Reliable predictions of the lifetime of offshore wind turbine structures are influenced by the limited knowledge concerning the inherent level of damping during downtime. Error measures and an automated procedure for covariance driven Operational Modal Analysis (OMA) techniques has been proposed with a particular focus on damping estimation of wind turbine towers. In the design of offshore structures the estimates of damping are crucial for tuning of the numerical model. The errors of damping estimates are evaluated from simulated tower response of an aeroelastic model of an 8 MW offshore wind turbine. In order to obtain algorithmic independent answers, three identification techniques are compared: Eigensystem Realization Algorithm (ERA), covariance driven Stochastic Subspace Identification (COV-SSI) and the Enhanced Frequency Domain Decomposition (EFDD). Discrepancies between automated identification techniques are discussed and illustrated with respect to signal noise, measurement time, vibration amplitudes and stationarity of the ambient response. The best bias-variance error trade-off of damping estimates is obtained by the COV-SSI. The proposed automated procedure is validated by real vibration measurements of an offshore wind turbine in non-operating conditions from a 24-h monitoring period.