, CARDD (Burt, 1983), BIVAL (Chevereau *et al.,* 1987), Liu *et al.* (1994), Durdu (2003 and 2004) as well as Clemmens and Schuurmans's works (2004). In feedforward control, the control action variables are computed from targeted variables, disturbance estimations and process simulation. The control action variables, also called outputs of the control algorithm, are variables issued from the control algorithm and supplied to the actuators of the check structures. They are either gate openings or flow rates. Some feedforward controllers of water level were evaluated by Liu *et al.* (1992), Tomicic (1989), Lin and Manz (1992), as well as by Baume *et al.* (1993).

Because of the large delay times that may be present in irrigation water delivery systems, feedback control alone may not be sufficient to provide adequate control. Thus, many researchers recommend using a combination of feedforward and feedback routines to automatically control irrigation water delivery systems (Clemmens *et al.* 1997; Malaterre *et al.,* 1998). Two examples of feedback with feedforward controller in irrigation canal were presented by Montazar *et al.* (2005), and Isapoor *et al.* (2010). Over the last few decades, the type of controllers applied to water systems have evolved from feedback in combination with feedforward towards such more advanced control methods as Model Predictive Control (van Overloop *et al.,* 2005 and 2007; Qin and Badgwell, 2003).

In this paper, a linear control theory is applied in the design of two centralized downstream PI controllers, with feedback technique as well as feedback+feedforward technique, for the west canal of Aghili irrigation district in I.R.Iran. The first order low pass filter (PIF) and decoupling of the pools are also taken into consideration.

MATERIAL AND METHODS

Irrigation District and the Study Canal

Aghili irrigation district (AID) is located in South West Iran, in the North of Khuzestan Province. AID is a part of Gotvand irrigation network. The annual (maximum *vs.* minimum) air temperatures and precipitation rates are 53 *vs.* 3°C, and 582 *vs.* 152 mm, respectively. The net cultivated area in AID is about 4000ha. The annual mean distributed water in the irrigation area is about 150 MCM.

AID includes a short main canal, 2 km long, along with two subsidiary canals, west branch at a length of 14.9 km *vs.* east branch with an 18.6 km of length. The west branch of the canal is considered in this study. This canal includes 12 pools (13 in-line check structures) and 27 offtakes. All the check structures are radial gates. The design discharge capacity of the canal is 7 m^3 s^{-1}. The canal is manually controlled. The operators deliver the demands of water users according to their requests (at 8 am every day). As the demands of the water users, in terms of flexible delivery, are increasing, there is an urgent need for supporting the operators through automation of the structure operations. Figure 1 shows a longitudinal view of the west canal of AID.

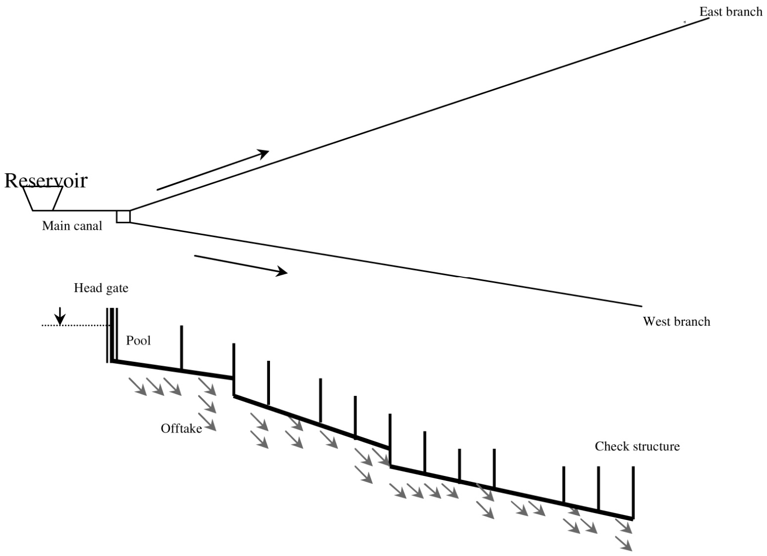

Figure 1. Longitudinal view (not to scale) of West canal of AID.

Proposed Control Algorithms

One of the simplest as well as widely applied controllers is the Proportional-Integral (PI) controller (Clemmens and Schuurmans, 2004; Litrico *et al.,* 2006; Montazar *et al.,* 2005; van Overloop, 2005; Isapoor *et al.,* 2010). In the course of this study, two different centralized downstream PI controllers are designed and evaluated. The proposed controllers make use of applied feedback, and feedback + feedforward control techniques.

The PI controller output for the check structure at the current time *t*, is the estimated one as based on the proportional and integral terms. The proportional term being the current value of the difference between the measured water level and the set-point, $e(t)$, multiplied by the parameter k_p, constitutes the basic control action, which depends directly on the magnitude of the error signal ($k_p e(t)$). The integral term provides the necessary control action to reduce the steady-state error ($k_i \int_0^t e(t)$). The parameters k_p and k_i are the proportional and the integral gains, and the calibration parameters of the controller, respectively. The controller parameters can be changed, to improve the settling time, to reduce the maximum error or to minimize a given performance criterion.

