Software package for short-term planning of the Croatian Power System

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Abstract – The short-term operative planning of the electric power system involves daily and weekly planning of consumption, inflows, exchange and generation of electrical energy. Planning has to ensure the secure and reliable supply with electrical energy, i.e. covering of the demand curve with keeping the necessary amount of operative and cold reserve at minimum cost. This paper presents software for the short-term operative planning of the Croatian Power System, based on the simulation principle, including some optimization modules. The software is designed in such a way that it enables a simple and quick making of different variants of the daily power system schedule. It also enables an improvement on all functions as well as the superstructure and redesigning, which will make possible the undisturbed functioning of the operative planning in the Croatian Power System during the process of restructuring, deregulation and privatization.

Keywords: power system, short-term operative planning, scheduling, software

I. INTRODUCTION

The Croatian Power System can be characterized as a mixed hydrothermal system of a smaller size, and with following essential guidelines:

- the big variety of generation units,
- the relatively great part of generation from hydroelectric power stations, which is followed by the strong dependence upon hydrology, but also by great daily and seasonal regulation capabilities of the system in regard to the major part of storage hydroelectric power stations,
- the unfavourable daily demand curve caused mostly by reduced consumption of the big industrial consumers due to the war conditions and unadapted tariff system
- relatively good exchange possibilities with neighbouring countries are temporary reduced because of war devastation; they are going to be essentially improved during 1999, when a new 400 kV line toward Hungary will be put in operation,
- problems with 220 and 400 kV transmission network (which is, inside the country, mostly radial), primarily with voltage conditions during low demands and sometimes with system stability,
- the unresolved status of thermal power stations witch belong to Croatia and were built in neighbouring countries,
- initiation of the process of deregulation, restructuring and privatization

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Under the circumstances, the making of adequate software support for power system operative planning becomes a complicated and specific process that should be continuously improved and adjusted, as it is practically impossible to find such software on the market that would be able to adapt to the existing particularity and to the future structural changes of work of the Croatian Power System, following the process and methodology of planning.

The D–PLAN (daily planning) software has come out in co-operation of the Faculty of Electrical Engineering from University of Split, Croatian Power Utility and software company Fractal, which was organized by the Energy Institute "Hrvoje Pozar", within a wider project of making and maintaining of adequate applications and data bases for operative planning of the Croatian Power System. The D–PLAN has been realized in such a way that Microsoft Excel is used for formating of input data, survey of calculation results, forming of outputs and data transfer towards other applications, while needful calculations have been realized as a separate program. The connection for data exchange has been established through the relating application in Excel, and through the external program for calling the particular calculation modules. Excel as a base for input/output has been chosen because of the application character (mainly spreadsheet data and diagrams), shortening of the time needed for programming and maintaining of the application, plainness and simplicity of the use for post-operational analyses, possibilities for the making of simple users modules, communication with other applications and the like. Due to the lack of complete database of the Croatian Power System technical parameters needed for the planning process, a temporary database has been made and maintained, also in Excel. All versions of the calculation have been saved and using as a basis for the calculation in one of the following days and post-operational analysis.

II. THE MAIN PURPOSE OF THE D–PLAN AND NEEDED INPUT PARAMETERS

The short-term operative planning of the Croatian Power System, which can be characterized as a mixed hydro-thermal system of a small size, has the following particularities:

- the unit commitment for thermal power stations, regarding their small number, is mainly used empirically and in such a way that a certain power station is always put into or out of operation for a longer period of time, depending on the hydrological situation; in other words, the set of commited thermal power stations is defined by the mid-term plan;

- the nuclear power station Krsko and combined heat and power stations are continuously commited; the nuclear power station Krsko always with the constant power, and combined heat and power stations depending on heat consumption;
- the variable part of the daily demand curve mostly covers hydroelectric power stations;
- mid-term and long-term contracts of exchange are mostly related to the import in baseload, or in the day part of daily demand curve, while the night surplus is exported during convenient hydrological situations.

The daily operative planning of the Croatian Power system, in regard to above mentioned characteristics, includes the following activities:

- the demand forecast,
- the inflows forecast,
- planning of daily contracts of exchange,
- planning of the power stations generation by hours,
- commitment of the pumped storage stations,
- the making of power balance, hydro balance and system economic indicators,
- the load flow calculations in regard to the planned consumption, generation, exchange and transit.

