Interactive simulation of electricity demand and production
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Document Version
Publisher's PDF, also known as Version of record

Publication date:
1996

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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Download date: 29-09-2019
8. General conclusions and reflections

This chapter returns to the main research questions posed in chapter 1. A combined scenario study is briefly presented, as an illustration of the possibilities of coupling the MEED and PowerPlan models. This also serves the general purpose of this chapter: exposing the strengths and weaknesses of the models MEED and PowerPlan. The chapter ends with some recommendations for future developments.

8.1 Introduction

In chapter 1 the subject of this thesis was formulated as: the research directed at the development and application of a set of tools (i.e. MEED and PowerPlan) for the interactive exploration of feasible (mid- to long- term) electric power system futures in terms of their technological, socio-economic and environmental impacts. For both models some sub-goals are defined. This section serves to reflect on the objectives described in chapter 1.

MEED
The MEED model is intended to serve as a tool in scenario studies simulating the development of electricity demand assuming the end-use approach. The MEED model should be a suitable tool for mid to long term scenario studies.

Chapter 6 shows that it is possible to perform scenario studies at a small scale (the Netherlands) as well as at a more aggregated level (OECD Europe). MEED can be characterized as a tool in the making, that can be useful in stand alone end-use studies and in combination with a capacity planning model like PowerPlan.

PowerPlan
Concerning PowerPlan chapter 1 stated: the main question is: is it possible to develop a tool for electricity supply planning for the mid to long term that is much more accessible, flexible, fast, cheap, interactive, dynamic, educational and still accurate enough for electricity scenario studies than chronological planning models like SCELEC [Dijk, 1988].

Since PowerPlan is intended for education, negotiation and is meant to be used by other people than the model builders themselves, accessibility is a necessity.
Accessibility is made possible by an easy to use interface. Because of the external use of PowerPlan, the model is made flexible i.e. it is easy to implement for other countries (by adjusting the input data file).

PowerPlan is an interactive and dynamic model; starting from an existing electricity generating system, users have to simulate from year to year with feedback on the input.

Because of its interactive character the simulation cycle (one or more years) should be fast: a minute at most. Even on a PC-XT, the calculation time per simulation round is for the Netherlands (the scenarios as used in chapter 7) less than 30 seconds.

The model should be available for as many potential users as possible (e.g. university education, non-governmental organisations in Second and Third World countries, contra-expertise), so the model should be cheap. The 1996 price of the model is $200,- for educational purposes (in comparison: the SEPU model costs $60,000).

The goal of PowerPlan is twofold: it should both be used in an educational context and for scenario studies. As far as known, PowerPlan is regularly used in at least three environmental courses in the Netherlands and in one such course abroad. Various scenario studies have been carried out with PowerPlan. From chapter 7 one can conclude that the results of PowerPlan in comparison to a chronological model (SEPU) adequately fulfils the criterion regarding accuracy.

PowerPlan has now been developed to a state of maturity in which it serves simultaneously the stated goals to adequate levels for a broad range of "electricity futures".

8.2 Coupling PowerPlan and MEED: an example

Chapter 1 mentioned the possibility of coupling the MEED model to PowerPlan. In the chapters 6 and 7 examples of scenario studies are described for MEED and PowerPlan. The possible coupling between both models has not been illustrated thus far. This section presents such a coupling by an example which is built on an scenario study used in chapter 6. The starting point is formed by the scenarios 1 and 3 described in section 6.2. In these scenarios the MEED model is used to calculate the conservation potential in OECD Europe (scenario 3, EAT) compared to a business as usual scenario (scenario 1, AUT). The resulting LDCs are given in section 6.2.3: Figure 6.11 and Figure 6.13. These LDCs in combination with the electricity demand growth (both MEED output) form the input for the PowerPlan model.

