

# **NEEDS FOR CONSTRUCTING AND POSSIBILITIES OF NUCLEAR POWER PLANTS INTERCONNECTION TO THE CROATIAN ELECTRICITY GRID**

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## **Abstract:**

Due to the development of electric power system and considering an increase of electrical energy consumption, needs for larger units in new power plants are obvious. Connection of large nuclear power plants to the grid, depending on their power and location, usually requires significant investments in transmission network development and construction. Considering the capacity of the 400 kV transmission network in Croatia, this problem is evident. This paper deals with the possibilities of nuclear power plants construction, as one possible option in electric power system development, and their interconnection to the electricity grid.

## **1 Introduction**

This paper is based on the preliminary results of the long-term development plan for Croatian Power Supply Industry (Master Plan). That study is made with parallel usage of two models that are used for electric power system development planning. That models are: WASP (made under the sponsorship of IAEA) and SIPRA (made in Energy Institute “Hrvoje Požar”, Zagreb). Two different models were used because we tried to decrease a model influence on the results of the study. Results, which are presented in this paper, should be considered as typical for both models. Very good convergence of the results was accomplished, and the differences between results of that two models are not of greater significance.

Only the most typical and interesting results are presented in this paper, considering the needs and possibilities of nuclear power plants construction as one possible option of power system development, although many possible cases are processed in the Master Plan.

Transmission network is essential part of every electric power system that determines its features and quality. Transmission network’s main task is a connection of a generation facilities and large groups of consumers which are more or less distanced, intending to transmit an electrical energy generated in any electric power plant to the all nodes in a network, over more possible ways. The transmission network, depending on its configuration, accomplishes most economical and favourable combination of electric energy generation and safely consumer supply.

Interconnection of neighbouring electric power systems with high voltage transmission lines enables more economical and safely operation. With interconnected electric power systems generation facilities are more economically used in different areas, differences and characteristics of power systems are less obvious in relation with interconnected systems which is of greater significance in power systems with large share of a hydro energy. Interconnection between power systems offers a number of advantages compared to the situation of independently operated subsystems through: sharing of common generation reserves and optimised expansion of generation, optimised generation unit size, reduced total spinning reserve, reduced operational cost, improved system reability, increased quality of supply, etc.

The main transmission network objects are high voltage transmission lines and transformer substations. Investments in a transmission network development are less part in overall power system investments but not irrelevant one, so careful and detail studies of its characteristics and abilities are very important in optimising its future development.

Possible constructing of larger nuclear power plants and interconnection to the Croatian electricity grid request for transmission network reinforcements, especially for 400 kV network. Present configuration doesn't allow safely transmission of larger nuclear power plants generation, independently on their locations.

## **2 Electric energy consumption**

The first step in long term power system development planning is electric energy consumption foresight. Period between 2000 and 2030 has been observed. MAED model, which determines energy demand for different sectors including electric energy, was used for that purpose. Different consumption sectors researches (transport, tourism, agriculture, etc.) were the basic for that analysis. That researches were made by specialised organisations under the co-ordination of the Energy Institute "Hrvoje Požar".

Depending on the long-term economical development scenarios and rate of GDP growth, several scenarios of electric energy consumption were made. This paper deals with referent electric energy consumption scenario that is determined by the GDP growth rate of about 5 %. Considering that electric energy consumption is determined in the Master plan we will not describe which suppositions are included in that electric energy consumption scenario. Yearly consumption and peak load are presented in the table 1.

## **3 Present Croatian electric power system**

Present Croatian electric power system has 17 hydro power plants (without those with installed power under 5 MW), with overall installed power of about 2000 MW and with average yearly production of about 6150 GWh. We've supposed that all hydro power plants will be in operation (with some reconstruction) until the end of a studying period (until 2030).

About 1500 MW of installed power in thermal power plants (with Croatian part of nuclear power plant Krško) is in operation. The main fuel for thermal power plants is liquid fuel.

Considering the years of thermal power plants constructing, we've supposed that all thermal power plants will be out of operation until the end of a studying period.

For the first studying year (2001.) TPP Plomin 2 (210 MW) and the new unit in CHP Zagreb (190 MW) are included in the present power system.

