The last frontiers of the resilience and failure indices

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This paper sums up the results reported in Creaco, Franchini, Todini (2016a; 2016b) concerning the use of the resilience and failure indices. These indices were originally introduced as a convenient and compact tool to express respectively water-distribution network (WDN) surplus and deficit in satisfying users’ demand, in terms of delivered power (Todini, 2000). In their original formulation, the mentioned indices, originally thought as WDN design tools, were developed only considering the demand-driven modeling approach, which would include pumps but not leakage. This paper extends the formulation of both indices and presents a generalized expression, more convenient for use when dealing with pressure-driven modeling and capable of including the effect of leakage. Following the original concept, the generalized indices were developed by calculating the power dissipated in the network as a function of the difference between the total power inserted through source nodes and pumps and the net delivered power, whereas the leakage-related power is considered as a loss similarly to the internally dissipated one. In particular, using the vector form, the resilience ($I_r$) and failure ($I_f$) indices can be written as in eqs (1) and (2) respectively:

\[
I_r = \max\left(\frac{q_{\text{user}}^T H - d^T H_{\text{des},0}}{Q_0^T H_0 + Q_p^T H_p - d^T H_{\text{des}}} \right),
\]

\[
I_f = \min\left(\frac{q_{\text{user}}^T H - d^T H_{\text{des},0}}{d^T H_{\text{des}} \right),
\]
where $\mathbf{q}_{\text{user}}$ and $\mathbf{d}$ are the vector of nodal outflows and demands respectively; $\mathbf{H}$ and $\mathbf{H}_{\text{des}}$ are the vector of actual and desired nodal heads, respectively; $\mathbf{Q}_0$ and $\mathbf{Q}_p$ are the vectors of pipe water discharges outgoing from source nodes and raised by pumps respectively. Finally, $\mathbf{H}_0$ and $\mathbf{H}_p$ are the heads related to source nodes and pumps respectively. $I_r$ and $I_f$ ranges from 0 and 1 and from -1 to 0 respectively. In particular, either index is different from 0, only under nodal head conditions when the other is equal to 0. In particular, when the network is under power surplus condition, $I_r > 0$ and $I_f = 0$. Conversely, when the network is under power deficit conditions, $I_r = 0$ and $I_f > 0$. In light of the continuity between the index, the generalized resilience/failure index can be defined as the sum of $I_r$ and $I_f$ and can be conveniently used in the framework of network optimizations.

Applications to WDN analysis and design proved that using the new formulation in the presence of leakage and pressure-dependent consumptions yields better description of the delivered power excess, compared to the original demand-driven formulation and to another pressure-driven formulation (Saldarriaga et al., 2010) present in the scientific literature. Further applications showed that the combined use of the resilience index (Todini, 2000) with a loop based diameter uniformity index yields a good indirect reliability measure, which can be conveniently used within the optimization processes of the water distribution system design.

References


to reduce non-revenue water." Urban Water J., 7(2), 121–140.