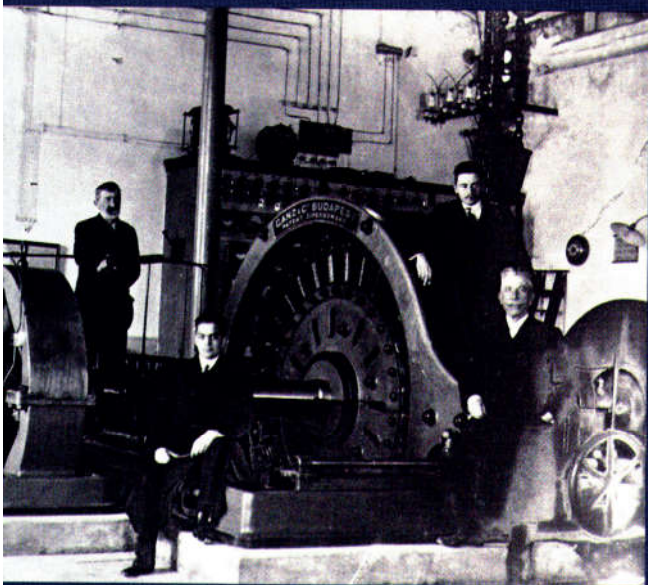
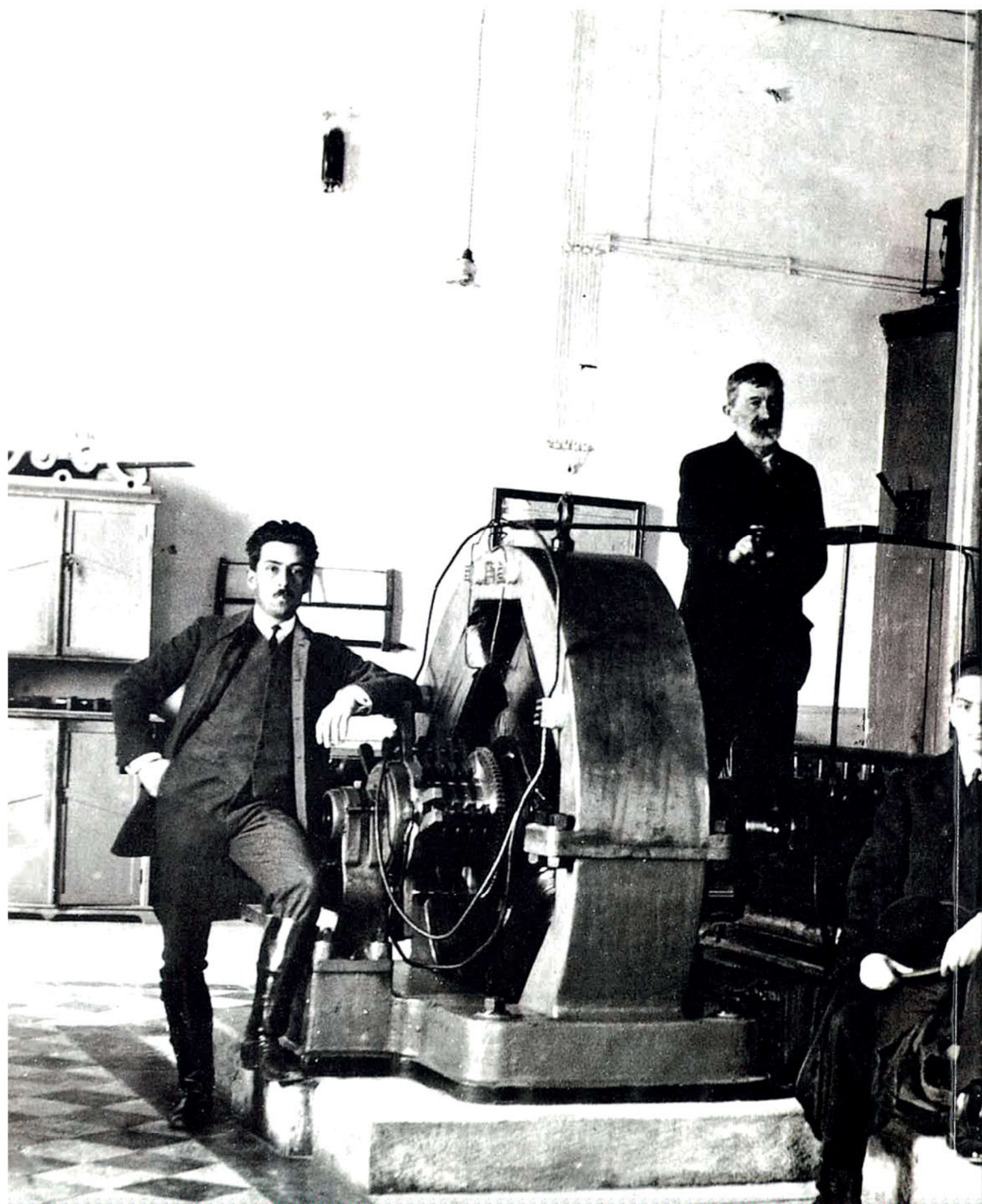
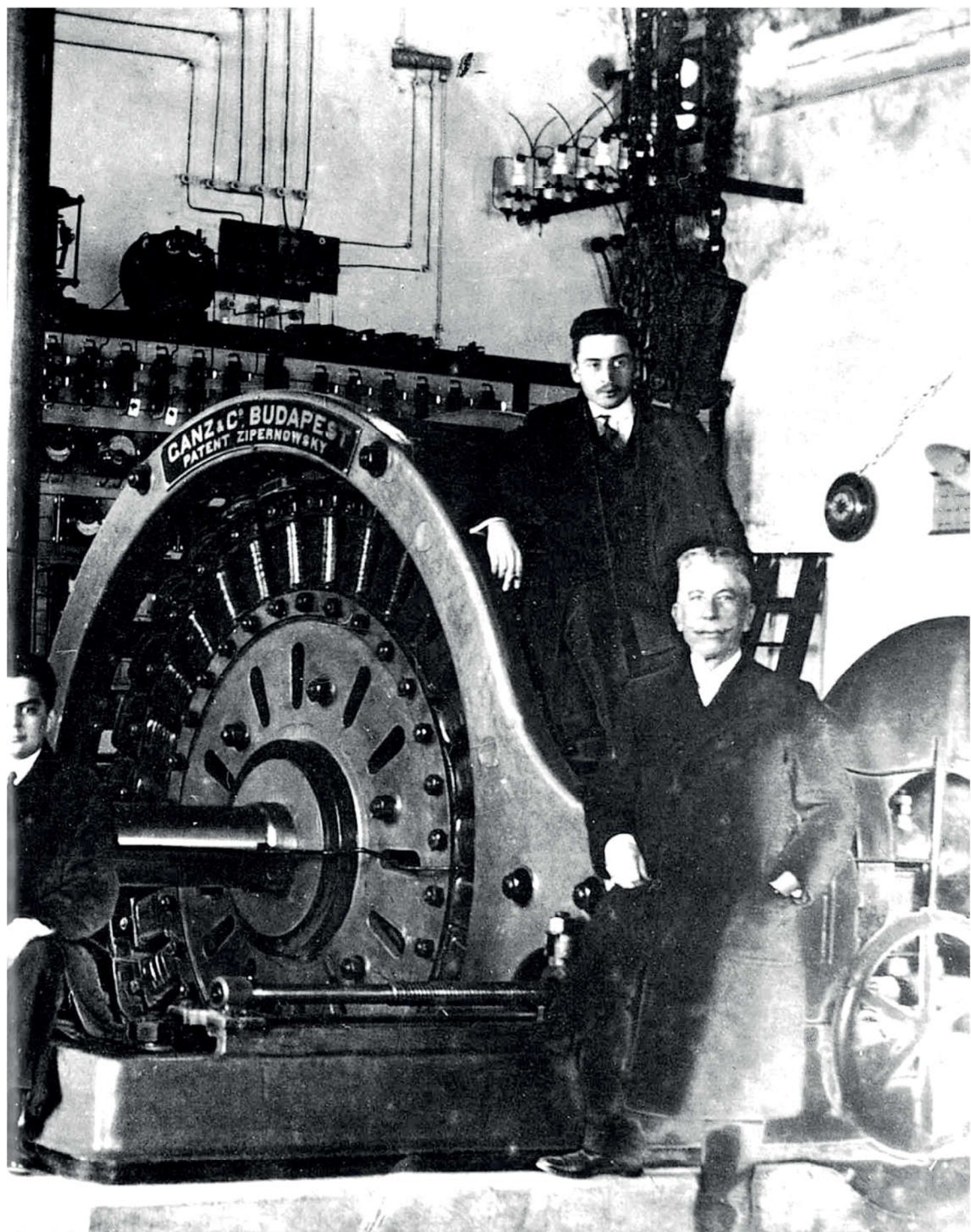




A CENTURY _____ OF HRVATSKA ELEKTROPRIVREDA





A CENTURY OF HRVATSKA ELEKTROPRIVREDA

A CENTURY OF
HRVATSKA ELEKTROPRIVREDA

Zagreb, 1995.

Through the power of spirit and work of hands...

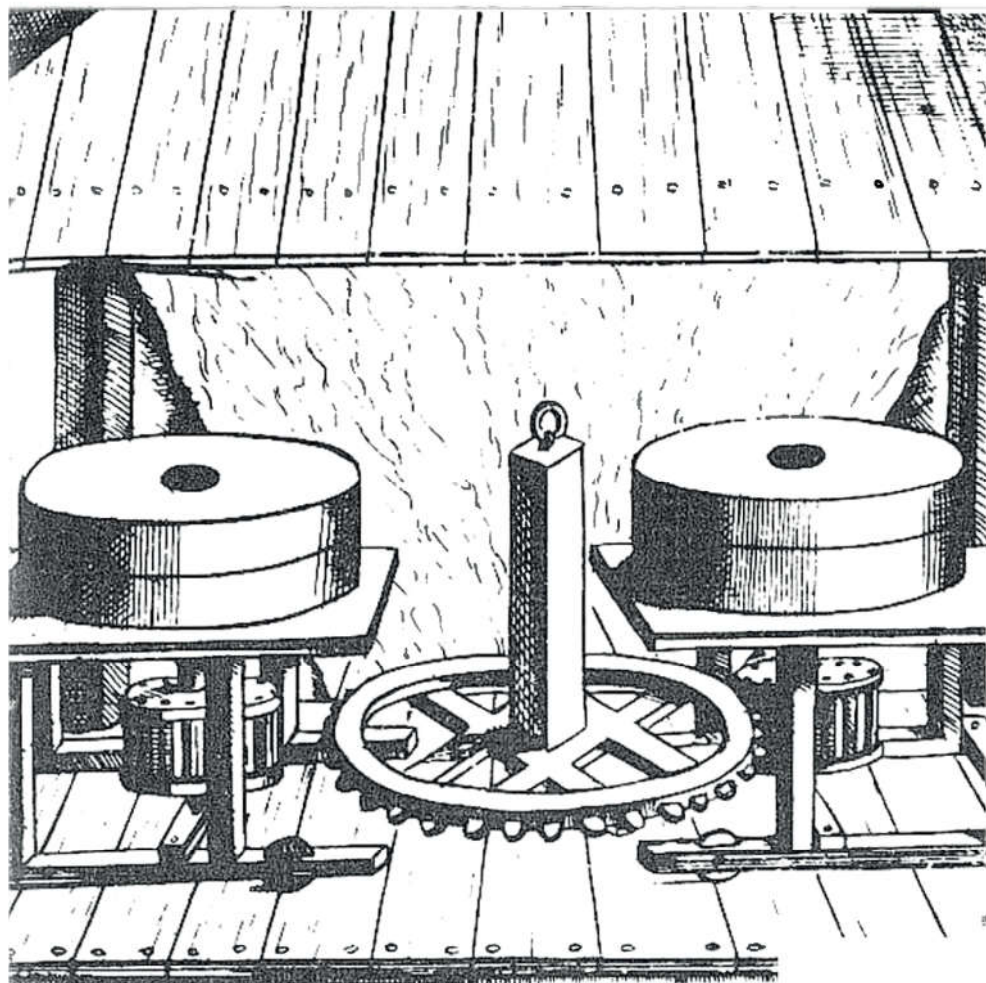
A number of official celebrations under the prestigious patronage of Croatia's President Dr. Franjo Tuđman have been held throughout 1995 to celebrate a century of Hrvatska Elektroprivreda. Exactly one hundred years ago Croatia was permanently inscribed on the energy map of Europe. Namely, on August 28, 1895 near the town of Šibenik on the falls of the river Krka the hydro power plant Krka with a multi-phase electricity generation, transmission and distribution system was put into service. Thus, on Croatian soil a system was built, one of the first of its kind in the world with all the elements which are still, even today, characteristic of the electricity industry. And, before that, in the mid-eighties of the last century Croatian electrical engineers started the never abandoned endeavors to take Croatia into the forefront of a modern, civilized, economically developed world. Today, in a free homeland this holds a special meaning as we can look back at the past in its entirety, and with confidence turn to the challenges ahead.

The Šibenik builders shared the challenge of their project with the then world leading manufacturers of electrical equipment. Similarly, we today wish also to share the importance and pride of our anniversary with our business partners with whom we cooperate in the construction, modernization and reconstruction of Hrvatska Elektroprivreda.

Hrvatska Elektroprivreda is entering the second century of its existence. Before us lies the paramount task of realizing the aims set by Croatia's pioneers of electrical engineering. The employees of Hrvatska Elektroprivreda will, by continuing the inheritance of building inspiration and through sharing the same visions, lead Croatia into a secure energy future.

We are firmly committed to continuing the deed of those who, one hundred years ago, *inscribed Croatia in the history of the world.*

Damir Begović



THE POLITICAL, CULTURAL AND ECONOMIC BACKGROUND OF CROATIA'S FIRST INTEGRAL ELECTRIC POWER

SYSTEM



△ Epigraph mentioning the Croatian Duke Trpimir, Rižinice near Solin, 9th cent.

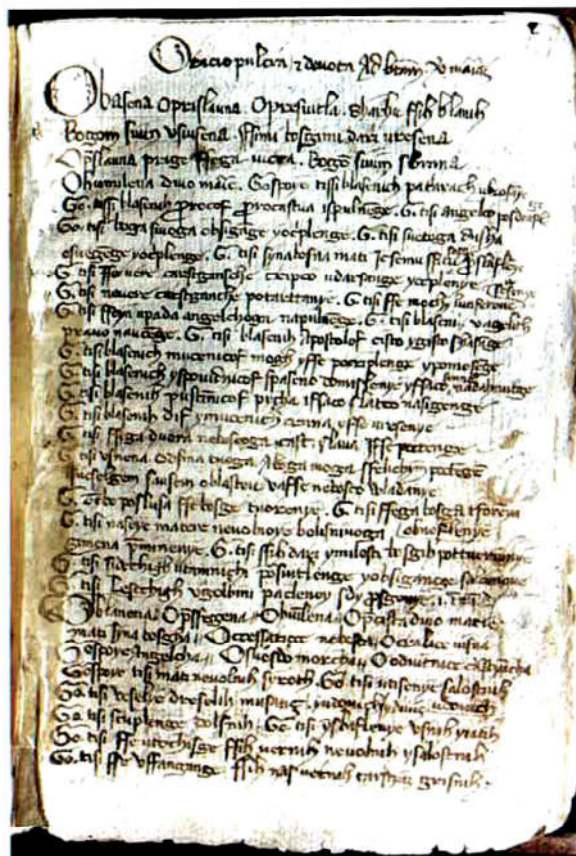
D

lux Chroatorum was first mentioned in Croatian history as far back as 852 in the Deed of Donation of Duke Trpimir, whose successors ruled from the Adriatic sea to the river Drava. The Croatian land, in its Mediterranean, Panonian and Dinaric figuration, has yielded a unique cultural and literary heritage, expressed in the trinity of the three dialects: chakavian, kajkavian and stokavian. The written word, from the *Baška Stone*



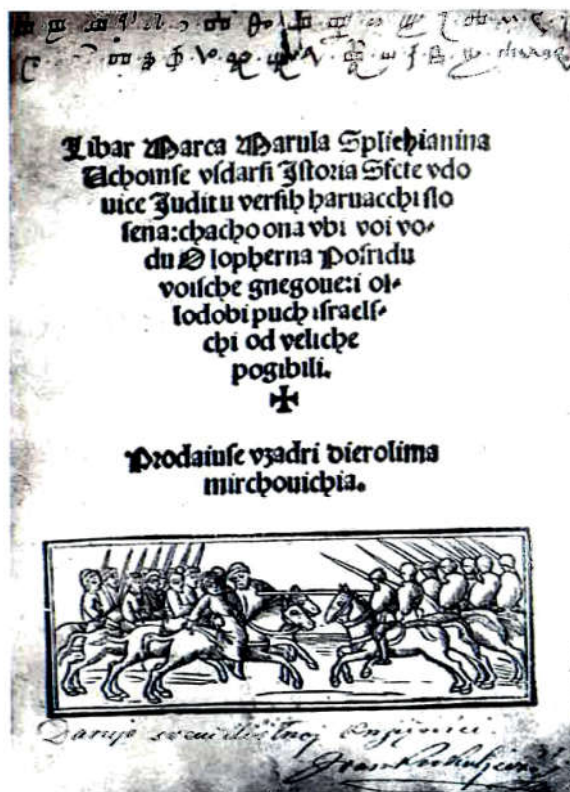
Tablet through Šibenik's *Prayer*, Marulić's *Judita*, Šižgorić's elegies, Vrančić's dictionary, Gundulić's *Osman*, Croatian National Revival to contemporary writers, has preserved the identity of the Croatian people through centuries and encouraged their aspirations for the restoration of their political and national sovereignty and independence. In this complex political atmosphere, under difficult economic conditions and heavy military pressure, the centuries-old aspirations of Croatian people for a free Croatia have persisted. Today we mark

△ The Baška Stone Tablet, one of the oldest written monuments in the Croatian language, c. 1100



△ Šibenik's Prayer, the oldest Croatian poetic text written in Latin script

the hundred-year anniversary of the first integral Croatian electric power system; Croatia was among the first in Europe and the world to apply one of the greatest scientific and technological achievements ever and cultural acquisitions of the modern era.

