



MAJALGAON DYNAMIC REGULATION PILOT PROJECT : A UNIFORM APPROACH TO CANAL MODERNISATION

Mr. R. G. KULKARNI¹

Mr. J. L. DELTOUR²

ABSTRACT

In India, research into improving water resource harnessing is a continuous process. One of the main focuses of its efforts has been on achieving better control of water consumption on surface irrigation schemes.

Under the impetus of the World Bank, the study and the implementation of new techniques no longer targets controlling scheme discharges but rather the actual volumes delivered to farmers. This requires enhanced monitoring and control of hydraulic parameters throughout the scheme networks, i.e., stored volumes, flows and levels.

A first series of full-scale experiments was successfully implemented in Maharashtra State using financial backing provided jointly by France and the World Bank. The technical options adopted for the scheme were original insofar as they associated proven techniques, certain of which are to the forefront of modern industrial technology (centralised process control), and others which are much more traditional

1 Secretary Irrigation

Irrigation Department, Mantralaya – Mumbai 400032 – INDIA

Tel.: (91) 22 202 3109

Fax.: (91) 22 283 4335

E-mail: irripoma.mumbai@gems.vsnl.net.in

2 Water Control Engineer, Société du Canal de Provence (SCP member company of GERSAR)

B.P. 100 - 13603 Aix en Provence cedex 1 - FRANCE

Tel.: (33) (0) 4 42 66 70 00 (ext. 70 53)

Fax.: (33) (0) 4 42 66 70 87

E-mail: SCP.Ingenierie@wanadoo.fr

(float gates, duckbill weirs, baffle distributors). The originality of the concept adopted resides in the fact that the entire control system for the project was designed to provide an integrated and uniform solution.

Primary results achieved by this pilot project have led the Maharashtra authorities to undertake a much larger operation (200,000 ha) on an extension zone.

Henceforth, the Majalgaon project will be an essential reference for controlling water consumption on gravity irrigation schemes.

INTRODUCTION

No system of canal control can be designed without considering the entire irrigation network on which it is to be installed.

Indeed, an open-channel irrigation network is a complex system of which the main canal is just one part. For instance, a 10,000 ha irrigated area will roughly consist of:

- 300 kilometres of tertiary canals (between 30 and 200 l/s flow),
- 100 kilometres of secondary canals (between 200 and 1000 l/s flow),
- 50 kilometres of main canal,
- 150 flow regulators,
- 300 offtakes (on secondary or tertiary canals).

To this must be added the channels which distribute the water within the irrigation units.

In practice, networks are operated globally; i.e. each supply configuration involves operation of all the regulators and field outlets. Steady flow conditions take time to stabilise (six hours in the example of a 10,000 ha network). Any change in the flow conditions must therefore be scheduled in advance and define the adjustments to be made at all the control points on the network.

Lastly, operation of the network has to overcome a series of constraints:

- Agronomic: gravity irrigation requires a minimum flow (10 to 30 l/s) at the farm turnout. Below a given area the flow can no longer be shared and has to be

replaced by intermittent rotational supply. The roster that is created allows individual supplies to the farm units so that their physical and crop differences can be taken into account, although it leads to discontinuous operation over the entire irrigation area.

- Economic and technical: in view of the scattered nature and the number of structures used to control canal discharge, total automation of the network cannot be envisaged. Consequently, operation of the latter implies a large number of manual manoeuvres by different persons. Modifications on start-up may be authorised to cope with impossible situations arising in the field.
- Hydraulic accuracy: operation of an irrigation network translates into a sequence of flow adjustments from upstream towards downstream. In fact, with transient flow conditions, these are inaccurate. This inaccuracy adds to the difficulty of controlling flows due to the slight head loss available at the structures. The result is accumulated errors from upstream to downstream with a falling probability of satisfaction.

There are other constraints that we shall mention for reference only, such as problems of social order, safety and reliability of supply, scarcity, etc.

All these reasons explain why control has to be designed globally by integrating water management from the farm turnout up to the resource. An analysis has to highlight the specific constraints which particular canals will have to deal with, and the performances that it will have to achieve.

