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[Information and Communication Technologies]

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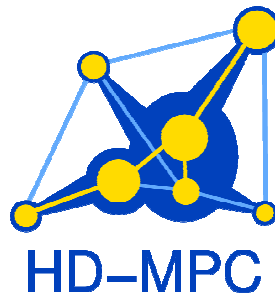
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<u>**Executive Summary**</u>

The present report describes the models developed for the hydro-power valley application.

A validation model is developed using SciCos with specific blocks solving the 1D Saint-Venant equations for the river reaches. The simulator will be used as a plant replacement or "virtual" power plant for the HD-MPC controller testing.

We also present embedded models that will be used in the MPC controllers that will be developed later on in the project.

The communication between the hydro-power valley controllers and the "virtual" power plant will be done within an OPC (OLE for Process Control) server/client architecture.

1   Introduction

Hydro-Power Valleys (HPVs) are subject to constraints on water levels and flow rates while fulfilling the requirements of the grid and the water users such as irrigation and navigation.

MPC controllers are thought to be a good approach to optimize this compromise in real time. A solution that respects the existing hierarchical control architecture is a motivation to develop a HD-MPC solution where the control consists of two layers: the lower one controlling the power and level for each plant and the upper one optimizing the behavior of the whole valley.

Testing and tuning advanced control solutions on real plants can be time consuming and expensive. The usual procedure adopted in the HD-MPC project is to develop and assess the solutions on a simulated case study given in Chapter 2. The validation model developed in SciCos is documented in Chapter 3 which presents the equations used to describe the main components, the implementation as well as the software. The open loop responses of the validation model are given in Chapter 4. Chapter 5 presents the models that will be used for the control design; one is developed in Simulink, the other in gPROMS. Chapter 6 treats the communication issue between the SciCos model and the controllers. Next, Chapter 7 gives information about the platform that will be used in the last year of the project to integrate and test the controllers for normal operations and for different perturbations on the water inflows, the power demand and the power plant production. Chapter 8 concludes the report.

2   Description of the HPV case study

The hydro-power plant is described in Figure 1. It is composed of a reservoirs' network connected to a river that itself consists of reaches separated by power plants.

Each power plant has its own local controllers and communicates remotely to the HPV control room where the operator sets the operating points (power, flow rate or level). The local controllers actuate the valves of the turbines.
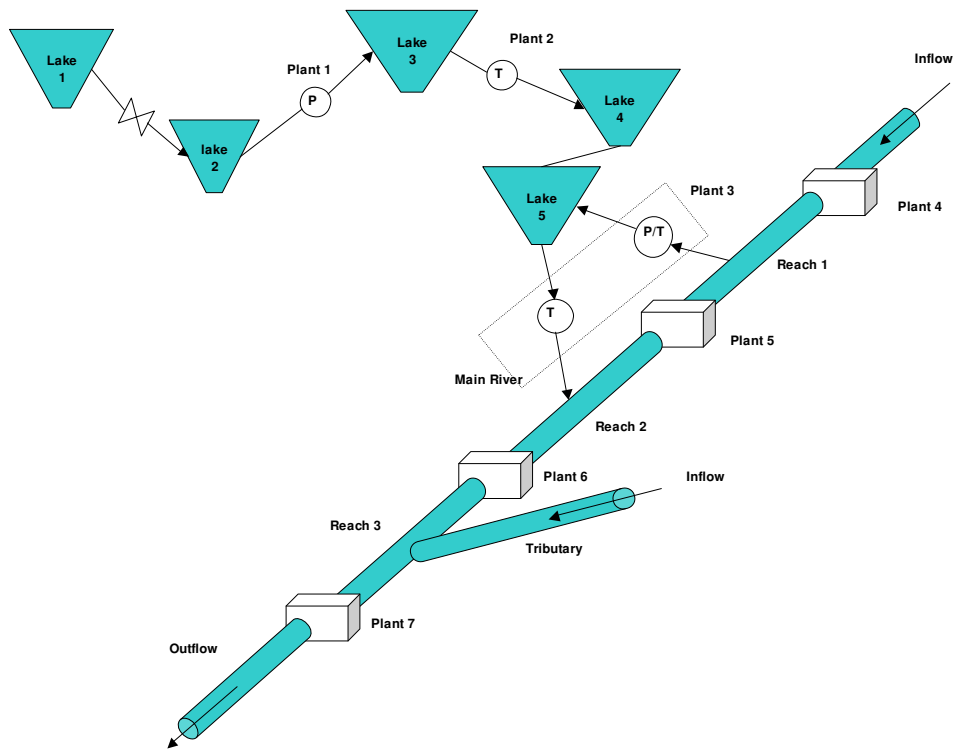
Figure 1 : Case study

3   HPV validation model

The HPV model corresponding to the case study shown in Figure 1 is developed with the tools Mascaret and SciLab/SciCos used by EdF to model hydro systems. In this paragraph the basic equations and the implementation in the tools are presented.

3.1 River reach equations (Barré Saint-Venant or shallow water equations)

The modeling software Mascaret uses a precise and detailed geometry for the river reach. The geometrical characteristics and the notations are given in the Figure 2 and in the table 1.

We consider a cross section and a flow rate across the section at each position along the river.
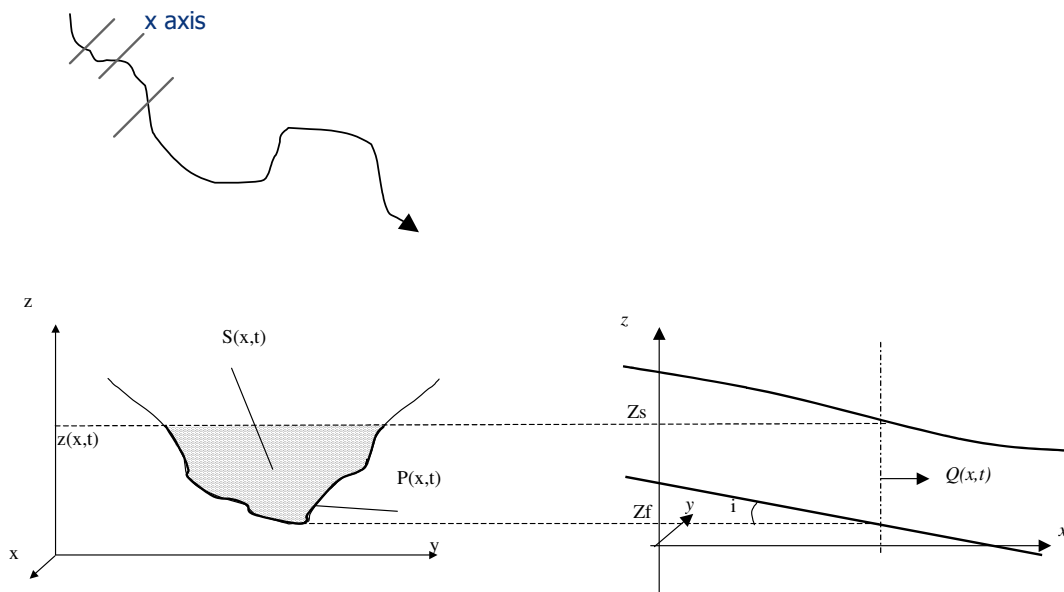

Figure 2 : River reach geometry.

x	Curvilinear abscissa	m
t	Time	s
$S(x, t)$	Wetted section	m^2
$P(x, t)$	Wetted perimeter	m
$Q(x, t)$	Volumetric flow	m^3/s
q_{lat}	Lateral inflow per unit length	m^2/s
$z(x, t)$	Level	m
K	Strickler coefficient	$m^{1/3}s^{-1}$
k	Lateral inflow coefficient	-

Table 1 : notations

To obtain a 1D model, the following assumptions are made.

- The velocity is homogeneous across the section (elimination of the y-direction).

- Each quantity U is averaged between the bottom Z_f and the free surface Z_s (elimination of the z-direction).

$$u = \frac{1}{h} \int_{z_f}^{z_s} U \, dz$$

- The fluid is incompressible.

- There is no flow through bottom and free surface.

- p = ρ.g.(Z_s-z) Only wall friction is considered, which means that the water viscosity is neglected.

The equations are derived from mass and momentum balance equation projected on the x-axis and are given in [1].

Mass Balance equation

$$\frac{\partial S}{\partial t} + \frac{\partial Q}{\partial x} = q_{lat}$$

Momentum Balance equation

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{S}\right) + gS\left(\frac{\partial z}{\partial x} + J\right) = k.q_{lat}.v$$

$$J = \frac{Q|Q|}{S^2 R_h^{4/3} K^2}$$

$$R_h = \frac{S(x,t)}{P(x,t)}$$

These equations are general and they lead to a simplified expression when we assume a specific form for the cross-section (rectangular, trapezoidal, …).

3.2 Other components (lake, penstock, turbine and pump, …)

The fast dynamics of the pumps, turbines and penstocks are not reproduced in the simulator. Thus low order and static models are considered for these components.

3.2.1 Reservoir model

The volume of water (V) stored in the reservoir is a simple mass balance equation where the water density is supposed to be constant. Q_{in} and Q_{out} is the volume rate of water inflow and outflow respectively. The water level in the reservoir (N) is related to the volume by a function (f) that depends on the geometry.

$$\frac{dV}{dt} = Q_{in} - Q_{out}$$

$$N = f(V)$$

3.2.2 Pump/Turbine

The power delivered (consumed) by a turbine (pump) is modeled by a static equation where Q is the volume rate of flow passing through the machine, ΔH is the difference of height between the water level upstream and the water level downstream. The efficiency η depends on the head and flow rate by a function h that depends on the machine. g is the acceleration of gravity.

$$P = \eta \rho g Q \Delta H$$

$$\eta = h(Q, \Delta H)$$

3.2.3   Duct between the lakes

The fast dynamics in the pipes are neglected; the pressure is hydrostatic and the flow rate is hence related to the water levels by a static equation:

$$Q = sign(\Delta H) \cdot \mu \cdot D \sqrt{|\Delta H|}$$

where H is the water level above each extremities of the pipe, D the diameter of the pipe, μ a coefficient and sign is the sign function. A valve can be modeled by a varying section D.

3.3 Case study HPV validation simulator

3.3.1   Mascaret

Mascaret is an industrial software package for simulation of one-dimensional flows that has been co-developed by EDF R&D and CETMEF (French Department of Public Works) for 30 years. It can be downloaded at http://innovation.edf.com.

Mascaret can be used to simulate

-    flow and water level,

-    cohesive sediment transport,

-    and water quality.

Mascaret is a 1D code, the flow is described as said above with one principal direction. Mascaret proposes different solvers: finite difference for unsteady sub critical flow and an implicit finites volumes scheme for trans-critical flow.

3.3.2   SciCos-Metalido

The models of the different reaches developed in Mascaret are integrated in SciCos/SciLab which is an open source software "similar" to Matlab/Simulink.