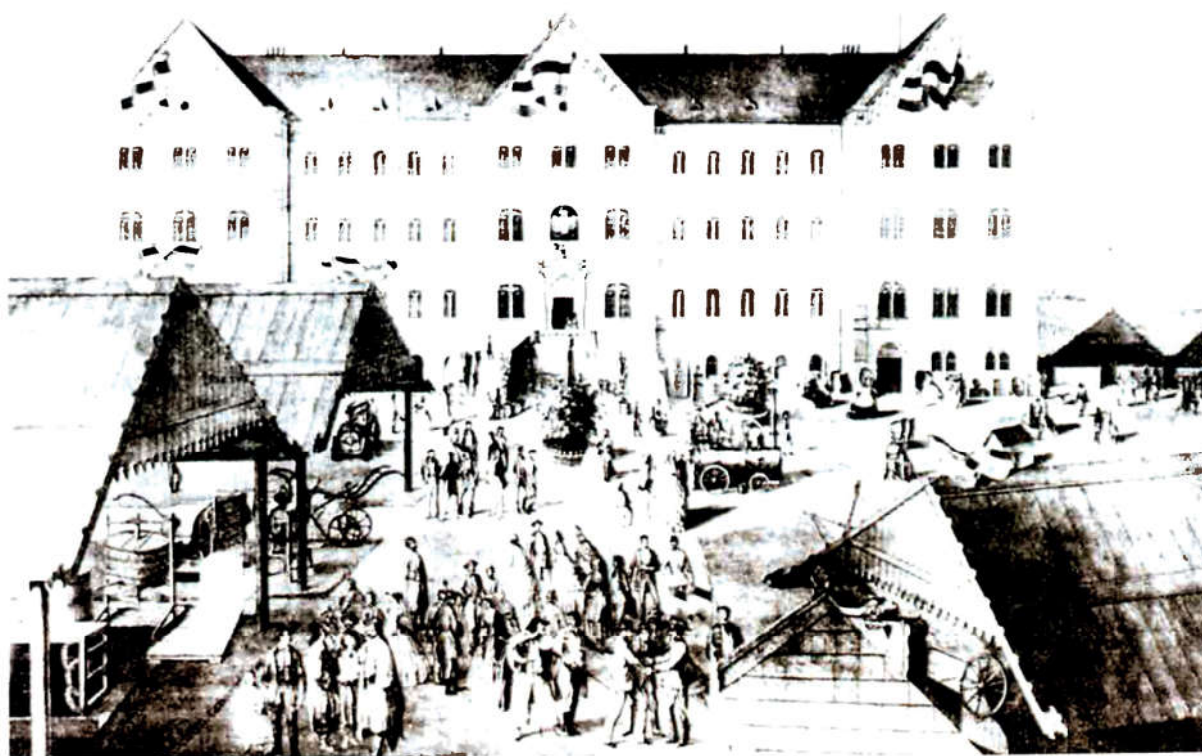


▷ Marko Marulić, Judith, 1521

EVENTS
IN
CROATIA
IN
THE
LATE 19TH
AND
EARLY
20TH CENTURY

From the last decades of the 19th century until World War I, the territory of Croatia was divided into several separate provinces, each of which had a different constitutional, administrative and political position within the Austro-Hungarian Monarchy. Territorial separation was the cause of economic lagging of Croatian lands. The Austrian centralized administration and domination of Great Hungary hindered economic activities of domestic entities and impeded the formation of a single economic space. Both centers (Vienna and Budapest) constructed radially-directed railroad tracks and roads towards the southern periphery of the state (Vienna-Trieste-Pula; Budapest-Zagreb-Rijeka) in an effort to maritimize. In these times of decisive changes, Croatia sought an opportunity for itself as it strived to unite with Dalmatia and Istria, for better transport lines and for promotion of the industrialization. Assessing the devel-

▽ First Trade Exhibition in Zagreb, 1864



D A N I C Z A

Horvatzka, Slavonzka y Dalmatinzka.

Teehaj I.

Dana 14. Szushcza 1835.

Br. 10.

Početak je večkrat dala
 Stvar velikoj sreći mala.
 Velike i dične stvari
 Stvar maljajna večkrat-skvari.
 Vitezović.

HORVATSKA DOMOVINA.

Ljpa naša domovino,
 Oj junačka zemljo mila,
 Stare slave dēdovino,
 Da bi vazda čestna bila!

Mila, kano si nam slavna,
 Mila si nam ti jedina,
 Mila, kuda si nam ravna,
 Mila, kuda si planina!

Vedro nebo, vedro čelo,
 Blaga persa, blage noći,
 Toplo lēto, toplo dēlo,
 Bistre vode, bistre oči:

Vele gore, veli ljudi,
 Rujna lica, rujna vina,
 Silni gromi, silni udi; —
 To je naša domovina!

Ženju serpi, mašu kose,
 Dēd se žuri, snope broji,
 Škriplju vozi, brašno nose,
 Snaša preduć mālō doji:

Pase marha, rog se čuje,
 Oj, oj zvenēi, oj, u tmine,
 K ognju star i mlad šetuje; —
 Evo t' naške domovine!

Luč iz mraka dalko sija,
 Po veseloj livadići,
 Pēsme glasno brēg odbija,
 Ljubni poje k tamburici:

Kolo vode, živo kolo,
 I na berdu, i v dolini,
 Plešu mladji sve okolo; —
 Mi smo, pobre, v domovini!

Magla, što li, Unu skriva?
 Ni l' to našiu jauk turobni?
 Tko li moleć smert naziva?
 Il' slobodni, il' su robni?

„Rat je, bratjo, rat junaci,
 Pušku hvataj, sablju paši,
 Sedlaj konjče, hajd pešjaci,
 Slava budi, gdi su naši!“

Buči bura, magla projde, —
 Puca zora, tmina bēži, —
 Tuga mine, radost dojde, —
 Zdravo slobost, — dušman leži!

Veseli se, tužna mati,
 Padoše ti verli sini,
 Ko junaci, ko Horvati,
 Ljaše kervcu domovini!

Teci, Sava hitra, teci
 Nit' ti Dunaj silu gubi,
 Kud li šumiš, svētu reci:
 Da svog' doma Horvat ljubi,

Dok mu njive sunce grije,
 Dok mu hrastje bura vije,
 Dok mu mertve grob sakrije,
 Dok mu živo serdce bije!

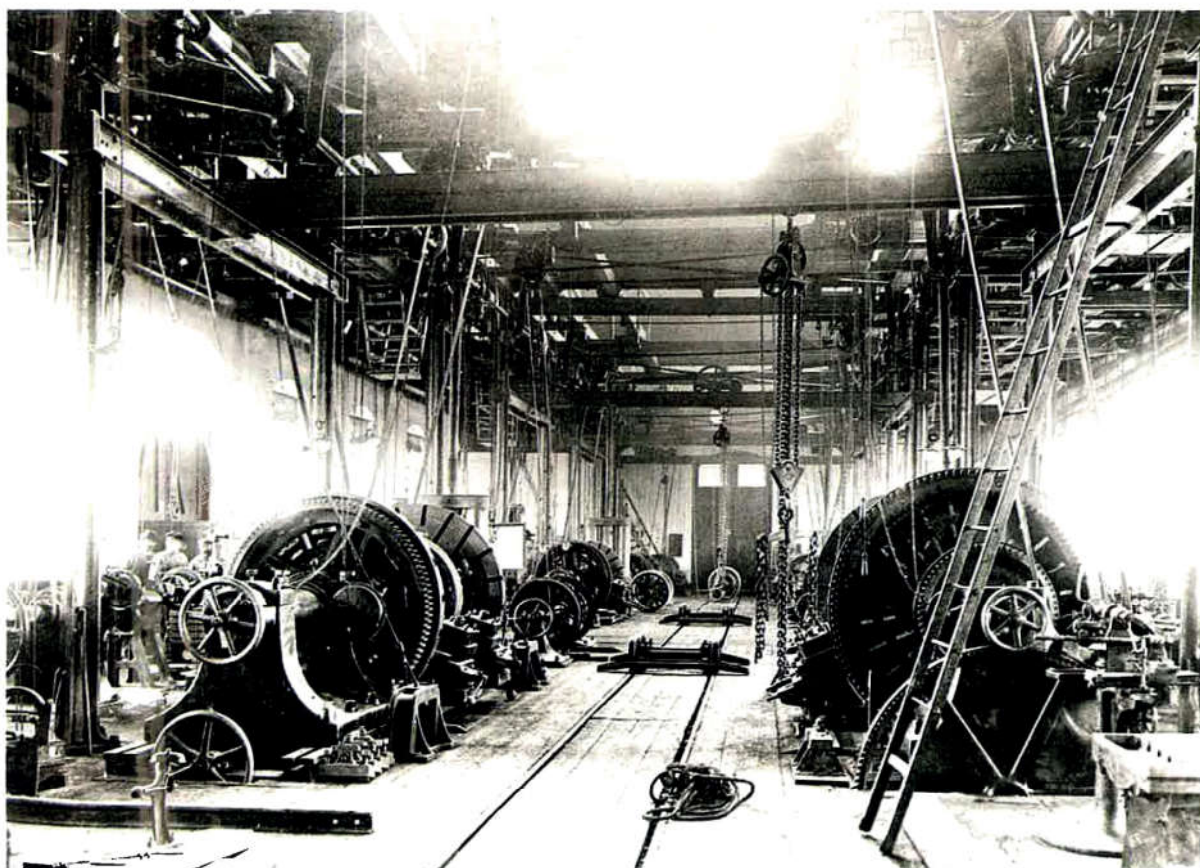
MI.....ć.

Δ Antun Mihanović, *Horvatska Domovina* - the national anthem named after the first verse *Lijepa Naša*



Δ Dragutin Weingärtner, Session of the Croatian Parliament 1848 in Zagreb

▽ Railroad Cars Factory, Zagreb, 1894



opment of industry in Croatia at the turn of the 19th century, the then Zagreb Chamber of Commerce and Crafts saw it as having made a considerable move compared to the preceding period. Domestic industry, with certain problems, mainly in the money market, showed steady progress. Croatian leather, timber, flour, wines and brandy met the requirements of the world market already by the end of the century. Such was the atmosphere in which the Croatian Trade and Crafts Museum was established in Zagreb in 1899, as a permanent exhibition of industry and crafts.

The rural economy started showing signs of development from the beginning of the 20th century to become an increasingly integrated bondage in the crafts-industrial complex. The industrial and maritime rise of Trieste, the military and maritime reinforcement

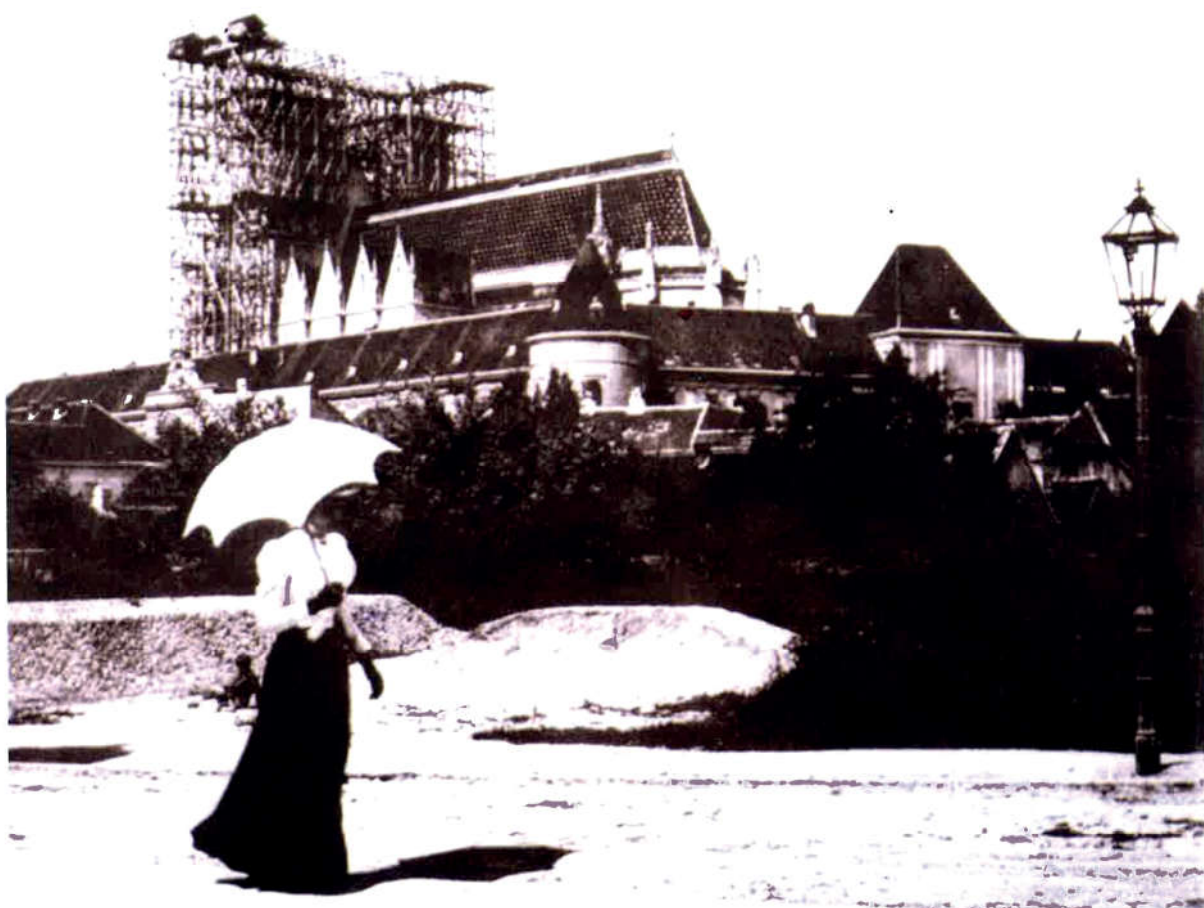
of Pula, and the industrial, mercantile and maritime growth of Rijeka were joined by Zagreb in its efforts as being the intersection point of horizontal and vertical railroad lines. Related to this was the development of the Trade and Crafts Chamber in Zagreb, founded in 1852, nine years after the national language was first used in the Croatian Parliament (May 2, 1843) and five years after being adopted as the official language (October 23, 1847) as well as the development of the National Association of Croatian-Slavonian Industrialists, founded in 1903. It was a period of marked awakening and the growth of the Croatian economy, in which, certainly, the centers of the two-part empire found interest and advantage for themselves. The economic rise of Zagreb allowed it to integrate more directly into the fast development of the overall life of the country. This also

reflected in the general political, economic and cultural rise of central and eastern Croatia. The influence of Zagreb spread to southern Croatia (Dalmatia) and western Croatia (Istria). It was an age of definitely formed national awareness, which strived for the integration of Croatian ethnic space that had been growing both in terms of population, and economic revival and innovation. This development, however, produced an occasional adverse trend, which required a slowing down of development. From the late 19th century until World War I as many as 58 industrial joint stock companies were founded in Croatia. All industrial activities were grouped into 12 branches, including utilization of spas. Leading industries were wood and timber, flour mills

and construction followed by agricultural, food, metal (metallurgy) and chemical industries. As a result, during the period from initial industrialization to World War I, central and eastern Croatia rose up to take the lead in industrial activities in Croatian lands.

At that time the electricity industry constituted an entirely new branch of the Croatian economy. The wide application of electricity was of utmost importance for the development of industrial activities in general.

The electricity industry was accepted in this country with all its applications so that, besides our people's contribution, the largest international companies contributed their know-how, experience and capital to its development in Croatia.



△ Ivan Standl, Zagreb, 1898

Croatia's first electric power system was based on a hydro power plant, but other power plants were springing up fast at the same time. Without electricity, either directly transmitted or through power lines, as a driving force or lighting source, the life in the then boroughs (or market-towns) and cities, even in some villages, was impossible to imagine. Electricity became the determinant of the economic growth of Croatia. Chronologists at the turn of the 19th century mention mining, lumber (timber), metallurgy (metal), leather, clothing (textile), artisan's (home-made), chemical, paper-graphic, food processing, construction, sanitary and other industries whose activities were based on electrically driven energy. They particularly emphasize spas and mineral springs (Apatovina, Lasinje, Jamnica, etc.) and, at that time already widely promoted, selling of parquetry, veneer, wood wool, caskets, car-bodies, furniture, wood houses, shoemaker's accessories, toys, baskets, brushes, tamburas, brooms, rods, cork and other articles and industrial products.

EVENTS IN DALMATIA

▽ Dubrovnik, 1904



Southern Croatia (Dalmatia) lived in an atmosphere of a peripheral province. Isolated in terms of traffic routes, it was in a more difficult position than central and mainland Croatia, even Istria. Northern areas and ports of eastern Adriatic coast had the advantage of the proximity and better connections with Central European centers of political and economic power. However, Dalmatia was trying to find a way of improving traffic routes with its hinterland and in particular, improving its maritime communications with Rijeka and Trieste at the time of industrial awakening and of replacement of sails with engines. The early industry was linked with the opening of coal mines (Siverić, Promina) cement-clay mines (Solín, Split, Omiš) and quarries (the white stone and marble of Brač), and erection of the first factories (calcium carbide and cyanamid in Šibenik



△ Bazilij Ivanković, *A Sailing-Ship*, Croatian merchant ship of the 19th cent.



Δ Šibenik, a coastal part, early 20th cent.

▽ Komiža, a coastal part



and Dugi Rat) in the vicinity of rivers convenient for electricity generation and for a more modern water supply system (Krka, Cetina, Jadro). The first fish canneries were also built at that time (Vis, Brač, Hvar, Dugi Otok, Silba) and for these purposes, along with the dominant foreign capital, domestic capital started to emerge, especially in shipping and the fish processing industry.

In the seventies and the eighties of the 19th century Dalmatia saw progress in its wine-growing, exporting largely to France (1878-1892) due to a grapevine disease in that country. Afterwards, the grapevine disease (oidium, phylloxera or fungus) through Italy reached Dalmatia too. Moreover, Dalmatia was additionally hit by a "wine clause" in 1892 which was designed to facilitate exports of Italian wines to Austria. If the decline of sailing-ships and rise of steamships, which Dalmatia was not able to follow, is also mentioned, the picture

of economic difficulties of our coastal area at that time becomes sharper still. The steam-shipping companies moved to Trieste and Rijeka, and so did the finance. As a result of this the first large-scale emigration of the most able part of the population from the Croatian coastal area, principally from the Dalmatian hinterland and islands, and from Kvarner began. In the period from 1880 to 1910 from Dalmatia alone, an estimated 58 thousand people (approximately 13% of the whole population in 1880) emigrated. Emigration continued to reflect the (un)favorable general regional circumstances in the departure and destination regions and countries.

The emergence and development of early industry based on the powerful sources of electricity did, however, reduce the range of potential emigration. Part of the labor force was attached to new factories and plants through the possibility of earning outside their own modest economy. This meant, at least to some, a



Δ Šibenik, public lighting

EVENTS IN ŠIBENIK

hope of better times for new, more literate and better educated, generations. This generally coincided with the efforts made by Croatian populists to secure better conditions for the general welfare of the overall population through changing the political circumstances in Dalmatia and in winning the elections.

Simultaneously with all these events, new traffic lines were built and the existing ones reconstructed between the sea coast and the hinterland: the railroad line Split-Šibenik-Siverić (1877) - Knin (1888) - Drvar (narrow-track, 1898), Metković - Mostar - Sarajevo (1891), Gabela - Gruž (Dubrovnik) - Zelenika and others, as well as the main roads from the coast centers towards the hinterland (Zagora). The first factories in Dalmatia were built in the early seventies in Split: cement factory (1870), tannery (1879), marble quarry (1882) and others. They were followed by cement works in Solin (1903 - 1908), Sućurac (1912) and Orniš (1908), the use of machinery in the Brač quarries (Pučište, 1906 - 1907) and in the shipyards of Split, Trogir, Korčula and others, industrial lime-kilns in Šibenik, Split, Trogir and elsewhere, industrial processing of the sour cherry, olives (on almost every larger island and mainland town), essential oil (Hvar and elsewhere), pyrethrum, rosemary, lavender and other herbs, depending on the demand on the market. Dalmatia got its first integral electric power system with certain rudimentary steam-driven plants, many of which were subsequently adapted to use electrically-driven power.

