MEĐUNARODNO REGIONALNO SAVETOVANJE O ELEKTRODISTRIBUTIVNIM MREŽAMA

REGIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION

Crna Gora, Herceg Novi, 5 - 8. oktobar 2004. / ***Montenegro, Herceg Novi, October 5 - 8, 2004***

BASIC CHARACTERISTICS OF POWER TRANSFORMERS AND SUBSTATIONS BASED ON THE CONSUMPTION OF PU EDB THROUGH 2000

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Abstract:

The paper deals with the basic parametres of power transformers and characteristics of switching installations in substations of all voltages within the consumption of PU »Elektrodistribucija Beograd« (PU EDB). The power transformers and switching installations were constructed in the period from 1950 to 2000 and are now in daily operation.

These parametres are part of large data bases on network elements within the consumption of PU EDB: they have been used so far for preparation of planning documentation on construction of all networks, as well as for preparation of various study analyses in connection with the existing and planned networks.

1. INTRODUCTION

Public utility »Elektrodistribucija Beograd« (PU EDB) delivers electrical energy to consumers in the area of cca 2500 km2; the urban consumption covers an area of cca 250 km2 and the suburban consumption covers an area of cca 2300 km2. The consumption covers over 600 000 consumers the share of consumers in the category of domestic households being over 90%.

The construction of an advanced existing generation and transmission as well as electric power distribution network in the electric power node began around 1953 with the first substation 110/35 kV (Beograd II) and a series of substations 35/6 kV and 35/10 kV. An intensive expansion of electric energy and power consumption implied a rapid construction of all networks, so that the first substation 220/110 kV was already in operation in 1960, and the first substation 400/220 kV was in operation in 1971.

Around 1971 the voltage levels in networks were 400 kV, 220 kV, 110 kV, 35 kV, 10 kV and 0.4 kV, and the first substation 110/10 kV with direct transformation (Beograd I, 2x20 MVA) was also in operation. By the year 1971, the 6 kV and 3 kV networks within the urban and suburban part of consumption »transferred« to the voltage 10 kV, and the corresponding sources-thermal power plants »Snaga i svetlost« and »Zemun« stopped their electric power production.

At the present, the basic voltage levels in the electric power node of Belgrade are that of 400 kV, 110 kV, 10 kV and 0.4 kV, and along with these networks, substation 110/35/10 kV and substation 35/10 kV are also to be constructed in the near future, for supplying urban settlements up to 10 000 inhabitants, with peak load from 3 to 10 MW.

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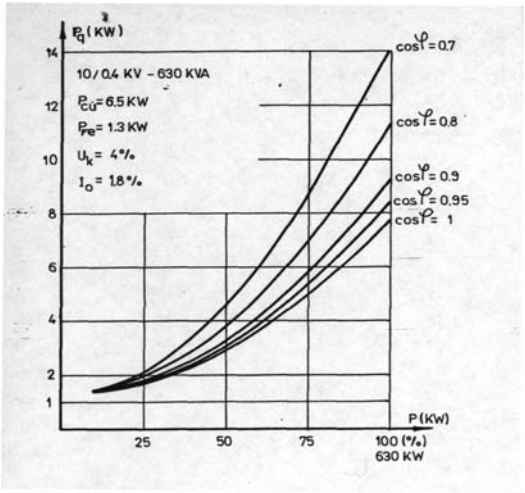
2. ELECTRICAL PARAMETRES OF POWER TRANSFORMERS WITHIN THE CONSUMPTION OF PU EDB PRODUCED IN THE PERIOD FROM 1950 TO 2000

Electrical parametres of standard power transformers of all voltages in operation which were produced in the period from 1950 to 2000, are shown in Table I They were obtained by measuring in test laboratories of manufacturers and the certificates can be found in the documentation of EDB, Elektroistok and EPS. Parametres of »block transformers« in hydro and thermal power plants which supply the consumption of EDB are not shown.

