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On the optimal capacity expansion of electric power systems

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The analysis of investment in the electric power industy has been the subject of intensive research for many years. The efficient generation and distribution of electrical energy is a difficult task involving the operation of a complex network of facilities, often located over very large geographical regions. Electric power utilities have made use of an enormous range of mathematical models. Some models address time spans which last for a fraction of a second, such as those that deal with lightning strikes on transmission lines while at the other end of the scale there are models which address time horizons consisting of ten or twenty years; these usually involve long range planning issues.

This thesis addresses the optimal long term capacity expansion of an interconnected power system. The aim of this study has been to derive a new, long term planning model which recognises the regional differences which exist for energy demand and which are present in the construction and operation of power plant and transmission line equipment. Perhaps the most innovative feature of the new model is the direct inclusion of regional energy demand curves in the nonlinear form. This results in a nonlinear capacity expansion model.

After review of the relevant literature, the thesis first develops a model for the optimal operation of a power grid. This model directly incorporates regional demand curves. The model is a nonlinear programming problem containing both integer and continuous variables. A solution algorithm is developed which is based upon a resource decomposition scheme that separates the integer variables from the continuous ones. The decomposition of the operating problem leads to an iterative scheme which employs a mixed integer programming problem, known as the master, to generate trial operating configurations. The optimum operating conditions of each trial configuration is found using a smooth nonlinear programming model. The dual vector recovered from this model is subsequently used by the master to generate the next trial configuration. The solution algorithm progresses until lower and upper bounds converge. A range

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of numerical experiments are conducted and these experiments are included in the discussion.

Using the operating model as a basis, a regional capacity expansion model is then developed. It determines the type, location and capacity of additional power plants and transmission lines, which are required to meet predicted electricity demands. A generalised resource decomposition scheme, similar to that used to solve the operating problem, is employed. The solution algorithm is used to solve a range of test problems and the results of these numerical experiments are reported. Finally, the expansion problem is applied to the Queensland electricity grid in Australia.

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