*Table 1 – Yearly consumption and peak load for the referent scenario*

<b>Year</b>	<b>W<sub>total</sub></b>	<b>P<sub>max</sub></b>	<b>Year</b>	<b>W<sub>total</sub></b>	<b>P<sub>max</sub></b>	<b>Year</b>	<b>W<sub>total</sub></b>	<b>P<sub>max</sub></b>
	<b>GWh</b>	<b>MW</b>		<b>GWh</b>	<b>MW</b>		<b>GWh</b>	<b>MW</b>
2001	15610	2841	2011	20884	3622	2021	25705	4182
2002	16144	2923	2012	21408	3691	2022	26206	4243
2003	16678	3006	2013	21932	3759	2023	26708	4303
2004	17212	3088	2014	22456	3828	2024	27209	4364
2005	17747	3171	2015	22980	3897	2025	27710	4424
2006	18269	3247	2016	23425	3942	2026	28228	4507
2007	18792	3324	2017	23870	3987	2027	28746	4590
2008	19314	3400	2018	24314	4032	2028	29264	4674
2009	19837	3477	2019	24759	4077	2029	29782	4757
2010	20360	3553	2020	25203	4122	2030	30300	4840

#### 4 Power plants candidates

Following hydro power plants are observed as a candidates for constructing:

*Table 2 – Hydro power plants candidates*

<b>Hydro power plant</b>	<b>Sign</b>	<b>Installed power</b>	<b>Yearly generation</b>	<b>Total investment</b>
		<b>MW</b>	<b>GWh</b>	<b>10**6 USD</b>
Novo Virje	HYD1-1	140	650	395
Podsused	HYD1-2	44	215	134
Drenje	HYD1-3	39	185	117
Lešće	HYD1-4	40	94	82
Ombla	HYD2-1	63	172	106
Krčić	HYD2-2	7,6	37	38

Combined cycle, coal and nuclear power plants with different installed power are also observed as candidates for constructing. Thermal power plants characteristics are presented in the following table:

*Table 3 – Thermal and nuclear power plants candidates*

Power plant	Sign	Installed power	Investment costs	Fuel costs
		MW	USD/kW	USD/GJ
TPP Gas 100	G100	102	640	3,9
TPP Gas 200	G200	204	550	3,9
TPP Gas 300	G300	306	495	3,9
TPP Coal 350	C350	350	1150-1475	2,2
TPP Coal 500	C500	500	1100-1375	2,2
AP600	N660	660	1600	0,5
CANDU-6	N715	715	1650	0,27
LWR 900	N980	980	1600	0,49

We can see from the previous table that investments for coal power plants are not fixed. When we had collected a data for power plants investments we saw that they are very dependent on an information source. All examinations were made with two extreme values of coal power plants investments (the lower and higher value), in order to see the results sensibility for a coal power plants investments.

Considering the new power plants fuels it's obvious that we shall have to import it, because Croatia doesn't have it in a greater quantities or not at all. Natural gas is specific problem because uncertainties in an available quantities for electricity generation at this moment.

Economical and energy value calculations of different power plants candidates have shown that gas power plants have the greatest economical and energy value with starting suppositions. Problem of available gas quantities should be considered, as well as maximum acceptable share of gas power plants in the electric power system, because of diversification and safely supply of consumers. Several cases were observed considering different available quantities of the natural gas for electricity generation. Available quantities of the natural gas were combined with different investments for the coal power plants in those cases. All eight examined cases are shown in the following table:

*Table 4 – Examined cases considering natural gas available quantities and coal power plants investments*

<b>Coal power plants investments</b>	<b>Available quantities of natural gas</b>	<b>Case</b>
lower value	unlimited quantities of natural gas	case01
	gas power plants up to 40 % of installed power in a new power plants	case02
	gas (700 + 150)* 10**6 m3 till 2010. extra 800*10**6 m3 after 2010.	case03
	gas (700 + 150)* 10**6 m3 till the end	case04
higher value	unlimited quantities of natural gas	case05
	gas power plants up to 40 % of installed power in a new power plants	case06
	gas (700 + 150)* 10**6 m3 till 2010. extra 800*10**6 m3 after 2010.	case07
	gas (700 + 150)* 10**6 m3 till the end	case08

Calculation for the first five cases (case01 – case05), based on a costs criteria's (target function is a minimum of total costs of the electric power system in whole calculation period) has shown that there are no places for a nuclear power plants. One or two nuclear unit type AP600 is included in the case06, case07 and case08 (all cases are referred on the higher coal power plants investment value). Structure of new power plants, as well as commission time schedule, are shown in the following table.

