XA9745295

IMPROVEMENTS TO THE IAEA's ELECTRIC GENERATION EXPANSION MODEL

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Abstract

This paper deals with the implementation of the IAEA's planning approach and software in Bulgaria. The problems encountered in the process are summarized, with emphasis on two of the limitations of the electric generation expansion model (WASP). The solutions found by Bulgarian experts to overcome these problems are also described, together with some comparative results of the tests performed.

1. INTRODUCTION

This paper aims at providing information on the use of IAEA planning approach and software in Bulgaria and some details concerning the introduction of IAEA's tools in Bulgaria, as well as the experience with WASP and ENPEP in Bulgaria since 1988.

As an introduction to the topics to be discussed, it is worth mentioning certain general aspects related to the use of IAEA models in Bulgaria, namely:

- The IAEA's planning software - WASP and ENPEP- are operative in several Bulgarian organisations / institutes;
- Different modules of IAEA's software are used in several official or non official investigations;
- The IAEA's planning software is known, verified and used often for research made on request by the Bulgarian Government and/or international or foreign financial institutions.

It should be noted that before 1980, several Bulgarian and Russian planning models were used in Bulgaria. These models were based mainly on linear optimisation and forecasts based on statistical figures. Since 1978, Bulgarian organizations have used the set of planning models - MACRO, MEDEE, MESSAGE, IMPACTS - that were originally developed by the International Institute for Applied System Analysis (IIASA).

The WASP model was introduced in Bulgaria in 1988/1989 as a result of the participation of a team of experts from ENERGOKIBERNETIKA in the IAEA's training course on Electric System Expansion Planning. At that time, the first official study using the IAEA's planning approach was performed, upon request of the Bulgarian Committee of Energy. Later, other studies were performed for the Bulgarian National Electric Company (NEC) and other organizations. In addition, some training courses were also organized to train national experts interested in using the WASP model, etc.

Training in the use of the ENPEP modules MACRO, DEMAND, MAED, BALANCE, PLANTDATA, LDC, ELECTRIC, ICARUS, IMPACTS was provided to Bulgarian Specialists during their participation in the IAEA Training Course on this subject at Paks, Hungary, 1994.

The time period of the introduction of IAEA's planning approach in Bulgaria coincides with the transition period from centrally planned to market economy. Meanwhile other models have been made available to Bulgaria, such as for example electric generation models obtained from France and from state Maine, USA; electricity/energy/environmental models obtained from EPRI, USA and the European Energy Commission (MARCAL/MACRO, EFOM/ENVIRONMENT with GAMS), etc.

In the beginning, the implementation of IAEA's software encountered misunderstanding and underestimation. Nowadays, due to several reasons, the IAEA's planning approach and software prevails over other models in Bulgaria.

During the several years of work with the electric system expansion planning model - WASP/ELECTRIC - different problems have been encountered. As it is known the model has some limitations, some of which were identified and dealt with, from the beginning, by Bulgarian specialists, for example:

1) static mode of modeling of power plants characteristics, which are maintained constant during all years of the planning study period;
2) modeling of maintenance as distributed into the year and average for all years which does not properly reflects the conditions of the Bulgarian power system;
3) missing of electricity production limitations on group or separate thermal power plants.

The first two of the above limitations are considered in this paper.

The implementation of electric generation expansion planning models in Bulgaria shows that the limitations mentioned above pose a problem for the representation of the conditions of the Bulgarian electric system. In our practice, most of the thermal power plant characteristics - minimum and maximum unit capacity, heat rate, FOR, operation and maintenance costs, etc. - change substantially along the years with deterioration of the plant performance as the plant becomes older. The reasons for this are: physical obsolescence of the devices, technology/technical/design features, and organisational and management weaknesses. Consequently, the performance values of the power plants during one maintenance period are changed, and the maintenance does not recover 100% of the values. As a result, after several years of utilisation, the average value of the above parameters in some Bulgarian thermal power plants is about 92-98% of the initial value. Owing to this problem, Bulgarian planners refused to work with a based on constant characteristics of PP (henceforth referred to as "static model") and distributed, average yearly maintenance.

The above explanation reveals the importance of modeling the power plant parameters in a dynamic way in long time electric generation planning studies.

There are several methods to overcome this limitation. One of these methods is to use dummy declared power plants (referred to as "PP" units), retiring the PP units at a certain time and putting into operation generation units for a plant type with modified values (referred to as "PP2" units). But the limitations on the number of thermal units which can be modeled, constrain the number of dynamically modeled units and the time intervals for dynamic changes. In addition, this method is exogenous and does not allow for a smooth change of the PP characteristics.

Another exogenous method is to use a series of model runs with different values of characteristics and extract some conclusions by combining the results. This method does not give a correct dynamic character of the behaviour of PP characteristics owing to the difficult task of making the input and output data, as well as the results, consistent.

A third exogenous method to overcome the two above stated limitations, is to have a set of several electric generation expansion planning models with different planning horizon and time unit. Another Bulgarian investigation shows that the third way is the best way, especially when the original model is complex enough and has run time and size limitations.