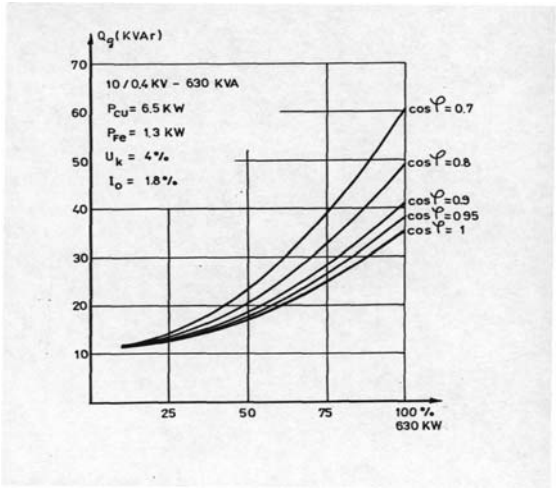
On the basis of these data, so-called »personal identity cards« have bee formed for each power transformer, covering Joule's losses in the function of active load and the power factor of consumers, reactive losses, rate of efficiency, percentage of voltage drop, percentage of Joule's losses etc. These diagrams are shown in Fig.1 referring to power transformer 10/0.4 kV, 630 KVA.

For the purpose of mutual comparison of characteristics of power transformers at all voltage levels within the consumption of EDB, Fig. 2 shows percentage of voltage drop in the function of active power (the power factor being 0.95) for power transformers 10/0.4 kV, 35/10 kV, 110/10 kV, 110/35 and 400/110 kV, and Fig.3 shows corresponding percentages of Joule's losses in the function of load (the load factor also being of the order of 0.95). Obviously, the high voltage power transformers have a significantly higher rate of efficiency compared to power distribution transformers, and the percentages of voltage drop in the function of load with all power transformers are approximately the same.

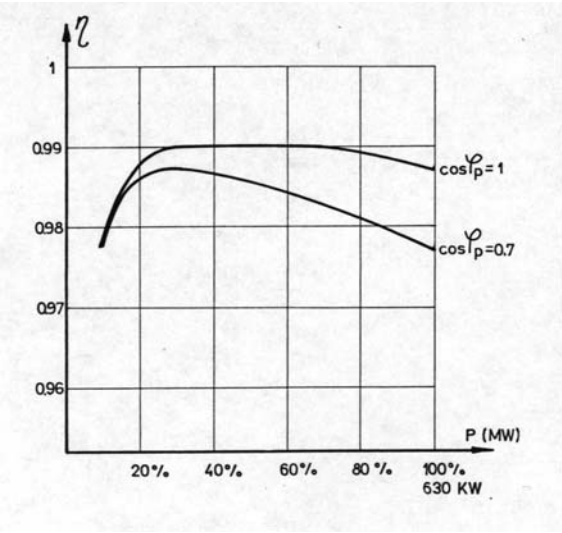
All these power transformers' electrical parametres within the consumption of EDB, as well as adequate diagrams, which give an insight into the quality of each transformer, are used in analyses of steady-state regimes in power distribution and transmission networks. For these purposes, EDB also uses conventional computer programmes, and develops a series of programme packages for various needs.



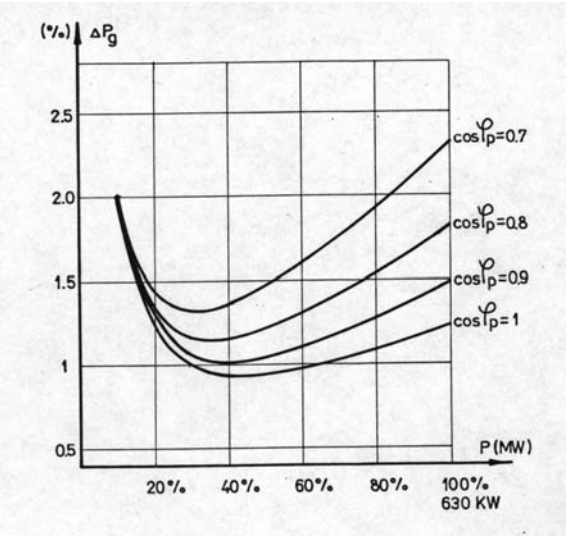
Joule's losses
in the function of active load and power factor



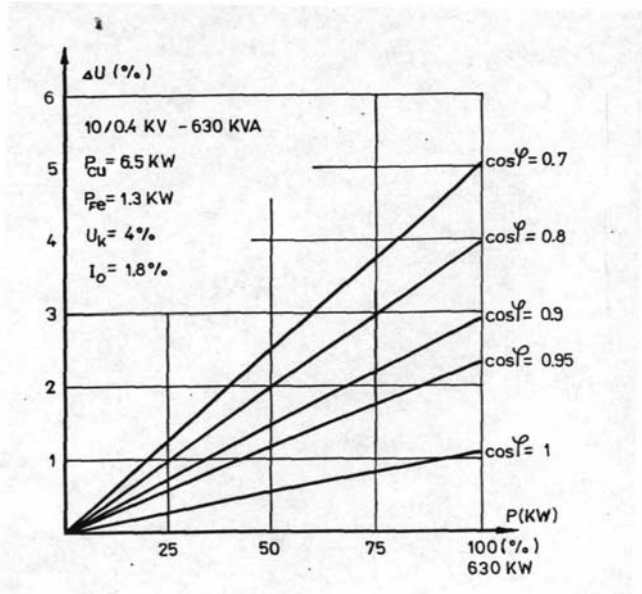
Reactive losses
in the function of active load and power factor