With the D–PLAN software, all mentioned activities could be realized except the last one, which is performed with appropriate load flow software. The required input data are:

- the realized hourly consumption in the last few working days, Saturdays and Sundays,
- the forecasted inflows for all hydro power stations (basins),
- availability of all units,
- starting elevations of basins,
- previously arranged plans of import, export and transit,
- prices of fuels for thermal power stations,
- prices of electrical energy for possible daily exchange contracts.

III. ORGANIZATION AND STRUCTURE OF THE D–PLAN

D–PLAN, as a base for defining input parameters as well as the survey of the results of calculation and forming of outputs, uses the Microsoft Excel, whereas numerical calculations are made separately, using the object-oriented model [2] in the C++ programming language, as a separate module which is being called by relating Visual Basic macros for transferring parameters needed for the calculation. Calling a particular calculating module from Excel, macros export the needful parameters to the temporary file and activate the outer calculating module. The calculating module takes over the transferred parameters from the temporary file in addition to the needful parameters from a technical data base, witch form the basis of making the requested calculation, and exports the results of the calculation into another temporary file. The macro from Excel reads the results from the file and transfers them to the relating fields. The completely described process is practically invisible for the user.

The temporary database of technical parameters in the Croatian Power System is also maintained in Excel, and calculating module approach it according to circumstances. The basic parameters of all power stations (technical limits, heat rate curves, curves of incremental discharge rate etc.), basins (the minimum and maximum elevation and volume, the volume/elevation curves, etc.) and other objects are stored in it.

Apart from being the connection with outer calculating module, there are also macros for two additional functions. The first one is the connection with a relating outer module that serves for upkeeping the files with a needful set of data witch define previously calculated working plans, so that it enables the loading and saving the different variants. This outer module also contains the necessary protection system, which makes impossible the unauthorized use or exchange the final daily working plans. Another additional function with relating macros is exporting the needful calculation parameters to other applications for various energy-economic analyses (e.g. the data export for load flow calculations).

The figure below shows an organizational scheme of the D–PLAN software.

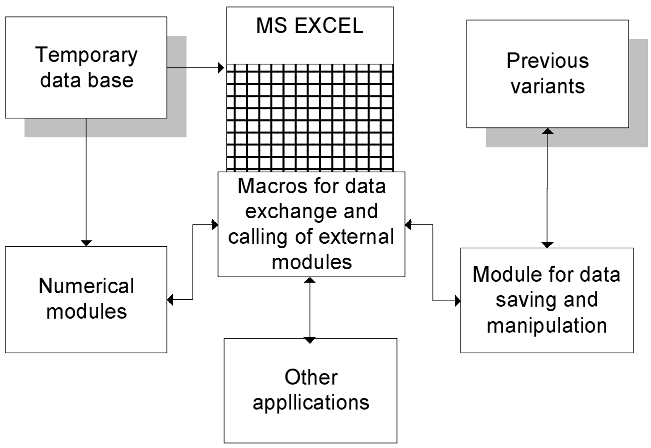

Fig. 1. Structure of the D-PLAN software

IV. DESCRIPTION OF THE D–PLAN

The progress of making the daily working plan starts with a load forecasting. On the basis of realized consumption from previous days, the hourly consumption is calculated for the following day. A relating module that use the simple method of shifting averages has been realized for the load forecasting, but it is also possible to use any external software of which the results are input into D–PLAN. A dispatcher can, from experience, additionally correct the calculated hourly consumption. The consumption of the pumped storage station is added to the final daily demand curve if the variant of its commitment in the pumping mode is examined. In order to define the final diagram of needful generation of power stations, the balance of import/export by hours is added to the demand curve.

The forecast of inflows is input on the basis of evaluation from realized inflows of previous days and from data given by the meteorological office. Starting elevations of accumulation and compensation basins include planned elevations at the end of the current day. They are required for the calculation of the specific discharge of water in hydro power stations, daily elevations of basins on the basis of hydro power stations schedule and for calculations of the water balance.

The information about the availability of units and adequate power limits of particular units are important for the control of the extent of scheduling of certain power stations.