In the absence of an overall approach, there is a high-risk of obtaining a theoretically effective control system, but which in practice is unsatisfactory and does not fundamentally improve overall network efficiency.

We will use the Majalgaon Irrigation Area Modernisation Pilot Project to describe the application of the different control techniques from design through to construction and initial monitoring of the system, including the invitations-to-tender phase. It also describes the control facilities at the different levels from the supply networks up to the main canal.

THE MAJALGAON PROJECT

General Description

The Majalgaon irrigation area is part of the Jayakwadi scheme (240,000 ha), one of the largest irrigation areas in Maharashtra state (India). The limited water resource has reduced the first stage irrigation area to 58,000 ha although it is planned to ultimately irrigate 119,000 ha.

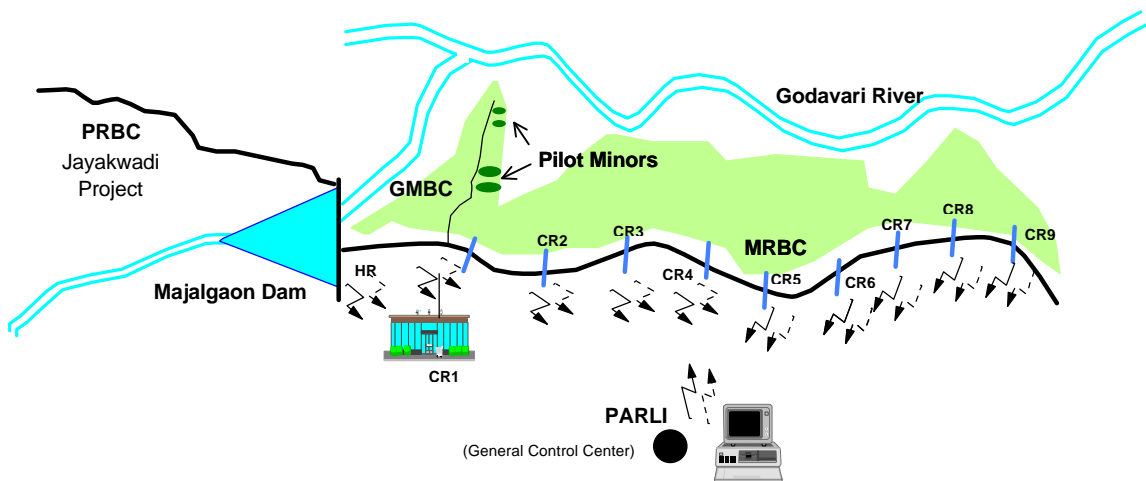


Fig. 1. Majalgaon System General Layout

The first phase of the scheme was financed by the World Bank and began in the '70s. Its main components were:

- an earth dam of 454 Mm³ capacity. This is partly supplied by water from the upstream part of Jayakwadi area,
- a main canal (Majalgaon Right Bank Canal - MRBC) with a head discharge of 83 m³/s. This canal transports water over a distance of 100 kilometres to supply more than 50 branches or secondary canals with discharges varying from 9 m³/s to less than 200 l/s. Apart from the head structure, MRBC has nine cross regulators consisting of two to three radial gates.
- networks of distribution canals, which ensure that the water is transported to the irrigation units, which vary from 5 to 40 ha.

The main and secondary canals (design discharge > 500 l/s) have been lined in order to reduce water losses.

Use of Water before Modernisation

In this region of India, rainfall is concentrated in irregular storms during July to October (monsoon). Rainfall averages 600 to 700 mm per year. The farmers are able to cultivate three crops per year:

- a main crop during the monsoon which is essentially watered by rainfall although irrigation can be required if the rains are late and during the dry periods which may occur during this season,
- a second crop from October to March (Rabbi season). This crop, which is essentially irrigation supplied, makes use of late monsoon rainfall or water stored in the ground after the monsoon,
- the final season from February to June. This hot season requires considerable water inputs, which can only be provided by irrigation.

