Reply to Thomas Walski
By Angela Marchi, Angus Simpson and Nesimi Ertugrul

We thank the reviewer for the correction and the useful inputs and additional details contained in the discussion.

Terminology

We thank the reviewer for the correction. This paper has been presented at the CCWI conference using the terminology of "inverter" as a synonymous of the more general "variable frequency drive" (VFD) terminology. The terminology "inverter" came from our colleague in Electrical Engineering so it likely to be discipline dependent.

Use of variable speed pumping with storage

The case study presented in the paper is an example that shows that variable speed pumps (VSPs) can save energy, but we specify throughout the paper that actual energy savings (or not) depends on the system specific conditions. VSPs do not always save energy: in the case study we show that the VFD decreases the efficiency of the whole system and that the energy usage of a fixed speed pump (FSP) is lower than the energy usage of VSP at full speed. We also specify that the running of a VSP at a constant speed is unlikely because of the system requirements and constraints (if the demand is large compared to the tank volume).
We limited the example to clearly show the details in the energy computation instead of re-computing the efficiency of each VSP component (VSD, motor and pump) at each time step.
We agree with the reviewer that usually water distribution systems with storage have a flat curve where the margin of operations of VSPs can be limited or null because of the efficiency issues or because the pump speed cannot be decreased (due to the system constraints as explained in section 3).
However, this is not always the case. Sometimes the existing WDS is not designed in the best way for the *actual* operating conditions and variable speed pumps can be a preferable option. A practical real-world case to which I am referring to is essentially composed by two towns, say A and B with nearly independent water distribution systems (I don't have the permission to divulge the names and data). At some point, because of issues related to water quantity and quality, the water company decide to supply (a large) part of the network B pumping water from the network A. The water was pumped through an intermediate pumping station with more than 5 pumps pumping to a small tank. Because of changes in demands and network operations, the system curve was steep. Also the pumps in the intermediate pumping station have quite close trigger level controls. During the low demand periods only one pump is required to pump. This pump was equipped with a variable speed drive and they reduced the pump speed so as to reduce pressures and water leakage.
We agree with the reviewer that VSPs are just one option among many others and that they do not always save energy. In a system that is well designed for the actual operating conditions (demand, tank size, pump size), it is unlikely that a VSP will be more effective than a FSP (or a set of FSPs) because of the efficiency and of the capital costs associated with the VFD. However,

because WDSs are usually applied in existing networks subject to changing inputs and requirements, VSPs *can* be a preferable solution. Obviously this has to be assessed taking into account the operating costs and capital costs of the interventions throughout the design life of the project and has to be compared with the other possible solutions to the problem.

Use of variable speed pumping with no storage

We agree with all the point made by the reviewer: 1. Pumping with no storage leads to a series of complications to ensure water supply for emergency situations; 2. This is done for small size network and that the easiest way to control the system is by measuring the pressure at the pump outlet. (More rarely, if the network is enough large, the controls are on the most disadvantaged node in the network to limit pressures during the low demand periods.); 3. The insertion of a VSP should take into account all components (the VSP itself and the additional components required to meet the design constraints, e.g. diesel generator and fire pump); and 4. The VSP case should be compared to other options available (FSP plus storage).

We thank the reviewer for highlighting that a total cost analysis is needed to compare the options. This is true for both the case with storage and the case without storage. The focus of the paper is on assessing VSPs: this assessment is the first step to include or exclude the VSP option from further evaluations. The decision of adopting VPSs should be based on the result that this option is the most effective for the system as an outcome of a comparative life cycle economic analysis.