In the proposed control algorithms, a first order low pass filter was added through the designed controllers to remove the resonance waves which play a dominant role in the water movements (Ljung, 2007). A PIF-controller is a PI controller set in series with a first order low-pass filter. Hence, besides the proportional and integral gain factor, also a filter constant has to be determined, which is used to filter out the effect of resonance waves on the measured water level.

In the irrigation canals under downstream control, a control action not only influences the downstream water level, but also has a direct unintended effect on the water level just upstream of the control structure. When the series of canal pools is controlled by a centralized controller, this effect can be taken into account. In other words, application of PI controllers presents a problem for long multi-pool canals. The problem is associated with transmission of demand changes in the upstream or downstream direction. It means that the

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disturbances in one pool influence all the pools throughout the canal and so the controlling process is complicated by the interactions between neighboring pools (Schuurmans, 1992). To reduce the impacts, the pools are coupled in the upstream and downstream direction. Here, this effect is considered by adding decouplers to the controller structure. The control actions, as output, are calculated based on the magnitude of the water level deviation which is taken as input to the controller. The calculated value is added to the upstream gate directly to make a centralized controller. In case of distant downstream feedback control, the water level at the downstream side of a pool is controlled by adjusting the gate at the upstream end of the reach, in reaction to the deviation from the set point (Figure 2).

In the feedback+feedforward control system, all the measurements are explicitly linked to control actions with the connections between inputs and outputs within the central control box being straightforward (Figure 3). All water-level measurements are the inputs while all the check structure flow adjustments being considered as the outputs. In this controller, each check structure is adjusted as based on all the pool water levels in the canal. With centralized control, based on the delivery schedule, observations and actions are carried out from a distant site through a supervisory control and data acquisition system.

One of the most difficult aspects of applying automatic control to irrigation water-delivery systems is the determination of the correct controller constants, or tuning. The proposed multiple-model optimization of PI controllers on canals by Overloop *et al.* (2005) was employed for tuning the controllers. In this technique, a linear controller is tuned in such a way that it stabilizes all models (for all sets of flows) and optimizes an objective function that is a sum of individual objective functions, each valid for one of the models from the set. By applying a multiple model optimization that minimizes the water-level deviations from target level in all pools, the tuning of decentralized PIF controllers on canals may be done in one design step, without the need for an extensive trial-and-error procedure. The tuning rules provide parameters for PI control, valid for various integrator-delay (ID) model parameters corresponding to

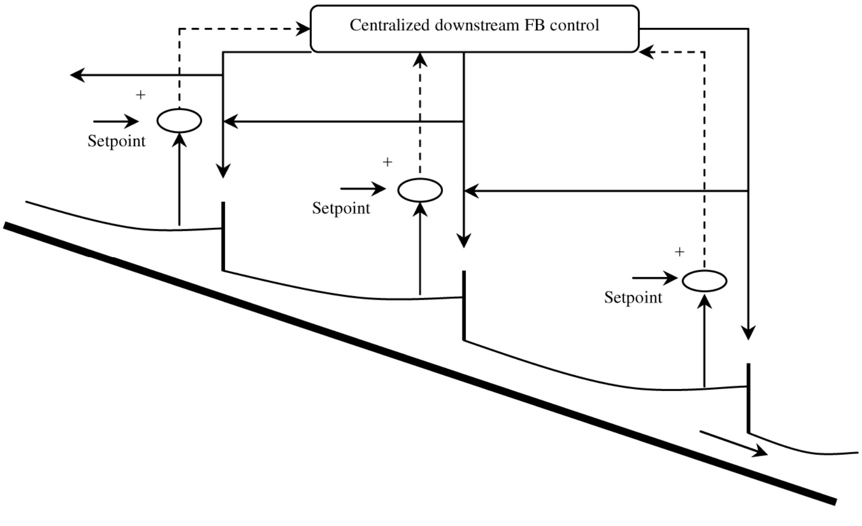

Figure 2. Centralized downstream feedback (FB) control.

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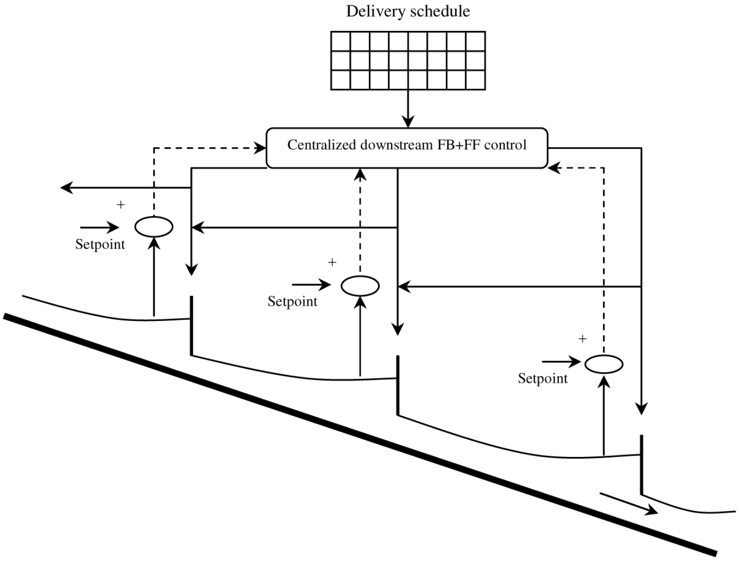