The type of crops may be seasonal such as sorghum, sunflower or peanut, or perennial such as sugar cane.

A large part of the area is cultivated during the rains, whereas the two other seasons are used to grow more profitable crops that require investments. As a result, the crops are varied over the irrigation area due to the different economic capacities of the farmers.

The irrigation in the command area is operated under the supervision of the staff of the Irrigation Department, Govt. of Maharashtra. The traditional method was based on on/off flow: i.e. a period with canal flows close to the design flow, which is followed by a period during which the canal was closed. The irrigation units were supplied proportionally by gated structures. A lack of level control in parent canals made it difficult to adjust canal operation to farmer outlet requirement. The stream available at the unit was shared rotationally.

This type of organisation led to sudden changes in the flow conditions, which were difficult to control. The fixed facilities (i.e. structures contributing to flow control but without possibility of adjustment, such as calibrated orifices) could not allow the volumes supplied to match the required volumes, since the needs were non-uniform in space due to the extent of the unit sizes and the farm practices which varied from one farmer to another.

The upshot was that the Irrigation Department decided to modernise the system.

MODERNISATION PROJECT

Aims

In order to improve supply efficiency and to thereby have sufficient water resource available at the plot, the Government of Maharashtra decided, based on the advice of the World Bank, to improve the control method and facilities used on this area. In particular, the improvements included:

- more reliable supply of water to Water Users' Associations, i.e. an association grouping farmers covering a 200 to 600 ha area,
- summing of the volumes distributed to each Association in order to bill them based on the actual volumes consumed,
- introduction of greater flexibility and more reliability into distribution.

Such objectives can only be achieved using an appropriate control method. This is why the control project was developed as a pilot Research & Development project using French government and World Bank funding. This project covers:

- 4 secondary canals supplying 1,800 hectares. These canals are fed by the largest scheme canal (Ganga Masla Branch Canal - GMBC) and feed the unit head structures (supplying the field outlets).
- One branch (GMBC) which supplies a total of 20 secondary canals (including the four canals mentioned here above) over a length of 19 kilometres, with 8.9 m³/s head flow.
- The main canal (MRBC).

Control of the Supply Network

The four distribution canals break down into two lined canals, which supply 1500 ha and two earth canals which supply 300 ha.

The aims of each control system on these canals were defined with the Irrigation Department to ensure accurate measurement and adjustment of the flows while allowing operating flexibility. These terms can be more explicitly defined as follows :

- Flexibility: the supply canal has to be able to operate in any flow conditions which may be defined based on users needs. Modifications to the flow conditions must involve the least possible number of actual controls.
- Accuracy: the canal offtakes and field outlets have to be designed to guarantee accuracy to within 5%. This accuracy must be maintained even if the canal flow conditions change. The canal operator only controls or adjusts offtakes when the discharge required at this point has to be altered.
- Simplicity: the method of controlling the flows has to be the same at all outlets. It has to be simple and understandable by everyone to avoid disputes.
- Reliability: the adjustment must be reliable so that farmers have confidence in canal operation and operators; the Irrigation Department will then have more credibility for imposing rules.

To satisfy these constraints, sharing of water between the four sectors takes places as follows:

- Supply canals use upstream control described below:
- All the irrigation units (chacks) are supplied with the same flow of 30 l/s. Within a unit, farmers use the available flow on a rotational basis. Sharing between the different units takes place based on the supply time. One unit receives 30 l/s for a time, which is proportional to the requested volume.

All the equipment installed on the distribution networks is manufactured locally.

Upstream Control

To guarantee a flexible supply, the canals must be operated at different flows (corresponding to the users needs). The structures set up have to guarantee reliable supply even during transient flow conditions.

To do this, upstream control relies on the association of two types of equipment:

- flow control devices which are only slightly sensitive to changes in canal levels and are easy-to-use: **baffle distributors**
- level control devices which maintain water levels within a small range when the flow carried by the canal varies: long crested or duckbill weirs.

Baffle distributors guarantee that the flow is controlled within 5% even when the level in the canal varies within a range from 15 cm (for structures whose design flow is less than 100 l/s), to 1.10 meters (when the structure discharge is above 5 m³/s).

