PHOTOVOLTAIC POWER PLANTS AS ACTIVE ELEMENTS OF DISTRIBUTION NETWORKS

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Summary

According to Grid Codes in many countries, the photovoltaic (PV) power plants are obliged to generate reactive power and to curtail active power if this is required. In the case study, presented in the scope of this paper, the impacts of reactive power generation and active power curtailment on yearly electricity production of PV power plants and yearly energy losses in the distribution network are discussed. Additionally, the suitability of existing distribution networks for the yearly net self-sufficient energy supply, introduced through the net metering, is evaluated.

In order to evaluate the impacts of reactive power generation and active power curtailment on yearly electricity production of PV power plants, the principle of inverter (micro-inverter) operation and inverter's limits of operation are discussed in relation to the active and reactive power generation. Presented is measured efficiency characteristic of an inverter (micro-inverter). The measured efficiency characteristic is approximated by a surface, given as a function of generated active and reactive powers. Based on the data, measured over several years of PV power plant operation, the capacity of the discussed power plant for reactive power generation is presented. It is shown that even in the cases when inverter is chosen in such a way, that its maximal apparent power equals its maximal active power, only around 40 hours per year the active power curtailment would be required to operate all the time with cos≤ 0.8. The measured active and reactive power in the discussed distribution network and the measured active power of several PV power plants were used to determine monthly maximum, average and minimum profiles. They are given as hourly values.

The described efficiency characteristic of the inverter, monthly load profiles for active and reactive powers as well as monthly profiles for active power generation of PV power plants, are applied to evaluate the impacts of reactive power generation in PV power plants on the yearly electrical energy production of PV power plants and the yearly energy transmission losses in several existing low voltage and medium voltage distribution networks. In order to determine the optimal reactive power generation of PV power plants, in each time interval of the discussed active and reactive power load profiles and profiles of active power generation in PV power plants, a stochastic search algorithm called Differential Evolution (DE) is applied as the optimization tool. The results presented in the paper clearly show that the reactive power generation in PV power plants can be used to control the voltage profile in the distribution networks to the certain level, whilst after that the curtailment of generated active power in PV power plants is required. The reactive power generation in PV power plants can be used also for reduction of losses in the distribution network, however on the costs of reduced energy production in PV power plants. The reduction of losses and the reduction of energy production in PV power plants are highly dependent on the level of network loading.

The discussed medium and low voltage distribution networks were also checked regarding their suitability for the introduction of yearly net self-sufficient energy supply. To do this additional PV power plants are installed in the vicinity of each load. The performed analysis is based on already determined active and reactive powers load profiles and profiles of active power generation in PV power plants. The results obtained clearly show that most of the discussed distribution networks are already suitable for the yearly net self-sufficient energy supply, but only in the cases when average load and generation profiles are considered. In the cases when maximum profiles for the PV power plants' active power generation are applied, the reactive power generation and sometimes even active power curtailment in PV power plants are indispensable to provide proper voltage profiles.

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