The other necessary PowerPlan input data are based on aggregated electricity supply data from the OECD [IEA, 1992c]. The age of individual power plants
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is estimated and the fuel use and emissions are calibrated on OECD energy statistics [IEA, 1991c, 1993a and 1995] and on OECD environmental data [OECD, 1993]. For the supply side scenarios, a business as usual scenario is chosen along with the expectations (for 2000) mentioned in the IEA study on electricity supply in the OECD. This scenario is characterized by a stabilization of oil-fired power plants, a small decrease of nuclear power and an increase of coal, natural gas and hydro power plants. This trend is continued for the years 2000-2020. Similar assumptions are made for the conservation scenario. The combination of the conservation measures and the construction programme of power plants leads to an over-capacity in this case and therefore less extra capacity is needed.

The MEED model starts with end-use demand patterns and results in electricity demand output data that can be used as input for PowerPlan simulations of the required capacity planning. The two scenarios differ considerably in their demand for electricity (cf. Figure 8.1), in the required generating capacity (cf. Figure 8.2) and thus also in the associated CO₂-emissions (cf. Figure 8.3). In order to match the time frames of the two models some parameters have been adjusted in comparison with the scenarios described in chapter 6. However these changes are irrelevant for the point to be made here.

The results illustrate the combined capability of the two models. Basic assumptions concerning end-use demand lead to capacity issues that of course also depend strongly on the electricity generating system at the start of the simulation runs. The PowerPlan results may trigger adjustment of parameters and data in the MEED exercise, etc. Such an iterative procedure can be
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imaged for the EAT scenario described above. Figure 8.2 shows that the strong conservation efforts generate for 5-6 years a situation of excess electricity production capacity - which may be an unwanted situation. Possible reactions are e.g.: export of electricity during that period, early decommissioning of plants with poor environmental or economic characteristics, etc.

Figure 8.2: OECD Europe: electricity generating capacity, business as usual scenario (AUT) and the conservation scenario (EAT), 1990-2020.

Figure 8.3: OECD Europe: CO₂ emissions, business as usual scenario (AUT) and the conservation scenario (EAT), 1990-2020.
8.3 Model strengths and weaknesses

The strengths and weaknesses of a simulation model can not be decoupled from the goal the model was aimed at; to put it strongly: an excellent detailed role description is not a strong point for a planning model. This section should be read in this context. One should also keep in mind that reality changes continuously, so new options emerge and old ones die. Model developments reflect this.

Model strengths
A saying is that: simplicity is the hallmark of truth. This is also true for models used in an educational context. The interface can play an important role in the simplicity of a model. The present interfaces of MEED and PowerPlan, although technically somewhat outdated (no Windows, no mouse) is still easy to use. An extra advantage of this simple interface is that the model, which should possibly be used in Second and Third World countries, can still run on a PC-XT.

Interactivity and clarifying graphical output are strong points in the PowerPlan model when the model is used in a negotiation and educational context. It is also possible to run the model batch-wise for scenario studies (for a 30 year period).

Another strong point of both models is the flexibility of the input data. The structure (of sectors and end-use categories) in the MEED model is not fixed but can be adjusted to focus on the relevant points of survey. Both models can easily be implemented for other countries.

The possibility to connect the demand model to the supply model as illustrated in section 8.2 can generate extra information on problems (change in the shape of the LDC) which can occur as a result of a shift in demand patterns (e.g., introduction of electric cars).

Model weaknesses
Looking at present day trends in expansion of cogeneration capacity, the generation of heat and electricity is becoming increasingly important. PowerPlan does not offer the possibility of producing/using heat. From cogeneration only the generated electricity is taken into account. In scenarios with an extreme penetration of cogeneration even an excess of generated electricity (due to the demand for heat) can occur. PowerPlan does not take this into account. A solution would require additional modelling of heat demand following CHP, resulting in aggregated electricity patterns.

PowerPlan does not offer the possibility of storage of electricity (e.g., hydro pump-storage loaded by nuclear power plants in base load hours). A solution would require additional modelling of LDC changes induced by storage options.
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8.4 Further developments

Model builders have the tendency to make their model more and more complex in order to do better simulations. It is obvious that all relevant relations of the system represented by a model should be present. A problem arises when choices have to be made if certain simplifications are tolerable and if certain less important relations could be left out. The preceding sections suggest several options to widen the scope of PowerPlan: towards a heat/electricity model, towards a gas/electricity model and other possibilities to build the existing models as sub modules into more encompassing models. This line of reasoning is not followed in this final section. Here the focus is chosen to be the MEED and PowerPlan model. There are three aspects (other than the motive to model reality as well as possible) which can influence the decisions to improve (i.e. make it complex) a model:

- the goal or target group (cf. section 8.3);
- time horizon (the shorter the time horizon the better the model should be in order to yield results relevant for the problem modelled);
- availability of data is an issue not to be neglected (if the model is more complex/detailed than the data permit, the accuracy of the simulation is determined by the data and not by the model).