Table 5 – Structure and the commission time schedule for new power plants

Year	case06	case07	case08
2001			
2002	G300	G300	G300
2003			
2004			
2005			
2006	G300		G200
2007			
2008		C350	
2009			
2010			G100
2011	2xG300	2xG300	C500
2012			
2013	G200	G100	C500
2014			
2015	G200	C350	HYD2-1
2016	G100 + N660	N660	N660
2017			
2018			
2019			C350
2020		HYD2-1	
2021	HYD1-1	N660	
2022	N660		C500
2023			
2024			
2025		C350	
2026	HYD2-1		C350
2027	C350	HYD1-2	
2028			
2029			HYD2-2
2030	HYD1-2	C350	HYD1-1

## 5 Transmission network reinforcements

Transmission network configuration problems have been noticed at the beginning of a political and economical independence. Developed as a part of electric power system of ex. Yugoslavia with well meshed network, Croatian transmission network characterised by the longitudinal structure with very long 400 kV and 220 kV lines which connect greater consumers areas was separated after the former state disintegration. Specific shape of the country with longitudinal structure of transmission network was the main reason for our experts to determine the following directions for transmission network development:

- Electric power system of Croatia should be developed and reinforced as a self-sufficient system that accepts present realities, perceivable development and interconnections with neighbouring countries.
- A framework of the electric power system should be 400 kV transmission network, which has to be reinforced in order to safely connect consumers area with power facilities.

- New 400 kV transmission lines should be built as double circuit lines considering a specific country shape.
- New 220 kV transmission lines should be avoided in accordance to network development in European countries.