In the early seventies of the 19th century Šibenik celebrated a great political victory - victory of the Croatian Popular Party in the 1872 elections. That was the end of the many years of 'autonomists' (Italian nationalists) rule. For the first time, a Croat, Ante Šupuk, was elected mayor. He was one of the heroes in the building of the first hydro power plant (Krka, 1895). It was the beginning of a twenty-year long rule of the Popular Party (1872-1893) and a period of many continued

▽ Šibenik, Poljana, late 19th cent.



and new economic achievements. It was the first major turning point in the life of our people, in their political, economic and cultural life. The Croatian language was instituted in schools, introducing the first spread of literacy amongst a wide circle of population. Learning of major foreign languages as an obligatory part of education opened the world for Croatian citizens, and inscribed Šibenik in the golden book of the history of cultural revival of Croats.

The Popular Party's rule in the Šibenik area, and elsewhere following its electoral victories by the end of the 19th century, led to the introduction of new crops and technologies in fruit and grape growing and farming. Fishing increased and the technology for fish processing advanced. Entrepreneurship of young local people was encouraged. It was a period of opening up to the north-east and to the power centers and capitals of Central Europe. The political, economic, cultural

and scientific forces of the time strongly affected the complex state territory. Despite all difficulties, as the position of Dalmatia in the Regional Council improved, it was necessary to attract foreign capital and allow it to be profitable in the new circumstances. With mutual agreement natural resources were exploited. Thus, in Skradinski Buk on the river Krka, in Jaruga, an idea turned into reality when our first integral electric power system was implemented. Our people proved themselves capable of accepting a technological novelty and recording the glorious moments for Šibenik and its area (Meichsner and Šupuk).

The Promina coal triggered the building of the local railroad line Split-Siverić, with the side-track Perković-Šibenik in 1877, which was later extended to Knin (1888). In this way the western Bosnian woodland was opened up for export of wood through the Šibenik port (Steinbeiss, Šipad).

Building of our first integral electric power system took place in the period of urban development of cities, and Šibenik alike: 1870 a theater was built, 1871 a new pier, 1879 the water supply system Krka - Šibenik and the first public wells, 1880 a new printing house, 1893 a multi-pavilion hospital, 1895 the city gardens, 1896 a court-prison building, etc. All this is indicative of rapid economic growth and the improved quality of life in a city of rich urbane, architectural and cultural heritage (humanistic and Renaissance achievements of Šibenik in the 16th and 17th century).

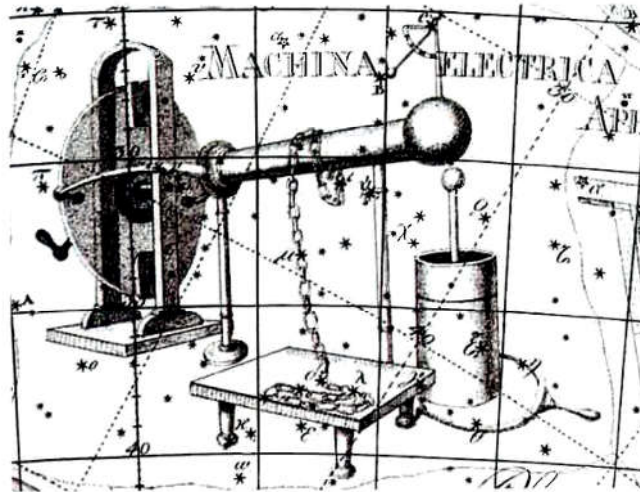
The technical and technological novelties that spread throughout the second half of the 19th century in Europe unfortunately resulted in some injuries to our towns. In Šibenik, for instance, the old city walls and their defense towers were knocked down in order to open the city to its suburbs, as a symbol of a free and new space. The beauty of the medieval city was spoiled, but fortunately parts of the city walls and all four citadels (one above the very core of the city, one on the access way from the sea and two on the access way from the mainland) remained untouched.

With the emergence of industry the epochal electric power works on the Krka made it possible to install the city's lighting, whose lanterns during night walks revealed the beauty of the oldest autochthonous Croatian city, first mentioned in the Deed of Donation of King Petar Krešimir IV in 1066. "All of stone and in stone", Šibenik is the city of poetry (Juraj Šizgorić), Christian spirit (Nikola Tavelić), painting (Juraj Čulinović), architecture (Juraj Dalmatinac), engraving (Martin Kolunić-Rota), historiography (Dinko Zavorović), music (Ivan Lukačić), diplomacy (Antun Vrančić), polemics (Jakov Armolušić). From the pleiades of great minds given by this small city, an exceptional renaissance personality should be singled out: Faust Vrančić, the author of the first dictionary of the Croatian language and inventor and anticipator of many technical ideas and projects.

Šibenik was founded at the estuary of the river Krka, from where the navigable waterways towards Liburnian and Roman Scardona (Skradin) were easy to survey. Almost a millennium thereafter, water resources

of the river Krka were to be adroitly assessed by early electrical engineers, for entirely different purposes. To the ancient grindstone was added a turbine - a sign and a means of the new technology at the end of the 19th century. On August 28, 1985, electricity began to flow from the Krka to Šibenik through an 11 kilometer transmission line - the first one in Croatia. The windows of Šibenik were thus opened to a new sun.

The new age of high technology and revolutionary information science imposes new thoughts about the future. Šibenik, the heir of natural beauties of two national parks and rich cultural tradition, a hero of the Patriotic War, will undoubtedly, together with our homeland Croatia, continue to be a participant in Central European and Mediterranean cultural circle. ■



△ The electrifying machine

THE FIRST DIRECT AND ALTERNATING CURRENT POWER PLANTS

▽ Michael Faraday



The first power plants built specifically for the purpose of using electricity as energy for lighting and engine startup started to emerge at the end of the 19th century. They represent the inception of the contemporary large electric power systems. The elements of an electric power system are: production plants - power plants, transmission plants - transmission lines and substations and switchyards of higher voltage levels, for transmitting electricity over distances, and distribution - lines, substations and switchyards of lower voltage levels intended for electricity distribution to consumers. Such systems also include consumption meters, and other elements necessary for protection, billing and operation. All of these elements are required for an electric power system to be integral.

The development of electrical engineering ideas was long-lasting and gradual. Not until the 19th century did development reach a level at which the first power plants could be built for the purpose of an economically profitable operation. From early knowledge about the attractive property of the magnet and of the electrical charge of amber, from which the name "electricity" is derived (Greek name for the amber is electron), until the discovery and experimental verification of the interrelation between magnetism and electric current, a centuries-long path was traveled. During this time many fundamental discoveries were made which constituted a chain of knowledge, including that of electrostatics and electrodynamics as parts of electrical engineering. The logical accumulation of this knowledge led to the discovery of the influence of the electric current on the magnetic needle in 1820. English scientist Michael Faraday experimentally demonstrated the existence of the reverse process: electricity can be induced by a magnet.

The discovery of the force induced by an electric current in the magnetic field was to become the foundation of the development of the electrical motor, and the reverse process the foundation of the development

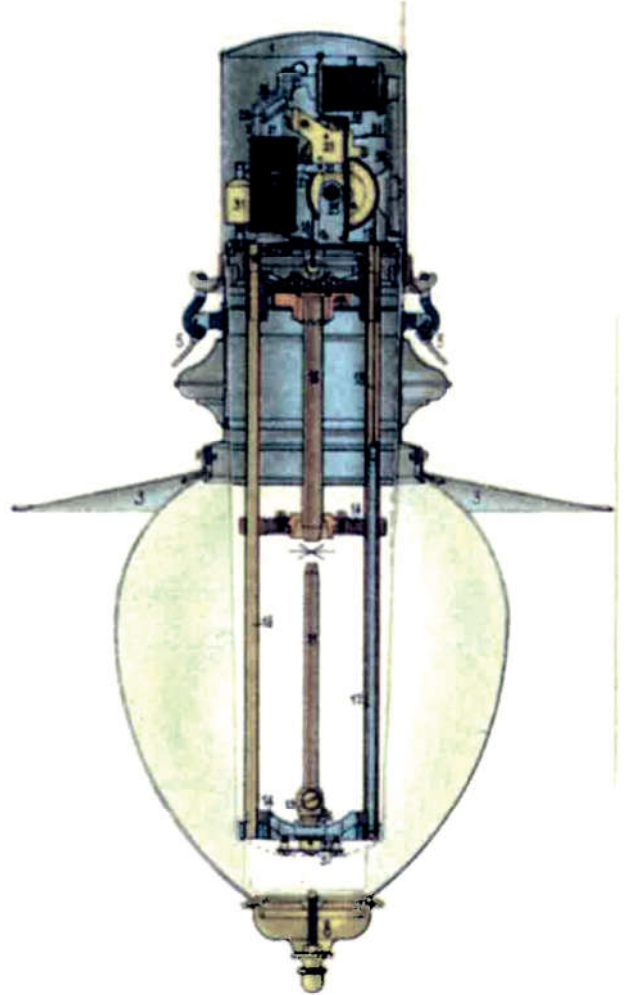
generator and/or electricity generating facilities. The discovery of electric and magnetic fields, and electromagnetic induction phenomenon, i.e. the interaction between these fields, was also to be used to develop the principle of transformer operation.

Between 1830 and 1880, numerous researchers studied the phenomenon of electromagnetic induction and its practical applicability; Moritz Herman von Jacobi in 1834 engineered the first electric motor of higher capacity. Werner von Siemens, following the discovery of the electric dynamo principle, in 1866 engineered the first direct-current dynamo substantially advancing the engineering of powerful electricity sources. Zénobe Théophil Gramme, a Belgian inventor, engineered a stationary (direct-current) generator which from 1870 onwards completely replaced the so-called magnetic-electrical generators.

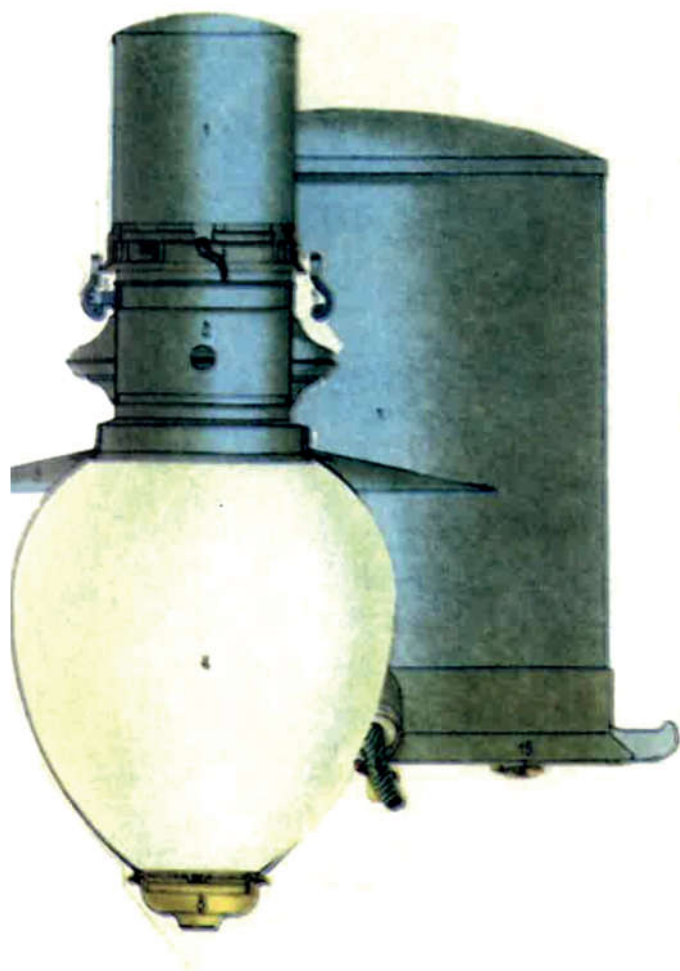
The practical application of these inventions required the development of the consumer part of the system, i.e. lighting and electrical motors. Electrical lighting, in the lighting of public areas, had to withstand the competition of the then highly developed gas lighting, and indoors, the competition of both gas and kerosene lighting. The development of the electrical lighting technique passed through three main phases, almost simultaneously with the development of electromagnetism.

The first arc lamp that could be used in practice was invented by Pavel Nicolaevich Jablockov in 1876. In 1878 Friedrich von Hefner-Alteneck engineered a differential arc lamp, and the coal filament lamp by Thomas Alva Edison emerged in 1879. It was not until after Edison's invention of the incandescent filament lamp that connections of a large number of lighting fixtures to a single machine were possible. This lamp had numerous advantages over previous arc lamps, especially in home lighting and other indoor areas. In initial electrification, therefore, lighting was provided, in addition to homes, to various representative buildings - hotels, theaters, offices, etc.

It was Thomas Alva Edison who recognized the need for building larger electricity sources in the vicinity



△ The arc lamp, Jablockov's invention of 1876

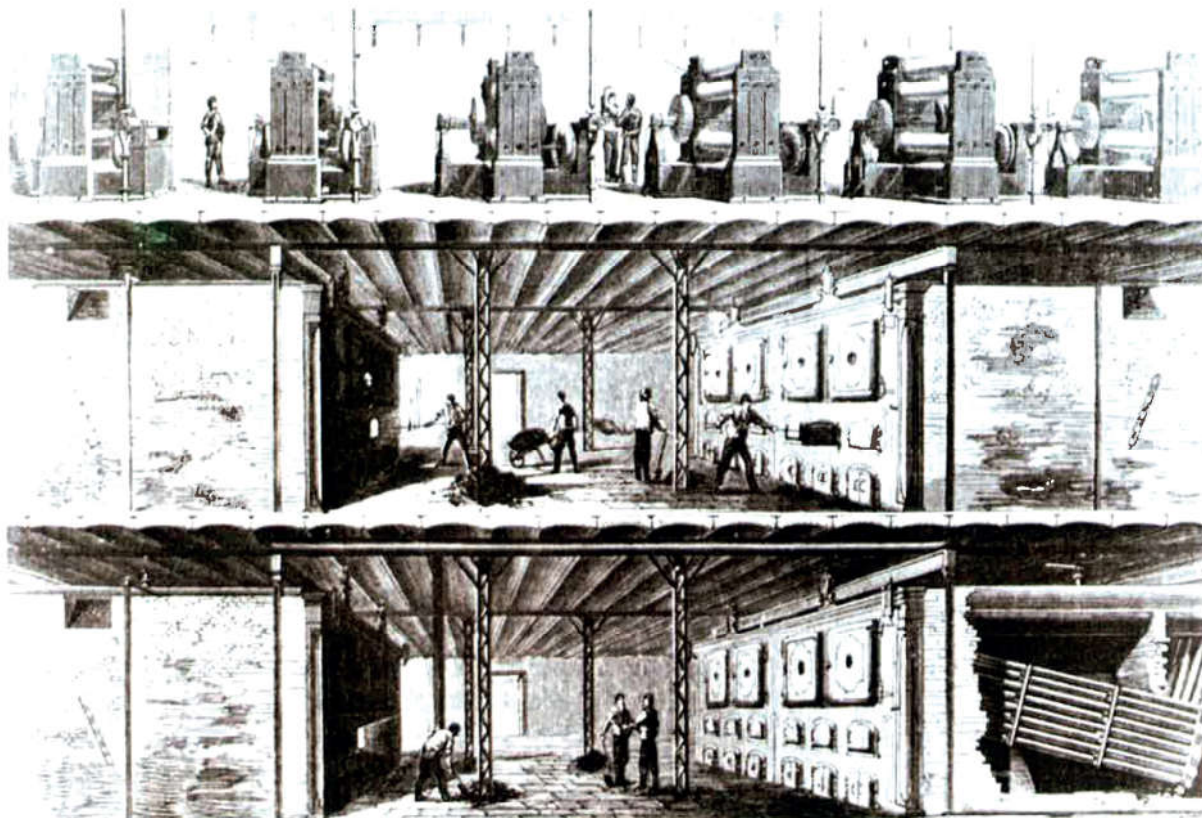


of city centers or larger housing blocks in big cities, as it was the only economical way of supplying a larger number of consumers. This was to be the beginning of the age of the so-called central stations (in Croatian) for electricity production from which the name in Croatian for a power plant "*električna centrala*" was derived. Central electricity generating plants with the first direct-current electricity networks were the forerunners of the activity that is today called electricity industry.

The first two larger direct-current power plants were engineered by Edison in 1882 in London (Holborn Viaduct) and New York (Pearl Street). The installed capacity of the New York plant was 540 kW supplying approximately 7 200 lamps at 110 V. It was considered a major power plant at that time. These power plants had to withstand the competition of a relatively low priced gas lighting. For this reason the London power plant was closed as early as 1886. By contrast, the Pearl Street one operated profitably and without failures up to 1890 when it was destroyed by fire.

The experiences gained in these first direct-current power plants were such that similar ones began to be built in many cities worldwide. These were chiefly thermal power plants, since they were driven by steam engines. Since big cities were generally away from abundant and usable waterways, the first direct-current hydro power plant was built in the small town of Appleton, USA. Numerous towns in Croatia made very early attempts to introduce electricity or to use electricity in industry, so that the first direct-current power plants were being built in Croatia as well, some ten years after New York.

Direct-current power plants were difficult to economically operate right from the beginning. The main consumers were arc lamps or light bulbs, therefore the load during day varied widely. In the day time rechargeable lead batteries were charged to help during night, the time of peak loads, making the whole process more expensive. A much bigger problem, however, was loss of electric power in lines and the impossibility of connecting distant consumers. As the voltage was fixed at 110 V, the increase in load with the square of the cur-



△ Interior of the first public DC thermal power plant Pearl Street, New York, 1882



◁ The first public AC hydro power plant Tivoli, Rome, 1892

rent intensity being transmitted increased losses, a direct current could be transmitted over a very limited distance. This is why numerous alternating-current power plants emerged in some cities, supplying just a single housing block. In New York, for example, there were about 450 power plants in service. Big cities competed in electrical lighting and Petersburg stood out as the best illuminated with 66 000 bulbs in its street lighting, which were supplied from ten power plants.

The solution to the problem that limited the development of the direct-current system - electricity transmission over distances - was the single-phase alternating-current. The development of the alternating-current system took place by the end of the 19th century in parallel with the development of the direct-current system. The first alternating-current generator was patented by Gramme, and his machine was used for a test lighting of the Opera Street in Paris in 1878 by Jablockov's arc lamps. This experiment demonstrated all the advantages of the new system, at least in the lighting of streets, squares and larger areas by the strong and blinding light of the electric arc. Only after the discovery of the electric light bulb was it shown that for illumination of any, even the smallest space, it was necessary to meet the requirement for constant lighting. In the early development phases this was not possible as the alternating-current light bulbs were connected in series.

The next step in the development of this system was made by Lucien Gaulard and John Daniel Gibbs who in 1882 in London patented a device they named the secondary generator. This was the forerunner of the transformer. This patent was applied in 1884 for the lighting of a 12 kilometer long section of the London city railroad. In this year at the Electrical Engineering Exhibition in Turin the first transmission by the new system over a large distance was demonstrated: from a Siemens alternator the voltage of 2 000 V and 133 Hz was transmitted over a distance of 40 km, supplying lamps of various types at the exhibition space and at the railroad stations along the line Turin - Lanzo.

Another very important invention was presented at the Turin exhibition. Leading engineers of the Hun-

garian company Ganz of Budapest, Carl Zipernowsky, Miksa Deri and Otto Titus Blathy, presented a self-excited alternating-current generator. Blathy is considered the inventor of the transformer, in the form we know today. It should be emphasized, however, that the three always appeared together, therefore in the history of electrical engineering they are invariably studied together under the name of the Great Three of Budapest. They applied their patents in early power plants and networks, as for example in 1895 in the Krka - Šibenik system, the first alternating-current system in Croatia. The invention of the Great Three of Budapest solved the problem of electricity distribution since the transformer enabled electricity to be transmitted over distances and distributed to a large number of consumers. It should also be mentioned that they were the first ones to use the technical term "transformer" of electricity.