Efficiency rate
in the function of active load and power factor



Percentages of Joule's losses
in the function of active load and power factor



Drop of voltage in the function of active load and power factor

Fig. 1 - Basic characteristics of power transformers of nominal capacity 630 kVA

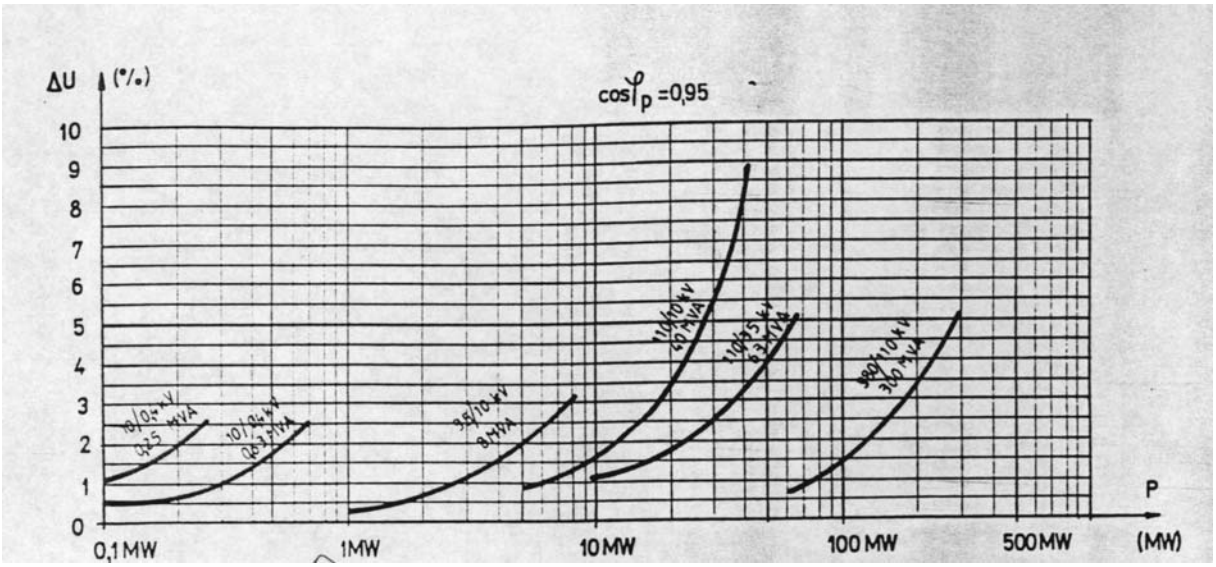


Fig.2 – Comparative review of voltage drop in power transformers within the consumption of PU EDB