SciLab is a high level programming language. Based on this language a lot of toolboxes are proposed to the users (2-D and 3-D graphics, linear algebra, sparse matrices, polynomials and rational functions, classic and robust control, LMI optimization, differentiable and non-differentiable optimization, signal processing, a large number of contributions for various domains…)

SciCos (SciLab Connected Object Simulator) is a simulation package based on a block diagram description. A SciLab toolbox Metalido has been developed to embed the Mascaret model in a SciCos block.

3.3.3   Implementation

The hydro-power valley shown in Figure 1 is implemented in the SciCos simulation software. Figure 3 shows the block diagram at the highest level. The lakes are situated on the upper-left side while the run-of-river plants are on the right side. The turquoise blocks represent the reaches or lakes. The white blocks containing a circle, represent the turbines or the pumping station. The other blocks manage the inputs, the outputs and the communication between the reaches/lakes/turbins ("GoTo & From" – like blocks).
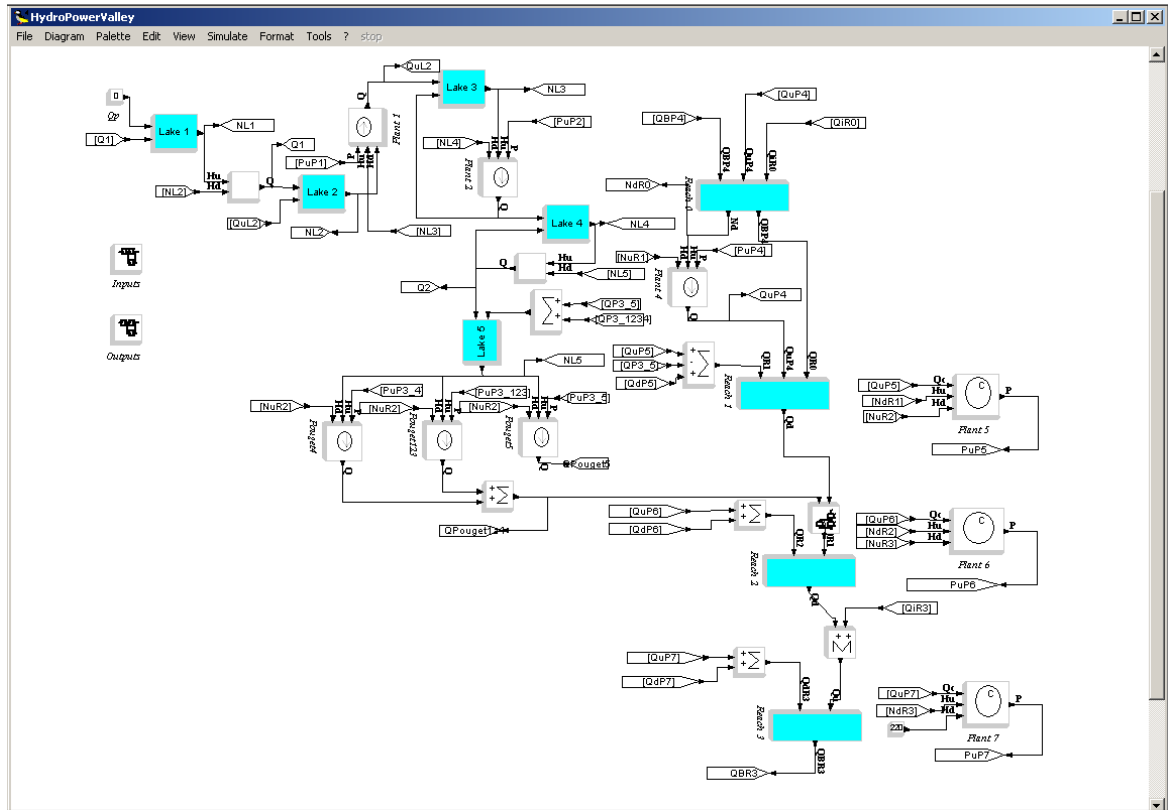
Figure 3 : Implementation in SciCos.

4 Open-loop simulation tests

In this paragraph the transients obtained with the simulator for different scenarios are presented.

The definition of the subsystems and the notations are those adopted in the HD-MPC deliverable D.7.2.1. "Report that defines the control specification for the hydro-power valley" (see Figure 1). The partition in different subsystems P1 to P9 is given in Figure 5.

We focus on the run-of-river hydro-power plants for which the dynamics are represented by Saint-Venant equations. For the other plants the dynamics are represented by simple integrators and won't be detailed.

Assumptions

- The initial river flow rate is about 200 m3/s and the flow rates of the lake networks are zero.

- The run-of-river plants (plant 5 to 7 as defined in Figure 1) follow a flow rate program: the controlled variable is the flow rate that is estimated from the power and the levels.

- Plant 1 to plant 4 (as defined in Figure 1) follow a power program: the controlled variable is the active power produced by the plant. Due to these control assumptions, coupling with upstream reaches are possible.

- The plant 3 contains two main groups, one is a turbine station, the other is a pump/turbine station.

- The excitation signal is a ramp up that starts at 300 min and lasts 10 min, followed by an hold until 600 min and a ramp down to the initial value. It will be applied on the set-points (power or flow-rate according to the controlled variable). The time response of the inner loop is neglected.
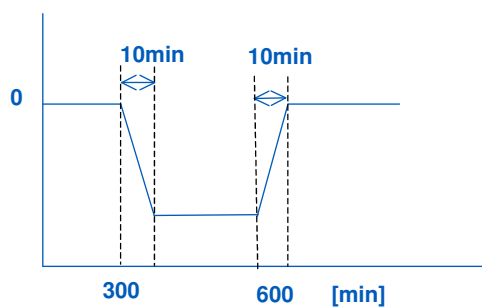

Figure 4 : excitation signal

For each subsystem, we will present the following responses:

- The levels at the entrance (nu) and the exit (nd) of the reach. In practice only the controlled levels located before the plants and corresponding to nd variables are measured.

- The power produced by the subsystem.

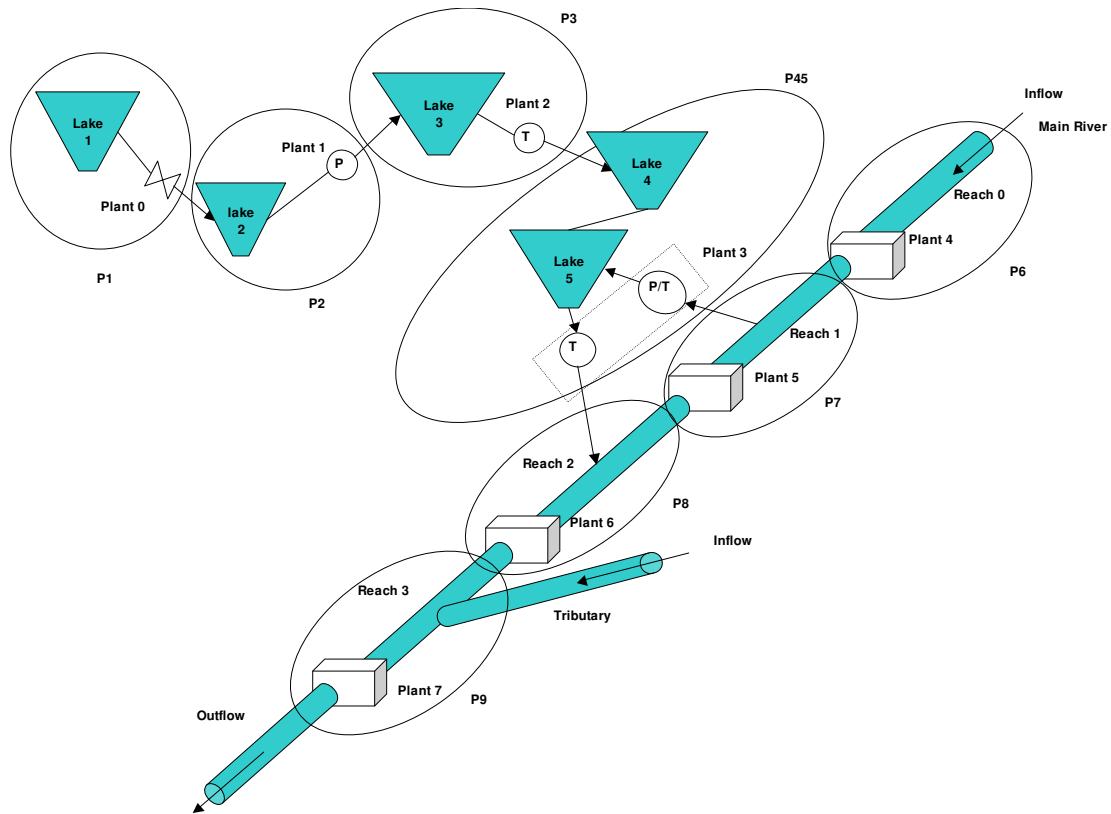- The flow rates at the entrance (qi) and the exit (qo) of the reach.

Figure 5 : Subsystem definitions

4.1 The response of the subsystem P6

The behavior of the subsystem P6 is shown in Figure 6 and Figure 7.

Figure 6 represents the response to an inflow variation. As the power is ideally controlled, no perturbations are seen on the power evolution. The level at the reach end just before the plant (nd) behaves like a delayed integrator (with a delay of 20 min), whereas the level at the reach entrance (nu) is responding like a first order. Due to the power control and the level increase, the output flow normally decreases, according to the turbine equation given in §3.2.2.

