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Abstract

Prior knowledge about the possible characteristics of demand and supply is vital in the planning and operation of economically sustainable isolated rural power systems. System modelling and simulation is one of the tools that can be used in planning and assessing the performance of these systems. This thesis presents a Monte Carlo simulation methodology for modelling, simulating and analysing the performance of isolated rural electricity markets applicable in developing countries. The definitions of possible power system operators managing these markets are introduced based on different economic objectives of operating the systems. The two system operators considered in the thesis are: altruistic and profit maximising operators. The concept used to define types of isolated rural electricity markets combines the definitions of the operators and the possible combinations of power supply options (purely thermal or hybrid system). It is anticipated that the rural electricity markets under consideration comprise uncertainties in demand and supply (both demand and generation are modelled as random variables from assumed or estimated probability distributions).

Demand is price sensitive and modelled as a product of two random variables: relative demand and peak demand. The price sensitivity of demand is shown by representing the peak demand using an economic price-demand function. The parameters (price sensitivity and demand factor) of this function are modelled as random variables reflecting the randomness of consumers' preferences.

The simulation algorithm is based on the theory of correlated sampling in order to compare the performance of systems under different operators. The thesis introduces the concept of nested Monte Carlo simulation to be able to manage the simulation of different operators subjected to the same market conditions. The operators are considered to operate in a monopolistic way in a single market. The impact of provision of subsidies and rate-of-return regulation on the performance of the defined markets is modelled. The performance of electricity markets is assessed by analysing three parameters (tariffs, profit and reliability) which are random variables presented using probability distributions in form of duration curves.

The methodology is tested on the case study of Kisiiizi Hydro Power plant, an isolated electric power scheme located in a rural community in Western Uganda. It has illustrated how to use the model, prepare the input variables and use the output to estimate and assess the possible performance of isolated rural power systems under different power system operators. The proposed methodology can be used by researchers, planners and utilities as a tool for planning, estimating and assessing the performance of rural power systems in isolated areas of developing countries.