Figure 3. Centralized downstream feedback (FB)+feedforward (FF) control.

different flow regimes. The ID model benefits from two properties: a delay time for flow changes upstream to be felt downstream and a backwater surface area, which describes how the downstream water level changes as a function of a pool's inflow–outflow mismatch (Schuurmans *et al.,* 1999). The parameters of the PIF controllers are tuned according to the tuning rules for open channels (Schuurmans, 1997).

Model Setup and Calibration-validation Process

The model of the West branch side-canal of AID was simulated with SOBEK simulation package. In this study, the Channel Flow (CF) and Real-Time Control (RTC) modules are employed. Real-time control is used to adjust the control structures depending on the actual situation. The Sobek CF module is the unsteady open-channel flow simulation portion of Sobek (Sobek Manual and Technical Reference, 2000). The Sobek RTC module allows the check gates in Sobek CF to be externally controlled by MATLAB. The setup preparation for the Sobek model involves specifications of canal path, cross-sections, layout of the canal network, regulators, upstream and downstream boundary conditions.

Data on geometry of the canals and hydraulic structures were collected from the Authority of Gotvand Irrigation Network. Based on the real conditions in West and East branches, the boundary condition at system source is a constant water level at the upstream side of the head gate in both canals. The constant water level at the source and the real flow hydrographs at downstream end of the canals and at each offtake were chosen as upstream and downstream boundary conditions. Manning's roughness coefficient and discharge coefficients were employed for the calibration of the model. The Manning's roughness coefficient as well as discharged coefficient are adjusted to obtain the required water level and discharge.

Model calibration involves checking the model results with the observed data and adjusting the parameters until the model results fall within acceptable range of accuracy. Calibration of the model was accomplished by matching the computed and measured water levels and discharges at various locations along the canal. For calibration and validation of the model, we used one month data out of two month daily gathered real operation data were taken into account (April and May 2008). Two sets of measured data are used for model calibration and validation (the first 15 days of April 2008 for calibration, and the second 15 days

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of May 2008 for validation). These data include measured discharge and water surface elevation at various locations along the canal. The data used for calibration of the model in steady state condition consist of a set of water levels at crest of AWC check structure for 80%, and 60% of the design discharge.

To calibrate the model, an initial run was made with default global values of Manning's roughness coefficient '*n*' and discharge coefficients. Later these parameters were manually adjusted and the model rerun. Based on the comparison, the model parameters were adjusted. This process was continued until the observed and simulated values were in close agreements. To further check the calibration and validity of the model Nash–Sutcliffe Efficiency Coefficient (NSEC) and Percent bias (PBIAS) are calculated. NSEC is a dimensionless indicator and has been recommended by ASCE (1993). NSEC values between 0 and 1.0 are generally viewed as acceptable levels of performance, whereas values ≤ 0.0 indicate an unacceptable performance. NSEC is calculated as:

$$NSEC = 1 - \left[\frac{\sum_{i=1}^{n} (Q_0{}^t - Q_s{}^t)^2}{\sum_{i=1}^{n} (Q_s{}^t - \overline{Q}_0)^2} \right] \qquad (1)$$

where Q_0^t represents observed discharges, while Q_s^t the simulated discharges at time t, $\overline{Q}_0$ is the mean of the observed data and n the total number of observations.

PBIAS measures the average tendency of the simulated data to be either larger or smaller than their observed counterparts. The optimal value of PBIAS is zero with lower values indicating better simulation. A positive value indicates a tendency of the model for underestimation while negative values are indicative of overestimation (Moriasi et al., 2007). PBIAS is determined as:

$$PBIAS = \left[\frac{\sum_{t=1}^{n} Q_0{}^t - \sum_{t=1}^{n} Q_s{}^t}{\sum_{t=1}^{n} Q_0{}^t} \times 100 \right] \qquad (2)$$

The Maximum Error (ME), as a measure of the maximum error between any pair of simulated and measured values, the modeling efficiency (EF), as a measure for assessing the accuracy of simulations, and the Coefficient of Residual Mass (CRM), as an indication of the consistent errors in the distribution of all simulated values across all measurements, are also determined (Jabro *et al.,* 1998).

Simulations

Following the calibration and validation of the model, it is used for simulation of the other desired scenarios and for evaluating control algorithms. The proposed control algorithms are programmed in MATLAB. Sobek is of the capacity to be linked with MATLAB (Matlab users guide, 1998). Automatic control algorithms can be written as MATLAB m-files that are then connected to the Sobek CF module through the Sobek RTC module. Within Sobek, the user determines that control is from an external source and selects the 'm-file' that is to be used for control from a directory list. The Sobek RTC passes the various hydraulic property figures (????)(water depths and flow rates) from Sobek CF to the controller code (i.e., m-file). Gate positions and water levels are available in MATLAB using IDs defined by Sobek. The controller code uses this information along with the information on the canal properties to calculate the appropriate adjustment to the individual check gate structure using MATLAB. Finally, this information is passed back to Sobek CF through Sobek RTC and the appropriate control actions implemented.