Figure 7 represents the response to a power variation of the Plant 4 (as defined in Figure 1). In that case the response of the reach end level (nd) is not delayed and the entrance level (nu) is almost not perturbed. The outflow response is due to the power control that compensates the level variations.
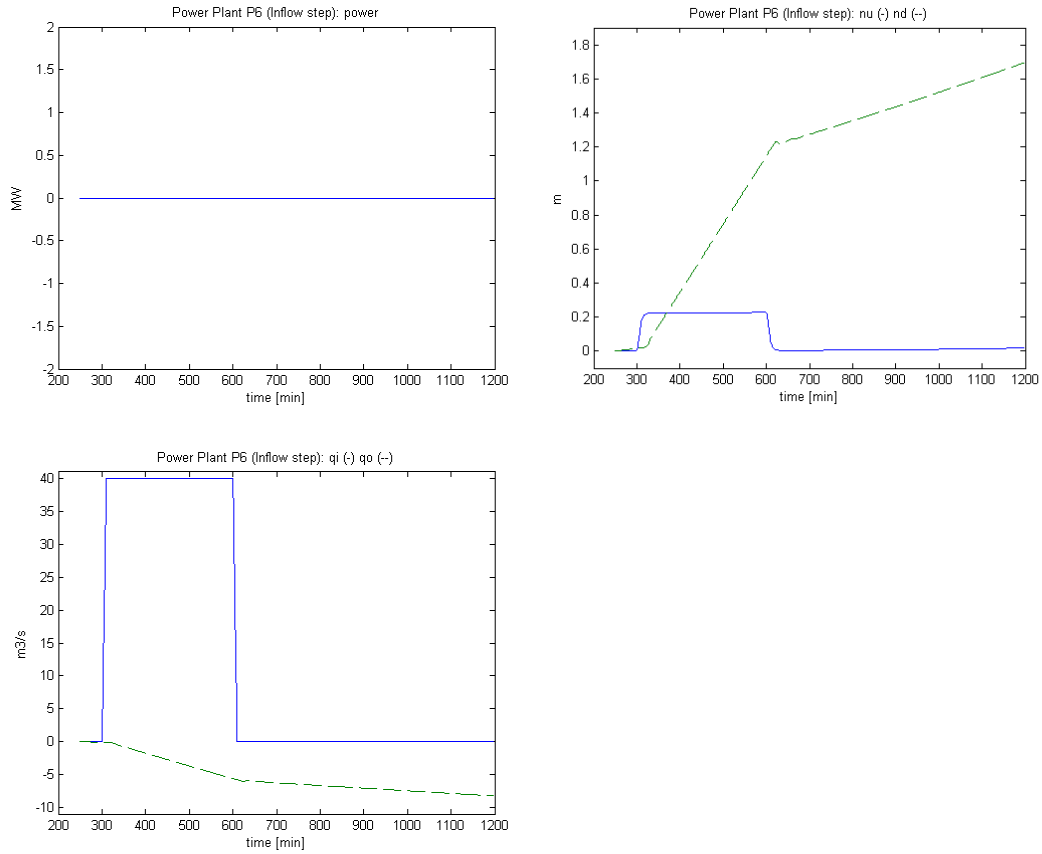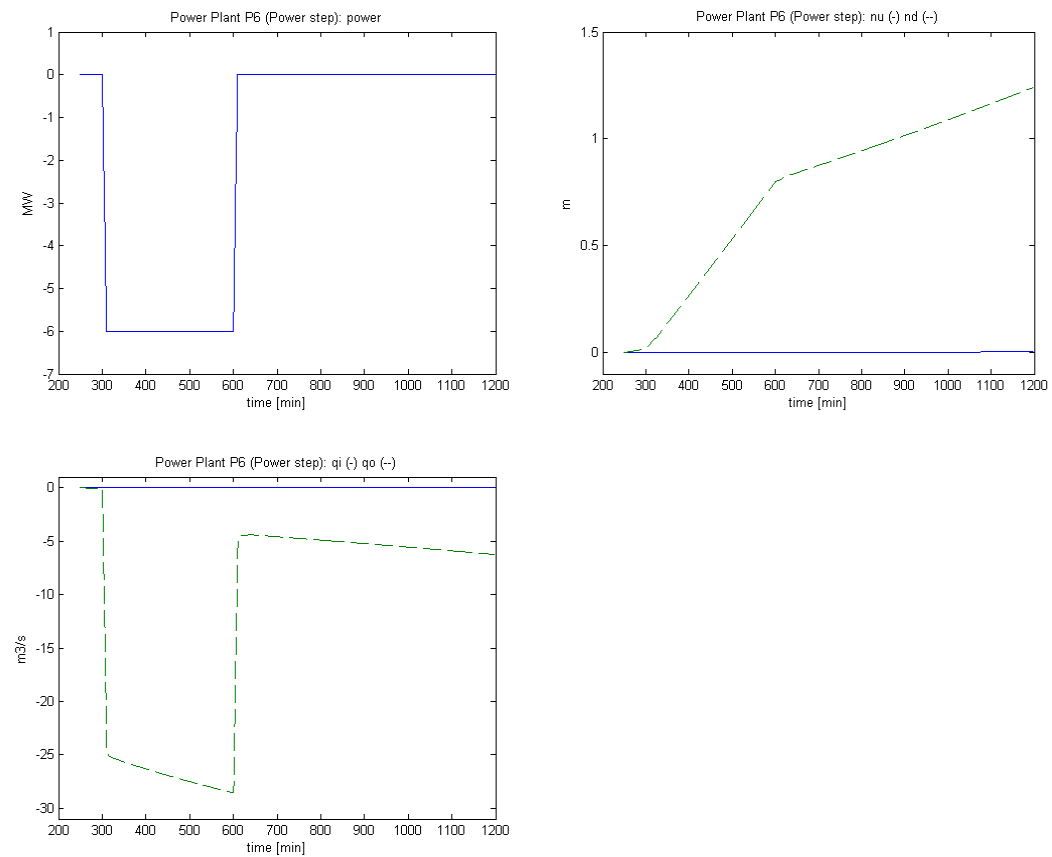
Figure 6 : Inflow variation for P6

Figure 7 : Power variation for P6

4.2 The response of the subsystem P7

The subsystem P7 responses are given in Figure 8 to Figure 12.

Figure 8 represents the effect of a bypass flow rate on the power plant of the subsystem P6 which is located upstream P7. As this upstream plant is in power control mode, the flow rate through its turbine is modified to compensate the level evolution. The total water (bypass and turbine) at the entrance is given in the last curve. The influence of this resulting inflow on the levels and power of the subsystem P7 are given by the other curves.
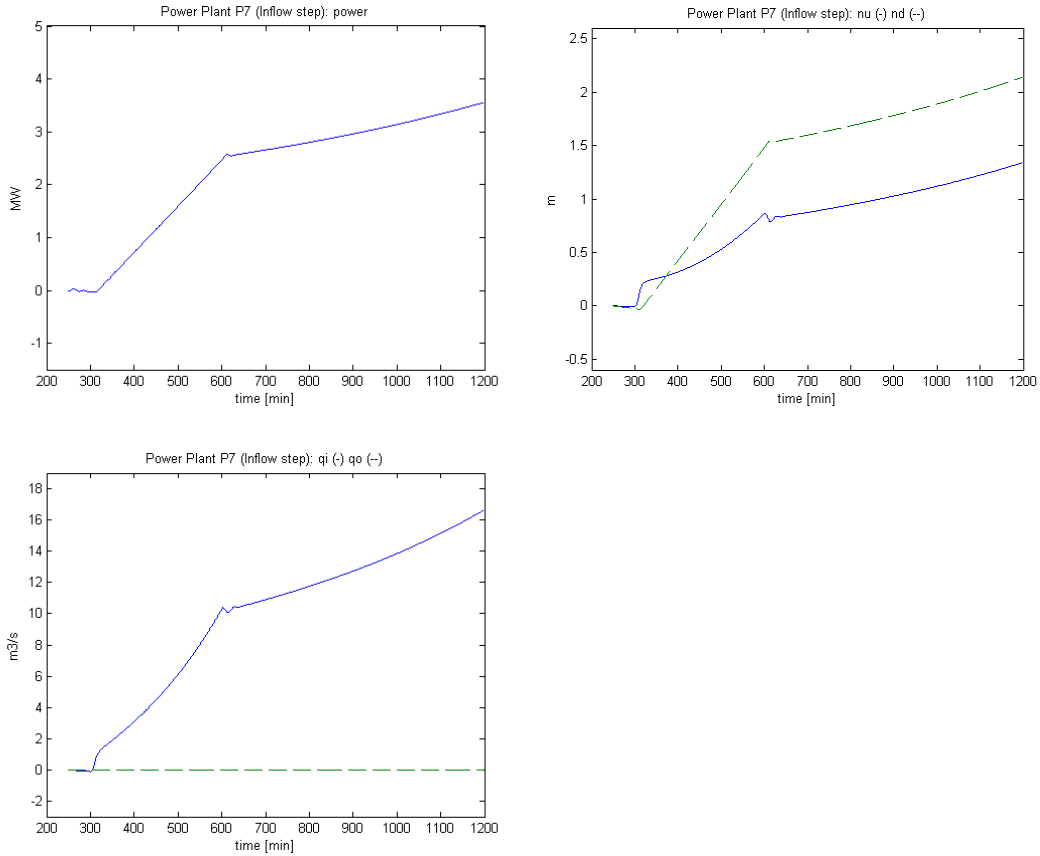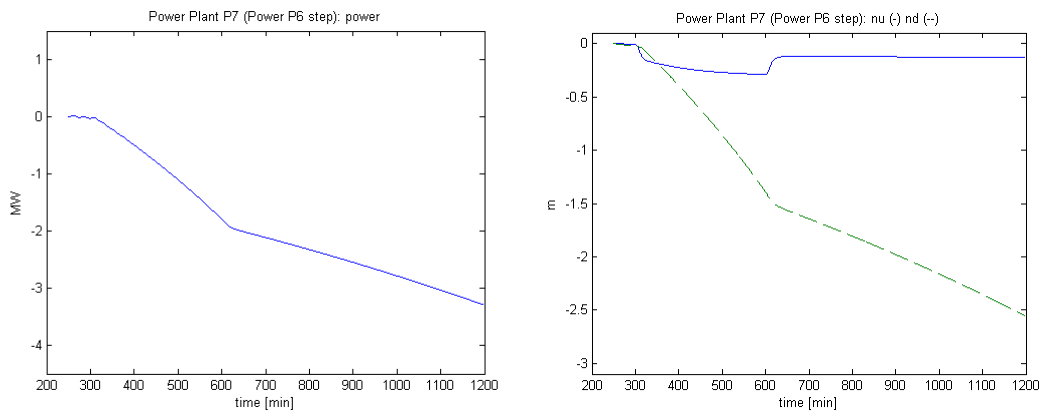

Figure 8 : subsystem P7 (inflow variations)

Figure 9 represents the effect the power variation of subsystem P6 (as in Figure 7) on the subsystem P7. For P7 the outflow is the controlled variable so the power produced by P7 decreases with the level. The level at the exit behaves again as a delayed integrator (with 10 min delay).
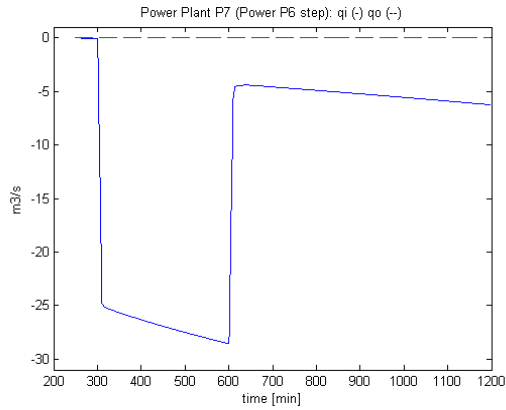
Figure 9 : subsystem P7 (variation on P6 power output)