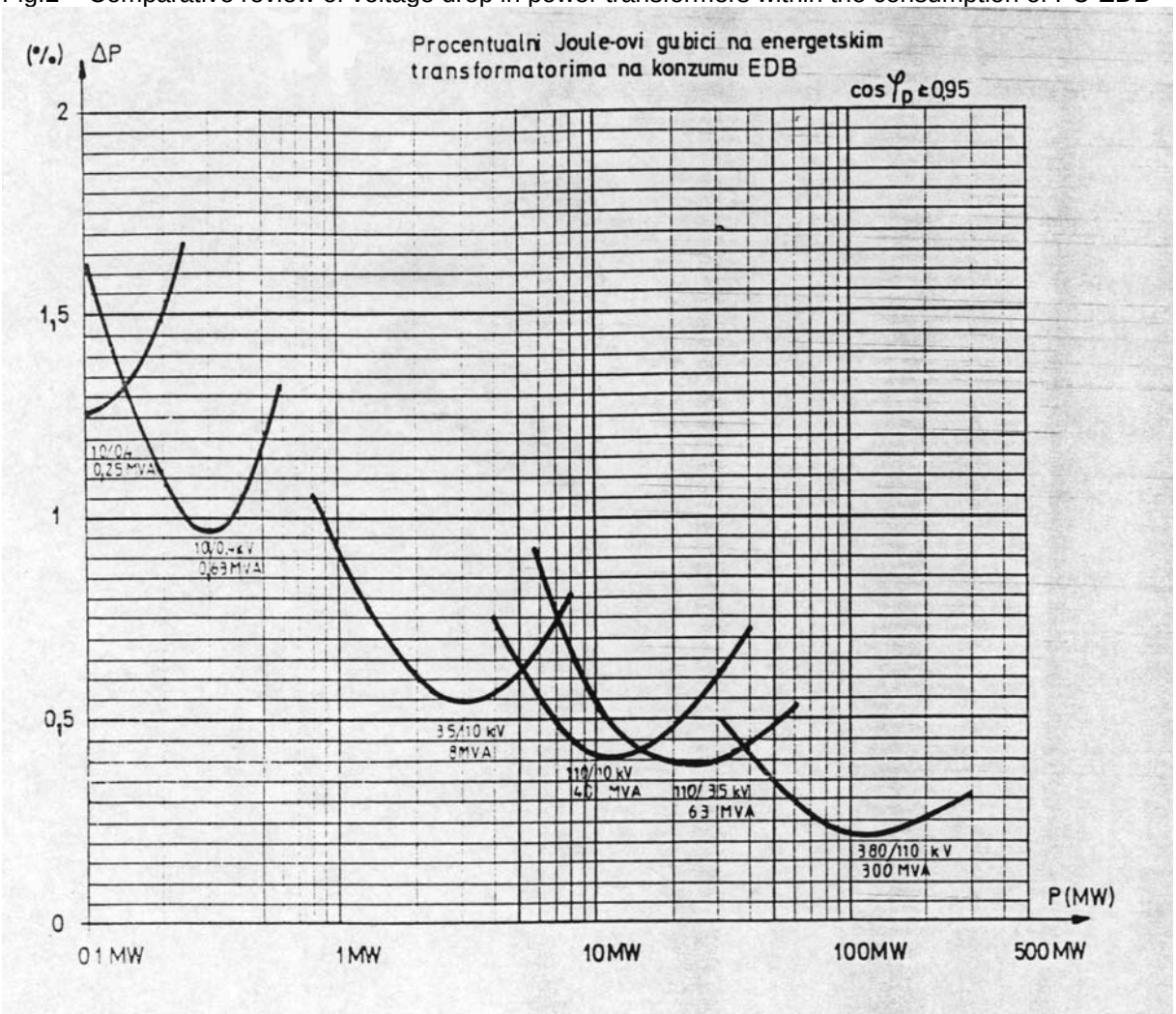


Fig.3 – Percentages of Joule's losses in power transformers within the consumption of PU EDB

Table 1 Characteristics of power transformers within the consumption of EDB

Transmission ratio (kV)	Specified capacity (kVA	Specified losses in copper (kW)	Specified losses in iron (kW)	Idle motion current (%)	Short circuit voltage (%)		
					1-2	1-3	2-3
10/0,4	50	1,1/0,94	0,19/0,16	2,6	4		
10/0,4	100	1,75/1,5	0,32/0,27	2,5	4		
10/0,4	160	2,35/2	0,46/0,39	2,3	4		
10/0,4	250	3,25/2,75	0,65/0,55	2,1	4		
10/0,4	400	4,6/3,9	0,93/0,79	1,9	4		
10/0,4	630	6,5/5,9	1,3/1,1	1,8	4		
10/0,4	1000	13,5/10,5	1,75/1,48	1,4	6		
35/10,5	4000	29,3	4,93	0,377	6		
35/10,5	8000	50,7	8,15	0,287	7,05		
35/10,5	12500	44,6	11,3	0,431	5,8		
110/10,5	31500/31500/10500	174,8	25,4	0,35	15,68		
110/10,5	40000	227,9	25,4	0,122	20(18)		
110/36,75	31500/31500/10500	124	28	0,2	11,62	10,49	9,8
110/36,75	63000/63000/20500	254	49	0,137	12,16	11,24	10,45
110/36,75	100000/100000/40000	411	67	0,16	20,41	11,6	7,975
110/36,75/10,5	31500/21000/21000	79,708/91,714/74,134	24,62	0,19	9,24	14,16	3,81
220/120	50000/50000/16700	193,6	49,4	0,7	12,2	7,1	2,26
220/115	150000/150000/50000	336,4	85,8	0,2	12,3	13,4	8,1
220/115	250000/250000/50000	505,7	98,75	0,2	14,23	9,68	6,92
400/115	300000/300000/100000	683	139,6	0,093	12,6	14	9,5
400/231	400000/400000/100000	728,7	136	0,38	12,4	18,59	14,17

