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Effect of load models on assessment of energy losses in distributed generation planning

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ABSTRACT

Distributed Generation (DG) is gaining in significance due to the keen public awareness of the environmental impacts of electric power generation and significant advances in several generation technologies which are much more environmentally friendly (wind power generation, micro-turbines, fuel cells, and photovoltaic) than conventional coal, oil and gas-fired plants. Accurate assessment of energy losses when DG is connected is gaining in significance due to the developments in the electricity market place, such as increasing competition, real time pricing and spot pricing. However, inappropriate modelling can give rise to misleading results. This paper presents an investigation into the effect of load models on the predicted energy losses in DG planning. Following a brief introduction the paper proposes a detailed voltage dependent load model, for DG planning use, which considers three categories of loads: residential, industrial and commercial. The paper proposes a methodology to study the effect of load models on the assessment of energy losses based on time series simulations to take into account both the variations of renewable generation and load demand. A comparative study of energy losses between the use of a traditional constant load model and the voltage dependent load model and at various load levels is carried out using a 38-node example power system. Simulations presented in the paper indicate that the load model to be adopted can significantly affect the results of DG planning.

1. Introduction

The load in a distribution system generally consists of three main types, i.e., residential, commercial and industrial load, with their proportion in the total load demand varying with time, e.g., hourly, daily and seasonally. The nature of these three types of loads is such that their active and reactive power components respond differently to variations in the voltage and frequency of the system [1,2]. System planners need to understand the exact nature of load sensitivity of voltage in order to precisely quantify the economic benefits of installing DG. Korunović et al. [3] studied the static load characteristics of a medium-voltage distribution network by conducting field measurements and concluded that steady-state distribution load can be modelled as exponential voltage-dependent model in a relatively wide voltage range, from 0.96 to 1.1 of the nominal voltage with errors less than 5%.

The variation in the actual power demand with voltage has become more prominent in recent years as increasing penetration of renewable DGs, such as intermittent wind, has made voltage profiles on the distribution feeders more dynamic. The connection of DG to distribution networks near load centre could change magnitude and direction of network power flows. This would impact on network operation and planning practices of distribution companies with both technical and economic implications. Investigations have therefore been carried out into DG planning in distribution systems in recent years [4–13], among which power system losses reduction due to the introduction of DG in distribution systems attracts much attention [10–13]. Most of these investigations focused on assessing the power loss reductions brought about by DG and utilised a constant load model in the power flow analysis, that is, the load power was considered to be independent of variations in feeder voltage. In general, the regulator sets a loss target for each of the UK distribution network operator (DNO). DNOs are rewarded if their real losses are lower than the loss target. Otherwise, the DNOs are economically penalised. Although at present the economic incentives to reduce losses are on the DNOs, it is possible that DNOs will pass part of the reward to DG owners for assisting reducing network losses in the future [12]. However, an accurate quantification of energy losses associated with DG largely depends on the load models employed in the power flow algorithms. Therefore, the load models will have a direct consequence on DNO's profit.

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