Figure 10 represents the effect of the outflow variation on the subsystem P7. In this case the output level (nd) increases without delay, but the input level (nu) dynamics present a delay and a high order dynamic response.
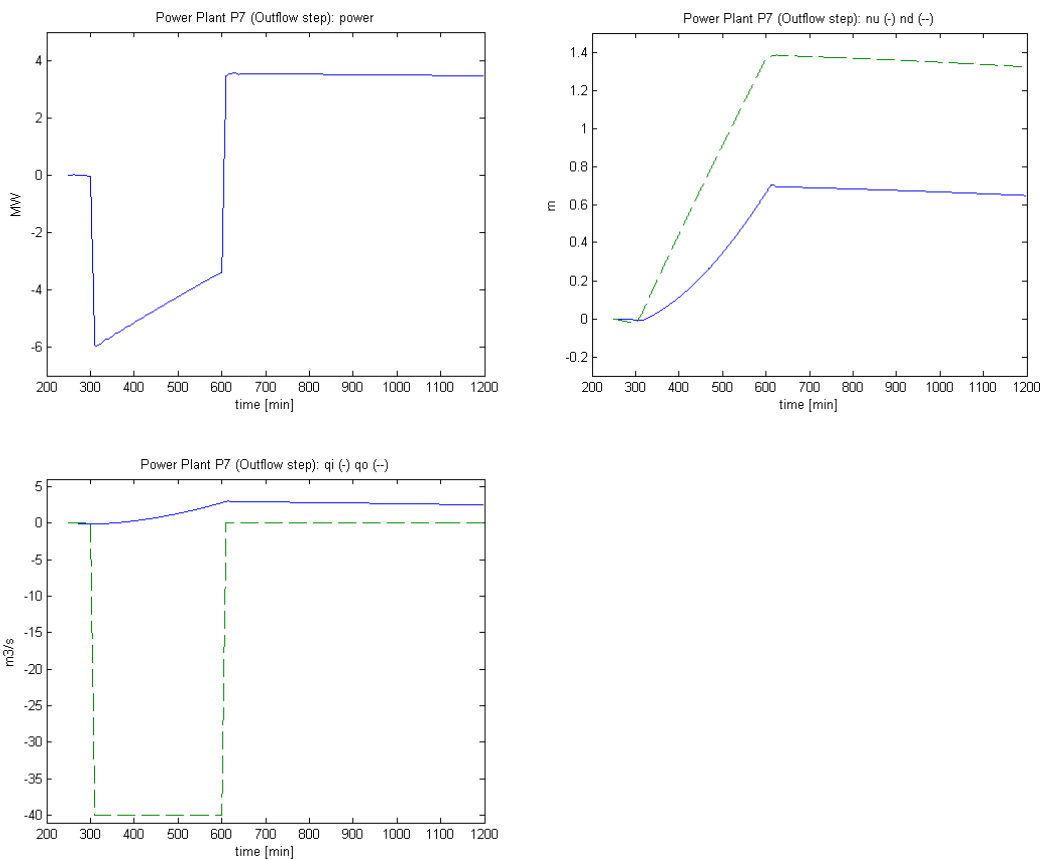

Figure 10 : subsystem P7 (outflow variation)

Figure 11 and Figure 12 give the response of the levels and of the in and outflow of the P7 reach when the pump/turbine (as defined in the plant 3 of the Figure 1) is operating.

The water pumping (Figure 11) decreases the water level at the exit of the reach (nu), and also in a smaller manner at the entrance (nd). This level variation explains the power variation and the input flow decrease due to the power control of the upstream power plant.

The water coming from the turbine (see Figure 12) makes the levels increase and has also a positive effect on the power generated by the power plant located at the end of the reach.
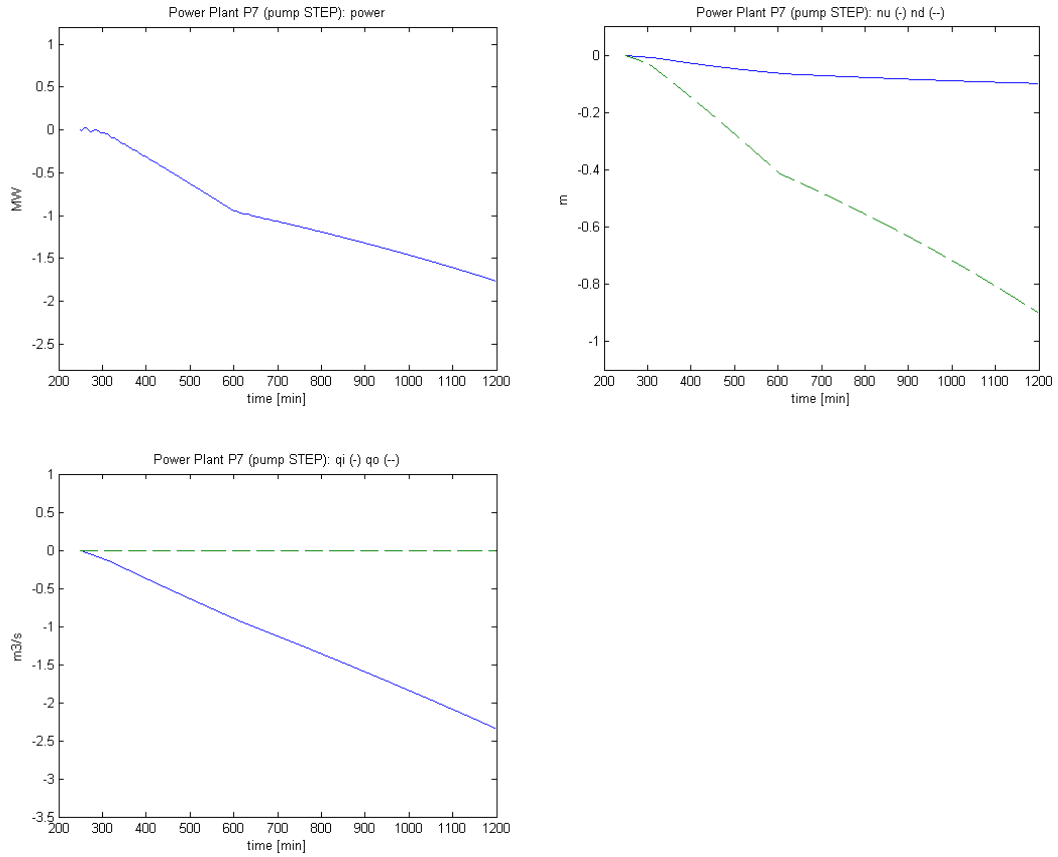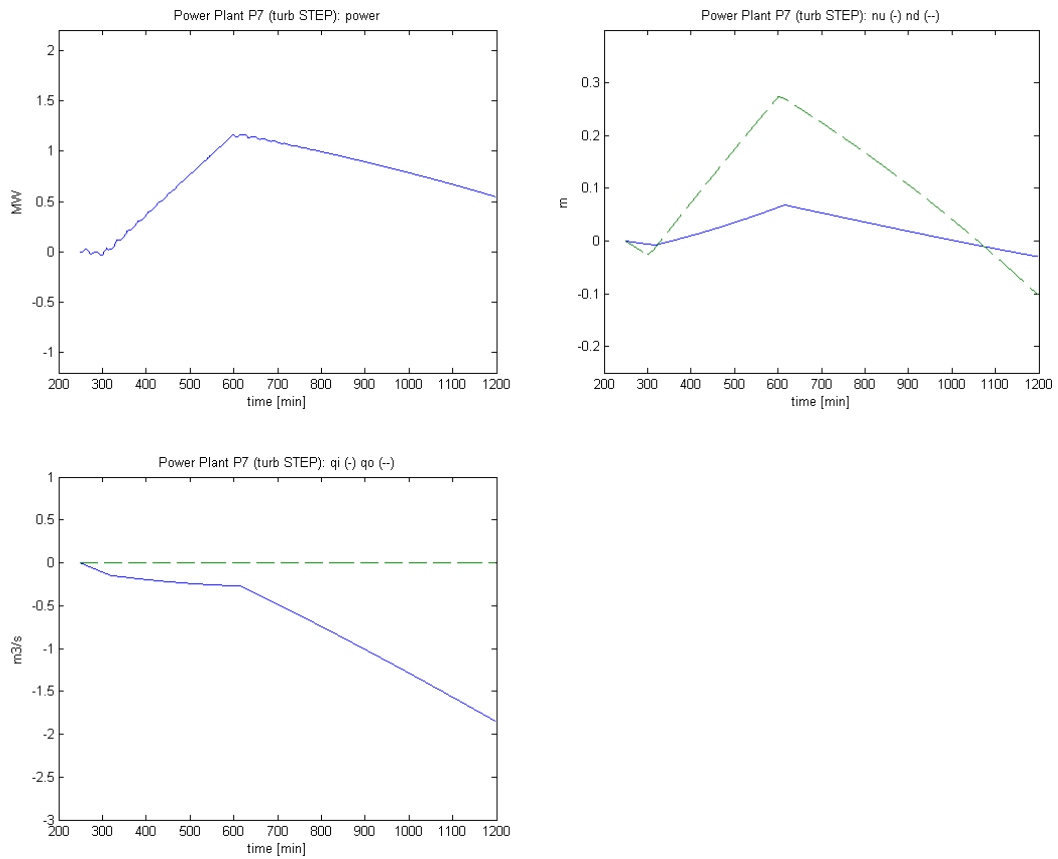
Figure 11 : subsystem P7 (pump flow variation)

Figure 12 : subsystem P7 (variation of turbine flow)