These baffle distributors are unrelated to the downstream conditions and associate three successive flow discharge conditions to keep the flow nearly constant when the level varies upstream of the structure.

The flow is adjusted by opening or closing small gates of different widths (the flow released is proportional to the width of the gate), so that the required discharge is obtained through the opening of a proper combination of gates.

Duckbill weirs are very long-crested weirs constructed downstream of flow control structures. These weirs have a V or W shape to maximise the crest length. This configuration allows them to control the water level in the canals. For example, the level can be kept within a range of 15 cm when the flow varies between nil and maximum flow by constructing weirs with one meter crest length per 100 l/s flow.

The combined use of these two facilities gives the operator total control of the adjusted and delivered flows. The irrigation schedule can be defined in advance based on the requirements of users and implemented by adjusting the control facilities at the different points of the irrigation network.

GMBC Control

The GMBC is a branch on the network. It supplies 20 secondary canals. The propagation time for a flow modification between the head and the downstream end of the branch canal is two hours.

It is small enough to allow a single team equipped with a four-wheel drive vehicle and two-way radio to operate this canal.

The upstream control principle is applied on GMBC. This makes use of baffle distributors associated with duckbill weirs to control the levels on the one hand, and flow limiters associated with spillways on the other.

The following structures have been constructed and installed on the canal :

- 7 duckbill weirs measuring 60 to 20 meters long,
- a series of 20 baffle distributors have been installed to control the flows at the head of each distribution canals,
- when necessary, baffle distributors have been associated with AVIO-type constant downstream level float gates,
- 3 flow limiters and emergency spillways have been constructed at each reduction in the canal capacity,
- the GMBC head structure has been fitted with a sequence of AVIO-type gate and baffle distributors in order to control the flow.

Most of the hydro-mechanical equipment (in particular AVIO gates, baffle distributors) has been imported from France.

Main Canal Control

Upstream control cannot be used on MRBC in view to its size: the number of users, the number of structures and the canal natural transit times prevent control based solely on forecasts of distribution without risking shortages at offtakes and excess releases at the dam.

Computerised centralised control or Dynamic Regulation has therefore been used on this canal. The structures are controlled by software installed at the General Control Centre. This associates:

- anticipation (open loop) of demand based on irrigation programmes prepared each month,

- real time adjustments (closed loop) after comparison of the volumes present in the canal with target volumes (needed to correctly supply offtakes while maintaining a safe level in the canal).

The canal, initially designed for a discharge of 83 m³/s, is in the first phase used at 40 m³/s. This results in over-capacity of the canal in volume. This surplus capacity enables the control system to cope with significant differences between the scheduled adjustments and the actual off-taking. The additional volume required is initially taken from the water stored in the canal before the control system adjusts the settings to meet actual needs. The same applies to the opposite situation, when the storage capacity is used for storing excess volumes of water.

The importance of these additional storage volumes have authorised longer duration between successive adjustments. The system can then operate automatically or manually (manual operation of gates) depending on the status (technical availability) of the equipment.

The architecture of the remote control system comprises the following:

At regulators (10):

- measurement sensors and signals,
- motors to operate gates,
- operation automation, operator interfaces,
- two radio systems: a radio network is used for sound communications between the centre operating staff and field staff; another radio network is used for data transmission taking place every five minutes
- electricity supply: batteries back up a low voltage supply, the MV supply of motors does not have a standby supply.

At the General Control Centre:

- all the information is displayed and processed by a computer (VAX station) which communicates with the canal through a central terminal unit
- a PC can be used to prepare irrigation schedules, this is connected to the workstation via the Ethernet network
- as on the site, the centre is linked with the site through two radio systems,
- all this equipment is emergency supplied from a generator set and an UPS (Uninterrupted Power Supply).

SYSTEM OPERATION

Organisation

Operation of the system is organised based on these three types of canal.

The personnel employed on the distribution networks and GMBC before modernisation have been kept on.