To evaluate the control algorithms potential, simulations are done for two scenarios as follows:

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1). The current operation of canal based on the delivery schedule during May 2008: In this scenario, the delivery schedule is changed based on the real operation of the canal. There are 28 offtakes on the West canal of AID. As an example, the discharge schedule of three offtakes of AWT-06, AWT-11, and AWT-17 on 1st to 30th May are shown in Figure 4. Daily operation of the others to deliver the water demand of the users is accomplished during this period.

2). The delivery schedule changes from 20 to 40, 40 to 60, and 60 to 80% of the offtake's capacity in six steps (the time period of the steps is 24 hours), either increasing or decreasing. The 24-hour period was chosen to reflect the operational objective of the irrigation authority. For this scenario, the flow control time step was 5 minutes. The discharge schedule for three offtakes of AWT-06, AWT-11, and AWT-17 is presented in Figure 5.

Controllers maintain the water level at target level (set-point) at the downstream end of the canal pools. Due to schedule variation of an offtake for operation purposes, set-point deviations are taking place at the end of each pool. The distant downstream PIF controller calculates a desired flow change for the check structures on the upstream side of canal pools on the basis of the magnitude of deviation and controller gains.

Performance Indicators

To judge the overall effectiveness of the

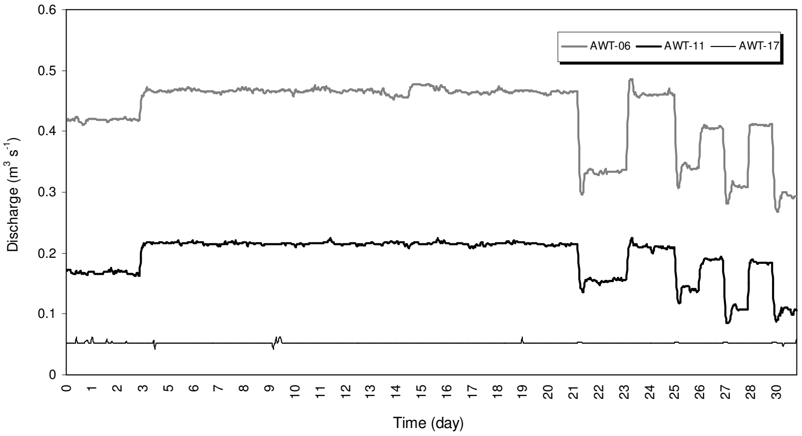

Figure 4. Discharge schedule of offtakes of AWT-06, AWT-11, and AWT-17 on May 2008.

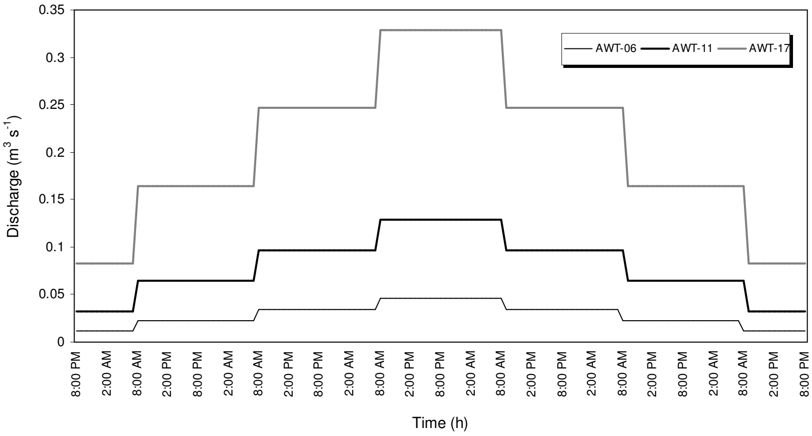

Figure 5. Discharge schedule of offtakes of AWT-06, AWT-11, and AWT-17 on the 6-day simulation period.

proposed control algorithms, four performance indicators presented by Clemmens et al. (1998) are used. The indicators include: (1) the Maximum Absolute Error (MAE) as a measure of the maximum deviation in water level from the desired set-point, (2) the Integrated Absolute Error (IAE) that indicates the speed at which the water levels return to the desired set-point, (3) the Steady-state Error (StE) as the maximum of the average error over the latest two hours of each 12-h test section, and (4) the integrated absolute discharge change (IAQ), which is an indication of the extent of gate movements required to achieve control. The indicators are determined for the controllers for each pool in West canal of AID in the same period as simulations.