4.3 The response of the subsystem P8

The behavior of the subsystem P8 is shown in Figure 13 to Figure 15. We observe that the levels at the entrance and at the exit have the same evolution and are slightly oscillating and delayed by 10 min. The reach water profile stays flat as in a reservoir.
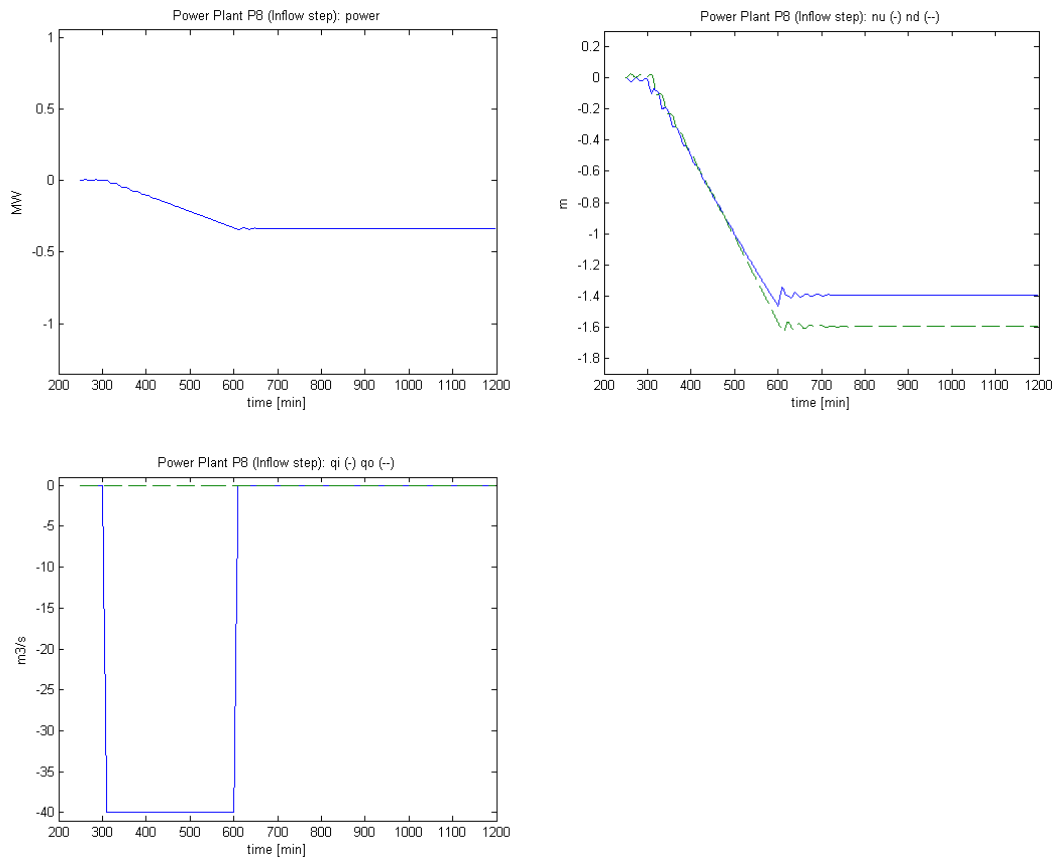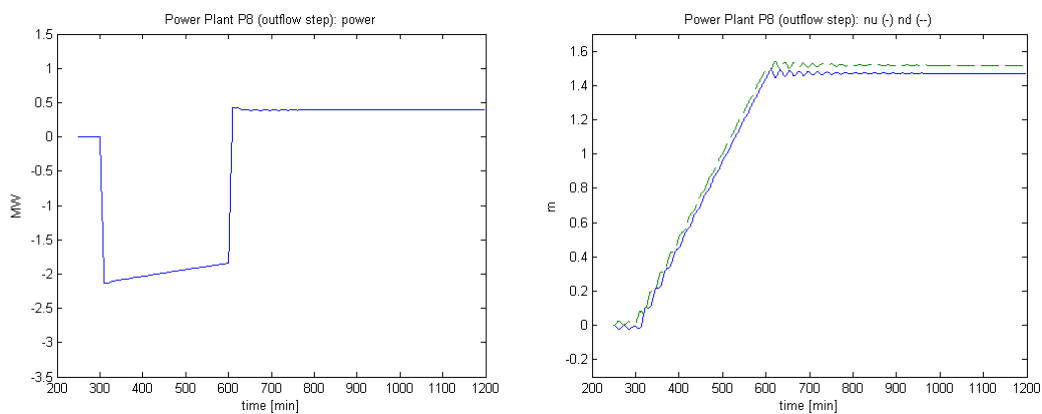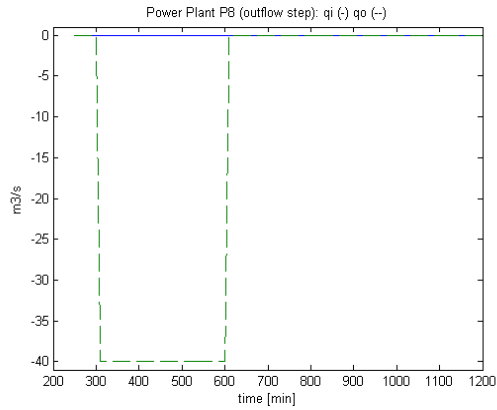

Figure 13 : subsystem P8 (inflow variation)

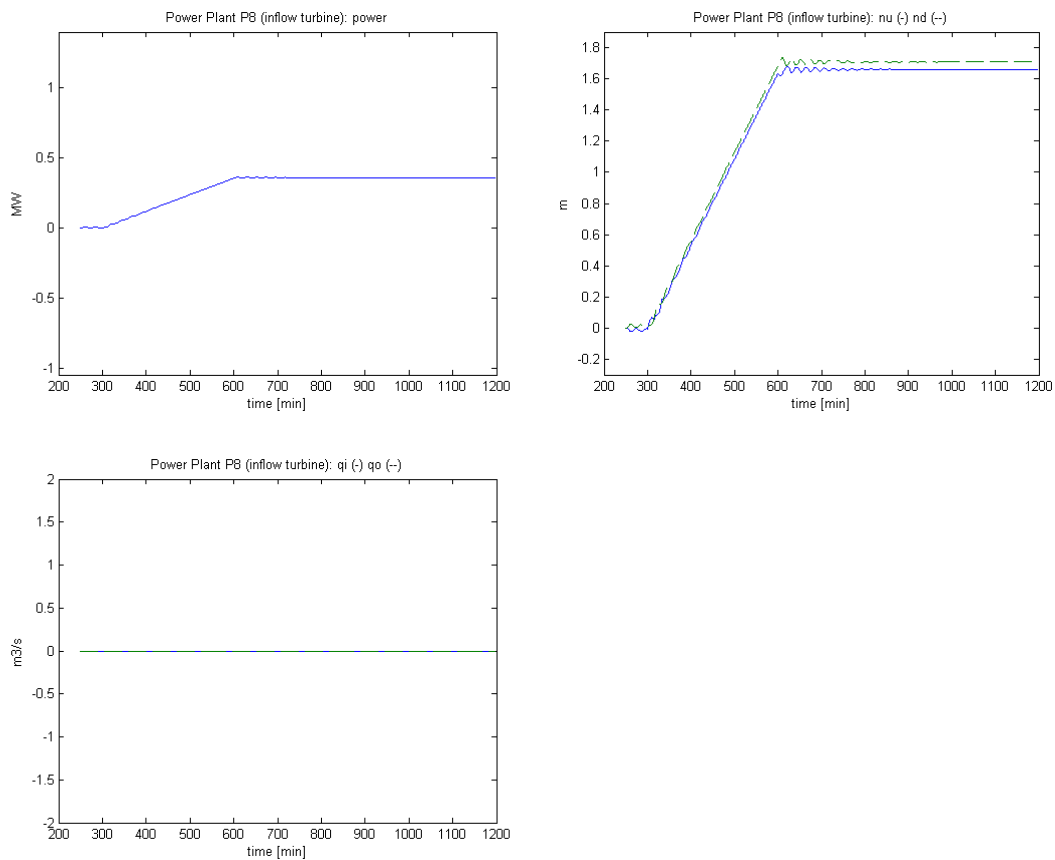Figure 14 : subsystem P8 (outflow variation)

Figure 15 : subsystem P8 (P45 turbine variation)

4.4 The response of the subsystem P9

The next figures (Figure 16 and Figure 17) are related to the last reach. Inflow and outflow variations influence both entrance and exit level. The latter is a delayed integrator.
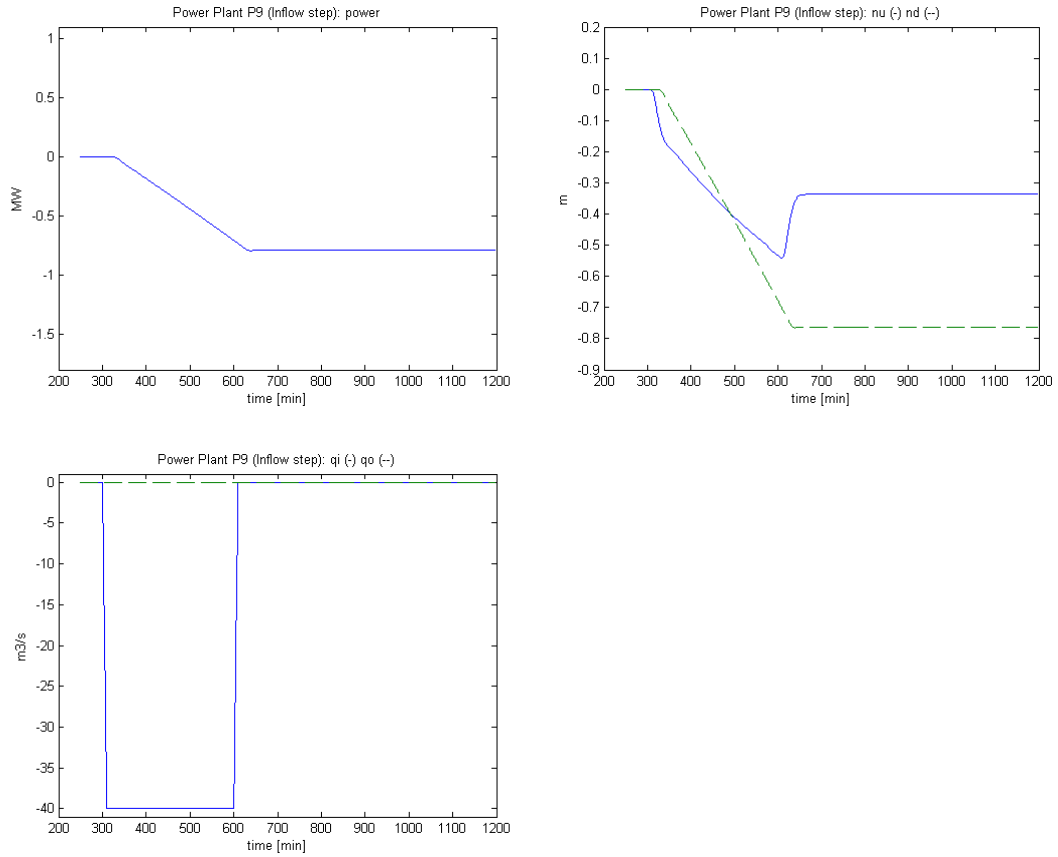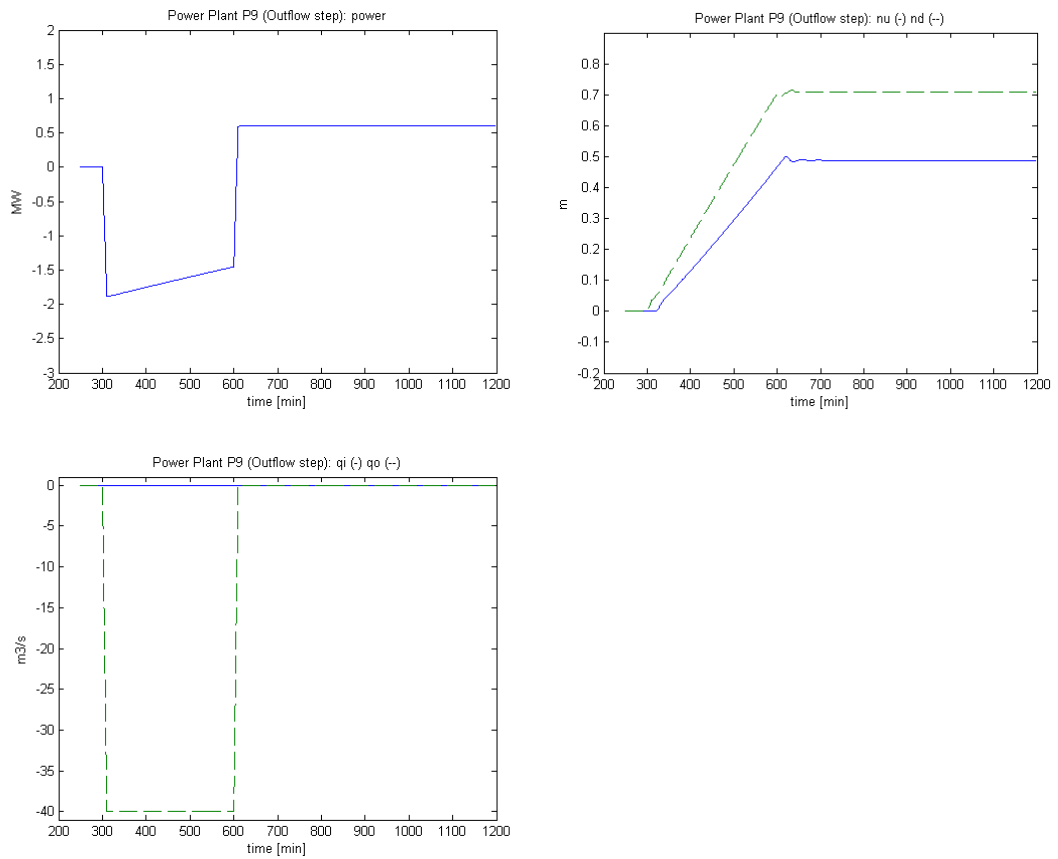
Figure 16 : inflow variation for subsystem P9

Figure 17 : outflow variation for subsystem P9

5   Models for control

The SciCos model presented in the previous chapters can be used for simulation but it is to complex to be integrated in a MPC controller. In this paragraph we present models developed within the HD-MPC project that can be used for control. They are developed within Simulink, ACADO, and gPROMS.