The organisation follows a cycle, which is repeated every 15 days or every month as follows:

- the requirements on each unit (chack) are defined,
- an irrigation programme providing a maximum of four operations per day at each point (morning, noon, afternoon, evening) is prepared. These operations are co-ordinated between the different points of the network,
- the irrigation programme prepared provide the base for the operation programme on the main canal,
- a water roster is set up. Each evening, canal employees may request changes to the irrigation programme for the following day,
- the water consumed by each Water User Association (WUA) is recorded ready for invoicing.

The main canal is operated and maintained at three levels:

- 3 teams on each cross regulator, each one comprising a technician and an operator working to three 8-hour shifts to monitor and if necessary operate the gates. The gates are operated automatically from the control centre every two hours, if all the equipment operates and is supplied correctly with electric power. If some fault prevents automatic operation, the operations are displayed on a local screen so that they can be executed manually.
- the control centre is operated by three engineers/operators who are present at the centre during working hours. Faults and alarms are managed through an alarm system with certain staff on call (each operator is on call one week out of every three weeks period).
- two maintenance teams deal one with electrical and electronic equipment and

the other with electromechanical equipment.

First results

The equipment was commissioned in December 1996. Since then three missions of 15 days each by three SCP engineers have been organised to assist Irrigation Department personnel taking over the entire system.

Problems have been solved at several levels, some examples of which are given below:

- The project used local expertise as far as possible. As a result, the equipment is from different origins and was not installed by the same company. Adjustments have improved the compatibility of the different parts of the system.
- The project was designed to cope with frequent electricity outages. We have also had to adapt to poor quality of power supply (frequent voltage drops to 170 V compared with 235 V announced).
- Personnel have had to be trained to operate the main canal from the centre using computers whereas operation was previously under the responsibility of an engineer working in the field.
- Maintenance teams have had to be trained in first level maintenance and repair of new equipment. Contracts with local companies are currently being prepared for more advanced maintenance.

With these problems behind them, the Irrigation Department has sufficient control of the system to start it without assistance by making a few modifications to equipment, and ensures operation thereafter of the canal during an irrigation season.

On the GMBC and the supply networks, structures have been executed by applying new construction methods to scrupulously comply with the dimensions and elevations established at the design stage. The principles behind operation of the structures were explained to the Irrigation Department personnel and to farmers.

After more than one year of operation, farmers are appreciative of the flexibility and accuracy which these new systems have brought to irrigation. They are demanding an extension of the project to neighbouring networks so that all the area can benefit from these improvements.

CONCLUSION

This case illustrates the synthesis, which needs to be developed to install an effective canal control system. Indeed, it will be necessary,

- to define the aims of the systems to be operated; these aims must take into account the theoretical needs but must be concrete and reasonable based on climatic, social, economic and technical conditions,
- to define the means to be implemented which have to be tested, adapted to the conditions of the country, and properly understood by future users,
- to ensure that the quality of work execution is sufficient not to place at risk final success of the project,
- to define the organisation to be implemented; this must take into account all the participants from the farmer to the engineer responsible for transporting water throughout the area,
- train and then monitor operation during the first period to ensure that the system installed matches local conditions and, if necessary, to correct certain imperfection.

Primary observations on the pilot project have indicated that the approach proposed can be adapted to the conditions prevailing in India. These observations have also indicated that an improved efficiency can be expected from this approach. This motivated the Irrigation Department to pursue their efforts to reorganise the irrigation area. As a result, the Irrigation Department plans to extend this method of operation to other canal on the Jayakwadi area. The second phase envisaged will confirm and

