Due to the increasing penetration of single-phase small generation units and electric vehicles connected to distribution grids, system operators are facing challenges related to local unbalanced voltage rise or drop issues, which may lead to a violation of the allowed voltage band. To address this problem, distribution transformers with on-load tapping capability are under development. This paper presents model and experimental validation of a 35 kVA three-phase power distribution transformer with independent on-load tap changer control capability on each phase. With the purpose of investigating and evaluating its effectiveness under different operative conditions, appropriate scenarios are defined and tested considering both balanced and unbalanced situations, also in case of reverse power flow. The experimental setup is built starting from an analysis of a Danish distribution network, in order to reproduce the main feature of an unbalanced grid. The experimental activities are recreated in by carrying out dynamics simulation studies, aiming at validating the implemented models of both the transformer as well as the other grid components. Phase-neutral voltages’ deviations are limited, proving the effectiveness of the phase-independent tap operations. Furthermore, minor deviations of the results from simulations and experiments confirm that all the system components have been properly modelled.