MEED

The MEED model has not reached the same stage of development as PowerPlan: e.g. PowerPlan is sold and widely used elsewhere while MEED is still being used on a more limited scale). So further development of the MEED model is necessary. One of the most important components lacking is a sub-program to build/edit a new/existing scenario. The MEED model at present is fully operational, it is tested but is not validated in the way PowerPlan is (c.f. chapter 7). Although the validation of MEED is much more difficult than it is for PowerPlan, due to the absence of reliable data, it seems possible to perform a historical validation of the Netherlands (1975-1995) [Van der Wal, 1995], at least for the residential sector.

PowerPlan

The wish for improvements goes hand in hand with two of the three goals which were defined for the PowerPlan model:

- scenario studies;
- educational context;

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1 A full assessment of the value added by constructing such models is outside the scope of this thesis. It would require another round of the model construction scheme, starting again with goals and specifications of users and contexts of use.
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- gaming purposes.
  This last goal which is a wish itself, was one of the first targets when the development of PowerPlan started in 1985. Because of the complexity and because of the lack of certain "game elements", this goal has yet to be achieved.

The possibilities and wishes to improve the PowerPlan model in terms of the other two goals, follow, at least partly, from the intention to eliminate weaknesses as described in section 8.3 and from the conclusions drawn in chapter 7.

GENERAL
- A thorough evaluation of the way PowerPlan practitioners use the model and of their wishes to improve the model.
- The indirect emissions, which gain a growing interest in present day pollution research should be implemented (in the form of parameters for the present types of power plants and the different fuels used) in the model and added to the output.

GAMING APPROACH
- There is a long standing wish to develop a game with the electricity supply system as a central theme. Taking PowerPlan as a starting point, the model should be simplified, some 'game elements' (such a performance indicator, a concrete goal) should be added, different social viewpoints should be emphasized and corresponding role descriptions should be developed.

EDUCATION
- Although PowerPlan is used at different locations in energy and environmental courses and students are satisfied with the program, an evaluative study about the effectiveness of PowerPlan as an educative tool has yet to be made.
- A set of tasks should be developed besides the already present tasks, specialized for a course to be given in a relatively short period.

SCENARIO STUDIES
- From the simulation results with the IEEE test system (section 7.2) it was concluded (section 7.6) that a non-equidistant LDC offers a possibility to gain substantially better simulation results. A non-equidistant LDC could be added as a possibility in the PowerPlan model.
- When scenarios are used in which time dependency plays an important role (wind, cogeneration, demand patterns), the option to choose a limited chronological approach [Jong, 1995] can be a valuable extension of PowerPlan.
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• The extension of PowerPlan to a limited chronological model (in combination with a MEED model with corresponding chronological demand patterns) offers the opportunity to make detailed scenario runs. These kind of scenario studies should focus on structural changes (e.g., the massive introduction of electric heat pumps and electric cars) in the electricity supply system. Such structural changes can influence the shape of the LDC, which in chapter 7 was concluded to be an important variable.

• The implementation of two of the shortcomings in PowerPlan versus SEPU (a less detailed merit order and the absence of a spinning reserve) could be implemented relatively easy in the PowerPlan model. The merit order issue requires structural changes in the software plus more detailed input data. The ‘spinning reserve’ issue can be implemented quite easily.

• A survey is needed to generate simple relations between factors such as:
  - efficiency and plant load;
  - NOx emission and plant load;
  - number of units and the fuel use for the standby, pre-heating.

  On this basis - without increasing the input data - the simulation results can be improved considerably.

With all these wishes in mind a balance must be found between the ever present tendency to improve models (i.e. make them more complex) and the elegance of simplicity.