TABLE I – CONSUMPTION AND EXCHANGE OF ELECTRICAL ENERGY (MW)

hour	1	2	3	4	5	6	Σ
Consumption	1205	1070	1080	1030	1050	1105	39955
Pumping	120	240	240	240	240	240	1440
Σ	**1325**	**1310**	**1320**	**1270**	**1290**	**1405**	**42395**
Import BiH	80	80	80	80	80	80	1920
Import OVG	50	0	0	0	0	0	950
Σ	**210**	**190**	**190**	**190**	**190**	**190**	**200**

TABLE II – INFLOWS, STARTING ELEVATIONS OF BASINS

hour	1	2	3	avg.
Rijecina (m^3/s)	30	30	30	30
Gacka (m^3/s)	20	20	20	20

Start. elevations (m)	
Djale	287
Prancevici	270

For scheduling of commited thermal power stations of which the timetable is not given in advance, the desired limits of power, that have to be within technical limits of available units, should be defined, as well as required daily energy from each power station. Calling the external module for scheduling of thermal power stations, in the first step the power by hours is counted so that generation of each power station is calculated by means of adequate weighting factors, which are defined by daily demand curve, with satisfying given limits in power and total energy. In the second step, the module for economic loading schedule is used for optimizing total fuel costs, taking into consideration specific heat-rate curves, prices and fuel calorific values, as well as given limits of the particular power station. Besides scheduling of thermal power stations, some relating techno-economic parameters are also calculated, such as total consumption of fuel and specific fuel costs for each power station as well as total, specific and incremental system costs. After scheduling of hydro power stations and insight into the total water balance in addition to system economic parameters, it is possible to repeat the procedure, i.e. to increase or to reduce the total energy from thermal power stations, maybe in combination with commitment of the pumped storage stations. Within the calculation of economic scheduling of thermal power stations, the adequate system incremental costs and import/export marginal costs by hours are also calculated. They form the base on which one can make decisions about the profitability, quantity and dynamics of daily exchange contracts for electrical energy.

TABLE III – INPUT PARAMETERS AND RESULTS OF CALCULATION FOR THERMAL POWER STATIONS

Pmin (MW)	Pmax (MW)	Wmin (MWh)	Wmax (MWh)	Wplan (MWh)	Thermal power station
100	190	2400	4560	4000	Sisak 1
70	95	1680	2280	2280	Plomin 1

hour	1	2	3	4	Σ(MWh)
Sisak 1	130	110	100	100	4000
Plomin 1	95	95	95	95	2280
Σ(MW)	**870**	**860**	**855**	**855**	**20530**

	kJ/kg	$/t	t	$	USc/kWh
Sisak 1	39774	80	984	78720	1.97
Plomin 1	24283	50	1164	58200	2.55

The total generation of pure run-of-river hydro power stations is calculated from available inflows, and generation by hours is distributed in accordance with the given dynamics of inflows. The scheduling of hydro power stations that have compensation basins for daily regulation, and do not belong to any set of hydraulic coupled hydro power stations, can be made as in pure run-of-river hydro power stations, but also in such a way that generation by hours is adapted for the daily demand curve by means of adequate weighting factors, thus optimizing generation in accordance with power system requests. The total available energy is defined by inflows, while the limits of power within which the power of the hydro power station may vary during the day, are being input. The same procedure is used for scheduling of the storage hydro power stations and hydraulic coupled hydro power stations, along with previous defining of the total discharge of water from each reservoir using the suitable energy equivalent. The decision about the use of the particular reservoir depends on the current energy equivalent and daily inflows, in accordance with previously established dynamics of the use of particularly reservoirs. The quantity of water, which is discharged from the last reservoir that gets in the calculation is not fixed but is calculated on the basis of needful power by hours for the final covering of daily demand curve, i.e. closing of the energy balance. If in certain hours the energy balance is not closed, the excess or deficiency of power is signalled, and repeating the calculation, with greater or smaller contribution of thermal power stations and/or storage hydro power stations annuls it.