The transformability of alternating current offered so many advantages over direct-current systems, as well as over the early alternating-current ones. In 1885 Ganz already began supplying the first transformers and complete alternating-current distribution systems. Following Lucerne and Milan, in the first three years these single-phase systems were in service in about 60 cities throughout the world. Almost all of them served for lighting. Though capable of it, the majority did not have a more significant component of electricity transmission. Among these cities was Rijeka.

The single-phase alternating-current power plant in the port of Rijeka, built in 1891, was the first power plant of the type in the Austro-Hungarian Monarchy. It was intended for driving crane engines and a large elevator, and was additionally used for the lighting of the port and some neighboring facilities. It had three generators of 80 kW and 2 000 V, and a 65 000 kg elevator was driven by synchronous motors of the same generator voltage. The rest of the power was transformed and used for the 100 V lighting requirements. As there was no transmission line, in the sense of electricity transmission over a longer distance, this system cannot be considered a complete electric power system, i. e. one which includes production, transmission and distribu-

tion of electricity.

In the period from 1885 to 1895 a "systems struggle" was going on. Edison defended his direct-current system, stressing its advantages. The main objections addressed to the Ganz experts and George Westinghouse, principal propagator of the alternating-current system in the USA, concerned the reliability of the parallel operation of direct current as compared to alternating-current systems, and greater safety of direct-current voltages of 110 V and 240 V. In the case of the alternating-current system, practically every electrified house in the USA was connected to a transformer of 1,000 or 2,000 V, which frequently caused substantial damages, even death. At that time the direct current was more suitable for electric galvanization and charging of storage batteries. The non-existence of a wattmeter for alternating current and an appropriate alternating-current motor was being very much emphasized. A Hungarian invention of the transformer and of the distribution system eliminated some of these objections. Soon, converters and meters with magnetic disc were designed. Thus the direct current began to

be used for specific purposes only.

The invention of an appropriate alternating-current motor, based on the discovery of the rotating magnetic field and polyphase alternating-current systems, enabled the alternating current systems to be applied in industry. Nikola Tesla's two-phase system (1888) laid the foundation for the development of polyphase systems. Michael von Dolivo-Dobrowolski developed the three-phase system. They enabled other practical inventions to follow and encouraged the development of technical novelties in the early days of electric power systems' development. One such invention was a patent by Franjo Hanaman and Alexander Just - the application of the tungsten metal filament in the making of an electric bulb - which eliminated numerous weaknesses of Edison's coal filament bulb. The tungsten bulb is today the most common source of light, as is asynchronous or induction motor the most common source of power. Both inventions were the work of inventors from Croatia, Hanaman and Tesla.

EARLY DEVELOPMENT OF THE ELECTRICITY INDUSTRY IN THE WORLD

The building of Edison's direct-current power plants and supply of towns with electricity is the first form of organized electricity industry. The invention of the electricity meter was designed to register and charge each user for consumption. This made electricity a commodity for sale, and at the same time obliged the producer to guarantee supply and quality of electricity. This applied equally to the alternating-current system, the only exception being that the electricity source moved from city centers to a longer distance, frequently onto waterways, from which electricity was transmitted by higher voltage level transmission lines to consumers.

INTERNATIONALE ELEKTRO-TECHNISCHE AUSSTELLUNG



MAI -
OCTOBER 1891

ZU FRANKFURT AM MAIN

The first more significant commercial transmission over a longer distance using Ganz's single-phase system was designed in 1890, and commissioned in 1892: from the Tivoli hydro power plant on the Aniene Falls, near the town of Terni, electricity was transmitted to a 28 kilometer far Rome, for a lighting network and electrical streetcar. This venture was overshadowed by another important event much written and talked about. Namely, during the International Electrical Engineering Exhibition in Frankfurt am Main in 1891, transmission of alternating three-phase current was achieved over a distance of 175 km between the Lauffen power plant on the river Neckar and Frankfurt.

Attempts to transmit direct current over a longer distance were made. In 1882 Michael Deprez at the Electrical Engineering Exhibition in Munich achieved a 57 km transmission from the exhibition space to Miesbach, but with very high losses. Due to too low a voltage and a small cross-section of the conductor, a telegraphic line was used. The efficiency level was only 22%. Such transmission proved to be non-profitable.

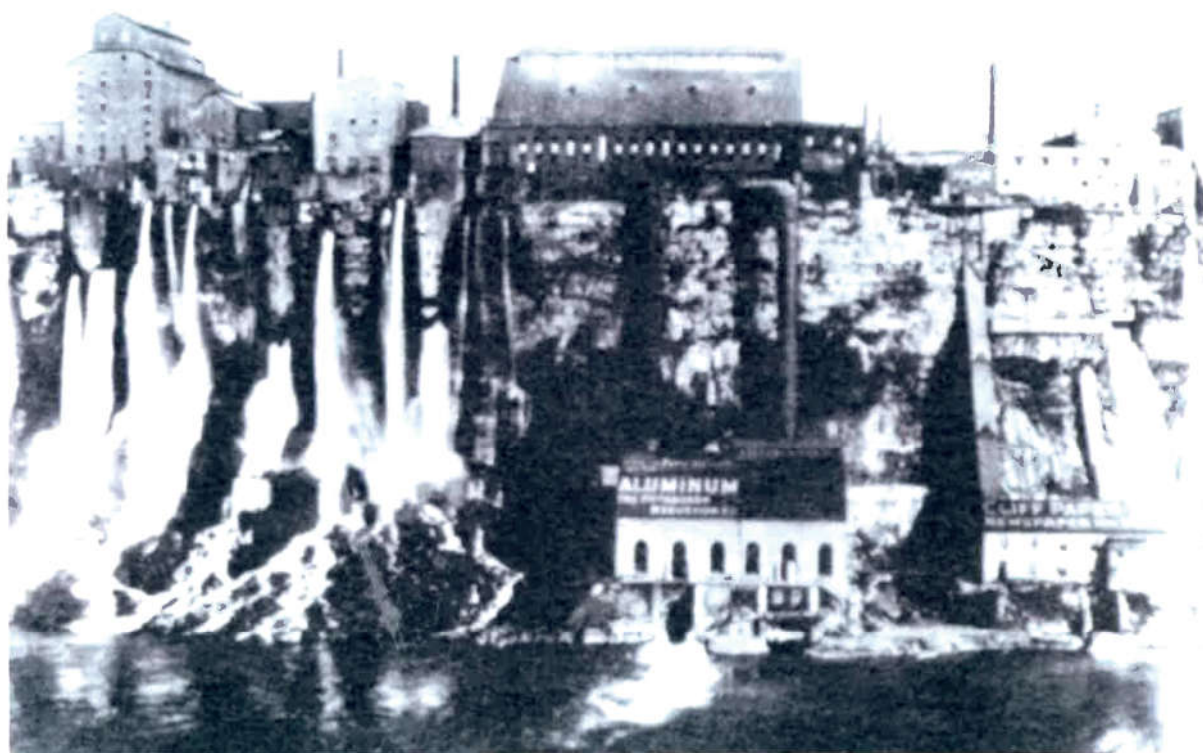
The first significant single-phase alternating-current transmissions were achieved in 1890 for the lighting of London (12 km, transmission voltage 10 kV) and Portland in the USA (19 km, transmission voltage 3.3 kV). The year 1890 is therefore considered to be the first year of modern electric power systems' operation, which include all the components of production, transmission and distribution of electricity.

The Frankfurt exhibition was organized for the purpose of selecting the best means of electricity supply for Frankfurt am Main. Based on his negative experience of the direct-current transmission to Munich, Oskar von Miller proposed that electricity for the exhibition space be transmitted by the first three-phase line from Lauffen, 175 km away. The 300 HP water turbine used there drove a three-phase generator of 210 kVA capacity. The generator voltage of 55 V was transformed to 8 500 V and electricity was transmitted to Frankfurt. The exhibition space was illuminated by about 1000 light bulbs. The main attraction was however, the three-phase motor driving a water pump that created an arti-

ficial waterfall. A high level of efficiency of 75% was achieved. During the exhibition, experiments were made also with voltages of 15 kV and 30 kV, which showed that voltage increase produced a higher efficiency level and/or lower transmission losses. Following its big success at the exhibition, the three-phase transmission of power over distance was proclaimed a major scientific event in treatises in technical publications. Von Miller became the first agent for building regional and national networks of polyphase systems and the first practical builder of electric power systems in the world. Indirectly, the exhibition had a substantial influence on the first system builders in Croatia. After the closing of the exhibition, at the end of October 1891, the city nevertheless chose the single-phase, so in 1892, instead of being used for Frankfurt am Main, this line was used for the three-phase transmission with 5,000 V to the neighboring town of Heilbronn. This was the first commercial three-phase transmission in Europe.

A second significant electrical engineering exhibition was held in Chicago in 1893. There, Westinghouse exhibited devices for the so-called universal system, which made possible a changeover from one system to another. The most renowned project and at the same time the first hydro power plant of high capacity was built on the Niagara Falls. In the first construction phase, in 1895, it had two two-phase generators per 5,000 HP, voltage of 2,200 V and frequency of 25 Hz, and converters of alternating into direct current, for supply of the nearby aluminum and carborundum plant. The power plant was put into service August 26, 1895, just two days before the Croatian and Šibenik's system on the river Krka. However, the first transmission of alternating current from this power plant, to the 43 kilometer far town of Buffalo, did not take place until November 1896, and the longer transmission, to Canada, not until 1910. Nevertheless, the Niagara Falls power plant was at that time considered a major technical venture, as it proved that high capacity power plants could be built and that these capacities could be economically transmitted over long distances by polyphase systems.

The Hungarian company Ganz introduced the



The Niagara Falls hydro power plant

two-phase systems in Europe, installed in 1895 in our first hydro power plant, Krka, a two-phase system with electrically shifted phase by 90 degrees. The historical significance of the Krka hydro power plant is therefore important, as it was the first experiment of this kind. Namely, in those years many larger cities (Frankfurt, London, Rome, etc.) opted for single-phase generators, as it was held that polyphase systems were much more unreliable. These cities subsequently adopted the polyphase system.

Niagara Falls





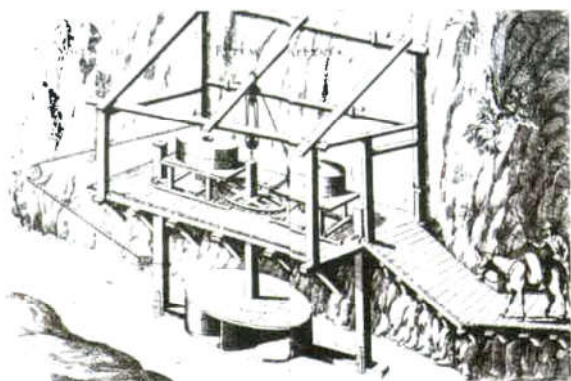
Δ Ruder Josip Bošković

THE CROATIAN CONTRIBUTION TO THE BEGINNINGS OF ELECTRICAL ENGINEERING

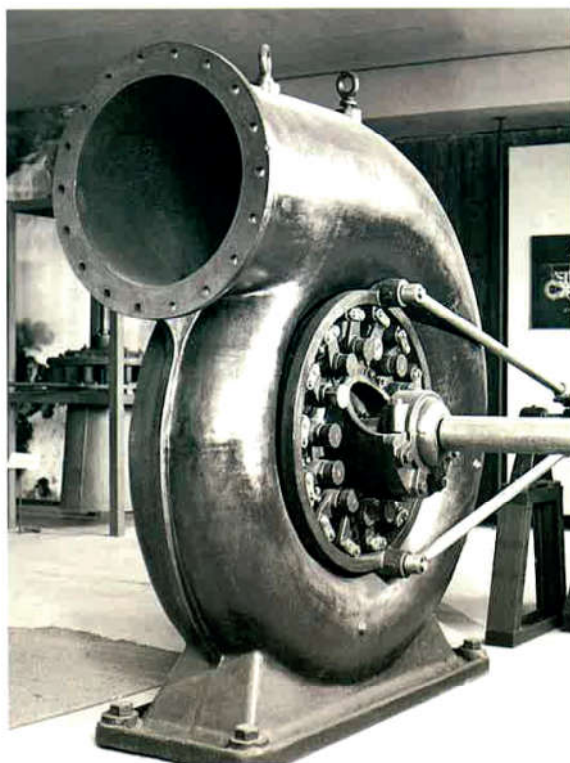
Throughout the history of electrical engineering many people from Croatia deserve a great credit. They are recognized worldwide for their work and have substantially contributed to an accelerated development of these scientific and technical disciplines. Based on their endeavor Croatia takes an important place in this field of development. These men, through their patents, or books, treatises and new ideas, by transferring foreign knowledge and experiences, made it possible for the first alternating-current polyphase system to appear in Croatia a hundred years ago.

As early as in the Renaissance and post-Renaissance period, Croatian scientists gave internationally recognized contributions to the development of natural sciences and techniques. The works of Faust Vrančić and Ruđer Josip Bošković, in addition to their general significance, were essential for the subsequent development of electrical engineering.

Faust Vrančić (Šibenik, 1551 - Venice, 1617) de-



△ Vrančić's water wheel, forerunner of modern water turbines



△ A modern Francis turbine

▽ Faust Vrančić



scribed numerous technical inventions and designs in his work *Machinae Novae* (*New Machines*) published in Venice in 1616. This work presented drawings with explanations of about fifty various devices and driving engines. Among them were several devices driven by water power, which may be considered forerunners of

water turbines used today in modern hydro power plants. This particularly applies to Vrančić's blade wheels, with sloping blades located between two round boards, which resembles very much the modern Francis turbine.

While he was not specifically concerned with problems of electricity, Ruđer Josip Bošković (Dubrovnik, 1711 - Milan, 1787) deserves great credit for the development of electrical engineering. This prominent Jesuit, mathematician, physicist, geodesist, astronomer, poet, writer of travels and diplomat, by his epochal work *Theoria Philosophiae Naturae* (*The Theory of Natural Philosophy*) affirmed substantially Newton's theory of gravitation, and described the mechanical, physical and chemical properties of objects in nature. Having postulated the dynamic-atomistic theory and relativity in understanding of space, Bošković's influence on the 19th century physicists, especially Faraday and Kelvin is decisive. Yet, it was not until this century that his work has been duly appreciated. His works in the field of geodesy and statics are important today in applied tech-



△ Nikola Tesla, inventor of the rotating magnetic field

niques. Bošković belongs to a small number of great world scientists who have substantially advanced human knowledge.

The Jesuit and physicist Josip Franjo Domin (Zagreb, 1754 - Zagreb, 1819) is the first Croatian scientist who was concerned with the issue of application of electricity, specifically in medicine and technique. He published a number of works on this subject, among them *Lampadis Electricae Optimae Notae Descriptio* (*A Description of a Well-Known Lamp*), printed in Budapest in 1800 in Latin, and a year later translated into the Croatian language.

Two scientists from Croatia gained international recognition and fame in the late 19th and early 20th century: Nikola Tesla and Franjo Hanaman.

Nikola Tesla (Smiljan, 1856 - New York, 1943) is a prominent innovator in various fields of electrical engineering. Born in Lika, he went to high school at Rakovac near Karlovac. He became interested in electrical engineering, spurred by his teacher Martin Sekulić, who persuaded him to study, from 1875 to 1878, at the Engineering College in Graz, and in Prague for some time. As he did not finish his studies, he found employment as a draftsman at a telephone service in Budapest in 1881. The idea of the rotating magnetic field occurred to Tesla in 1882, and in 1883 in Strasbourg he demonstrated the operation of the first alternating-current motor without a commutator. He moved to the USA where he worked with Thomas Alva Edison, inventor and propagator of the direct-current system. In 1887 he founded his own company, Tesla Electric Co., and built a laboratory in which he experimented and designed motors and generators. He established relations with the company of George Westinghouse, later to develop the alternating-current system in the USA. Tesla became famous after delivering his first lecture at The American Institute of Electrical Engineers entitled *On the New Alternating-Current System of Motors and Transformers*. During the many years of his work, he patented more than hundred inventions from the field of electrical engineering.

Although he lived outside our country, Tesla kept

constant interest in technical work in Croatia. In May 1892 he visited Zagreb, attended the Society of Engineers and Architects, and delivered a lecture at the City Hall on alternating currents during which he proposed building an alternating-current power plant in Zagreb. On this occasion he said: "I consider it my duty, as a natural son of my country, to help the city of Zagreb in every respect". For the site he proposed the waterfall of Ozalj or the Plitvice Lakes. Although the hydro power plant on the Niagara was built by Forbes, the generators installed there were Tesla's patent, he is, therefore, considered to be its builder. For Tesla's merits for the development of electrical engineering speaks the fact that the unit of magnetic field density was named after him, and received numerous acknowledgments, honorary doctorates and membership in world-renowned



Δ Franjo Hanaman, inventor of the tungsten filament light bulb

academies. He was a honorary member of JAZU and a honorary doctor of the University of Zagreb.

Franjo Hanaman (Drenovci near Županja, 1878 - Zagreb, 1941), graduated from the Royal High School in Zemun, where his teacher of physics was Stanko Plivelić. He studied and graduated in chemistry at the Engineering College in Vienna, where in 1900 he became an instructor. Together with his colleague Dr. Alexander Just (1872-1937) he cooperated with the Vienna company Schneider und Co. on improving the coal filament bulb, invented by Edison. By that time, about 3,000 various materials, which appeared to be suitable for the incandescent filament, had been tested. Due to its high melting point they chose tungsten. Manufacturing of tungsten filaments required a complex technological process, they nevertheless succeeded in producing a metal filament from tungsten powder. In 1903 they patented this process and in early 1905 made a contract with the company Vereinigte Glühlampen und Elektrizitäts AG, Ujpest, Hungary, for application of the patent. For this reason they left Vienna and moved to Budapest. In 1910 Hanaman and Just sold their patent to the American company General Electric Co., after which the tungsten filament bulb spread worldwide and completely replaced incandescent filaments made of other materials.

Franjo Hanaman turned thereafter to other problems. In 1911 he went to Berlin where he received his Ph.D. During World War I he lived in Vienna, was the organizer and head of the then most modern metalographic laboratory. When in 1919 Zagreb Engineering College was founded, he joined as a lecturer and in 1922 became a full professor of organic chemistry and metallurgy. He was dean of the Department of Chemistry in 1922 and 1923, and rector of the College in 1924 and 1925. Thanks to his effort and diligence this College was included in the University of Zagreb as the School of Engineering. On Professor Hanaman's initiative, a separate Department of Mining-Metallurgy was set up within this School.

Bogoslav Šulek (Subotiče, 1816 - Zagreb, 1895), secretary of JAZU for many years, was a prominent

▽ Oton Kučera, great promoter of electrical engineering in Croatia



linguist, who was not concerned with electrical engineering but had a major influence on the creation and preparation of technical terminology, including that from the field of electrical engineering. Besides his *German-Croatian Dictionary* in 1860, Šulek published in 1874/75 his *Croatian-German-Italian Dictionary of Scientific Terms*. While many electrical engineering terms from the Dictionary are changed today, their important role is indisputable in the creation of Croatian technical and scientific literature in the fields of electricity and electrical engineering.

