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Improving water supply systems efficiency using optimisation techniques

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Abstract

The energy costs due to pumps operation in Water Supply Systems (WSSs) constitute a large quota of the global costs. Pumps control optimisation can provide considerable improvements in WSSs efficiency since most of the times their operation reveals to be completely inefficient. A numerical methodology to optimise both the rotational speed and the operating time of variable-speed pumps is proposed. For the automatic application of such methodology in distinct networks, a computational tool combining EPANET 2.0 with an optimisation module was developed using C++ language. In the presented case-study, the Particle Swarm Optimisation (PSO) algorithm with the proposed methodology allowed to reduce significantly the energy costs associated to water pumping.

Introduction

The fast expansion of several WSSs due to the population growth and the immediate consumers supply without any planned strategy have led to inefficiently operated systems. In most WSSs, the optimisation process by *trial and error* methods can present difficulties due to the complexity of these systems: multiple pumps, valves and reservoirs, head losses, pressure limitations, several demand loads, etc. For this reason, innovative optimisation techniques are becoming more widely explored in the optimisation of the water supply systems.

Methodology and Implementation

The proposed methodology considers distinct rotational speeds for pumps and allows the pumps to operate in intervals inferior to the common fixed 1-hour time-steps defined by the hydraulic simulators.

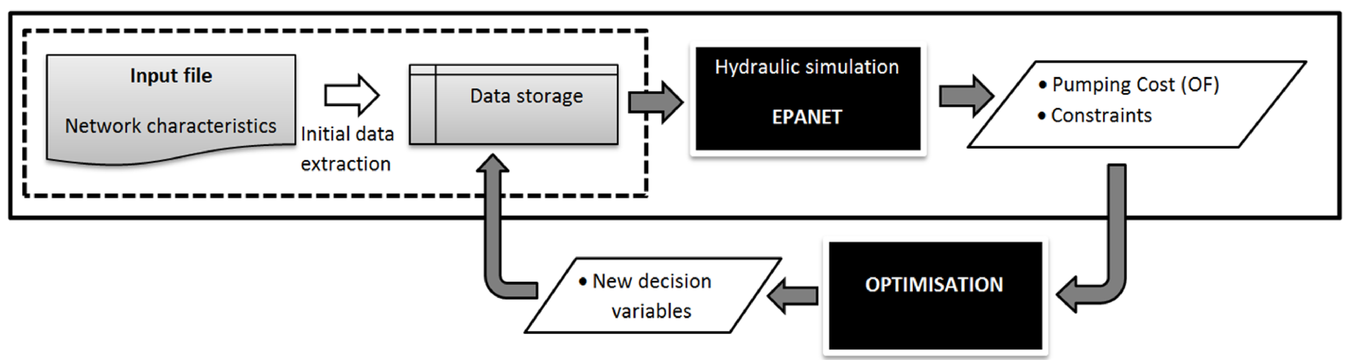

Fig 1 / General scheme representing the numerical tool developed for the implementation of the proposed methodology.

Case-study

The proposed methodology was applied to a simplified test model of the Richmond network (Fig. 3), firstly presented by Van Zyl *et al.* (2004). The PSO algorithm, a meta-heuristic algorithm based on a cooperative behaviour observed in nature (see Fig. 4), was used in this case-study. Results obtained were compared to the results of other authors using distinct methodologies.

Results comparison

Algorithm	Variables	Authors	Initial cost (£/day)	Optimal cost (£/day)	Energy cost reduction (%)
GA	Tank level controls (on/off)	Van Zyl *et al.*, 2004	-	344.19	-
Hybrid GA				344.43	-
EA	Level controls	López-Ibáñez *et al.*, 2011	-	337.20	-
	Time controls			315.90	-
ACO	Pump on/off	Hashemi *et al.*, 2013	389.00	388.04	0.25
	Pump speed			349.43	10.17
PSO	Pump speed and time controls	Coelho and Andrade-Campos, 2013	345.24	224.53	**34.96**

Conclusion

In addition to the already presented, the developed tool was also tested with distinct optimisation algorithms in other networks, including one real WSS, and has resulted in significant improvements in their operations.