RESULTS AND DISCUSSION

Calibration and Validation of the Model

Table 1 shows the statistical parameters used for model calibration and validation. The values of ME, CRM, NSEC, and PBIS are estimated <0.033, <0.013, <0.93, and <0.13, respectively. It is evident from the table that the values of the indicators for different discharge levels are small, falling within the acceptable range as discussed earlier. Therefore, the model is considered calibrated and validated. The Simulated Water Level (SWL), matched closely with the measured water level (MWL), (SWL= 0.9605MWL+7.8924, R^2= 0.98) at full supply discharge within the first 3km of the canal as shown in Figure 6.

Table 2 shows the optimized PI parameters of the pools obtained for the PI controllers. Using these parameters, the water-level deviations may be minimized from the target level in all pools.

Controllers' Comparison

Water level deviation and the controller requested gate flow deviations are mainly considered as performace criteria. The

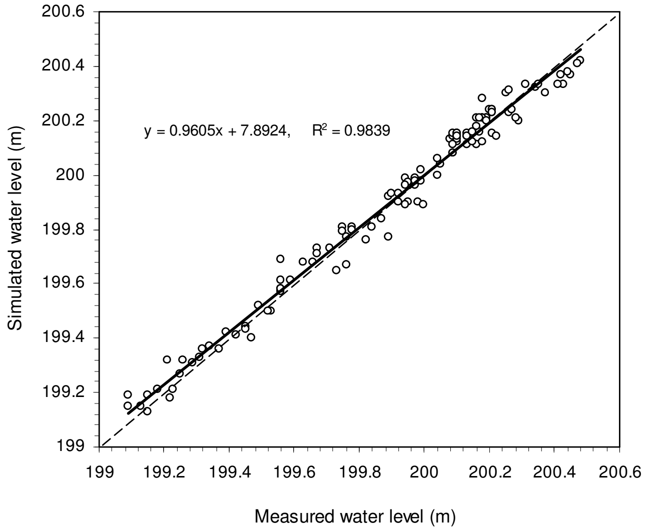

Figure 6. A comparison of measured *vs.* simulated water levels (the first 3 km of the canal).

Table 2. Controller parameters resulting from system identification.

Pool no.	1	2	3	4	5	6	7	8	9	10	11	12
K_p	-1.231	-4.123	-1.363	-0.796	-2.043	-2.385	-1.197	-0.595	-0.592	-0.861	-0.929	-0.656
K_i	-0.110	-0.618	-0.093	-0.054	-0.139	-0.163	-0.082	-0.041	-0.044	-0.129	-0.066	-0.045

deviations of discharge, water level and crest level of the check structures for the scenario 1 of DPIF and DPIFF centralized controls for pool no. 4 (at the end of the upstream pool) are shown in Figures 7 and 8, respectively. The figures clearly show that both controllers try to achieve the desired water levels as promptly as possible. It should be mentioned that desired the flow rates of offtakes can be provided when the desired water levels in the canal are sufficiently achieved. Based on operation behavior of the canal, the offtake flows undergo more changes in the latest 10 days of the simulated month.

As can be seen from the figures, the oscillations in DPIF controller are higher than those in DPIFF controller. The water level at the upstream side of check structures, for downstream FB+FF control with decouplers (Figure 8) renders a smooth change in water level. By a visual comparison of the controllers, it is apparent that the downstream FB+FF controller is more effective than the downstream FB controller.

The ability of the controllers to improve the capacity of the Water Authority to deliver its water supply service is also shown by the behavior of the performance criteria (Table 3). These values demonstrate that the controllers result in a robust control system which during the current operation of the canal could control the water level at the set-point with relatively small deviation from the desired set-point. The evaluations

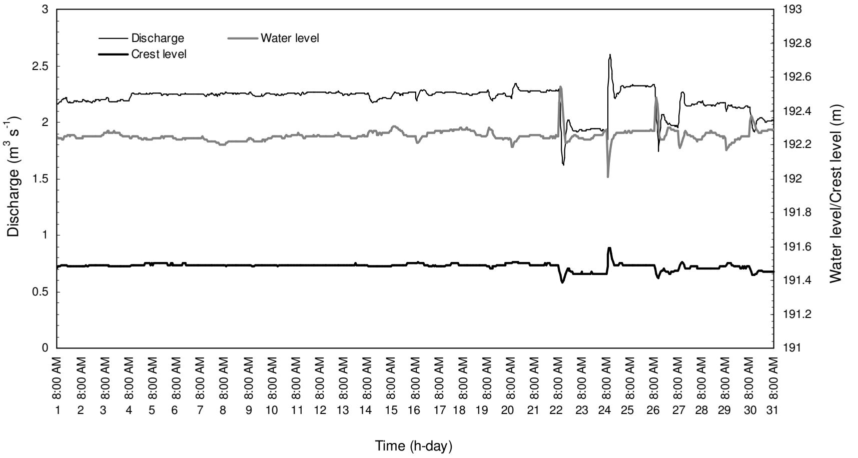

Figure 7. Discharge, water level upstream and crest level of CHAWC-3105 check structure in pool no. 4 (DPIF controller-scenario no. 1).