During 1989-1990 Bulgarian specialists from ENERGOKIBERNETIKA and other Institutes made a successful attempt to improve the electric generation model concerning the above discussed limitations. Two approaches were used to reach these goals.

2. 0 First approach to solve the problem:

The basic principle of the work was to keep all existing methods and tools, but incorporating new features and possibilities. During the development of the project the specialists performed an analysis of the model hypothesis, structure and consistency, analysis of software structure, sub-programs, model input, output and consistency, analysis of new ideas, model design, verification tests.

2.1 Dynamic behaviour of PP2

The WASP model consists of 7 main modules - LOADSY, FIXSYS, VARSYS, CONGEN, MERSIM, DYNPRO, REPROBAT - which are designed to be run in a step-by-step fashion, usually in sequential order, to determine the economically optimal expansion plan of an electricity generation system. Each module takes information mainly from the previous module and gives information mainly to the next module.

The input and output from FIXSYS and VARSYS are structured similarly, according to the principle of groups and types (of information). The input and output files are simple and easy to understand. A very important fact is that the algorithm (input/output data manipulation) is standard each year along the planning study period.

All this allows simple manipulation of the above described modules' information and modules' interconnections. Another convenient feature is that the values of all parameters of one power plant are described in one input record. As a result, it has been discovered that it is possible to model each thermal PP (TPP) each year with new values of parameters, such as that the old TPP is retired and a new TPP is put into operation in the next time interval with the same name, code and sequential number. After execution of the module 'description of old, existing TPP', every year the TPP has different characteristics and the module 'simulation of power plants operation' works with dynamic forecasted parameters and gives dynamic operation analysis and real dynamic optimisation at the end. In this case, the structure of the input files remains the same, only the file size increases. Similarly, the execution of the algorithm and sub-programs remains unchanged, only the execution time increases. There is no need to input new data types, new record types or new record size. In fact, data input and output remain the same, the data flow is the same as in the original code.

The results from this modified model and software are consistent with the results from other methods of dynamic generation expansion analysis. The difference between one run of the static and the dynamic model depends on:

- the number of TPP/units dynamically modeled; weight of cumulative, common capacity of dynamically modeled TPP/units in all electric generation system capacity;
- the mode of TPP modeling- each unit could be modeled separately as one TPP, or all similar units in one real TPP could be modeled in one multiple units TPP;
- the difference in values between static (PP) and dynamic (PP2) units;
- the number of years of operation with changed values for PP2 units.

The average difference between a run of the static and the dynamic model is around 10-20% as a structure and more as a quantity (costs, etc.). The difference changes from year to year. There could be different type (3-5%) and/or unit size of new capacities involved into the operation (4-11%), different age structure of the electric generation system (5-15%). Most of all, as a direct result, the schedule of TPP retirement is influenced (7-18% more capacities and 2-5 years anticipating before the basic static run schedule), and the schedule of new capacities involvement in the operation (1-4 years).

It should be pointed out that every case study has to be separately analysed and to keep in mind special assumptions, hypothesis, forecasts, etc. But the work performed, structure and approach of modeling are verified and valuable.

As a result of the above, Bulgarian WASP users have the possibility to investigate different trajectories of PP2 change, for one or several TPP, to check different forecast' methods and software. The planners can perform studies using input information as close as possible to reality and the result would be more adequate.

The important yield of this exercise was new quality of the software, model, analysis and conclusions.

2.2 Maintenance schedule

The problem of maintenance scheduling of TPP generation units is important in generation expansion planning/modeling. It is very important in Bulgaria due to the relatively large amount of old TPP capacities and the financial and organisational problems being faced during the transition period from centrally planned to a market economy. Nowadays, maintenance is planned by NEC and is performed by state and private companies. As the rules of the game are still not clear, the maintenance schedule and quality are strongly influenced. On the other hand the maintenance is sensitive to the generation mix, four (4) nuclear units of 440 MWe and two nuclear units of 1000 MWe, and to the requirements of nuclear fuel cycle (refueling, etc.) and lastly, to the requirements of modernisation of all nuclear units and a large portion of the other thermal units. These facts point out to the interest on the maintenance modeling.

The goal of the planners was to modify the maintenance algorithm of TPP used in WASP, at least for the largest thermal units. This would improve the quality of the generation simulation and planning study.

The practice in the Bulgarian system shows that the maintenance of most thermal plants and units is usually performed during the summer, and the remaining part of the capacities has a less weight and does not pose big financial, labour or organisational problems.

The WASP analysis schedules units for maintenance in a given month. As WASP can be run for up to 12 periods (i.e., the model time unit is a month), it is not possible to schedule a unit for maintenance in a given week. Our survey indicated that using the ICARUS model together with ELECTRIC provides a more accurate representation of the scheduling of units for standard maintenance.

The functional structure of the WASP model separates maintenance data input only in FIXSYS and VARSYS sub-modules, while the maintenance simulation is performed in MERSIM sub-modules. The maintenance data input and simulation are simple and standard.