The development and popularization of knowledge on electrical engineering in Croatia in the late 19th and early 20th century was greatly influenced by a series of five books entitled *The New Era Inventions*. The first book was written and published by Ivan Šah, and subsequently published by Oton Kučera, Stanko Plivelić and Juraj Božičević.

Ivan Šah (1824 - Zagreb, 1904) was a teacher of mathematics in Prague and Zagreb. He wrote his most comprehensive work in Zagreb: the first book of *The New Era Inventions*, published by Matica Hrvatska in 1891. This work is of great importance for Croatian technical culture. A part of it addresses the issues of electricity and electrical engineering. Šah writes about "lightning current", "lightning magnets" and "electromagnets". Šah introduced the term "electromagnet" into Croatian technical literature, and his book was the first in this country to describe the principle of hydro power plant operation.

Oton Kučera (Petrinja, 1857 - Zagreb, 1931) completed natural science studies in Zagreb. He taught mathematics and physics. During his service in Požega he wrote an elaborate book, *Sketches on Magnetism and Electricity*, as the second book in the edition *The New Era Inventions*, published by Matica Hrvatska in 1892. In the book, he describes "dynamo-machines" and other electrical machines, and utilization of waterfalls for electricity generation. In 1903, Matica Hrvatska published Kučera's book *Waves and Rays* in which he very elaborately writes about electrical engineering. Together with Plivelić and Božičević, Kučera published in 1910 his third book of *The New Era Inventions* writing again very elaborately about electrical engineering, and in 1913, with Plivelić, the fourth one, in which he describes a dynamo of alternating current and electricity transmission over distance. Finally, Kučera is the author of the fifth book of *The New Era Inventions* in 1925, entitled *Telegraph and Telephone without Wires*. In addition to numerous articles and treatises, Kučera wrote 21 works in which more than a thousand pages are dedicated to the issues of electricity and magnetism.

Stanko Plivelić (Karlovac, 1868 - Krapina, 1925) graduated from the School of Humanities and Social Sciences in Zagreb where he received his Ph.D. degree in 1900. He published numerous articles from the field of electrical engineering, among them the article *Electrical Factory of GANZ et Co. in Budapest* in 1900, in which he describes in detail and expertly a factory that was the leading European manufacturer of equip-

ment for the alternating-current and polyphase electricity system. He emphasized Ganz's contribution to building of our first alternating-current system Krka-Šibenik and pointed to its significance for the development of our electrical engineering. His most important work is the book *Lightning Devices*, published in 1910 in Srijemska Mitrovica. It contains the first regulations in the Croatian language on lightning-conductors. In the third book of *The New Era Inventions*, Plivelić wrote the very elaborate chapter *Electrical Vehicles* in which he describes the electrified railroad and city transportation by streetcars. In the fourth book he wrote the chapters *Electrical Storage Batteries and Electrical Lighting*. In 1918, he patented in Vienna a special type of lightning-conductor, for which he became widely known.

Several other people in the late 19th and early 20th century contributed to the development of electrical engineering in Croatia - mostly high school teachers: Moritz Antolić, Martin Sekulić, Ferdinand Kovačević, Antun Laska, Vinko Dvoržak, Franjo Divić, Václav Pavlata, Ivan Zoch and Josip Mencin, and particularly Ivan Stožir, Ivan Paspas and Ladislav Stjepanek.

Ivan Stožir was an interesting person (Rožna Dolina, 1834 - Zagreb, 1908). A teacher at a high school in Zagreb, we know that on March 14, 1873, he operated the lighting in the Croatian National Theater during the performance of *Margarita*, or *Faust*. It was the first application of electric lighting in Zagreb and Croatia. In 1877, on the occasion of a ball at the Croatian Music Institute, on the corner of Illica and Gundulićeva Street, Stožir placed an electric arc lamp, which for several hours was supplied by a galvanic battery. This first electric street light in Zagreb was a major sensation in the city.

Ivan Paspas came to Zagreb from Vienna in 1893, with the reputation of being "the master of light". Namely, he had been the manager of the electrical lighting in the famous Vienna's Burgtheater. He was brought to Zagreb by Stjepan Miletić, manager of the Croatian National Theater. Paspas first installed electrical lighting in the old city theater on Marko Square, using the steam engine from the Rope Railroad which was installed there in

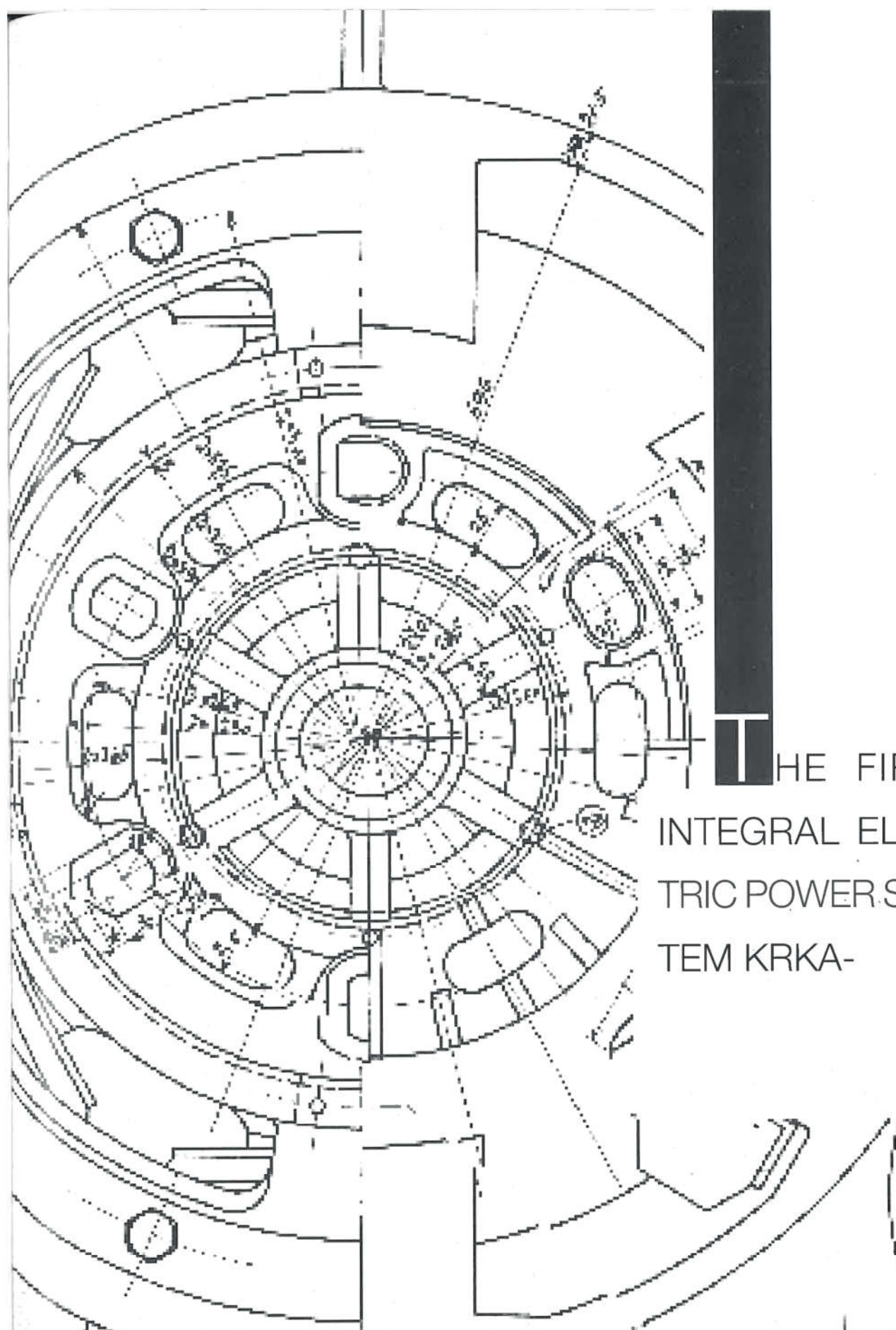
Ivan Paspas, organizer of the first electrical equipment industry in Croatia



1888. Following the opening of the new building of the Croatian National Theater in 1895 he became supervisor of electrical lighting in the new theater which had its own electricity source: a power plant located in the building of the Croatian Folk Dance Club, opposite the Theater. In 1896 Paspas was granted an operating license from the city authorities for Ivan Paspas & Son to manufacture electrical batteries and flashlights. This factory - the first electrical equipment industry in Croatia - is still in existence today, under the name Croatia Battery Factory.

Finally, we should mention Ladislav Stjepanek (Novi Sad, 1874 - Zagreb, 1951), who studied at the School of Humanities and Social Sciences in Zagreb, where he received his Ph.D. degree in 1900 on the subject *Maxwell's Theory of Electricity*. In his dissertation, Stjepanek systematically and exhaustively presented

Maxwell's theory and investigated its roots, especially in relation to Faraday and Bošković. In 1902 he published his new work *Maxwell's Electrodynamics and Induction* on the same subject. In addition, he published a few works from the field of the theory of magnetism and electricity. In 1912, he was elected to be the first professor of theoretical physics at the University of Zagreb and retired as a full professor in 1946. Professor Stjepanek was a witness of the founding of the Engineering College in Zagreb and its Department of Electrical Engineering in 1919 at which point a new era in the development of electrical engineering sciences in Croatia began. ■



THE FIRST
INTEGRAL ELEC-
TRIC POWER SYS-
TEM KRKA-

SIBENIK



△ The Krka hydro power plant, 1895

BUILDING OF THE KRKA - ŠIBENIK SYSTEM



△ Art Nouveau Lamp, end of 19th cent.

In Frankfurt am Main, a major international electrical engineering exhibition was held, notable for having a substantial influence on the development of electrical engineering in the whole world. The grand success of the alternating-current system in Frankfurt was written about by all the world press; not only in technical publications, which was the normal way of transferring new knowledge at the time. It is not surprising, therefore, that this success was known about in Šibenik where notables and businessmen excitedly accepted the idea that on the Krka Falls, near Skradinski Buk, a hydro power plant should be built and Šibenik illuminated therefrom.

The builders of the alternating-current two-phase system Krka - Šibenik, Croatia's first integral electric power system, were: Ante knight Šupuk (Šibenik, 1838 - Šibenik, 1904), mayor of Šibenik and delegate of Dalmatia to the Empire's Council in Vienna, his son Marko (Šibenik, 1864 - Šibenik, 1903), navy captain, and Vjekoslav pl. Meichsner (Šibenik, 1847 - Šibenik, 1916), Šibenik city chief surveyor and city councilor. All of them were much ahead of their time and influential. Ante Šupuk had numerous flour mills and stamping-mills which later on, managed by his son Marko, were the basis of the industrial Šibenik. After staying in Russia in 1884, Marko returned to Šibenik for good, dedicated himself to running his businesses and numerous crafts, among which was the running of the electric power system. For many years, Meichsner was the city's surveyor, engineer, builder of the District Courthouse, the regional hospital, as well as of the first municipal water supply system and other significant facilities in Šibenik.

All three builders of this system had been making preparations for a longer time to install the electric lighting in Šibenik, and to build a power plant. These preparations lasted from 1891 to 1893 when Meichsner, as a civil engineer, completed the drawings and designs for building of the first power plant on the Krka Falls and, in parallel, a transmission line and the city's lighting net-



△ Ante Šupuk

work.

On May 1, 1893, having completed all the drawings and designs necessary for building the hydro power plant, transmission line and city's distribution network, Meichsner requested the district authorities to allow him "to establish a crafts association to produce and operate electricity for lighting purposes, to transfer power, and for other crafts and home-made articles" and to allow him to use "certain quantities of the river Krka waters, starting from that flowing along plots no. 961/10, 961/27 and 961/8 (Lozovac tax authorities) being his property, then to transfer it by means of an existing channel being also his property, which would in accordance with the attached drawing, be expanded and improved as a factory founded by him to produce and transfer electricity, and return it to the same river, even before it leaves the borders of the above mentioned plots".

This request initiated a big administrative proce-

dure. On July 6, 1893, a reconnaissance by a committee was carried out to ensure that the requested building would not cause any public or private damage. From October 10 to 14, two governmental committees did the field work. One was responsible for establishing as to whether the requested concession concerning water utilization could be issued, and the other, the more numerous, examined the route of the transmission line from the Krka to Šibenik. Altogether twelve salient people toured the route and city streets in which "extension of wire - cable - in the air" was planned.

Based on the reports of these committees, on December 18, 1893, district authorities issued a *Decision (Razsuda)* to Meichsner, No. 15936, allowing him to open the requested firm, on the following conditions:

"I. that the building of the founded company strictly comply with drawings presented, of which one copy duly certified shall be given to the requesting party.



△ Vjekoslav Meichsner

Broj 15936

Razsuda

1893

Gospodin Vjekoslav pl. Meichsner

Sibenik

Na rješavanje molbe d. p. 1. Sribnja t. g. Gosp. Vjekoslava pl. Meichsnera iz Sibenika, da mu bude u smislu § 86 pokrajinskog Zakona o Ogruzka 1873 (Z. S. R. 32) udiojena na temelju predanog nacrtu dozvola za upotrebu - zbog ustanovljenja jednog obitništa za proizvodnju i odjenu munjivo a sorku razvoje, prenašanje i ino obitne te kućne porabe - neke količine vode rieke Krke, ureši ju od one koja teče uzduž katastralnih čestica 961/10, 27, 961/8 (porazno obitno Lorovac) njegovog vlasništva, pak primije ti ju sredstvom jedne ovi postojeće jače (konala) također njegovog vlasništva, koja polag predloženog nacrtu biti će vhodno razporena i uređena a trošnicu od njega osnovanu za proizvodnju i prenašanje munjivo, te ju povratiti istoj rieci, jer prije nego ona izađe sa granica gosnarnacionih vlastitih čestica.

Vidio da su dne 6 Sribnja 1893 bili na lice mjesta, po smislu § 89 spomenutog pokr. Zakona o Ogruzka 1873, izvedeni potrebiti izvodi glede pripuštenosti poduzeća i načina da se osvostrani.

Vidio da onom prigodom bilo je konstatovano da u obci odgovaraju, nacrti kao i molba prikazana od protivlja, odredbam u istom §. normacionim, i ureši neke male promjene predloženih nacrtu koje su kasnije naknadno od protivlja izošćene bilo, te da namljenim podhvatom nebi se ma kako vjetovale prava javne niti privatno naravi.

Vidio da poglavarstvom oglašom - predomito proglašeno 14 Listopada tg. R. 13392, bilo je doneseno na zemlje pograničnih zamiranih obitno, pak protivlja i inih povratih zamiranih stranaka, da poglavarstvom razprava u smislu § 83 nio normacionog

u svrhu razvijanja, pronašanja sila i one obitne te kućne
parabe - neke količine vode rieke Krke uzevši ju od one koja
teče uzduž katastralnih čestica 36/10, 22, 96/8 (posebne obćine
Lorance) njegovog vlasništva, pak primijeti ju urednom jedne
već postojećim jaru (konala) također njegovog vlasništva, koja po la-
pu državnog načrta biti će vodna razvoda, i uređena, u
tome od njega osnovanu za proizvodjivanje i prenosnje mu-
ne, te ju, povratiti svoj rieci prije nego ona istupi sa gra-
nna razvoda njenih vlastitih čestica, a pod uvjetom uvjetima;
I). da gradnje osnovanog poduzeca, bude točno skladiti po-
laž državnog načrta, kojih jedan primjerak običajen sa
urednom potvrdom ureduje se prositeljju.

II). da točenje vode, imade se ograničiti na mjenu od 25:8
m² za hip doticni da se ne smije proizvesti kakva prepreka
na konala doticju.

Kao i kod Kras koji osnovana gradnja, ima će se dovesti
ustanovljeno se deha od drvo godno.

Ansuda razsuda intimira se tako prositeljju Gosp.
Vjekoslav pt. Reichsneru, Kras i Gosp. Yvanu Lipuku, Emilionu
Lipuku i Josu Kulibicu sa Sibenikom, kao omirna Kras sa
primjeriti doticno primjeriti bili u pogledu osnovanog po-
nuala, gromnom da prohi ovaj razsudi ostaje prost ulak
pe smisla 894 uvidenog Zakona, koji se prikazati imma postova
ovaj ureda na listu K. namještrstvo u Zadru u roku od 14 da-
na od dostave, doim u ovo K. kotarsko Poglavaru prirediti
obmaniti Gosp. Vjekoslava pt. Reichsnera netom ova razsuda
intimira - Knežestvom postati



Sibenik 18 Prosimca 1873

Ok. Kotarski Poglavaru.

Seifert v. e.

La presente fu da me celebrata. Invece conforme al suo originale depositato il dicembre
1891 al 1892. esistente presso la giunta austriaca nella persona del signor Francesco Bernardi e presso
centrale la ditta Sibenik ligni e legno, presso la ditta austriaca.

Seifert e nella data del 1891.



Giuseppe de Vito
O. A. N.

II. that the consumption of water be limited to 25.81 cubic meters per second, or that no change shall occur on the channel of flow; and the time limit for completion of the said building is specified to be two years."

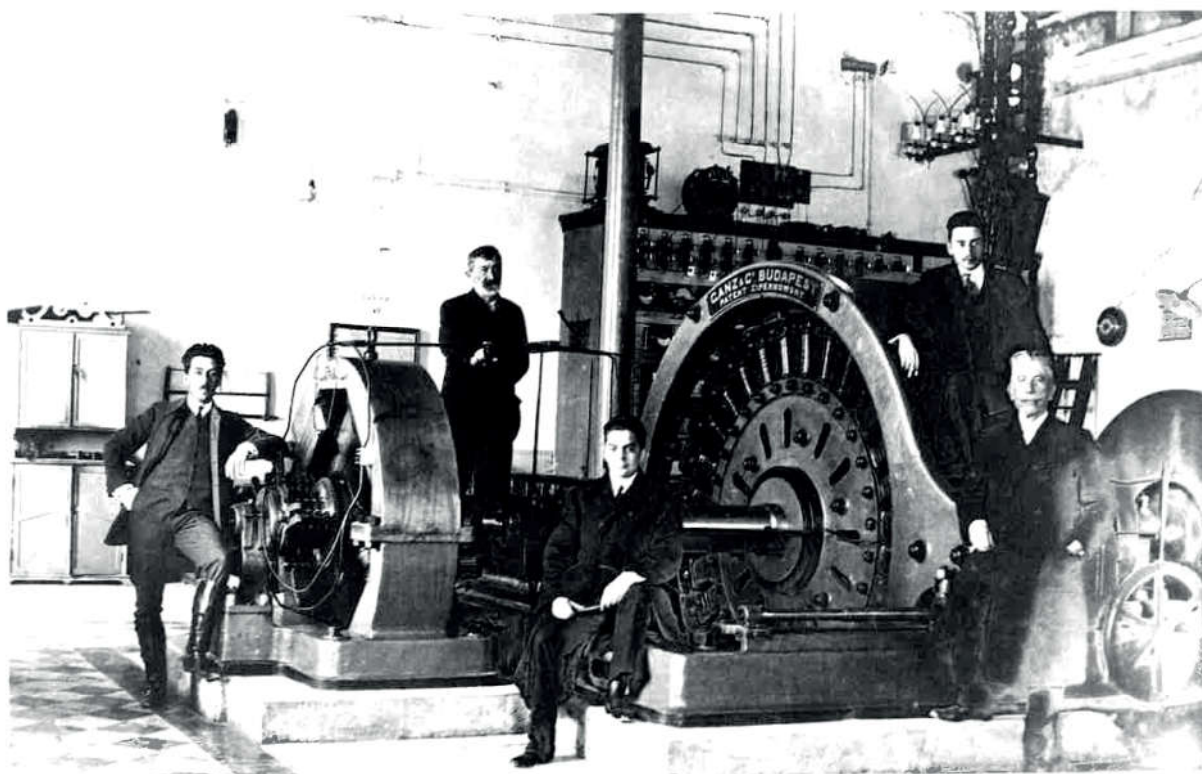
Under the Decision of March 22, 1894, No. 6522, Meichsner was also granted an "industrial concession". The last necessary permit was issued by Šibenik municipal authorities on April 30, 1894, No. 1579, which read "that he may place poles on the municipality-owned land for transmission of electric power and may also make the necessary network over the city's streets for lighting purposes".

