Numerical simulations are of vital importance to the development of turbomachinery components. While experimental investigations serve as main contributors to the analysis of the performance of turbomachines, the presence of challenging conditions during testing, such as high temperatures, high-Reynolds number and strong compressibility effects, make the exploration of large design spaces almost prohibitive. Moreover, a certain level of uncertainty still exists due to the presence of measuring devices, which inherently represent a disturb for the incoming flow, especially in high-speed regions, along with underlying assumptions necessary to obtain derived quantities. For these reasons, fostered by increasing computational resources, a numerical approach needs to work in conjunction with experimental investigations, allowing for initial assessments of design features, along with providing insights into local flow features which cannot be directly measured.

In the present work of thesis, the development of a high-order Finite-Volume code for turbomachinery applications is detailed. The work starts from an existing solver developed at the University of Florence, which has been largely revisited to implement state of the art modeling and solution strategies, which are of interest for the study of turbomachinery components. The first part of the thesis reviews the original solution strategy of the code HybFlow, addressing some inherent weaknesses reported by its developers. In the second chapter of the thesis, the implementation of a parallel linear solver is detailed, focusing on the analysis of two different preconditioners to allow the speed-up of the nonlinear convergence for steady-state problems. In particular, three different linear solution algorithms are compared for laminar and turbulent computations: an Algrebraic Multigrid preconditioned GMRES, an ILU preconditioned GMRES and the point/block implicit solver LU-SSOR.

In the third chapter of the thesis, the extension of the code to higher-order reconstruction methods is detailed and assessed over both reference test-cases and turbomachinery simulations. Two different reconstruction methods are compared. The first method is based on a Least-Square reconstruction, where flow gradients and high-order derivatives are computed all together, while guaranteeing the preservation of variables mean value. The second method is based on a Successive Correction, where high-order derivatives are computed from lower-order ones over a compact reconstruction stencil.

The last chapter of the thesis addresses the application of the solver to a new open-source low-pressure turbine blade test case, studied in the framework of European project SPLEEN. The chapter details two-dimensional, three-dimensional and unsteady characterization of the cascade.

Eventually, some open points of the current implementation will be discussed, along with the strategies for further advancements of the code performance and capabilities, in view of its application towards high-fidelity simulations.