References

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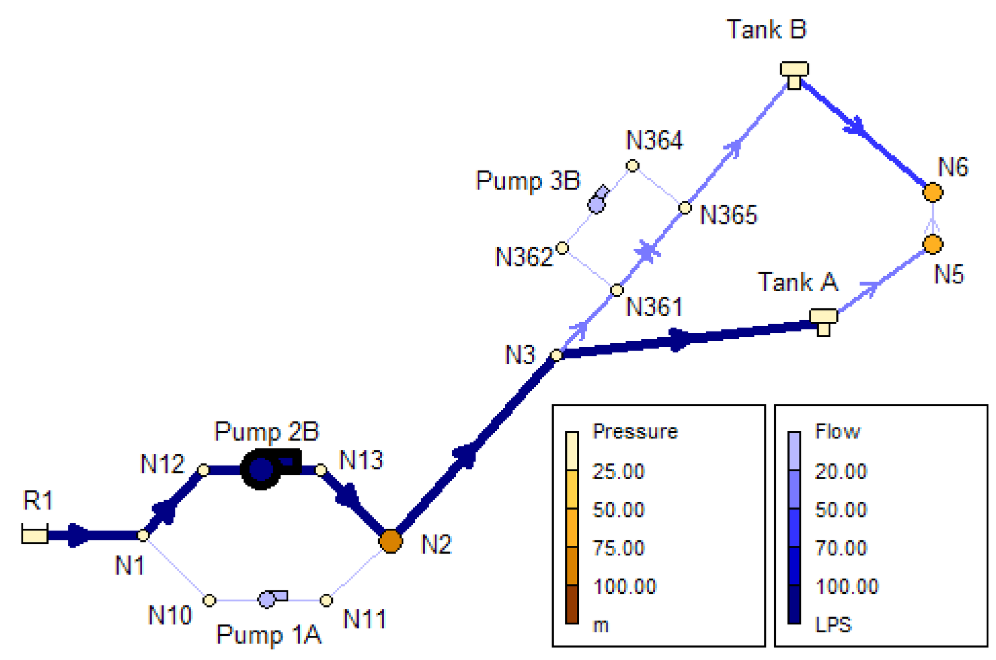

Fig 3 / Model of a test network for the Richmond water distribution system optimisation (Van Zyl *et al.*, 2004).

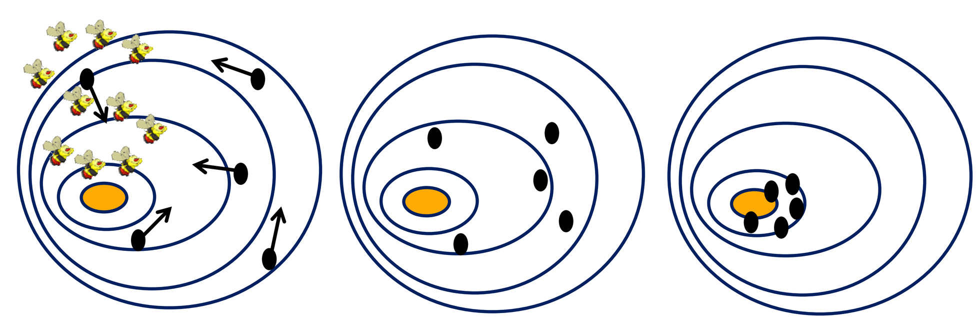

Fig 4 / Illustration to explain the meaning of "cooperation" in PSO algorithm.