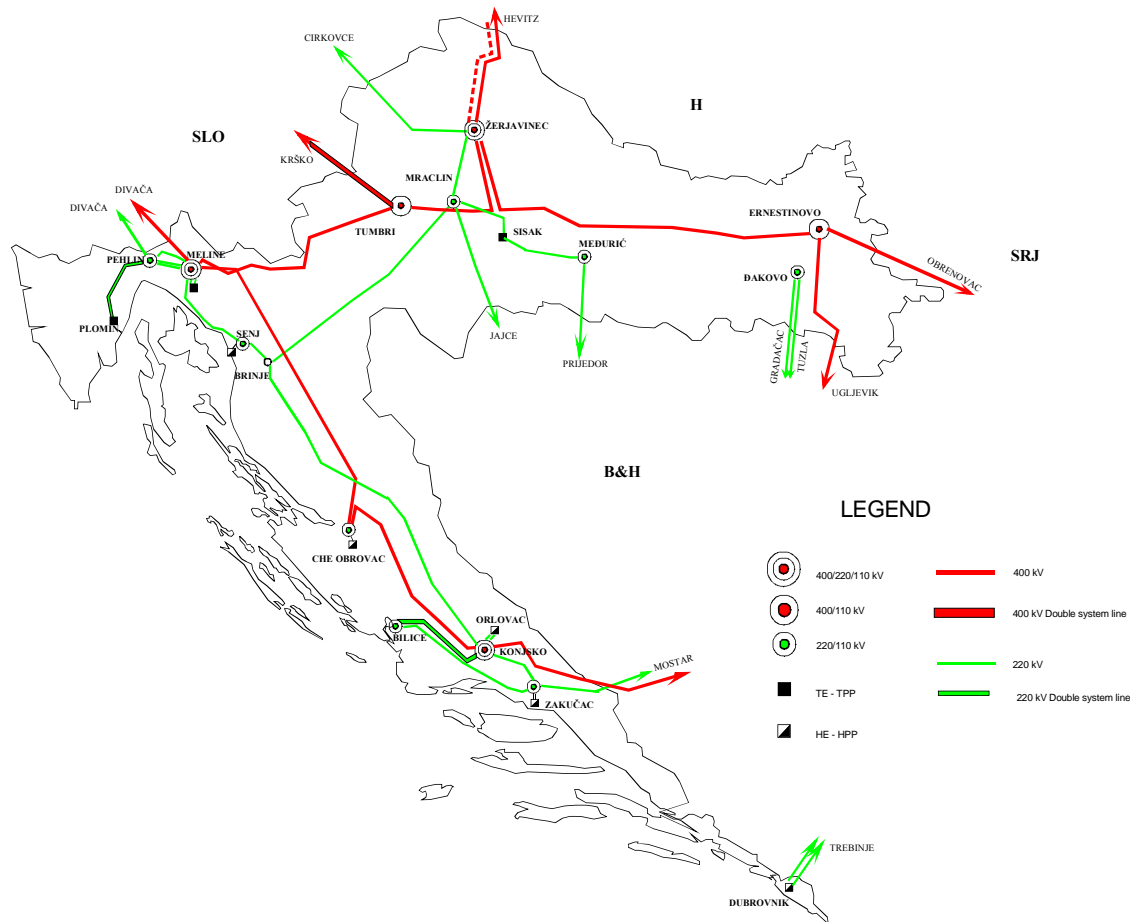


Figure 1 – 400 and 220 kV transmission network in Croatia (expected configuration after the restoration)

Connection of greater generation facilities on the transmission network with present configuration doesn't allow safely transmission of their power to greater consumers areas. Possible transmission over neighbouring countries (Slovenia, Bosnia and Herzegovina) is reasonable if it is founded on economic interests, but unfortunately present experiences with unavailability of Bosnian network (and questionable future reliability), and ELES (Slovenian transmission company) restrictions of transit for Croatian needs (up to 300 MW) justify the conception of self sufficient electric power system. In that way defined electric power system development strategy is in accordance with globalisation and enlargement of electric energy market, because strengthened connection between UCPTe and the south-east countries will be achieved. New power plants locations will strongly determine a future development of 400 kV transmission network, and it is expected that it will be necessary to reinforce it in its whole length. New lines as double circuit lines strategy will have to be economically justified for some lines, considering a forecasted consumption raise, possible size and locations for new generation facilities, as well as expected transits in the future.

Following picture shows acceptable transmission network configuration after the connection of two nuclear power plants at Dalj and Prevlaka locations. For the connection of the nuclear power plant (660 MW installed capacity) Dalj it's necessary to build a double circuit 400 kV line to transformer station 400/220/110 kV Ernestinovo, and to connect eastern part of electric power system to the western part with new 400 kV and 220 kV lines. Safely transmission of NPP Prevlaka generation will be ensured with new 400 kV line to the region of Dalmacija (Obrovac and Konjsko transformer stations) and new 400 kV line to the TS 400/110 kV Tumbri.

These preliminary results should be assured with more detail calculations of power flows, short-circuit, and transient and dynamic stability of the Croatian power system interconnected with the UCPT. Different locations for new nuclear power plants wouldn't change strategy of 400 kV network strengthened in its whole length, but different solutions for some lines and possible building of new transformer stations 400/x kV could be more visible.