5.1 Simulink model

In order to use a simpler model for a MPC control, a Simulink model is developed and tuned on the SciCos one.

5.1.1   Description of the Simulink model

The full model is composed by interconnecting the 9 subsystems presented in Figure 5, each one is described by its appropriate set of equations.

Subsystems containing lakes simply implement the mass conservation equation, where the section A is supposed to be constant:

$$\frac{dL}{dt} = \frac{q_{in} - q_{out}}{A}$$

Subsystems containing reaches implement a set of equations grown out from a spatial discretization of the Saint-Venant equations, where spatial derivatives are replaced by finite differences. The simplifying hypothesis of a rectangular river section is assumed, so the state variables are the flow rate Q_i and the level H_i at each spatial discretization step i.

In order to avoid stiffness in the simulation and to correctly describe the physics of the system, the spatial discretization steps of the two variables are overlapped, so that each height H_i depends on the previous and forward discharges Q_{i-1}, Q_{i+1}, and vice versa.

Following this principle, the reach discretization scheme and the finite difference approximation equations are reported below:

$$\frac{\partial H_i}{\partial x} \cong \frac{(H_{i+1} - H_i)}{dx} \qquad\qquad \frac{\partial Q_i}{\partial x} \cong \frac{(Q_i - Q_{i-1})}{dx}$$
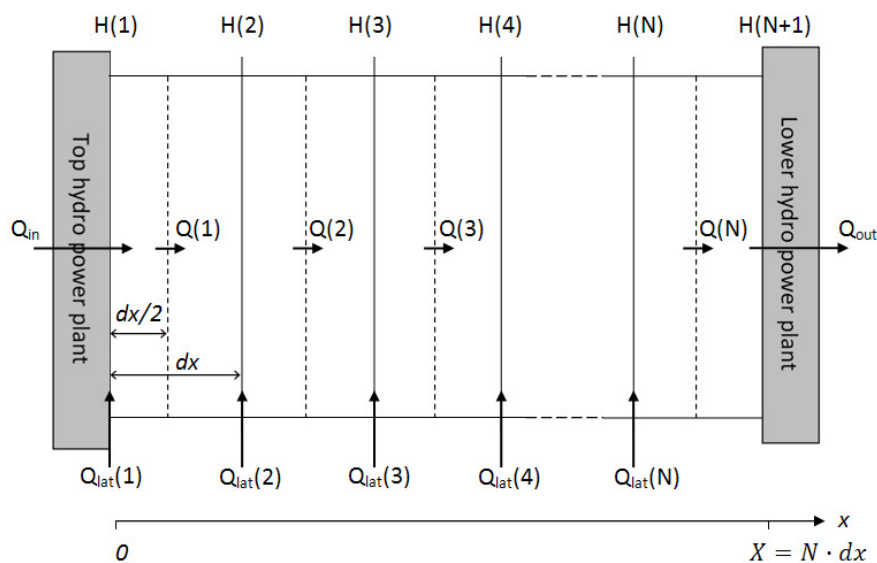

Figure 18 : spatial discretization

The full Simulink nonlinear model obtained in this way is shown in the figure below :
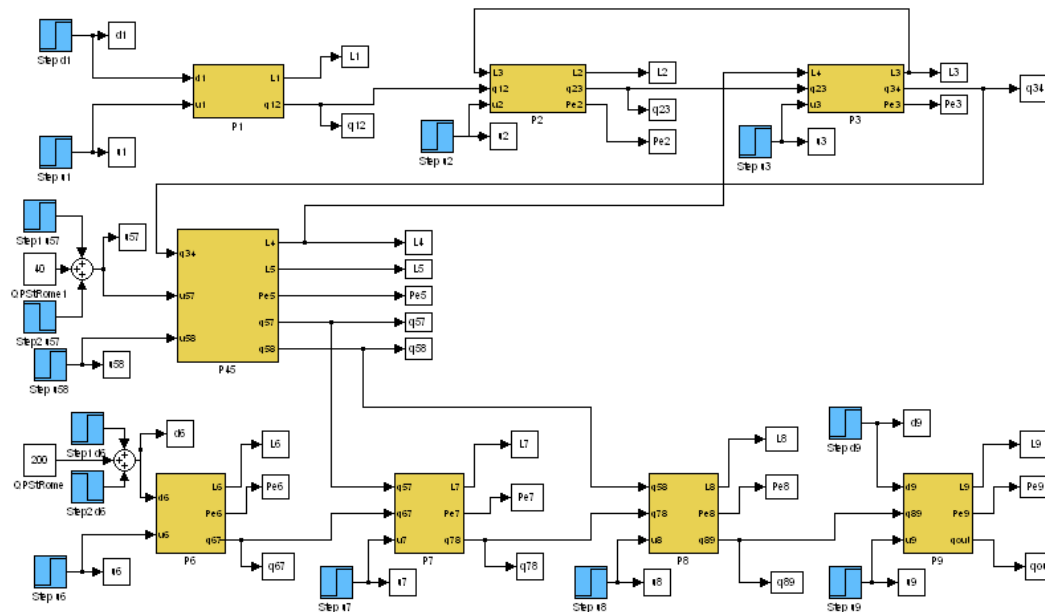

Figure 19 : Simulink model

As Simulink employs explicit simulation methods, it is necessary to guarantee the stability of the simulation while the simulation step increases.

Particularly for the integration of the de Saint-Venant equations, the "Courant criterion" [2] must be respected. The Courant criterion fixes a maximum simulation step Δt when the length dx of the N discretization sections is chosen.

$$\Delta t < \frac{dx}{c} \qquad c = \sqrt{g \cdot H_{av}}$$

where c is the sound celerity and H_{av} is the average height of the water. A maximum simulation step has been chosen coherently with this maximum step theory.

5.1.2   Model tuning

The correspondence between the Simulink nonlinear model and the SciCos model is tested by evaluating the system responses in a common scenario of inputs.

The tuning of the Simulink model consists in looking for values of the fitting parameters which makes the behavior of the two models similar.

Particularly, the Strickler coefficient is estimated by minimizing a goal function based on the difference between the returned values of the two models at the end of the transients (at steady-state).

As the real values of width and depth of the reaches are very variable along the stream, linear approximation of those parameters is necessary. The resulting approximation is coherent with the SciCos results.
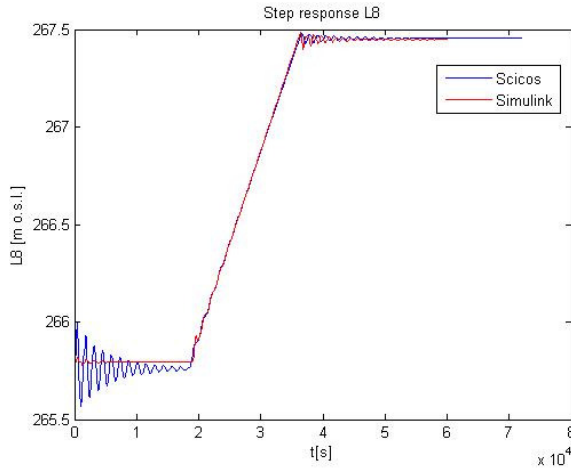
Figure 20 : comparison SciCos/Simulink for reach 2 according to Figure 1.

5.1.3   Linearization

Once the nonlinear Simulink model obtained and tuned, a linear one, more suitable to develop a first version of the controller, can be obtained either by a hand-made linearization of all the equations around a steady state or by the Simulink Time Based Linearization.

The second solution is faster and more flexible to potential change on the non linear model. Its reliability is tested by comparing the responses of the linear models obtained by the two methods.
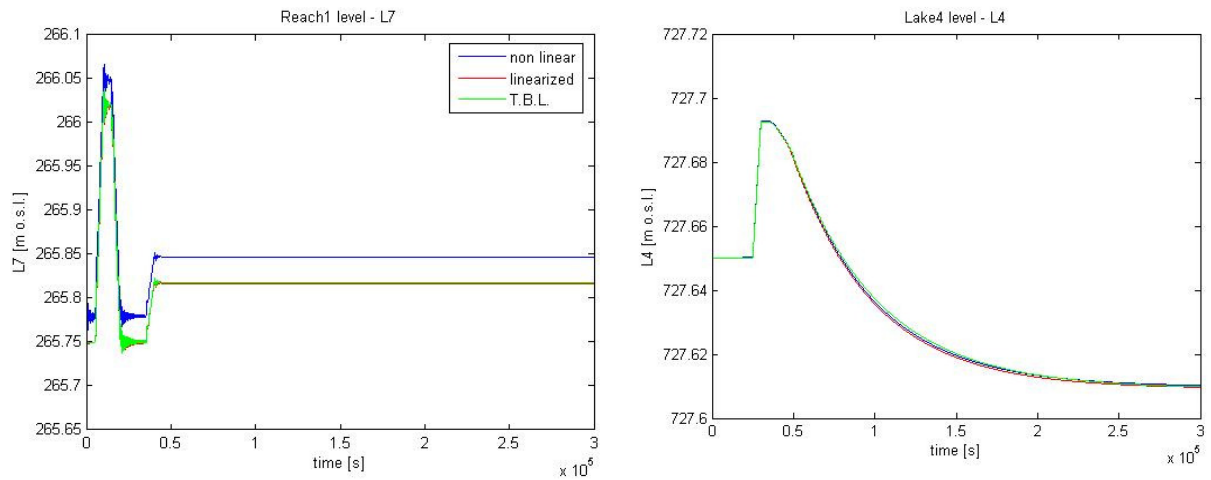

Figure 21 : Linear vs nonlinear Simulink model

5.2 ACADO model

A model including only the river reaches and the dams has been implemented in C++ using ACADO. The model is based on the Saint-Venant partial differential equation. An ordinary differential equation describing the system dynamics has been obtained using a finite difference approximation for the space derivatives of the flow and water level similar to the one used for the Simulink model. This model has been employed to implement a nonlinear MPC scheme which has been simulated with good results.