With this the administrative procedure was completed for all the documents necessary for the building of the first alternating-current power plant, 11 kilometer long transmission line and the city's low voltage net-

work in Šibenik - that is, our first integral electric power system.

In the meantime, negotiations were held with city authorities and mayor Šupuk about the price at which the city would be illuminated. This defined an important element of the system - consumption. For lighting the city by electricity an annual fixed sum of 5,000 forints in monthly installments was to be paid.

Parallel to the building permit and water concession procedure, Meichsner and Šupuk made a draft and then the final agreement concerning the setting up of a mixed company "una societa di commercio in nome collettivo". These documents were drafted by Šibenik's public notary, Giacondo Petris de Herrenstein in Italian. The agreement superseded earlier agreements made between Meichsner and Ganz of Budapest, and the new company assumed all obligations relating to pay-



△ Members of the Šupuk family and associates by the Krka hydro power plant generator

ments of the equipment ordered. It was agreed that the new company's name would be Šupuk e Meichsner - Prima Concessionata Centrale Elettrica in Dalmazia "Krka", or translated from its Croatian equivalent Šupuk and Meichsner - First Privileged Power Plant in Dalmatia "Krka", based in Šibenik. The company began to operate on June 1, 1895. By that time building was at its peak, as the entire system was put into service on August 28, 1895, by switching on the city's public lighting.

The Krka hydro power plant (only later the name Jaruga would prevail) had two parts. A lower, underwater, for accommodation of turbines, and an upper, for the power house and a switch tower. It was designed for two generating units, although initially only one was installed. It had a Girard water turbine of vertical type and 0.8 atm pressure, which, through bevel gears, transmitted power onto the horizontal generator shaft. In the power house a two-phase alternator manufactured by Ganz, under Zipernowsky's patent, of A2 type, 320 HP and 315 revolutions per minute, 42 Hz, was installed as well as on the same shaft an appropriate exciter made by the same manufacturer. From a few preserved photographs it can be concluded that there was a manual regulation of water turbine, as well as manual voltage control.

Our first alternating-current two-phase system was poorly protected. Protection consisted of melt fuses and mercury protectors with horns and parallel connected resistors. This design was meant to provide protection against atmospheric overvoltage and discharge.

The alternator produced the voltage of 3 000 V and was directly connected to the transmission line, which transmitted energy to the 11 km far Šibenik. Any larger atmospheric discharge burnt the generator windings and caused rather serious stoppages and breakdowns. A consequence of the then ineffective overvoltage protection.

Works on the hydro power plant were managed by Vjekoslav Meichsner and Marko Šupuk, and electrical engineers of Ganz, Zerial and Zorzenoni. All auxiliary labor force was domestic, and construction work was performed by the builder Bonamico and Šibenik

craftsmen Cinotti and Grubelić. Ettore Zorzenoni would after the power plant was commissioned, stay in Šibenik as its chief operator and subsequently, chief engineer.

Parallel to building the hydro power plant, work on the building of the transmission line and network went on. Wooden poles were installed from the Krka to Šibenik with channel bar consoles which carried insulators. There were three crossarms on every pole. The upper two were equipped with glass insulators for two conductors of 7 mm (top crossarm) and 9 mm (middle crossarm) in diameter for the voltage of 3,000 V. The conductors corresponded to the 35 and 50 mm² Cu cross-sections. The lowest crossarm carried a telephone line from the hydro power plant to Villa Meichsner.

It is interesting that the first insulators for 3,000 V were made in the shape of a bottle and filled with oil to improve insulation levels of the line. The transmission line, 11 km long, with 360 poles, was installed along the road Lozovac - Šibenik, to facilitate access in case of repairs, and because farmers believed it would devalue their land. This is why the transmission line zig-zagged and had many more poles than it would have had, as a straight line.

A 3,000/110 V distribution network was built in the city, including 2 switching stations and 6 substations installed on roofs of houses.

The Krka hydro power plant was put in service on "August 28, 1895, about 8 o'clock in the evening" according to Zadar's newspaper *Il Dalmata*, in which the euphoric atmosphere surrounding this event was described. The builders were struck by a feverish tension of expectation. As the same poles between the power plant and the city carried the telephone line linking one of the first electrified houses in Šibenik, Villa Meichsner - the home of the system builder, a conversation was recorded between Meichsner and a mechanic in the power plant. After reporting from the power plant that "...machines are running excellently" and asking "...how's the lighting in the city doing", the answer came: "fantastic - just in time!". Thus Villa Meichsner took the function of the first dispatch center, by reporting to the 11 km far mechanics on the functioning of their product.

▽ A substation on the Šibenik coast

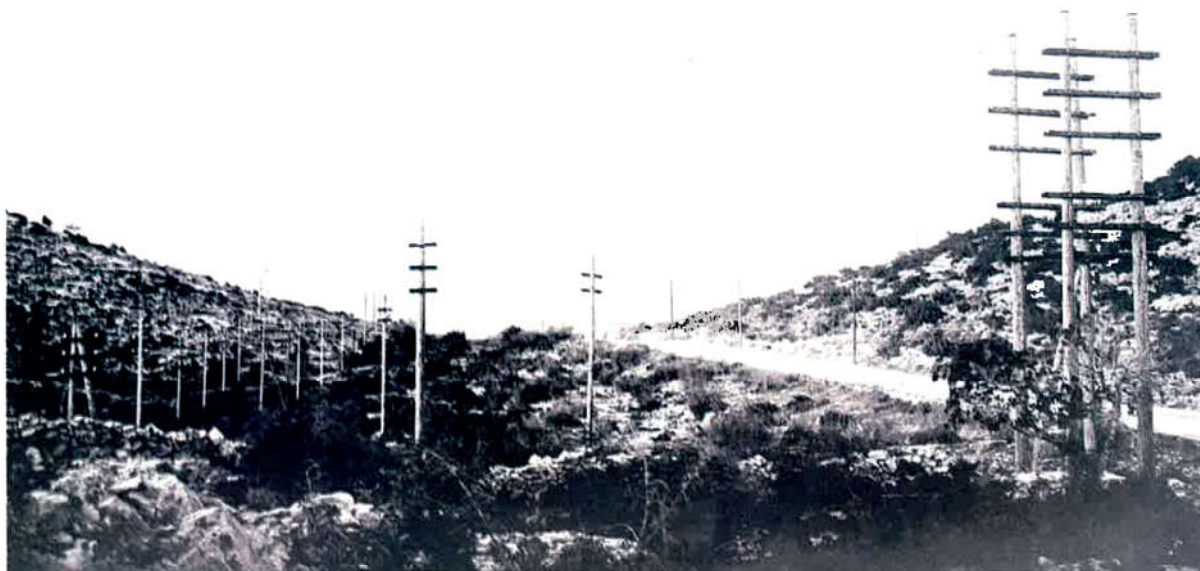


UTILIZATION OF THE KRKA - ŠIBENIK SYSTEM

At the beginning the most important consumer of electricity was the city's public lighting. Households rarely chose to introduce this novelty since common people feared the "electric lightning", as it was believed that "the electric lightning kills, attracts thunder-bolts and fire". The first larger consumer was Ante Šupuk with his flour mills, and it was not until about 1900 that some ten households of the most eminent Šibenik citizens installed electricity connections, for lighting.

The building of the Krka hydro power plant and the electric lighting in Šibenik were a sensation of their time, and Meichsner offered electricity from the Krka to the cities of Trogir, Kaštela and Split, but was refused. Obviously, the builder of the first system in Croatia was not lucky enough to repeat his venture.

▽ Transmission line towards Šibenik, poles under construction



As early as in 1897 interest arose in expanding the utilization of the river Krka waters. Specifically, Šupuk and Meichsner's rival company, Cramer et Brod, which owned the coal mine Velika Glava near Skradin, intended to build a hydro power plant on the right opposite bank, 20 times the Krka capacity. The company's owner, Ludwig de Piette, an industrialist from Plzen, Czech, together with land owners from Skradin, the Marasovičs and the Marunas, requested a concession to build a hydro power plant of 7,200 HP, with 8 turbines and a 45 meter head. The Dalmatian regency in Zadar approved only 12 cubic meters of water per second, which was insufficient.

Although after a long dispute with Šupuk and other owners of the mills on the waterfalls, de Piette eventually obtained the concession, up to 1904 he kept on requesting ever larger amounts of water. He had the technical documentation prepared, but the power plant was never built.

Meichsner's role in that is not known. It may be suspected that he had something to do with the project, as in that very year, 1897, he terminated his agreement with Ante Šupuk, after which the ownership of the Krka

hydro power plant and the whole transmission and network system was transferred to Šupuk and his son Marko. Meichsner ceded all his rights under all concessions by way of an agreement made on April 27, 1897, No. 50981.

The true reasons for Šupuk and Meichsner going their separate ways, are not really known. The reason may have been Meichsner's poor health, but also, which is more likely, his closer relationship with the rival Skradin group. Following the termination of cooperation between Šupuk and Meichsner, the company Krka changed its name into Ante Šupuk & Son - First Privileged Power Plant in Dalmatia "Krka" and Factory of Pyrethrum and Corn Grinding by Electric Power. The company was based in Šibenik. Immediately after the power plant was built, Ante Šupuk built in Šibenik, on the seafront, at Vrulje, on the site of today's bus station, an electric flour mill. It was the first electrified industrial plant in Šibenik.

In parallel with requesting approval to build a hydro power plant on the Skradin side of the waterfalls, the company Cramer et Brod was granted a permit to build a chemical plant on the Krka. Later the company

▽ Art Nouveau wall-mounted lantern support in the old city center



▽ Galatea, the ship sunk by the Šibenik seafront



sold this permit to the Venice company *Societe Veneziana Elettrochimica*, which, about 350 meters downstream of the Krka power plant, built a carbide plant, named Garbura. Two Wilson electric furnaces were installed in the plant, for electricity was needed to operate the plant. As the administration board of the Venetian company approved the purchase of the water power of the Krka Falls, a decision was made to build a new power plant. This did not however materialize, so that Ante Šupuk & Son remained the sole owner of the concession on the river Krka waters. Another generating set was installed in the Krka hydro power plant, increasing its final installed capacity to 640 HP (about 470 kW) and maximum water flow 3.2 m³/sec.

It is interesting that the carbide plant, commissioned in September 1899, was one of the most modern industrial plants in the world. However, it did not remain long in service as it was completely destroyed in a fire in 1900. It has never been reconstructed as a production unit. The plant is significant in that it opened the door to Italian capital to the Šibenik area. Following the fire in the plant, the Krka hydro power plant had an excess of electricity, so that Ante Šupuk had to look for

new consumers. There were few in the city as the industry had only just started to develop, and electrified households were rare. The first domestic entrepreneurs began using electricity in 1900. For instance, through its own transformer, First Dalmatian Pastry Plant - famous for its cleanliness, owned by A. Inchiostro, connected to the network. Electric lighting was installed in some cafes as well. It was recorded that on April 15, 1903, at 10.45 am, while installing lines at the Zanchi Cafe, an "artisan of the power plant" was killed by an electric shock. This was surely the first victim of an electric shock in Šibenik, and perhaps in Croatia. In 1905, the Post Office was electrified, and the City Theater, electrified in 1896, three years later recorded the performance of "the first, experimental show of the EDISON movie theater". Electric lighting was used in 1907 for the salvage of Lloyd's ship *Galatea*, which sank due to bad weather in the shallow sea by the wooden seafront. As work continued into the night, "electric lighting was set, even on the mast".

On July 12, 1901, in Trieste, an agreement was signed at public notary Vessel's office, between the company Ante Šupuk & Son, owner of the concession

on utilization of the river Krka waters totaling 25.81 m³/sec., Societa Veneziana Elettrochimica, owner of the concession on production of calcium carbide, and Societa Italiana per Carbuco di Calcio, Acetilene et Altri Gas. A new company was founded to utilize hydraulic power in Dalmatia, Societa Anonima per l' Utilizzazione delle Forze Idrauliche della Dalmazia, or SUFID for short, with its headquarters in Trieste.

The agreement consisted of the following:

1. The company Ante Šupuk & Son shall cede to the Company the concession on the unused part of the water flow of Skradinski Buk, or 22.61 m³/s, for a 29 year period. For their own needs, Ante Šupuk & Son will retain water to the amount of 3.20 m³/s, the amount being sufficient for the existing Krka hydro power plant.

2. The company Societa Italiana per Carbuco di Calcio, Acetilene et Altri Gas will purchase the right to manufacture calcium carbide in Dalmatia for the purpose of building a new factory on a suitable site. The Company further undertakes to build a new hydro power plant in the vicinity of the old one, using the unused excess water. And finally, it undertakes in its own name and on behalf of any legal successor to transfer to the company Ante Šupuk & Son all the facilities it has taken over after the end of the agreed period of 29 years without compensation.

Under the Agreement, the company Ante Šupuk & Son continued to have the right to "their earlier line, serving to transmit electricity from their small power plant

to the city of Šibenik", and Societa Italiana per Carbuco di Calcio, Acetilene et Altri Gas would transmit energy from their new power plant by "a special overhead line to its SUFID plant at Crnica in Šibenik".

Thus SUFID built, at that time, as the press put it, a big and powerful calcium carbide plant in Crnica "near Šibenik", with 8 single-phase electrical furnaces per 750 kVA, totaling 6,000 kVA. The plant started to operate in April 1903, first on trial, with one furnace and later, from September, at full capacity.

At the same time the company Ganz completed building of the Jaruga hydro power plant of 5,250 kVA total capacity, which could produce about 15 million kWh a year. The generator voltage of 15,000 V was transmitted to Šibenik by a special overhead transmission line, 12 kilometers long. The line had four copper wires (double, two-phase) of 9 mm in diameter and 64 mm² in cross-section. It was borne by about 360 wooden poles placed along the road bordering on plots of land.

At the peak of building the Jaruga hydro power plant, later named Jaruga II because the Krka power plant was called Jaruga I, on June 4, 1903 captain Marko Šupuk, one of the masterminds of Šibenik's electrification, died. And hardly a year after, on May 11, 1904, Ante Šupuk died of heart stroke, having served as Šibenik's mayor for a full 28 years, the man who worked tirelessly for the progress of his city. In addition to installing electric lighting, he was the initiator of building a



Δ Calcium Carbide Plant in Šibenik, c. 1905

water supply system, introduced the railroad, built the courthouse, high school and hospital, the latter being the largest in Dalmatia at the time. The company Ante Šupuk & Son was taken over by successors from the Šupuk family.

Numerous documents have been preserved that give evidence of the expansion of the electricity network and establishment of a true electricity company. The development advanced in parallel with the development of the Crnica plant, up to World War I. For military needs, the twenty year old Krka (Jaruga I) hydro power plant and the old transmission line were dismantled. Of the equipment, copper and iron were taken for military purposes. The other power plant and the carbide plant were left intact since they manufactured strategic war material. In short, the company Ante Šupuk & Son lost their production and transmission part, forcing it to associate with SUFID. From an integral electricity company it changed to an electricity distributor.

In addition to building the Jaruga II HPP, in 1904 as needs increased SUFID started building a hydroelectric plant on the Manojlovac Falls near Kistanje, 38 kilometers from Šibenik. There, usage was made of the 110 m head so that the total turbine capacity amounted to 24 000 HP, and the generator 20 800 KVA, or 16 600 kW. The Manojlovac HPP was put into service in April 1906 (first generating set) and full capacity in 1907. A double circuit transmission line ran from the power plant to Crnica in Šibenik, at 30 000 V. Up to 1910 this was the most powerful hydro power plant in Europe, and the voltage of the transmission line was the maximum envisaged at that time for transmission over distance.

At the beginning of World War I, following the closure of Krka (Jaruga I) HPP, Šibenik had problems due to a shortage, whereas the plant at Crnica had an excess of electricity. It was logical, then, for the company Ante Šupuk & Son and SUFID to arrange their further cooperation. Under a separate agreement, they renewed the lease for water flow used by the Krka HPP, on condition however that SUFID provide from its power plants one million kWh a year to the company Ante

Šupuk & Son which could distribute this energy to the city and the area. If more electricity would be needed, then a price would be set on a commercial basis for the company to buy this additional amount.

On August 1914, the Austro-Hungarian army took control over the company Šupuk & Son. The company SUFID was also put under governmental control in 1916. Instead of its Italian name, it was given a German name, Aktiengesellschaft für Nutzbarmachung der Wasserkräfte Dalmatiens - Werk Sebenico, which is the German translation of the earlier Italian name, which it kept until the end of the war, i.e. until the fall of the Austro-Hungarian Monarchy. In spite of the wartime circumstances, during 1916, a first major reconstruction was carried out on the Jaruga II HPP; the turbine was uprated, and the power plant switched from a two-phase to a three-phase system.

After the war, Šibenik was temporarily occupied by the Italians, who were quick to return SUFID its old name, as well as all the former rights to the company Ante Šupuk & Son. All the agreements between these two companies made from 1901 to 1914 remained in force. During the Italian occupation electrification was advanced. In March 1919, public lighting in Skradin was commissioned. In Šibenik, electricity consumption increased to reach the pre-war level of about 1.9 million kWh. There were more than 1,500 electrically-connected households.

When the Italians left Šibenik in 1921 all was as before: the relations between SUFID and the company Ante Šupuk & Son were honored. Both companies however struggled with the post-war economic difficulties. In 1923 a tariff-based billing system was introduced and fixed sum system of payments abandoned. The first rises in electricity prices followed as well as a more serious expansion and reconstruction of the city's electrical network - the replacement of overhead with cable lines.

Already in 1925 the company SUFID anticipated its own liquidation as the then royal government did not want to renew the expiring agreements. The government of the Kingdom of Serbs, Croats and Slovenes,

sought to replace the Italian with other partners. On April 13, 1929, it reached an agreement with the French Association of Tunisia Phosphates, Fertilizers and Chemical Products A.D. and founded a new company, SEFFHIED, which soon changed its name into La Dalmatienne and purchased all assets of SUFID. As the lease agreement made in Trieste on July 12, 1901, was to expire in 1930, SUFID in 1929 returned the ownership of Jaruga II HPP to the company Ante Šupuk & Son, which then reconstructed the power plant and made it capable of supplying the city, thus completing the electricity industry in Šibenik.