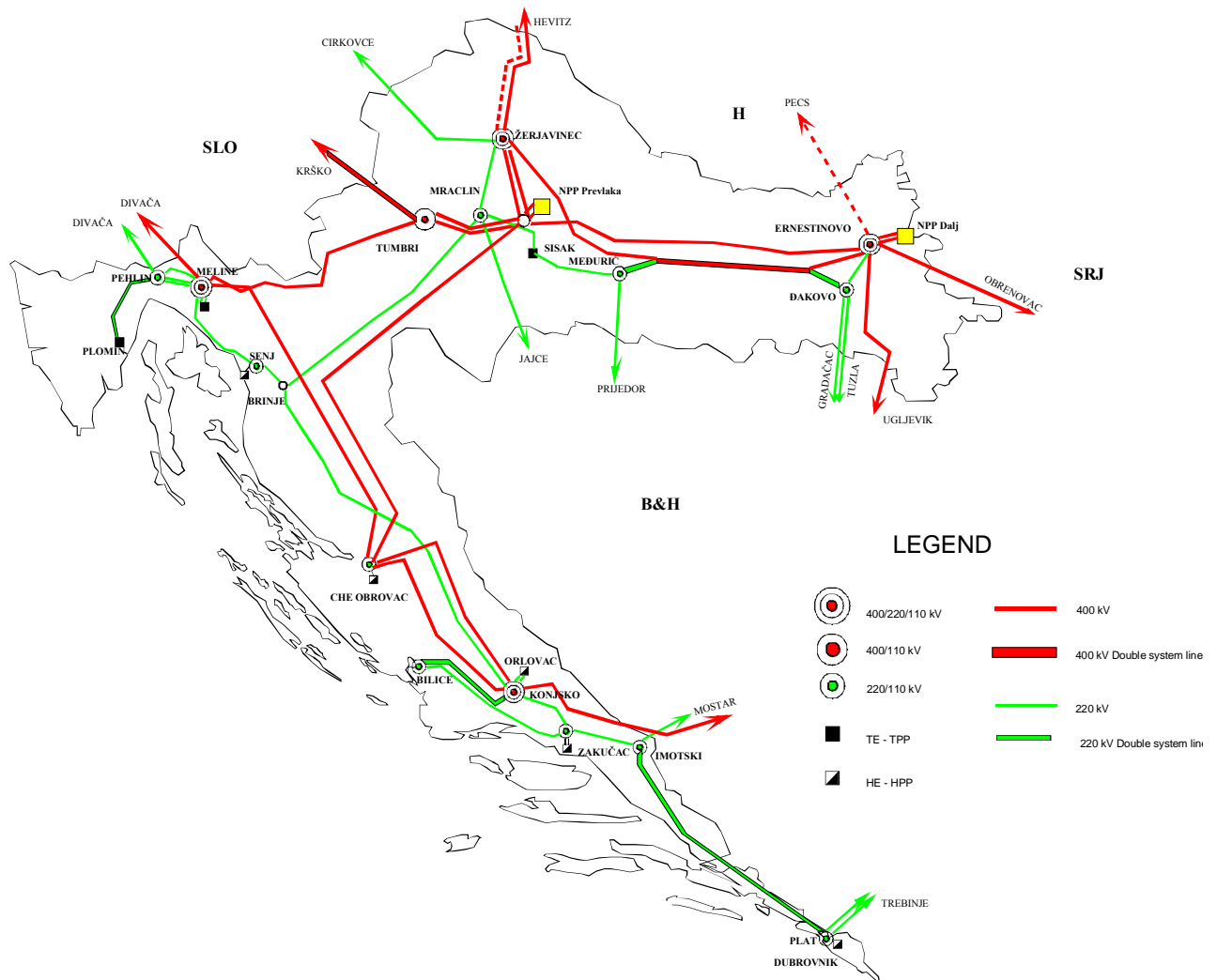


Figure 2 - Possible configuration of 400 and 220 kV network for NPP Dalj and NPP Prevlaka connection

## **6 Conclusion**

Third United Nations conference about global climate changes, which was held in Kyoto at the end of 1997, has obliged Croatia to reduce an emission of green house gases for 5 %. Energy in general, and electric energy sector is the most significant source of green house gases, so it is expected that great part of reduction could be accomplished inside it. Considering the electric energy sector, reduction of green house gases will go in two main directions. One is increasing of energy effectiveness, and the second one is an introduction of renewable energy sources and nuclear energy. Aspiration for green house gases emission reduction will open a chance for nuclear energy option. On the other side, measures for increase of energy effectiveness will reduce a rise of electric energy consumption, and the renewable sources will take over a part of generation that could be reserved for nuclear power plants. Although, as far as we could know, nuclear power plants will be one of the most effective measures for reducing green house gases emission, which could introduce them in the electric power system of Croatia.

Transmission network, especially 400 kV network, will have to be reinforced in its whole length, when larger generation facilities (especially nuclear power plants) will be connected to the power system. Reinforcing of 400 kV network with double circuit lines will have to be economically valued. Described network configuration will allow safely transmission of a new power plants generation to larger consumer areas, and the network will be capable to support a considerable transits on the south-east and north-west line. Exchanges and transits will be based on the economic interests, and the power system independence will be achieved.

## **REFERENCES**

- [1] Needs for constructing a new generation and transmission network facilities until 2020, with a view for 2030 – Basis, Energy Institute “Hrvoje Požar”, Zagreb, 1997.
- [2] Croatia power investment master plan – Transmission network data for 1995, 2000 i 2005, Energy Institute, Zagreb, 1995.