5.3 gPROMS : model library for distributed water systems

In order to apply nonlinear optimization methods and nonlinear model predictive control methods, it is necessary to model the considered process using an equation-based modeling tool, such as gPROMS or Modelica. The advantage of these equation-based modeling tools is the fact, that analytic Jacobians

as well as Hessians of the system equations can be derived, which are essential for nonlinear dynamic optimization methods.

Distributed water systems, such as a hydro-power valley or irrigation channels, are strongly modular. This means that they consist of only few different elements, i.e. subsystems. Hence, the idea is to implement a library for these distributed water systems, which is exemplarily done in gPROMS. The advantage of the modular model library is the flexibility and reusability of the models.

The library features on the one hand to different ports to connect the different submodels. On the other hand, it contains different models to model systems of streaming water systems, such as rivers and channels, as well as closed water systems in tubes.

5.3.1   Connecting ports

The library features two different types of ports, in order to explicitly take care of the physically different connection types:

1.   OpenFlow: For open water systems, there is the OpenFlow port. This port features the two properties height as well as volumetric flow.

2.   PressureFlow: This port is required to connect systems in closed tubes. It features the properties pressure and volumetric flow.

5.3.2   Model library

The model library consists of the following models:

-   RiverSection_QQ

-   RiverSection_QH

-   RiverSection_HQ

-   RiverSection_HH

-   GeneralLake

-   RiverPowerPlant

-   PumpingPowerPlant

-   Connector

-   PressurePipe

In the following, we will describe the different submodels.

<u>RiverSection_xy</u>

RiverSection contains the physical model of an open water system, such as a river or channel: It is described by the Saint-Venant partial differential and algebraic equations. In addition, there are two algebraic boundary conditions at the two ports, which are indicated by the suffix of the model. It is necessary to have different models in order to ensure that the resulting differential algebraic equation (DAE) system is index 1 or lower. The model features two ports of type OpenFlow.

<u>GeneralLake</u>

The general lake has ports for the inflow from a river, outflow into a river and a pipe flow into and out of the lake. Hence, it features four ports, two of type OpenFlow, and two of type PressureFlow.

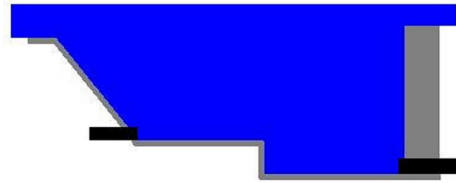The equations for the lake are given by:

$$\dot{V} = Q_1 + Q_2 - Q_3 - Q_4$$

$$V = h * A$$

$$h_{1in} = h - h_{10}$$

$$h_{2out} = h - h_{20}$$

$$p = \rho h g 10^{-6}$$

The change of the volume depends on the incoming and outgoing flows. The geometry of the lake up to now only considers a constant area and a difference in high of the ground but can be extended if required.

RiverPowerPlant

The RiverPowerPlant is a power plant to be connected to two sections of a river, i.e. it features two OpenFlow.

The equations for the river plant are:
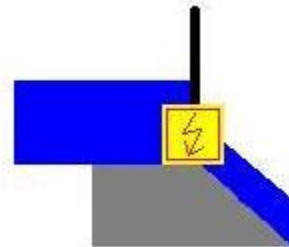
$$Q_p = A_p \sqrt{2gh_1}$$

$$Q_w = A_w \sqrt{2gh_1}$$

$$Q_1 = Q_2$$

$$Q_2 = Q_p + Q_w$$

$$W_t = Q_p \rho g (dh + \frac{h_1}{2} - \frac{h_2}{2})$$

$$W_{el} = \eta \cdot W_t$$

The incoming volumetric flow is divided in a flow through the plant and a volume flow against the weir. Depending on the different water levels, the produced mechanical power is calculated. The efficiency describes the relation between mechanical and electrical power of the plant.

PumpingPowerPlant

The pumping power station has only ports of the type PressureFlow. The equations for the PumpingPowerPlant are:

$$W_t + Q_1(p_1 - p_2) = 0$$

$$Q_1 = Q_2$$

$$W_d = \eta \cdot W_t$$

Mechanical power is a function of the volumetric flow as well as the difference in pressure. The electrical power is, as for the RiverPowerPlant calculated as a function of mechanical power and efficiency.

Connector

The submodel Connector is necessary to connect a pipe to an open streaming water system like a river.

Thus, the connector has 3 ports, two incoming and one outgoing.

One incoming OpenFlow port is for the river and the other one for the pipe (PressureFlow). The outgoing port is for the river which contains now the water from the pipe (OpenFlow).

The equations of the connector are:

$$Q_1 + Q_2 = Q_3$$

$$p = 0.1 MPa$$
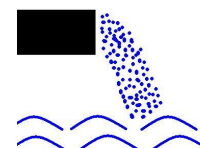
The volumetric flows are added.

For the pressure at the end of the pipe it is assumed the ambient pressure. The height of the river is assumed to be the same for the two different OpenFlow ports.

PressurePipe

The PressurePipe models a closed pipe, connecting to systems on different levels, e.g. two lakes. PressurePipe has two PressureFlow ports.

The pipe is so far only described by algebraic equations, as we want to neglect the high frequencies, which would come up by a dynamic hydraulic modeling. The equations of the pressure pipe are:

(1) $Q_1 = Q_2$

(2) $p_2 = p_1 + \rho g h 10^{-6}$

This means that the volumetric flow is the same for both ports (1) and that a difference of high of the two part is resulting in pressure drop between the two ports (2).

5.3.3   Evaluation

We have evaluated the new model library for a small scale and a large scale example.

Small scale simulation and optimization example:

The small scale example consists only of one RiverSection. On port 1, there is a manipulable inflow. On port 2, there is a constant level as a boundary condition. We first simulated the system for a constant inflow, and then performed a dynamic optimization using the dynamic optimization software DyOS (AVT - Process Systems Engineering, RWTH Aachen University). The goal of the optimization was to control the level of the water in the middle section of the river. The results can be seen in the following two figures.
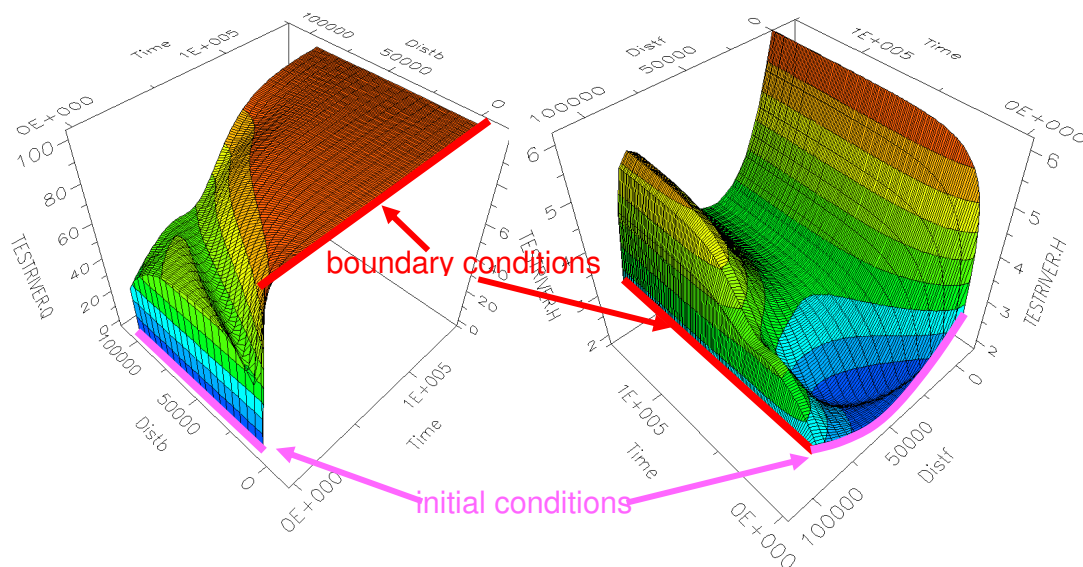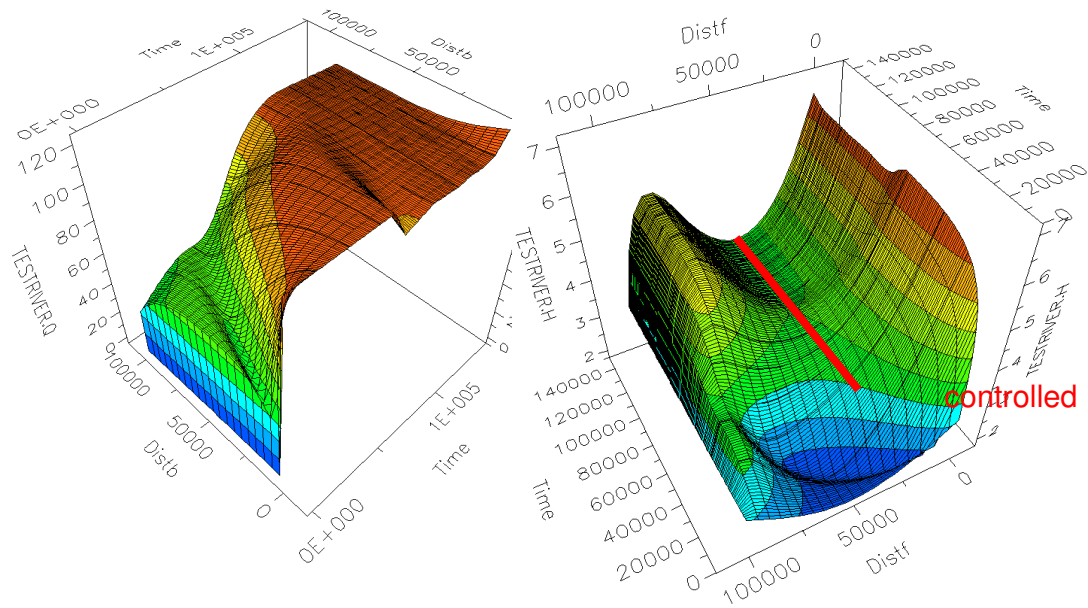
Large scale simulation example:

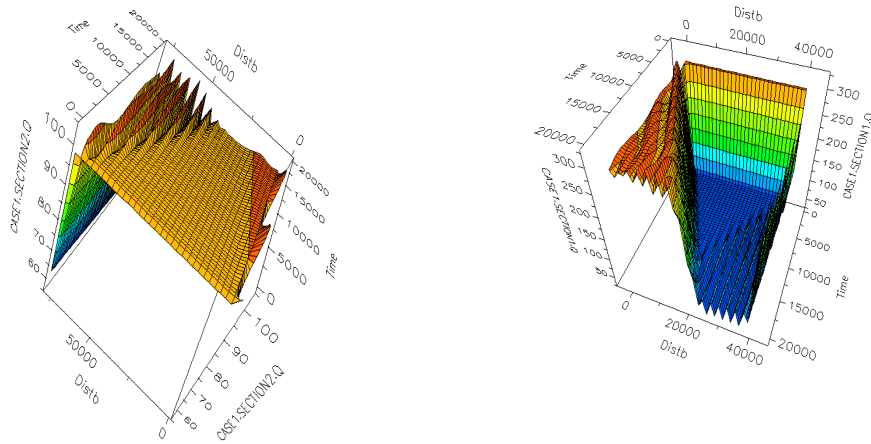For the large scale example, we composed a network of several subsystems, as shown in the following picture:
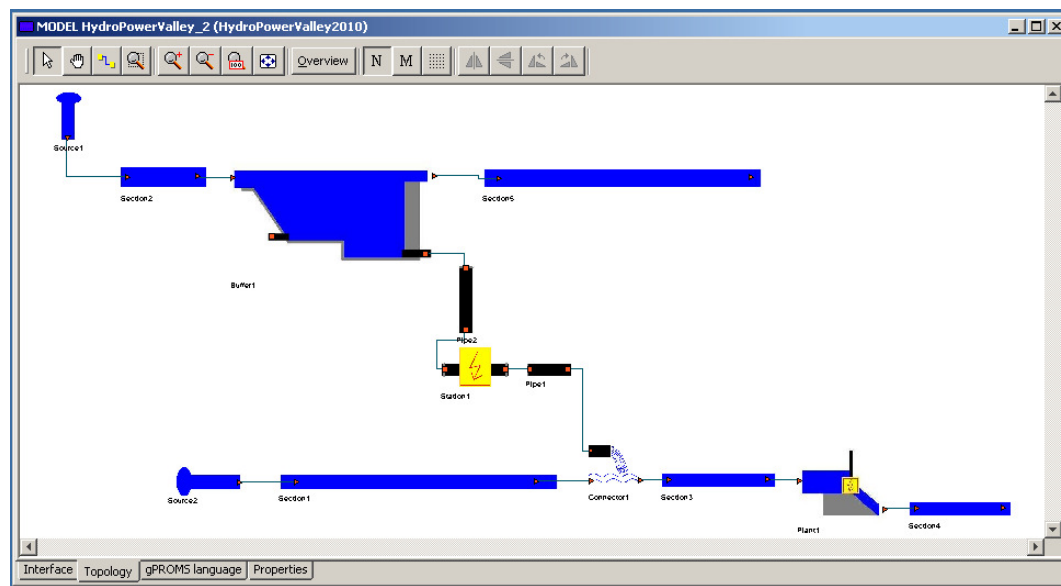
The network was simulated, while it was disturbed by several sine inflows. Some exemplary simulation results can be seen in the following figures.

5.3.4   Conclusions

A model library to simulate and optimize large scale water distribution networks has been completed. In order to use this library for the control of the real plants, i.e. the hydro-power valley or the irrigation channels, it is now necessary to parameterize the model according to the real plants. In addition, numerical applications for control objectives have to be defined, in order to run dynamic optimizations and implement model predictive control.

6   Connection control to simulator

6.1 Context

In the HD-MPC project, several different solutions and software will be used to implement the controller (ACADO, Matlab, DyOS, …). In order to validate these controllers, there must be communication between the validation model and the controllers. A generic communication type is privileged, in order to reduce the amount of work for integration of the controllers on the validation model.

6.2 Connection candidates

This paragraph shows some possibilities for connection between the model and the controllers.

Matlab/Simulink

An OPC toolbox is sold complementary to the Matlab software. It is user-friendly and the user interface is simple. A local and a server version are available of this toolbox. An interesting point is that the connection to remote OPC servers to read/write values is easy.

ACADO

The connection between the simulation model and the ACADO controller can be done by c-code (integrated in SciLab).

Another possibility for connection is via an OPC client, indirectly by using the Matlab or SciLab toolbox.

Remark: operating system issues (compatibility Windows/Linux) should be clarified for both of the communication possibilities.

A third solution that avoids operating system compatibility issues consists in exchanging the data in a ASCII file.

GPROMS/DyOS

In former and running projects at RWTH, a communication via OPC has been implemented for real plants as well as simulation environments, in order to evaluate and apply advanced control methods, such as nonlinear MPC and real time optimization. RWTH has promoted this solution at the Aachen meeting as a good candidate and is fully compatible with the DyOS software.

Dymola/Modelica

The simulation model of the HPV is made in the SciLab/SciCos language, but the sister example (the combined cycle model) is written in Dymola/Modelica. In the aim of using a general type of connection, the communication possibilities are studied. There is no OPC client toolbox available for Dymola, but an interface to Matlab/Simulink exists (and thus the use of the OPC client of Matlab is possible). In some published articles a DDE (dynamic data exchange) gateway to an OPC server is implemented by researchers.

The simulation model [SciLab/SciCos]

OPC seems to be a common denominator. In this paragraph, the communication between the simulation model and the OPC server is studied.

There exists a SciLab toolbox for OPC. It can be found at http://forge.scilab.org/p/opc-client/For testing, the version 1.2 is used, but a new version (1.3) is available since 12 may 2010.

The basic functions available in this toolbox are:

-   Connexion/Deconnexion to OPC server

-   List of available items

-   Read/Write values (float) and strings

An interesting aspect is the availability of the source code. In order to adjust the OPC client to our needs, some modifications are made to the code. For example

-   the number of variables was limited to only 20,when we need at least 120, this has been

            modified to more than 120 variables

- the type of the variables was adjusted to the OPC server

Some SciLab functions were written to simplify the *write to OPC* and *read from OPC* operations.

The simulation model is in SciCos, thus additional SciCos blocks have been developed to integrate the OPC functions, see Figure 22 : OPC blocks in SciCos.
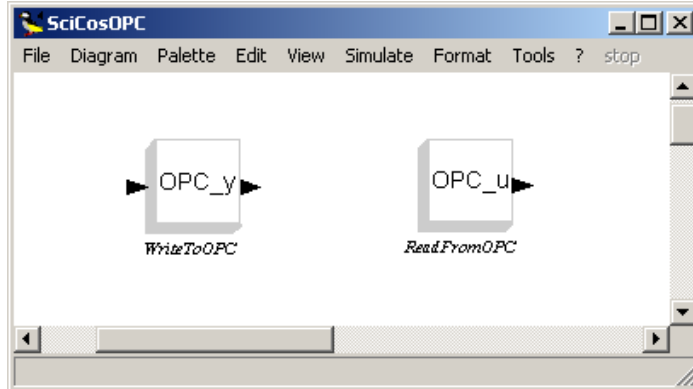

Figure 22 : OPC blocks in SciCos

Initially, the toolbox is limited to the local computer, which means that the Simulation model and the OPC server need to be on the same computer. This limitation can be bypassed by changing the configuration of the registry keys of windows. In this way values can be read and written to a remote OPC server.

6.3 Conclusion

An OPC based solution seems a good candidate to fulfill the communication between the different types of controllers and the simulation model. It is also well developed in the industry so that the implementation on the real plant can be done. The architecture is shown in Figure 23: OPC scheme.
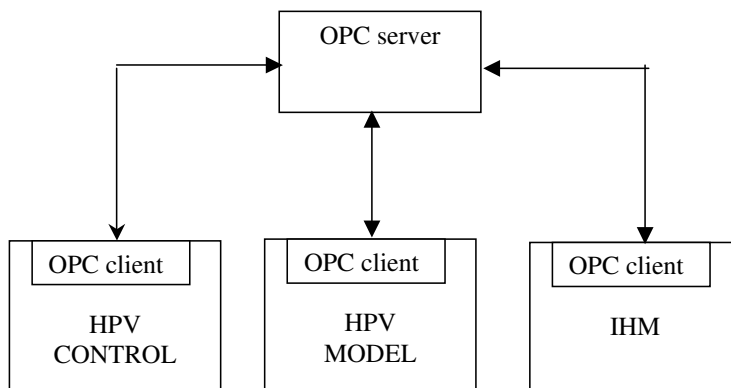

Figure 23: OPC scheme

All clients can be on separate PCs.

7   The Hydro platform

A Hydro platform exists at the EDF R&D center. On this platform, HMI software can be tested and the installation was build to be as close as possible to the real hydro-power plants.

This platform contains for example:

- An OPC server

- Several HMI (editor and supervisor) software

- An Alarms management system

- A Data historian (measurements)

Figure 24: Platform elements, shows the above mentioned parts in grey. The *Controller* and *Simulation Model* complement this platform to a simulator that is independent of historical measurements.
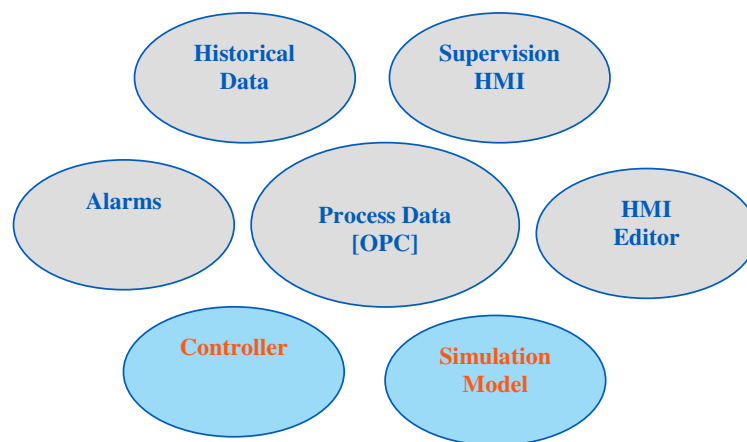

Figure 24: Platform elements

The software added to this platform:

- SciLab/SciCos

- Simulation model

- Matlab + OPC toolbox

- SciLab OPC toolbox

8   General conclusion

This report presents the simulator developed for the HPV case study. The simulator is implemented in SciCos and calls Mascaret, a dedicated software package to solve the 1D Saint-Venant equations. Some simulations made for step inputs on the in & outflow, and on the power demand for the HPV case study, show the main interaction. It is shown for instance that the levels of the reaches have an influence on the power and flow. The SciCos model is integrated into a platform with OPC communication. This will make the connection with the HD-MPC controllers more easy for the validation phase in the last year of the project.

Different control models have been created.

- A non linear Simulink model has been developed and tuned to fit the SciCos model. A linear state space model is derived from the non linear model.

- Saint-Venant models have been coded in ACADO and optimization problems have been solved for cascaded river power plants.

- A model library has been created in gPROMS, which can be used to modularly model a nonlinear plant for nonlinear model predictive controllers or dynamic real time optimizers. The model for the HPV corresponding to the case study plant is still to be developed.

The next step is to finalize the model predictive controllers for the case study using the control models (in Simulink, gPROMS and ACADO) and define appropriate objective functions representing the goals of the control problem.

9 References

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