The examined possibilities to improve maintenance modeling in the electric generation expansion model are:

1) giving the exact months during which the maintenance is planned this year;
2) giving the starting month and the duration of the current year maintenance.

In this modified model it is assumed that the beginning of the maintenance is the first day of the initial month. The user could give any kind of maintenance duration, scheduling and combinations between different TPP maintenance scheduling during one year and in the course of the years of the planning period.

Of course there are constrains on the number of allocated TPPs for which maintenance can be assigned and the number of years with allocated TPP maintenance. But there is at least one serious constrain- the user given maintenance schedule has to fulfil the free space between installed generation capacity of the electric system and the load. This has to be checked preliminary by the user when preparing the maintenance allocation during the year. This is very important due to possible time and labour lost from 'dummy' running (after 'electric system description' steps) two other modules to the 'simulation of electric generation operation' where analysis will point to the inconsistency.

The comparison of results from the original model run and the one with allocated maintenance shows that the main change is in the available thermal power capacity, in the capacity load factor and of course in the operation and maintenance costs during the time intervals along the year. The influence of the maintenance allocation depends on the following aspects:

1) the number of thermal PP/units allocated; weight of units capacity with allocated maintenance in relation to the total electric system generation capacity;

2) the number of years with allocated maintenance of TPP within the planning period;

3) the mode of TPP modeling as one or as multiple units PP.

When TPP are modeled as multiple units then the difference between the original and the allocated maintenance model is less than with model run using single unit modeling of TPP. The former analysis is not clear, not user friendly, allows disturbances and errors. The difference is small when there are small number of TPP with allocated maintenance.

The results could be identical on an annual basis, but have very different period-level results. The results can provide twelve different, new monthly pictures of TPP operation, new mode of operation of all TPP, not only of the allocated TPP. The difference between the original model and the one with allocated maintenance model could be in average from 30 to 50 % of the monthly TPP load factor. A similar difference is found for the working capacities and for operation and maintenance costs. All these are very important for planners working with yearly/monthly generation planning.

The above proposed modification of WASP model is very appropriate for planning studies covering a short term planning horizon or any planning horizon but with strong interest to the role of different maintenance allocations during the first several years of the planning period.

2.3 Conclusions

The analyses described above indicate that the modifications introduced to the WASP model are a convenient way for making a connection between long term and short term planning; they could serve as an intermediate step between both basic planning stages.

The modifications of the WASP model described above are serious and successful attempts by Bulgarian specialists to go in IAEA's planning approach and tools. The results are very useful.

3.0 Second Approach to Overcome the Problem

The work performed in trying to modify the WASP model, as described before, has shown that modeling of dynamic character of TPP2 and maintenance allocation inside the long term generation expansion model is a complex task with many side effects. These difficulties need high qualification and responsibility.

The other way to overcome the model weaknesses mentioned above and to perform full scale planning study is to use a set of several models for long term and short term. This was analysed in special investigation with ENPEP modules ELECTRIC and ICARUS, with electric generation operation model build by ENERGOKIBERNETIKA, with other Bulgarian and foreign models. The results from this research are under preparation to be published in the near future.

4.0 Common Conclusions to Both Approaches

The main conclusions could be stated as follows:

1) both approaches are valuable, each one has its advantages depending the goals and terms of the research;

2) the first approach could be used if there are a special interest and support to the modification work while the second approach is preferable when it is easy to obtain different models;

3) the first approach provides inside/endogenous decision of the problem; while the second one provides external/exogenous decision.

5.0 Conclusions

The work performed by the Bulgarian specialists and the experience gained in the use of the IAEA's planning approach and tools permits drawing the following conclusions:

1) The work of Bulgarian ENPEP' specialists and high level IAEA official support have an important role for positive results from IAEA's planning approach and software introduction in Bulgaria;

2) Bulgarian specialists succeed to win the public opinion and to introduce IAEA's approach within the Bulgarian Government sphere and as a result, when it is necessary to conduct planning studies, ENPEP is first in the list of candidates;

3) The main achievement of Bulgarian specialist work was learning new methodologies and skill, and the introduction of new planning approach in Bulgaria. A very important ancillary result of these activities was developing a set of modifications of the electric generation expansion planning model;

4) IAEA's planning approach and tools and especially ENPEP are convenient for electric planning studies for countries with economy in transition;

5) IAEA's planning tools and especially ENPEP have to be used only after serious training has been provided to national experts, otherwise the results are weak and fully.

Nowadays the Bulgarian economy and especially energy planning analysis requires:

- different models, methods, software tools;
- trained specialists for use of these tools;
- development of consistent planning systems and approaches.

There exists many possibilities to improve IAEA's models, methods and software which could be developed by the Agency in cooperation with interested users.

The future use of IAEA's planning approach and tools in Bulgaria depend mainly on the continuous work for increasing personal qualification of ENPEP users, and on the support that can be provided by the IAEA to Bulgarian specialists.

SOURCES:
1. WASP USER GUIDE.
2. ENPEP USER GUIDE.
3. 'ENERGOKIBERNETIKA' REPORTS.