Table 2 Role of substations in the electric power system, types of busbars and switching apparatus

Types of installations in substations within the consumption of EDB from the aspect of role of installations in the network and type of busbars and installations		Role of installations in the electric power system (%)				Types of busbars in substations' installations (%)							Types of installations according to switching apparatus installations (%)			
		Node role	Temporary role	Final role with several feeders	Final role	Single busbars	Single busbars with retractable circuit breakers	Single busbars with by-pass disconnecters	Single busbars with auxiliary busbars	Double busbars	Double busbars with auxiliary busbars	Without busbars	Installation in outdoor space	Installation in a one-level building	Installation in a two-level building	Installation on one level in a field-concrete or sheet iron plant
Installations in substation 380/220kV	380 kV	-	-	100	-	-	-	-	100	-	-	-	100	-	-	-
	220 kV	100	-	-	-	-	-	-	-	-	100	-	100	-	-	-
Installations in substation 220/110kV	220 kV	-	-	100	-	33	-	-	-	67	-	-	100	-	-	-
	110 kV	100	-	-	-	-	-	-	-	-	100	-	100	-	-	-
Installations in substation 110/35kV	110 kV	30	50	20	-	50	-	-	-	30	20	-	90	10	-	-
	35 kV	100	-	-	-	10	-	-	10	80	-	-	10	-	90	-
Installations in substation 110/10kV	110 kV	7	93	-	-	93	-	-	-	7	-	-	65	35	-	-
	10 kV	100	-	-	-	-	70	7	14	7	-	-	-	79	21	-
Installations in substation 35/10kV	35 kV	20	50	8	22	48	8	14	19	7	5	-	30	39	31	-
	10 kV	100	-	-	-	46	10	13	17	7	7	-	5	39	31	25
Installations in substation 10/0,4kV	10 kV	10	75	-	15	89,9	-	-	-	0,1	-	10	10	64	1	25
	0,4 kV	100	-	-	-	100	-	-	-	-	-	-				

3. BASIC CHARACTERISTICS OF SWITCHING INSTALLATIONS IN SUBSTATION WITHIN THE CONSUMPTION OF PU EDB CONSTRUCTED IN THE PERIOD FROM 1950 TO 2000

Substations in the transmission and distribution part of the electric power system within the consumption of PU EDB include one or more power transformers. Substations 400/220 kV, 220/110 kV and 110/35 kV in the transmission network generally have two power transformers although, in parallel with the development of their consumption some sunstations have been »enlarged« and therefore have up to 4 power transformers. All substations 110/10 kV and 110/35/10 kV within the consumption of PU EDB have two power transformers each, and substations 35/10 kV have from 1 to 4 power transformers. Almost all substations 10/0.4 kV have one power transformer (over 95% of the total number of substations).

Power transformers in transmission networks are in outdoor space along with around 80% of highvoltage distribution transformers, while the power transformers in substation 10/0.4 kV within the urban consumption are in indoor space. A significant number of power transformers 10/0.4 kV within the suburban network are, however, in outdoor space in the fit of so-called »pillar« substations 10/0.4 kV.

The substation installations in the transmission network 400 kV and 220 kV are in outdoor space along with a significant number of installations 110 kV in substation 110/35 and 110/10 kV. The 35 kV and 10 kV installations in almost all substations 110/35 kV, 35/10 kV and 110/10 kV are in an indoor construction plant. The installations 10 kV and 0.4 kV in urban substations 10/0.4 kV are in indoor space and »pillar« substations 10/0.4 kV within the suburban consumption are in outdoor space. The basic characteristics of substations are shown in Table II.

4. THE AGE OF POWER DISTRIBUTION SUBSTATIONS

Here in Fig.4 is shown the age of the network within the complete consumption of PU EDB – through the presentation of constructed substations up to 1960, as well as in all the following ten year periods up to the year 2000.

As the enclosed review shows, a series of investment interventions have to be taken in many microregions of the consumption in PU EDB, in order that the average age level of networks, both the global network and the networks in all microregions could be brought to a satisfactory level, by construction of new sunbstations. after an extremely restrictive investment policy in the electric power industry in the period from 1991 to 2000.