TABLE IV – INPUT PARAMETERS AND RESULTS OF CALCULATION FOR HYDRO POWER STATIONS

Pmin (MW)	Pmax (MW)	Wmin (MWh)	Wmax (MWh)	Wplan (MWh)	Hydro power station
60	80	252	1920	500	Vinodol
50	210	6912	5040	4000	Senj
0	20	484	480		Sklope

hour	1	2	3	4	Σ(MWh)
Vinodol	0	0	0	0	500
Senj	125	105	100	100	4000
Sklope	10	10	10	10	380
Σ(MW)	**980**	**810**	**805**	**800**	**28530**
ΔP (+/- MW)	**0**	**0**	**0**	**0**	**-5**

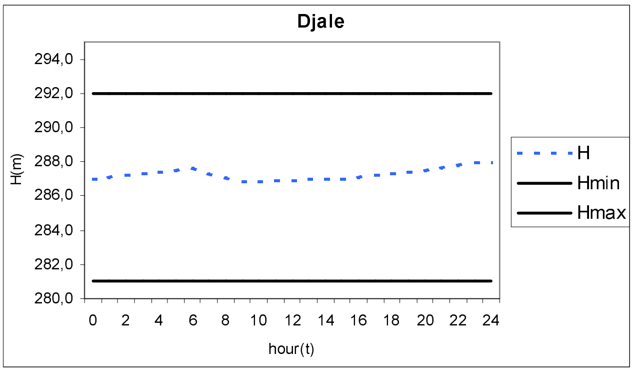

Fig. 2. Elevation of the Djale compensation basin

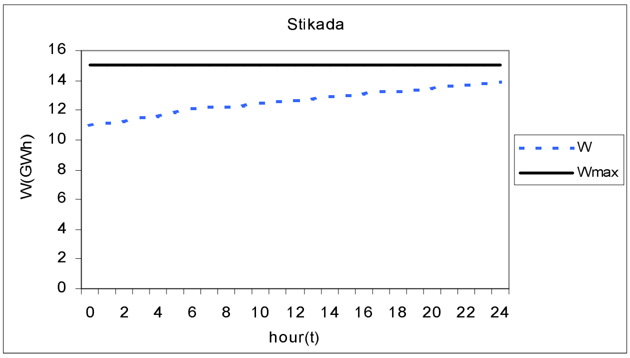

Fig. 3. Energy equivalent of the Stikada basin

On the basis of generation of hydro power stations, daily elevations, energy equivalent and possible spillage of each basins are being calculated. This data are primarily important for the control of the condition of compensation basins and for possible repeating of the calculation due to spillage or essential deviations of elevation from optimum value.

After doing the calculation, tabular and graphic energy balances and power system economical indicators have been given: the structure of consumption and production, the water balance, the state of reservoirs, the consumption of fuels, the total and incremental system costs, etc. The separate outputs are also formed, and used in the central dispatch centre as well as in the local dispatch centres for want of the operative system control.

TABLE V – ENERGY BALANCE

Sat	1	2	3	23	24	Σ
Run-of-river hydro	120	105	55	145	140	**3485**
Nuclear	0	0	0	0	0	**0**
Thermal - coal	0	0	0	0	0	**0**
Thermal - gas	50	50	50	50	50	**1200**
Thermal - oil	790	790	790	805	805	**19330**
Import	110	45	45	365	170	**8730**
Storage hydro	550	500	490	695	695	**16365**
Σ	**1620**	**1490**	**1430**	**2060**	**1860**	**49110**
Consumption	1620	1490	1430	2060	1860	**49110**
Pumping	0	0	0	0	0	**0**
Export	0	0	0	0	0	**0**
Σ	**1620**	**1490**	**1430**	**2060**	**1860**	**49110**

TABLE VI – WATER BALANCE

	W(MWh)
Generation of run-of-river HPP	**3485**
Generation of storage HPP	**16365**
Reservoirs +/-	**-1400**
Compensation basins +/-	**434**
Spillages	**0**
Energy value of inflows	**18887**

TABLE VII – SYSTEM ECONOMICAL PARAMETERS

	Energy (MWh)	Cost ($)	Spec. cost (Usc/kWh)
Nuclear	0	0	0,00
Thermal	20530	383911	1,87
Import	8730	242694	2,78
Export	0	0	0,00
Σ	**29260**	**626605**	**2,14**