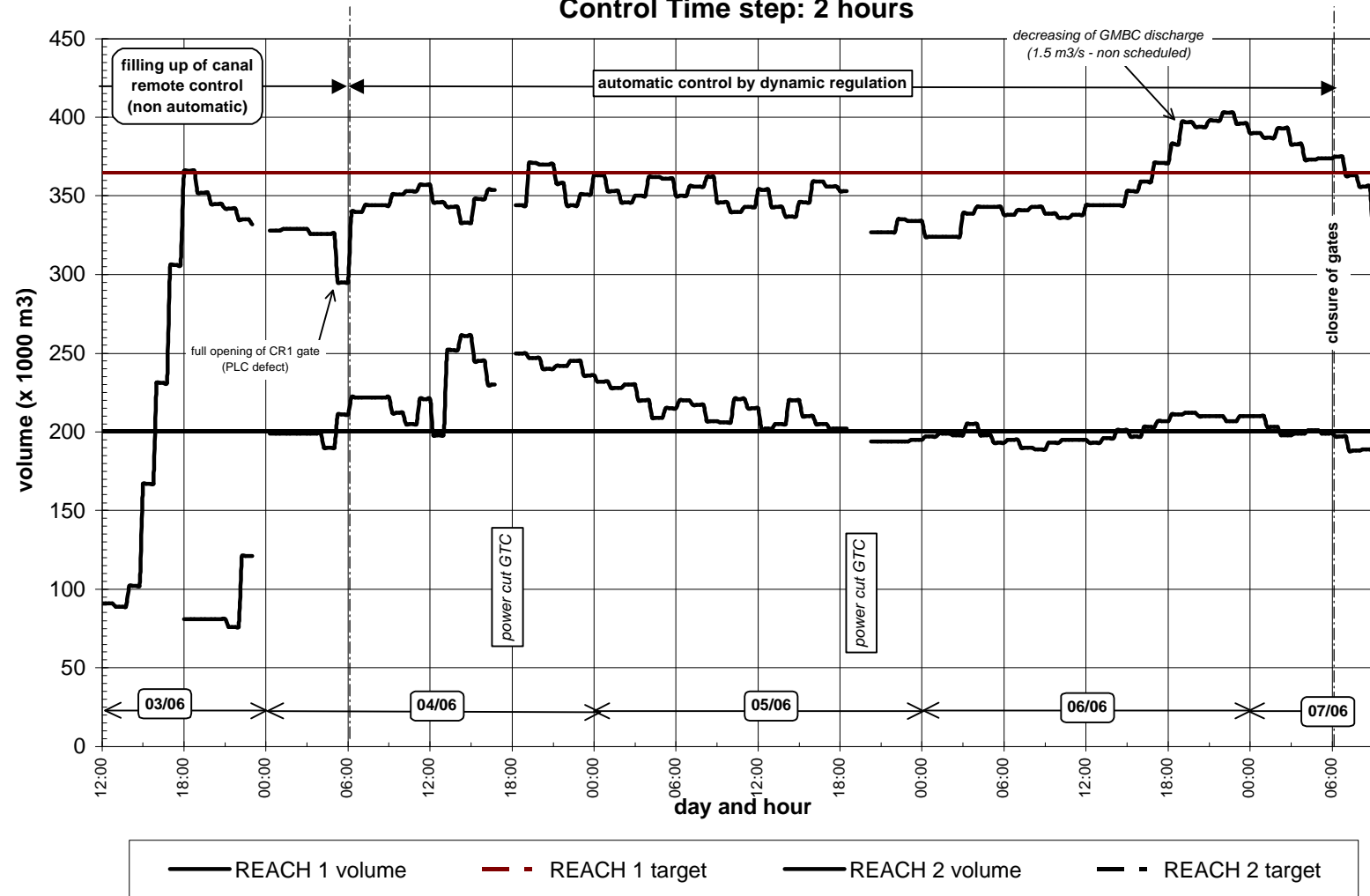
detail the organisation implemented to make best use of the improvements on the structures.

As an example, two graphics show hereafter the operation of the system during one week of June 1997. Constraints of operation as complete filling and emptying of the canal in one week, frequent power failures, mismatch between scheduled and actual demand at offtakes, appear clearly on these graphics. The system has been able to adapt itself and to supply the required demand at the Main Canal Level.