Given that La Dalmatienne ceased to be supplied from the Jaruga II HPP, the city had an excess of electricity. A solution was found in building an aluminum factory at Lozovac. It was built in 1936 by an industrialist from Belgrade, Ivanović, who made an agreement with the company Ante Šupuk & Son for the supply of considerable amounts of electricity, and for the security

and constancy of supply. In the meantime a litigation against the mills' owners - the Marasovići and their heirs from the Skradin side - was resolved in favor of the company Ante Šupuk & Son. In 1937 a major reconstruction began on the Jaruga II HPP. Ganz of Budapest was there again.

The Jaruga II HPP was not only a significant source of electricity for Šibenik and its industry, but also for the aluminum plant at Lozovac. Although Šibenik and Jaruga were occupied by Italians this was also true during World War II. Even the sporadic shutdowns caused by bombing did not affect the operation of the plant to a considerable degree. After 1945, damages done in the war were repaired and the power plant was included in the electric power system of Šibenik, Dalmatia and Croatia. Its last owner from the Šupuk family, Marko, grand-grandson of the builder Ante knight Šupuk and Marko's grandson, originator of the idea of building the HPP, was sentenced in 1945 in Šibenik by



Δ The Jaruga hydro power plant and Krka hydro power plant, 1904



△ A pole with a lantern on Poljaria

The People's Court to confiscation of all assets for "collaboration with the enemy". By this document, the hydro power plant and all assets were taken from him and transferred to "people's property". ■

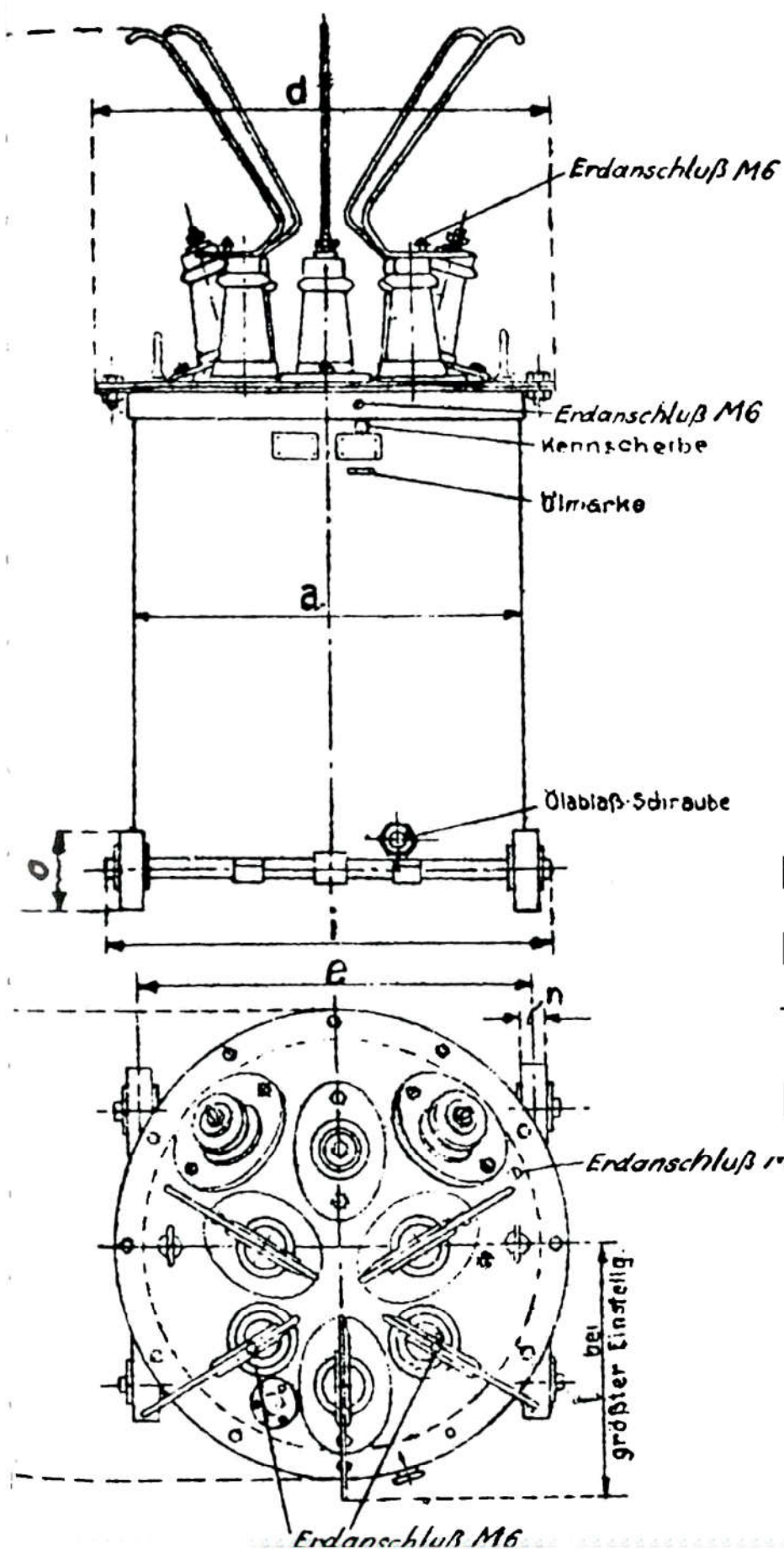
▽ City Hall in Šibenik







Δ Krka Falls, Skradinski Buk



GROUND-
BREAKING PUB-
LIC ELECTRIFICA-
TION PROJECTS
IN CROATIA

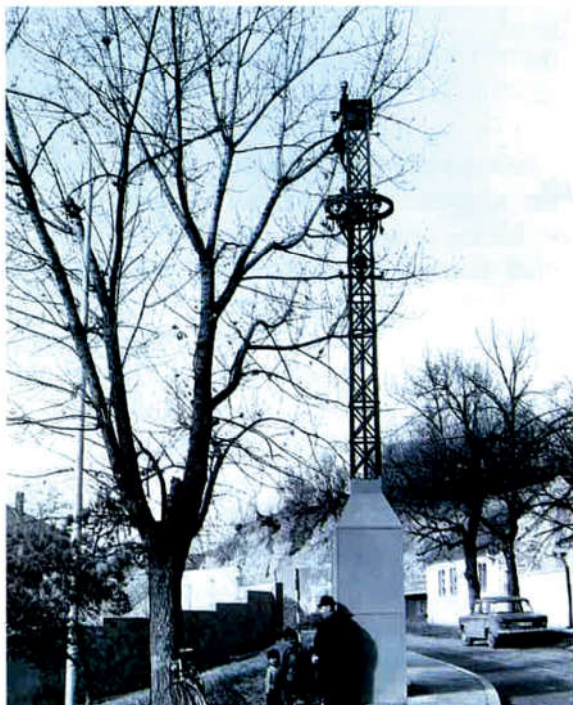
geore

TILL 1918



△ Pula, end of the century

CONSTITUTIONAL AND ECONOMIC CIRCUMSTANCES AT THE BEGINNING OF ELECTRIFICATION



Δ A 3/0.11 kV street substation in Vukovar, 1909

At the time of the first electrification activities, from the last decade of the 19th century to the end of World War I, Croatia was within the Austro-Hungarian Monarchy and was divided into several separate provinces and regions having different constitutional, administrative, and political status. After the Austro-Hungarian Compromise of 1867, Istria and Dalmatia, still within this Dual Monarchy, were under the rule of Austria, and northern Croatia (Croatia proper, Slavonia, the Croatian Military Border, and detached region of Rijeka) under the rule of Hungary. In the Hungarian part of the Monarchy, after a separate Hungarian-Croatian Compromise of 1868, northern Croatia (Kingdom of Dalmatia, Croatia, and Slavonia) was under the government of a ban and the government in Zagreb, and the region of Rijeka under the direct government of Budapest.

In 1890, the population living in the territory of Croatia totaled 2.85 million, to be increased to 3.16 million by 1900, and 3.46 million by 1910. At the beginning of the century, 23 towns had more than 5,000 inhabitants. The largest towns were Zagreb, Rijeka, Pula, Osijek, Split, Karlovac, Varaždin, Zadar, Šibenik, Rovinj, Vukovar, Sisak, etc. From 1869 to 1910 Zagreb, whose population almost quadrupled i.e. increased 3.8 times, recorded the largest growth. The towns also recording population growth were Rijeka and Pula with an increase of 2.7.

Economic development of Croatia in the late 19th and early 20th century was faster in northern than in southern regions. In that period a process of large-scale investments in industry was building up: in saw-mills, textile industry, food industry, the first oil refinery, coal-mines, shipbuilding, cement mills, and chemical industry, and in the development of shipping, trade, and banking. Between 1890 and 1910 the largest increase in the number of industrial workers was in Osijek (7.8 times) and then in Zagreb (3.5 times). In several towns the number of workers in industry and crafts was more than one fourth of the working-age population. In general, there was a larger number of craftsmen, except in

▽ Foundations of the Osijek power plant



Zagreb where there were more industrial workers.

By the eighties, that is before the beginning of electrification, the first railroads were constructed in Croatia: Sisak-Zagreb-Zidani Most (1862), as a branch line of Vienna -Trieste main railroad; Zagreb-Karlovac (1865); Pivka-Rijeka (1873); Subotica-Dalj-Osijek, and Dalj-Slavonski Brod (1869-1879). In 1876, the Pula-Divača and Kanfanar-Rovinj branch lines were connected to the Vienna-Trieste main railroad. In 1877, the Split-Siverić and Šibenik-Perković railroads were completed. By World War I a railroad network was constructed in central Croatia and Slavonia which is still used - the direction of Podravina and Posavina with seven transversal branch lines. With this a railroad traffic system was established in Croatia except for Lika and Dalmatia. It was only after the construction of the Lika railroad line (1925) that Lika and Dalmatia gained traffic and business connections with other Croatian regions.

The first examples of local public electrification in

Croatian towns date from the nineties of the last century, some ten years after the first such events in the world. By that time electric power was used in industry for lighting of different workshops, in flour- and saw-mills, in railroad stations and harbors, or in private hotels, health resorts, theaters, and similar institutions and private properties. As public interest in electrification grew, which was among other things encouraged by demonstration of electric lighting in public, the same source of electricity began to be used for both industrial and private needs. Finally, it took only a few years for the first plants and organizations to be set up whose only line of business was the generation and sale of electricity: public electricity supply.

At first, public electrification included primarily the lighting of streets, squares, and quays. Towns which used gas for public lighting and in the households were lagging behind in the introduction of electricity. At that time, there were gasworks in Rijeka, Zagreb, Pula, Osijek, Rovinj, Poreč, Pazin, Koprivnica, Brod, Bjelovar,

Vinkovci, Split, and Crikvenica. Since the advantage of electricity was found in the comfort of using it, by an easy on/off switch, no impact on air quality in rooms, with time it fully took the place of gas and paraffin lighting.

At the beginning of electrification there were separate local supply systems - power plants with the local distribution network. Until World War I such systems were not interconnected. The examples of electrification with DC generators are more numerous although AC generators - single-phase, two-phase, and three-phase generators - were also used at the very beginning of the electrification process. Until 1900 the capacity of a power plants ranged from some ten to some hundred kW and kVA, respectively. They were mostly thermal power plants with steam piston engines,

and less with gas engines (gas from gas generators with incomplete combustion of solid fuel, mainly agricultural or industrial waste), or diesel engines. During that period only a few hydro power plants were constructed.

Public electrification of Croatian towns can be roughly divided into two periods: the period up to 1900, early and of a limited scope, and the period from 1900, during which it got a certain momentum, in particular after 1906, but unfortunately stopped by World War I. In the period until 1900, there was an equal number of local public electrification based on the combined use of power plants and those based exclusively on public power plants. Later on, this ratio constantly changed in favor of public power plants.

FIRST PROJECTS OF PUBLIC ELECTRIFICATION IN CROATIA

SLAVONIA AND BARANJA

The initial industrialization phase in Slavonia and Baranja relates primarily to wood and timber processing, and production of flour and food. It relied on engagement of local large estate owners and entrepreneurs and on Hungarian and Austrian, rather limited, capital. In 1893, SlavoniaUs agriculture used 284 locomobiles and two stationary steam engines totaling 1,500 HP; 77 locomobiles and 137 stationary steam engines of 7,300 HP were used in industry, mostly in the flour- and saw-mills.

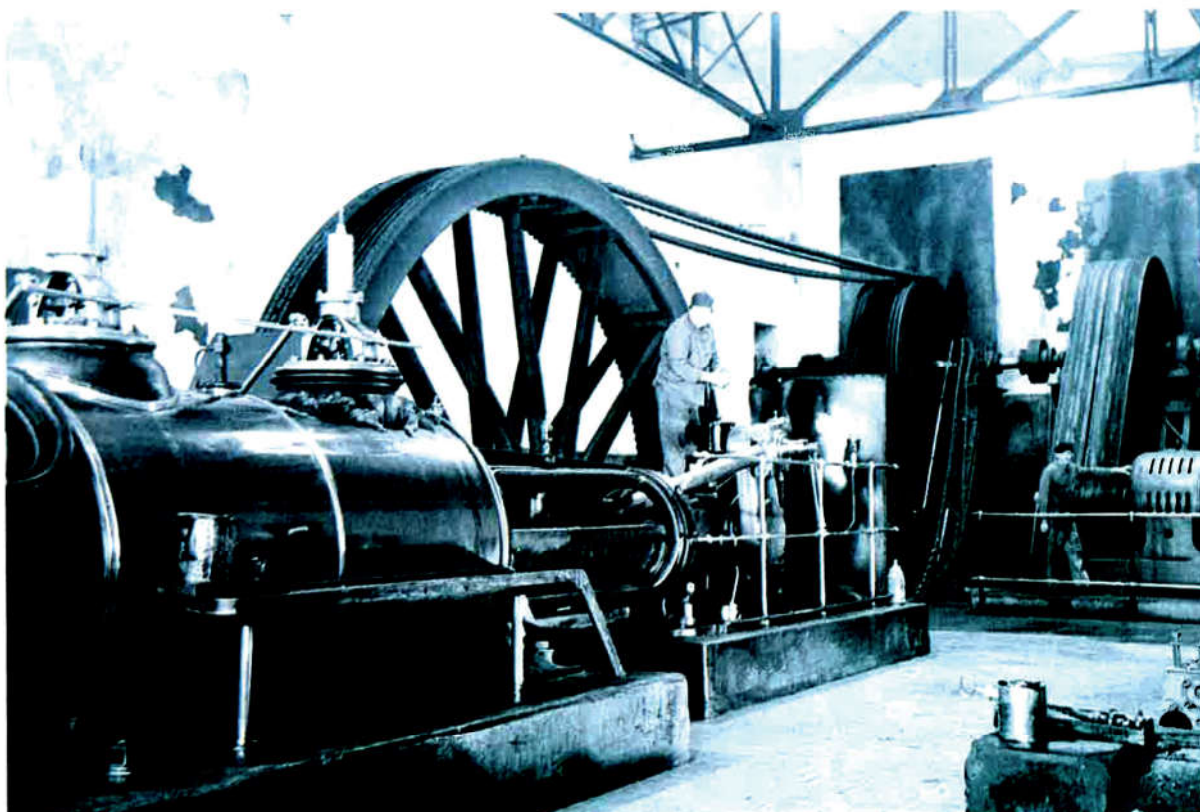
In 1880, the steam engines in the Županja Tannin and Barrel Factory were retrofitted with dynamo engines for the factory lighting, wherefrom the public lighting was implemented in 1883. In 1884, a generator for lighting in the saw-mill and the warehouse, and later on for the workers' settlements nearby, was added to the steam engine in the Belišće saw-mill in 1884. In Cereale,

a flour milling industry in Đakovo, a generator was in service from 1885. The first recorded use of electricity in the villages in Slavonia dates from 1890 in the flour-mill in Vrbanja near Županja. The Royal hotel in Osijek had its own electric power plant since 1904, and the Post Office Building since 1912.

From 1881 electricity was used for the service supply in the saw-mill in Đurđenovac. A 120 kW DC generator was driven by a steam engine. From this place started the first electrification phase of the town that year. A part of the workers' colony was electrified along with workers' settlements and the villas and apartments of the factory managers. Electricity was free of charge, it was used for lighting only, and was available from the evening till the morning. It is interesting to know that the generation of electricity in this factory circle has not been abandoned to this very date: by firing the steam gen-

erators the combustible wood and timber processing waste has been rationally utilized.

Electrification of Vukovar was founded under a contract signed between the municipality of Vukovar and Hungaria-Hanffabrik, the biggest shareholder in the Vukovar Hemp-Spinning Mill. According to the contract, the Hemp-Spinning Mill power plant had to supply electricity to the town by its three-phase, 400 kVA, 42Hz generator driven by a steam engine. Steam boilers were fired by waste produced in hemp processing. A high voltage 3 kV, 3.5 km long transmission line was built on steel lattice towers. In the town, a low voltage 110 V network connected to 3/0, 11 kV transformers, partly shared the towers with a high voltage transmission line. On December 19, 1909, the first light bulbs in the streets of Vukovar were turned on, and the next day in the first institutions and apartments.



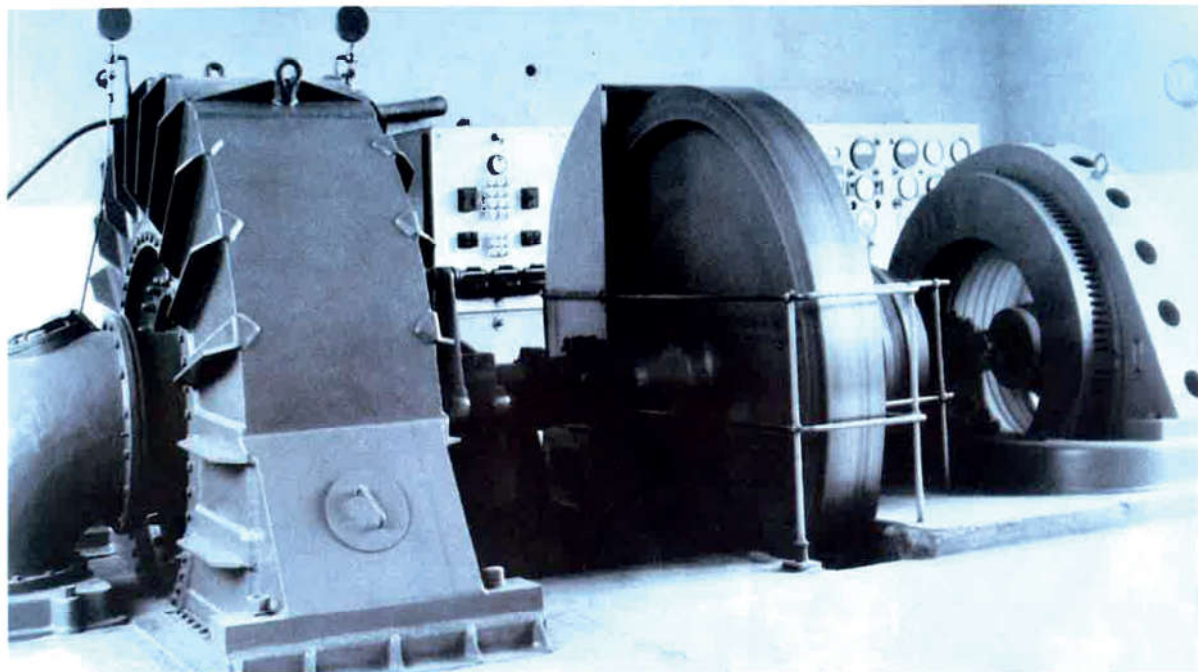
Δ Industrial DC power plant in Đurđenovac, machines of 1891

▽ The Našice power plant



△ Installing streetcar conductors in Osijek

▽ The Kuzmica hydro power plant, 1912



In Beli Manastir, electricity has been used since 1910; first in the Central Dairy and the lighting of homes of the Dairy white- and blue-collar workers, and the public institutions and households in the neighborhood. Therefrom electrification started slowly but systematically spreading around the town. The initial 65 kVA capacity of the AC generator in the Dairy was increased to 295 kVA in 1942. From 1912 in the Branjin Vrh Sugar Refinery, near Beli Manastir, an industrial power plant with a 250 kVA generator was in operation. The Sugar Refinery workers' colony was also supplied with electricity from the Dairy power plant during the sugar beet processing off-season. For this reason a 5.5 kV and 2.3 km power cable was laid between the Sugar Refinery and the Dairy. Such manner of supplying Beli Manastir with electricity, i.e. exclusively from the Refinery and the Dairy without regional connections, was applied up to 1954.