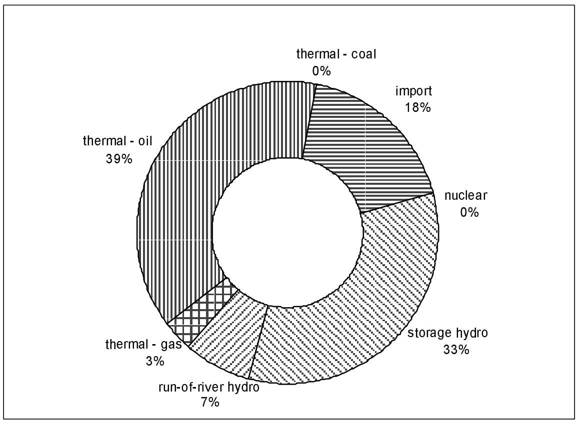

Fig. 4.Structure of generation

The calculation can be repeated by changing the wanted parameters, practically from any stage, which enables a quick variant analysis of the various possibilities of forming the power system daily working plan. Especially important for the Croatian Power System is ensuring the adequate hydro-thermal co-ordination appreciating the working plans of the reservoirs, covering the peak demand, avoiding the night spillage, and examining the techno-economical effects of all the possible short-term exchange contracts which form the base for making right decision.

VII. CONCLUSIONS

The presented software primarily serves in the central dispatch centre for variant short-term planning of the Croatian Power System that makes possible a quick and simple insight into, analysis and examination of techno-economical consequences of changing all the relevant input parameters and assumptions, in other words, the simple change of daily working plan in case of any kind of changes of input parameters, primarily the changes of the load, availability of power stations, inflows, exchange, etc. The calculation of marginal import/export costs of given amount of electrical energy has also been enabled as a support for making right decisions about the profitability of short-term contracts of exchange with other utilities. Besides, this software can serve for various power system energy and techno-economical analyses of different variants of daily demand curve, availability of generation units, hydrology, state of reservoirs, possibilities of exchange, commitment of the pumped storage power stations, availability and accessibility of fuels, installation of new power stations in the system, and the like.

Basic characteristics of the software are the simplicity of use, flexibility, simplicity of superstructure and improvement by new modules, capability of use for post-operational analyses, study analysis for planning of power system, the use for educational purposes, simple communication with other applications, the possibility of linking up with internet and intranet system, etc. Besides, such a concept can be very easily adapted to all demands for planning methods that are imposed by the process of restructuring and deregulation of the Croatian Power System (forming of pool). It can also serve as a base for making similar software for want of planning (e.g. weekly plan), analysis and control of the Croatian Power System.

VIII. REFERENCES

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IX. BIOGRAPHIES

Ranko Goic, M.Sc, was born on the island of Brac, Croatia, on April 11, 1969. He graduated from the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, where he also received his M.Sc. degree in 1997. After graduating, he has been working at the same faculty, in the Power System department. His main research interests are the power system network analysis and power system planning and optimization. The great part of his research and engineering interests include design and modelling of software tools for network analysis and power system planning, which are in operative use in Croatia and Bosnia and Herzegovina. Besides, he has been working in many research and practical investigation projects for the Croatian Power System Utility. He is member of IEEE and Croatian Committee of CIGRE.

Marko Lovric, B.Sc, was born in Livno, Bosnia and Herzegovina, on April 19, 1949. He graduated from the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split in 1972. He worked in Croatian Power System Utility (HEP) from 1974 to 1989, as operative dispatcher. From 1989 he has been working as manager of local dispatch centre in Split. The great part of his interests includes planning, control and expansion of power system. He is member of Croatian Committee of CIGRE.

Matislav Majstrovic, Ph.D, was born in Dragljane, Croatia on December 24, 1949. He graduated from the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split. After graduating, he has been working at the same faculty, in the Power System department. He received his M.Sc. and Ph.D. degree from Faculty of Electrical Engineering, University of Zagreb, in 1979 and 1986 respectively. Since 1998, he has been working in Energy Institute "Hrvoje Pozar" in Zagreb as a senior researcher. He also work as a consultant of Croatian Power System Utility and Croatian Chamber of Economy. His main research interests are the power system network analysis and energy sector development planning. He is member of IEEE and Croatian Committee of CIGRE.