MAJALGAON RIGHT BANK CANAL - DYNAMIC REGULATION

target volume and effective volume

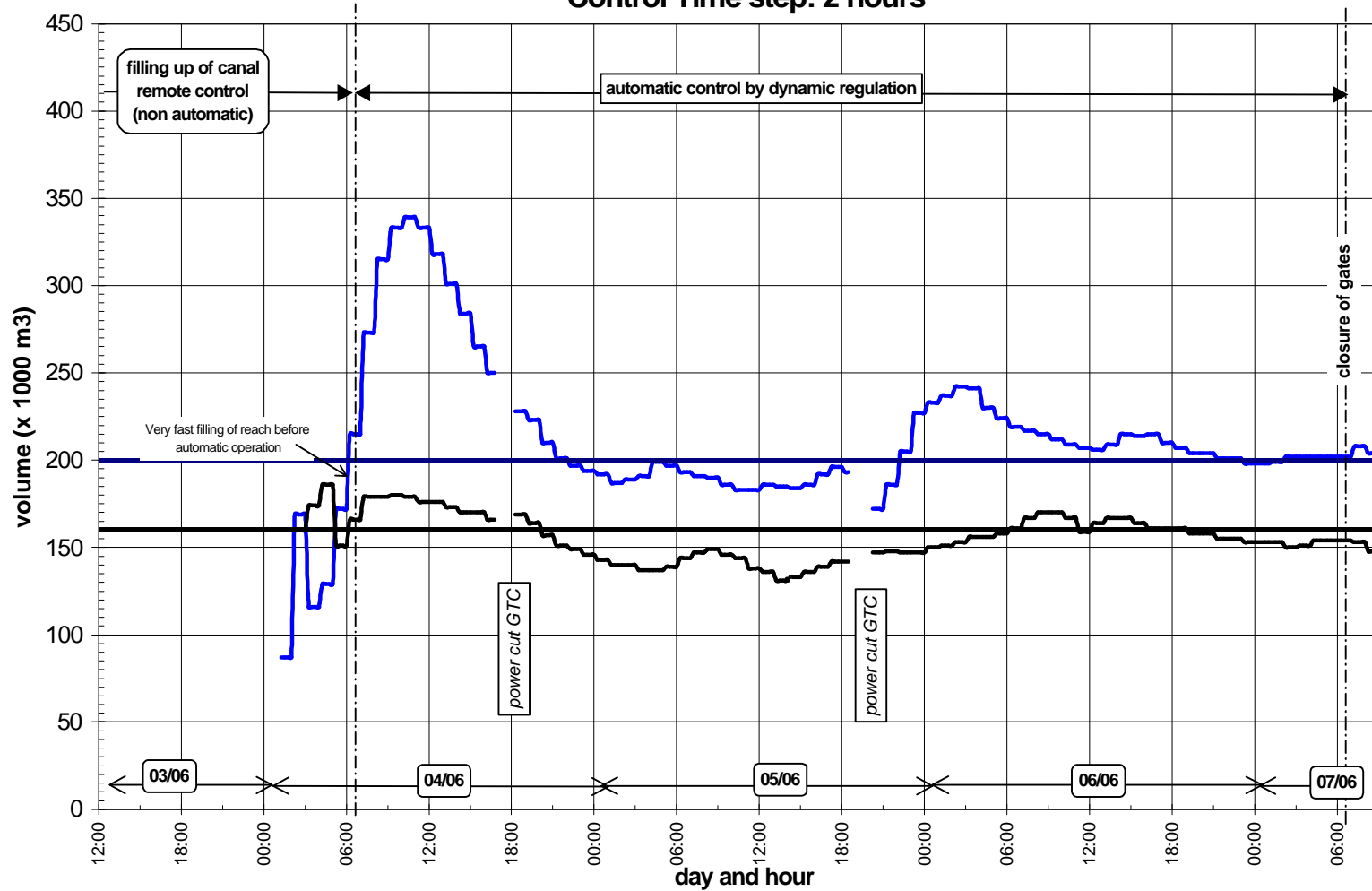
Control Time step: 2 hours



MAJALGAON RIGHT BANK CANAL - DYNAMIC REGULATION

target volume and effective volume

Control Time step: 2 hours



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— REACH 3 volume - - - REACH 3 target — REACH 4 volume - - - REACH 4 target

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