5. INSTEAD OF CONCLUSION

This paper presents the basic parametres and characteristics of power transformers and substations within the consumption of PU EDB, with a purpose to provide on one place the basic parametres on these elements of Belgrade energy node. In this manner, it is possible to compare the existing transformers' and installations' characteristics with the previous periods and, of course, future comparisons will be possible in similar situations.

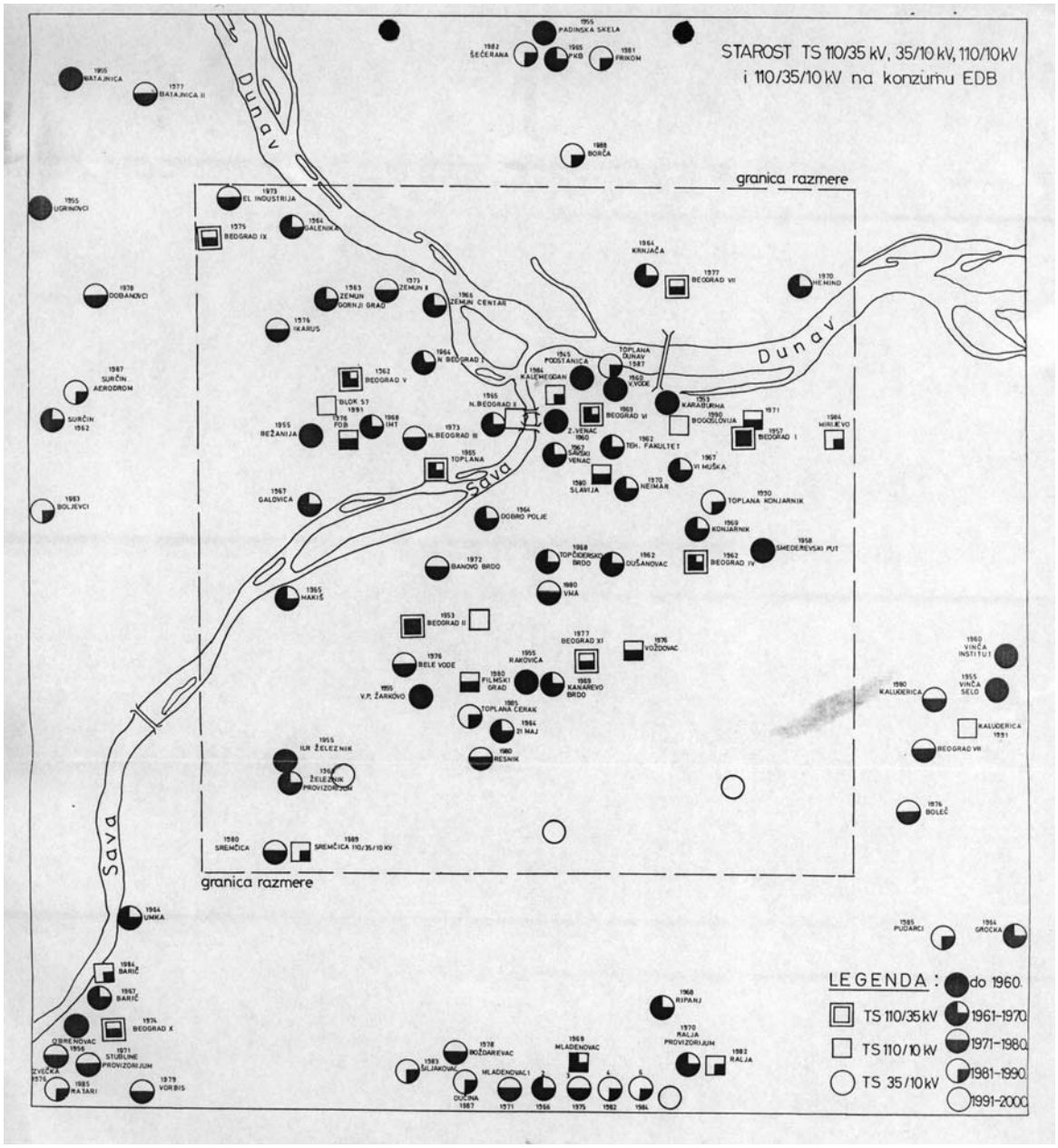


Fig. 4 – Network age in planned periods from 1960 to 2000 within the consumption of PU EDB

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