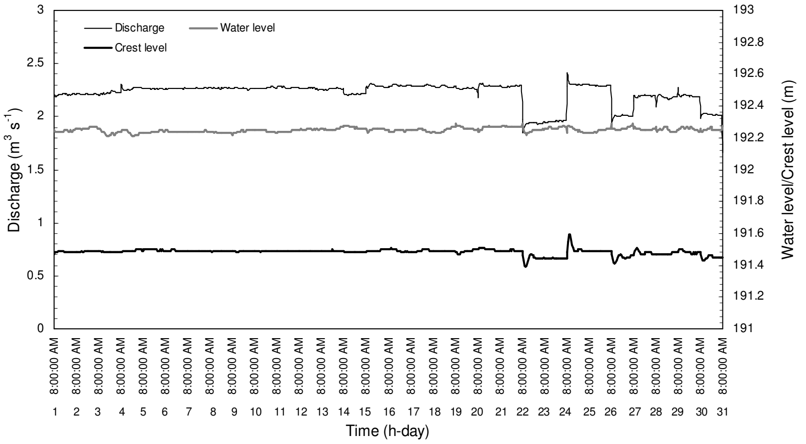

Figure 8. Discharge, water level upstream and crest level of CHAWC-3105 check structure in pool no. 4 (DPIFF controller-scenario no. 1).

Table 3. Performance indicators of the controllers for the pools (scenario no. 1).

Pool	DPIF Control				DPIFF Control			
no.	MAE (%)	IAE (%)	StE (%)	IAQ (m^3 s^{-1})	MAE (%)	IAE (%)	StE (%)	IAQ (m^3 s^{-1})
1	0.75	0.22	0.11	0.142	0.12	0.18	0.03	0.081
2	0.95	0.17	0.16	0.102	0.58	0.07	0.05	0.092
3	9.89	1.11	1.78	0.216	8.76	0.87	0.23	0.205
4	5.83	1.06	0.71	0.112	3.52	1.02	0.45	0.110
5	2.94	1.72	0.29	0.252	1.01	1.46	0.26	0.120
6	2.58	0.55	0.29	0.135	2.03	0.33	0.16	0.105
7	3.71	0.80	0.70	0.110	3.11	0.62	0.42	0.085
8	0.94	1.62	0.78	0.251	0.87	1.28	0.59	0.212
9	5.57	1.66	0.68	0.216	4.92	1.33	0.22	0.147
10	3.79	0.89	0.28	0.181	3.17	0.83	0.15	0.117
11	7.78	1.37	1.68	0.167	6.06	1.11	0.74	0.109
12	12.84	1.99	3.44	0.273	10.93	1.54	1.10	0.216

indicate that both controllers present effective control methods for West canal of AID. The average values of MAE, IAE, StE and IAQ for DPIFF controller are obtained 3.75%, 0.88%, 0.36 and 0.13 m^3 s^{-1}, respectively, while these indicators for DPIF controller are 4.78%, 1.10%, 0.91% and 0.18 m^3 s^{-1}, respectively. The index StE is computed for the latest remaining 2 hours of simulation for each pool. This index presents the ability of controllers to bring the controlled variables back to set-point fast and without any constant overshooting. The values of indicators show that both controllers could bring the water level to the set-point.

However, significantly greater oscillations occur for pool no. 12. For this pool, the values of MAE, IAE, StE and IAQ for both control methods are at a maximum. The values of MAE, IAE, StE and IAQ for DPIF controller are 12.84%, 1.99%, 3.44% and 0.27 m^3 s^{-1}, respectively. The indicators for DPIFF controller are 10.93%, 1.54%, 1.10% and 0.21 m^3 s^{-1}, respectively. This pool has the smallest delay time value of all the pools. Because of the smaller length of the pool, reflecting waves (resonance effects) may have a dominant influence on the hydrodynamics.

The simulation results of scenario 2 for four check structures (CHAWC-1380 at the end of the upstream pool no. 2, CHAWC-4650 at the end of the upstream pool no. 4, CHAWC-6500 at the end of the upstream pool no. 6, and CHAWC-7955 at the end of the upstream pool. no. 8) are presented in Figures 9 and 10. The results of discharge deviations (Figures 9-a and 10-a), and the offtake flow change schedule (Figure 5) are similar. The comparisons show that the oscillations in DPIF controller are higher than those in DPIFF controller. As is visible, the deviations resulting from upward and downward steps are the same. Figures 9-b and 10-b show the water-level changes at the end of the pools for the mentioned tests. Both the desired flow rates and water levels are quickly achieved under the modes of operation. From the simulation results, it can be seen that the desired flow conditions are achieved within 86 and 118 minutes of changing flow rates according to the schedule for DPIFF and DPIF controllers, respectively. However, it is noticeable that the controllers can quickly bring the water level back to the set-point, with the water-level fluctuations at the end of the upstream pool quickly damped.