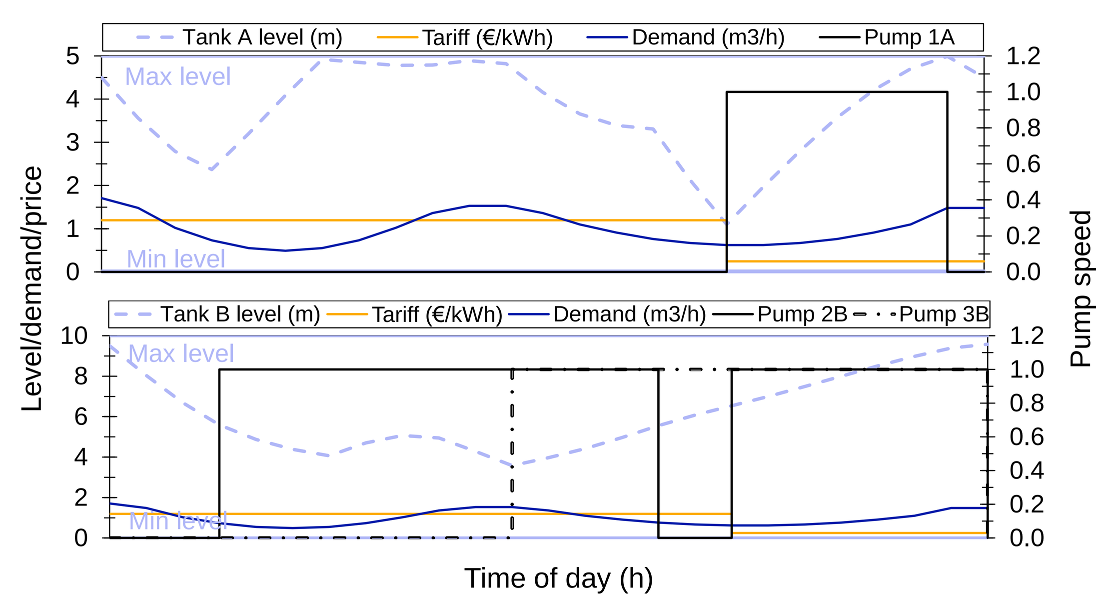

Fig 5 /Initial solution considered for the operation of the case-study network, starting the day at 7h00.

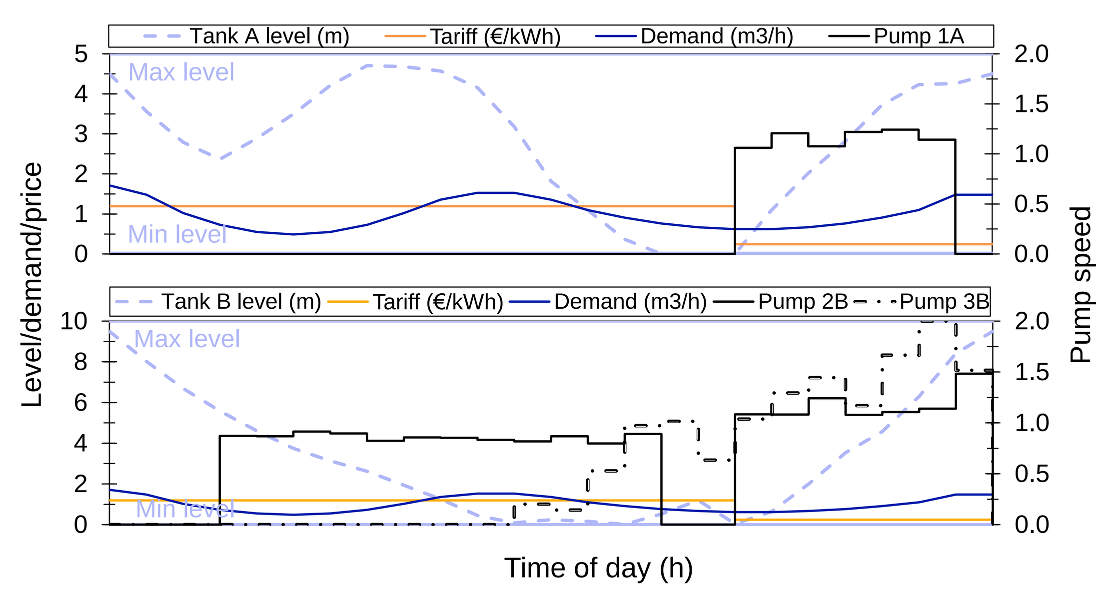

Fig 6 / Best solution obtained for the operation of the case-study network using the proposed methodology with PSO. The day also starts at 7h00.

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