Table 4 presents the computed performance indicators for the controllers in this scenario. The average performance indicators MAE, IAE, StE and IAQ are calculated for each pool for a 6-day simulation period. For all the indicators, the average value is reported. However, significantly greater oscillations occur for pool no. 12. For this pool, the maximum values of MAE, IAE, and IAQ for DPIF centralized controller are 21.24%, 0.24%, 1.07% and 0.10 m^3 s^{-1}, respectively. Also, values of the criteria for DPIFF centralized

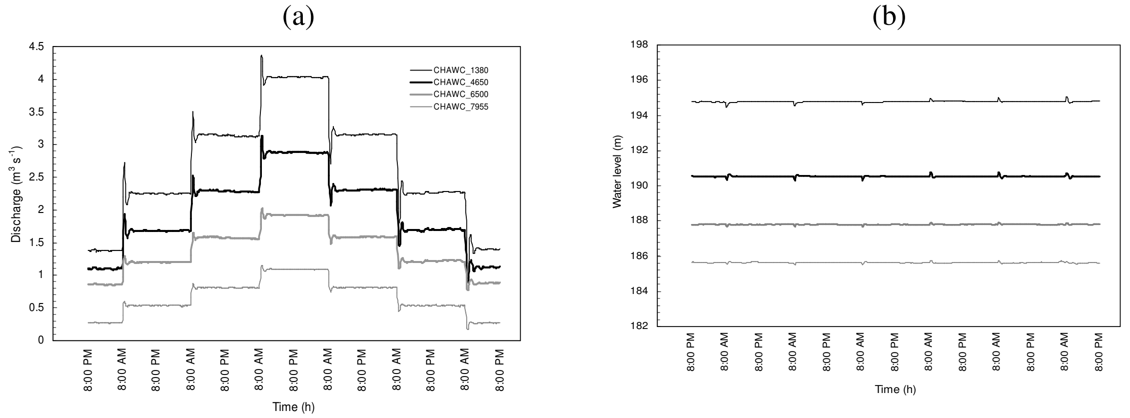

Figure 9. Discharge and water level upstream deviations of check structures (DPIF controller-scenario no. 2).

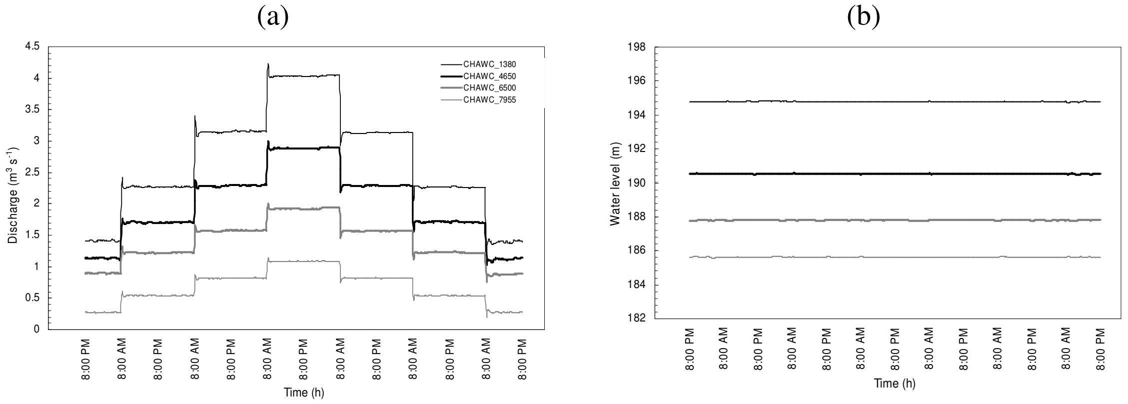

Figure 10. Discharge and water level upstream deviations of check structures (DPIFF controller-scenario no. 2).

Table 4. Performance indicators of the controllers for the pools (scenario no. 2).

Pool	DPIF Control				DPIFF Control			
no.	MAE (%)	IAE (%)	StE (%)	IAQ ($m^3 s^{-1}$)	MAE (%)	IAE (%)	StE (%)	IAQ ($m^3 s^{-1}$)
1	1.97	0.03	0.57	0.215	1.14	0.03	0.41	0.182
2	8.26	0.03	0.45	0.239	1.28	0.02	0.42	0.174
3	17.82	0.19	0.88	0.360	9.03	0.11	0.61	0.230
4	13.97	0.20	2.20	0.127	11.03	0.13	0.63	0.089
5	18.71	0.12	2.46	0.354	5.03	0.07	0.40	0.294
6	11.77	0.10	3.80	0.331	2.44	0.05	0.18	0.124
7	12.98	0.13	1.30	0.263	4.03	0.09	1.04	0.083
8	15.03	0.20	2.56	0.178	11.19	0.16	2.45	0.129
9	14.84	0.21	1.31	0.081	7.41	0.14	0.71	0.080
10	12.83	0.12	1.97	0.113	6.23	0.10	0.62	0.101
11	14.29	0.19	0.05	0.029	11.94	0.15	0.01	0.004
12	21.24	0.24	1.07	0.104	19.31	0.22	0.87	0.033

controller are obtained as: 19.31%, 0.22%, 0.87% and 0.03 $m^3 s^{-1}$, respectively.

Discharge deviation of DPIF controller, compared with DPIFF controller within the check structures is computed. As an example, the results during 21 days of the simulation period, in scenario 1 (day of 8th to 28th), are presented for three check structures of CHAWC-3105 (at the end of the upstream pool no. 3), CHAWC-4650, and

CHAWC-5700 (at the end of the upstream pool no. 5) in Figure 11. The results demonstrate that the variations range from -0.25 to +0.33 $m^3 s^{-1}$. The deviation of the check structures' discharge is affected by the offtake discharge schedule. The value of this parameter is arisen after day 21st, because of the changes in offtakes' capacity. The average values of the parameters during this period are obtained as -0.051, -0.054, and -0.064 $m^3 s^{-1}$ for the gates of CHAWC-3105, CHAWC-4650, and CHAWC-5700, respectively. This means that the underestimation figures of DPIF controller as compared with DPIFF controller are 2.5, 3.2, and 4.1% of the routine discharge for the gates of CHAWC-3105, CHAWC-4650, and CHAWC-5700, respectively.

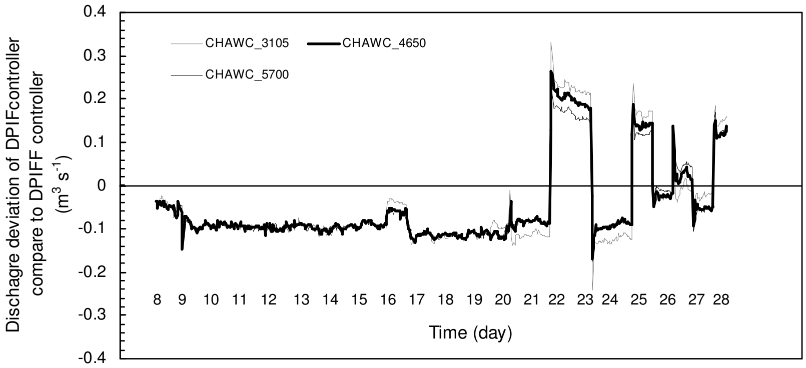

Figure 11. Discharge deviation of the controllers within three check structures.

CONCLUSIONS

Two centralized downstream PI controllers for on-demand operation of West canal of Aghili Irrigation District are proposed. The algorithms (downstream PI feedback control with decouplers, and downstream PI feedback+feedforward control with decouplers) are programmed in MATLAB and connected to the SOBEK canal flow module through the SOBEK real time control module. The results of the design and tuning of these controllers show that either of the proposed controllers benefit from significant potentials to closely match the discharge at the downstream check structures with those ordered by water users, while maintaining the water level throughout the length of the canal. The proposed controllers can provide timely deliveries to local farmers with little wastage of water under predicted as well as unknown demands (perturbations). It becomes apparent that DPIFF controller is more effective than DPIF in providing a desirable performance. A comparison of the performance indicators shows that the DPIFF as a centralized control is a satisfactory controller for the canal, but it may be recommended to implement this controller, as the main control system, with a local controller as a backup system.

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کنترل کننده های مرکزی از پایین دست PI برای کانال غربی منطقه آبیاری عقیلی

ع. منتظر و س. عیسی پور

چکیده

نظر به محدودیت منابع آب تجدید شونده، بهره برداری مطلوب از شبکه های آبیاری ضروری می نماید. بکارگیری سیستم های کنترل یکی از مهمترین شیوه های دستیابی به این مهم می باشد. در این تحقیق دو کنترل گرمرکزی برای کانال غربی شبکه آبیاری عقیلی در ایران مورد بررسی قرار می گیرند. الگوریتم های کنترل شامل کنترل‌کننده سراسری پایین‌دست فاصله‌دار با تکنیک تناسبی-انتگرالی پس‌خورد و دی‌کوپلینگ (DPIF) و کنترل‌کننده سراسری پایین‌دست فاصله‌دار با تکنیک تناسبی- انتگرالی پس‌خورد + پیش‌خورد و دی‌کوپلینگ (DPIFF) می باشند. در هر یک از کنترل گرها، عملیات تنظیم آب هر سازه تنظیم بر اساس وضعیت سطوح آب کلیه بازه های کانال انجام می گیرد. مدل سازی و شبیه سازی گزینه های بهره برداری کانال با استفاده از مدل سوبک صورت گرفته و کنترل گرها با استفاده از نتایج این شبیه سازیها مورد ارزیابی قرار گرفتند. نتایج نشان می دهد که هر دو الگوریتم کنترل از پتانسیل قابل ملاحظه ای در تنظیم شدت جریان سازه ها بر اساس نیاز بهره برداران و کنترل سطح آب در سرتاسر کانال آبیاری برخوردار می باشند. در این رابطه عملکرد کنترل گرDPIFF نسبت به کنترل گر DPIFمطلوب تر است. کاربرد الگوریتم های کنترل مورد مطالعه امکان تحقّق توزیع آب تقاضامدار و ارتقاء عملکرد بهره برداری سیستم را فراهم می نماید. به منظور دستیابی به یک سیستم کنترل هوشمند کارا در کانال، اجرای تلفیقی کنترل گرDPIFF به عنوان سیستم کنترل اصلی و یک کنترل گر موضعی به عنوان سیستم کنترل پشتیبانی پیشنهاد می گردد.

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