Našice had a power plant from 1910, with two locomobile engines and four DC generators each of 16 kW, 220V. An installed storage battery of 216 Ah was

charged over the night and supplied electricity to the network during the daytime when the demand insignificant. The distribution network had 90 public lighting fixtures. The Savings Bank of Našice, the owner of the power plant, signed a contract with the municipality under which it undertook to meet the completion date of the plant and to guarantee the quality and security of electricity supply. The power plant had to pay penalties to the municipality for voltage variations greater than 5% and if repeated during the month or lasting longer, the penalty was increased. The penalty was also paid if remedying a failure was not started within 30 minutes from the time of occurrence.

The bulbs in the public lighting were to be replaced if they burned out or their lighting efficiency reduced by 25%. The on/off switching time was determined by a yearly calendar.

After thirty years of dilemma between gas and electricity, the Požega Town Authorities invited tenders for construction of a hydro power plant on the river Orjava or a power plant fired by steam or other fuel,

and for construction of a network, public lighting, and the fixtures in the Town Hall and the Boys' School. The offer submitted by Peyer & Co. from Karlovac was accepted, and the Kuzmica HPP was constructed. It was put into service on October 6, 1912. The evening illumination made the skeptics see it was a steady, strong and nice lighting. The tariff rates and regulations were published, and a notice to the public that "touching the power plant lines is a danger to your life". At the end of the year, in addition to public offices, lighting was also installed in privately-owned companies. The power plant had a hydro-generating set with a 3-phase 295 kVA generator and a diesel generating set with a three-phase 155 kVA generator which provided the power supply when the water inflow was insufficient. A 6 kV transmission line to the town was 6.2 km long. The high voltage network in the town, about 2 km long, was a cable network. Six 6/0.19 kV substations were built, and the low voltage three-phase overhead network was 13 km long. Public lighting had 134 wall mounted lighting fixtures, 125 hanging lamps and 5 arc lamps.

CENTRAL CROATIA

Over the last decades of the past century, the concentration of trade capital for investment in industrial projects and transformation of middle-class traders into industrial entrepreneurs was most distinctive in northern and central Croatia. Zagreb was the leading area: in 1883, 6 out of 14 industrial companies in central Croatia, with more than 50 employees, were situated in Zagreb (e.g. Steam Flour-Mill, Tobacco Factory, and the Paper Mill with over than 700 employees). In other parts of central Croatia bigger plants were coalmines (Zagorje), food industry (Petrinja, Karlovac), textile industry (Duga Resa), tannery (Karlovac), chemical industry (Koprivnica), and saw-mills (Podravina).

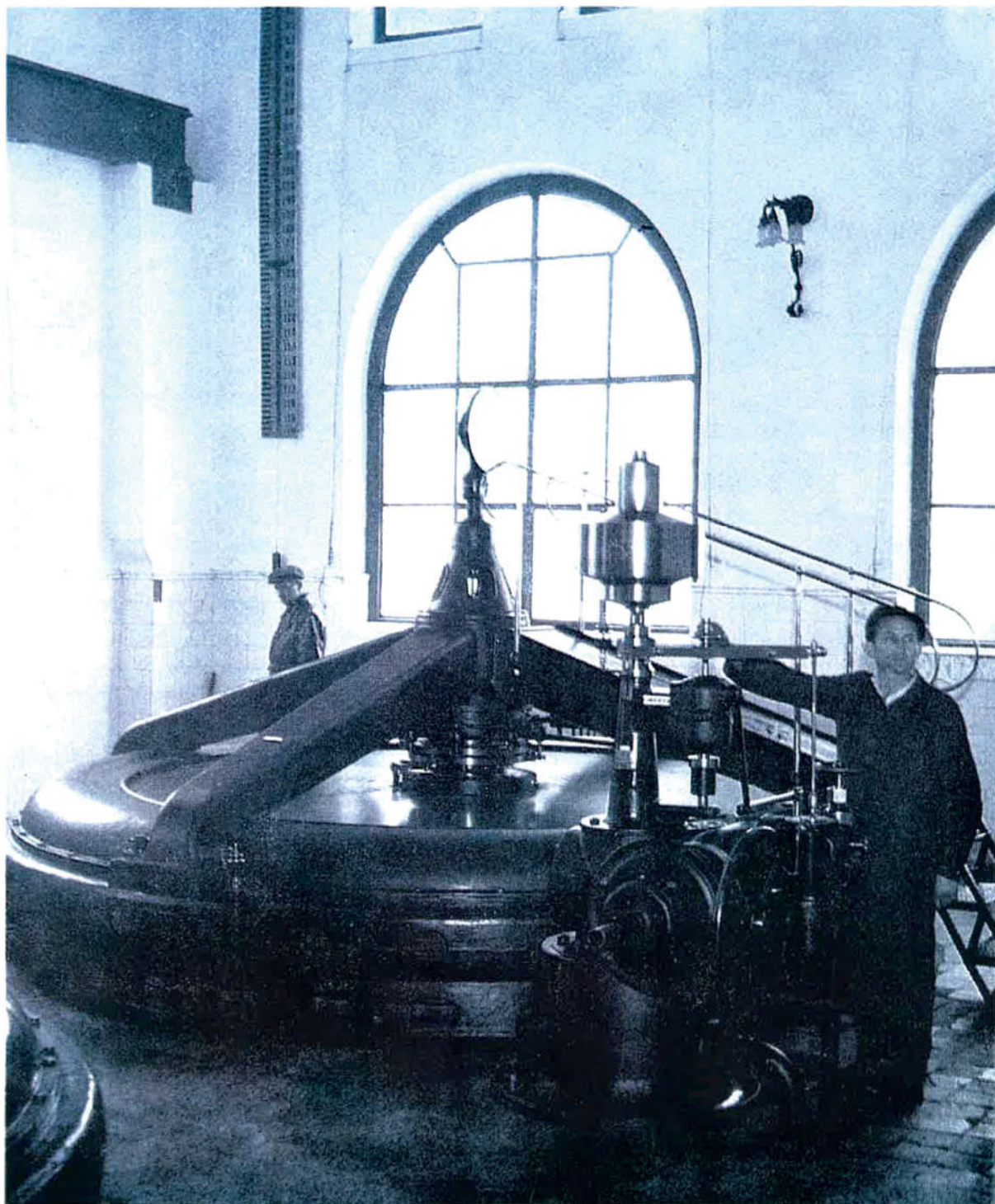
Decision-making on gas public lighting in Čakovec was stopped when an offer was received for construction of a new mill together with a power plant. The town accepted the offer, and provided a free of charge land

plot for the new mill. On October 1, 1893, the town was illuminated with 131 electric lamps and 105 houses with 1400 lighting fixtures. The power plant had a 2x175 V DC generator; the local network and the house fixtures were operating at 2x150 V. Ten years later, in 1903, the power plant capacity was increased and the local network expanded. The capacity was further increased in the 1920s. The combined use of the mill in the plant was stopped in 1932 when Čakovec was connected to the Fala HPP by a 35 kV transmission line.

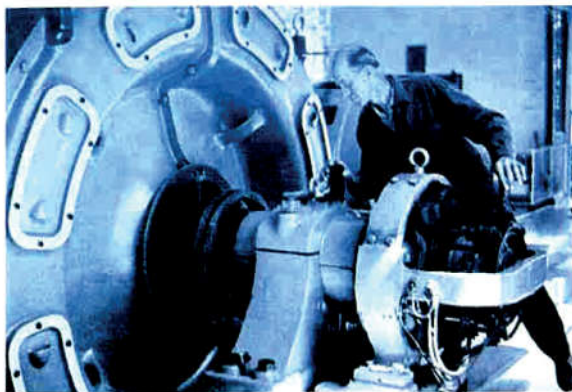
The Varaždin Industrial Cooperative was granted a 50 year concession by the town of Varaždin to electrify the streets, squares, and other public places. The lighting to be installed comprised 280 half-night and 100 whole-night lamps for which the Cooperative was to be yearly compensated by the town. The shares for the electric lighting were registered under the new name of the Cooperative - The First Croatian Joint-stock Company of Varaždin for Electric Lighting. Electric light was switched on for the first time on December 17, 1895. At the beginning, the power plant had three steam engines with AC generators each of 50 kVA, 42 Hz. Later on, it was refitted and expanded. In 1928, when Varaždin was connected to the Fala HPP by a 35 kV transmission line, the power plant became a stand-by plant.

Daruvar Brewery p.l.c. was given a 20 year concession by Daruvar to supply electricity to the town from upon constructing a power plant in the Brewery. At first, the power plant had a DC, 18 kW, 220 V generator started by a steam engine, and later on by a gas engine. In May 1907, the town was illuminated with light bulbs in 106 places and with arc lamps in 6 places. Also connected to the network were 36 households. On expiration of the concession, the municipality built its own power plant and put it into operation in 1928.

The Prague company F. Křižík was offered a 5 year lease provided that they design and construct a power plant in Sisak, and supply equipment. This power plant was put into operation in 1907. It had two steam generators with two steam engines and two 65 kW DC generators, and a storage battery serving as an electricity source when the engines were out of operation.



Δ Generator, Ozalj I hydro power plant



△ Power house, Zeleni Vir hydro power plant



△ A concrete pole carrying the 30 kV double-circuit line Zagreb - Karlovac



△ A 10 kV substation in Bjelovar

A low voltage network operated at the 2×110 V for lighting and at 220 V for engines.

City gasworks was built in Zagreb in 1863. Streetcars pulled by horses were used from 1892. This is a period when the Shooting Society Center began to install their first own power supply generating sets (1882), today's University Administration Building, for the needs of the Trade Exhibition (1891), theater in the Upper Town (about 1893), Steam Flour-Mill (1886), Parquetry Factory and Leather Factory. In 1892, on the invitation of the city mayor, Milan Amruš, Zagreb was visited by Nikola Tesla who suggested the city authorities should build its own power plant and an AC system. Hesitation about electrification was stopped by Amruš being re-elected the city mayor; he invited tenders for construction of the power plant in 1904. A dispute arose between Zagreb and Karlovac over the use of the river Kupa near Ozalj concerning construction of the hydro power plant. It was decided to build a thermal power plant in the area of the water pumping well, and to reconstruct the waterworks to use electricity, to off-load the gasworks from supplying gas for lighting and to replace the horse-pulled streetcars with electric ones. On November 5, 1907, the public lighting was switched on. The power plant had steam engines, three-phase 865 kVA, 5 kV, 50 Hz generators, and a 200 kW DC generator for supplying the electric streetcar utility. Seven and a half km of 5 kV cables were laid from the power plant to nine 5/0.5 kV substations including a single-phase 500 V network with about 20 km of cables. Some buildings were connected to the network by 500/2x55V transformers. In mid 1907, there were 247 house connections, and at the end of the year the first three electric motors were connected, except for water pumps. Already in 1910 the power plant was retrofitted with steam boilers and turbines, and a three-phase 1250 kVA generator, and later with an additional 200 kW DC generator. In 1914, the power plant was retrofitted and upgraded with a three-phase 3,000 kVA generator.

The Electric Power Plant of Zagreb (GEC) had a considerable influence on electrification in the territory of Croatia, both in terms of professional assistance in

construction of particular power supply systems in other towns and establishing local networks in the wider area of Zagreb, after World War I.

Building design for the Ozalj HPP, which provided lighting for the town of Karlovac, was developed by Valerijan Rieszner, a civil engineer from Karlovac, who designed a water dam on the river Kupa with a 9 m water head. The power plant was built by Peyer & Co. from Karlovac. During the initial construction phase, two hydro-generating sets with three-phase generators of 750 kVA, 5kV, 50 Hz were installed. Two 17 km, 20 kV long overhead lines were laid from the power plant to Karlovac and a 5 kV overhead line to Ozalj. A 20/5kV substation was built in Karlovac with two cables towards the town where 13 substations of 5/0.19kV were set up. The 5 kV network was 5.3 km long and the low voltage network 20 km. From this place on August 18, 1908 the town was provided with electric street lighting. Already in 1913, another hydro-generating set with a 750 kVA generator was retrofitted to the power plant. As natural oscillation of the river Kupa water level did not allow uniform power supply, in 1925 a diesel generating set with a 900 kVA generator and a synchronous capacitor of 400 kVAr was refitted.

As from 1908 the Ozalj HPP was the source for public electrification of Ozalj. It is really a nice example of a hydro power plant, which, built primarily to supply the town of Karlovac (on the power plant building there is still its old name: Karlovac) made it possible to electrify the small town, in the vicinity of which a rich water course enabled generation of large quantities of electricity.

With money from selling forests the administration of Petrinja started the construction of a town power plant. The power plant was put into service in 1911. It had three diesel engines with DC generators: two of 60 kW and one of 18 kW. A storage battery was installed to balance the power plant load. The cables, 2x110 V service voltage for lighting and 220 V for motors, were laid from the power plant to the overhead network poles. The Town Statute for Power Plant Management prescribed the rules for the power plant control and man-

agement, rules for installations and the relations with consumers. The tariff rates for total and motor consumption were also stipulated (the ratio was 2.4:1).

The Croatian Health Resort in Topusko pumped thermal water by means of two DC generators each of 30 kW, 230 V installed in the power house. Trial electric lighting was switched on in the Health Resort in May 1911. From this place the local electricity network, 2x110V, was implemented. The town got its first street lighting in January 1912.

In central Croatia there were a few more small towns, in addition to the already mentioned ones, which had street lighting before World War I: the data are rather scarce. Pakrac retained electricity for electrification from the Electric Power Plant of the Pakrac Market Place, put into service in 1906. The power plant had a 68 kW DC generator driven by a gas engine. From 1909, Novska had a power plant with a water turbine for driving a 10 kW DC generator. Križevci had a town electric power plant from 1912. It had three diesel generating sets and DC generators totaling 150 kW. The municipal electric power plant in Nova Gradiška, in operation from 1913, was equipped with two diesel generating sets, with DC generators totaling 130 kW. Ivanić grad had a public power plant, Hubený, from 1914. It was equipped with two diesel engines and DC generators totaling 27 kW. In 1894, a power plant was built in the Health Resort in Lipik with a wood-fired steam boiler, a steam engine, and a 16.5 kW DC generator providing the electricity for the street lighting and for some wealthy residents.

ISTRIA

At the end of the last century goods offered on the Istrian market were wine, olives, oil, fish, wood, salt, and other products of farm and livestock production, along with coal mining, quarrying, and tannery. The ship-building industry of Lošinj was declining due to new steel steamships taking the place of wooden ships and steamers with sails. The decision of Vienna to make



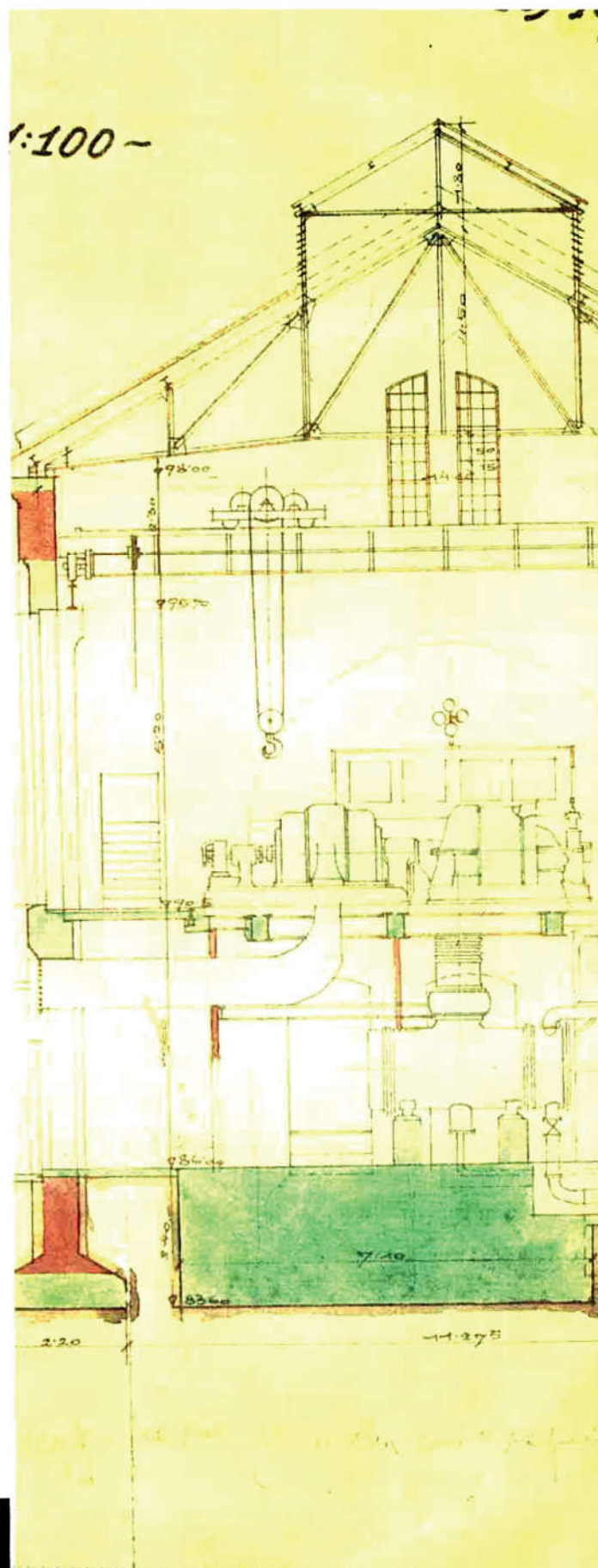
△ An early 5 kV substation in Zagreb

Pula the main war harbor of the Austro-Hungarian Monarchy resulted in a capital inflow into the region. In 1890, the Navy Depot, Theater, and the Miramar coffee-house started using electricity.

The isles of Brijuni, neglected and infected with malaria, started to develop when a steel industrialist from Vienna, Paul Kupelwieser, bought them from a Trieste merchant. Water for watering numerous plants and trees was pumped by a wind mill that also drove the crushers and cooling equipment. The roads, sport grounds, and bathing places were built, a post office with a telephone exchange was set up, and construction of big hotels started. All these works set Brijuni up as a fashionable jet-set European center. In 1898, a 25 HP steam locomobile with a 110 V DC generator was installed which supplied electricity to the islanders in addition to industrial facilities. In 1904 a power plant with a 50 HP diesel engine was built and subsequently retrofitted with two diesel engines with a final capacity of 300 HP.

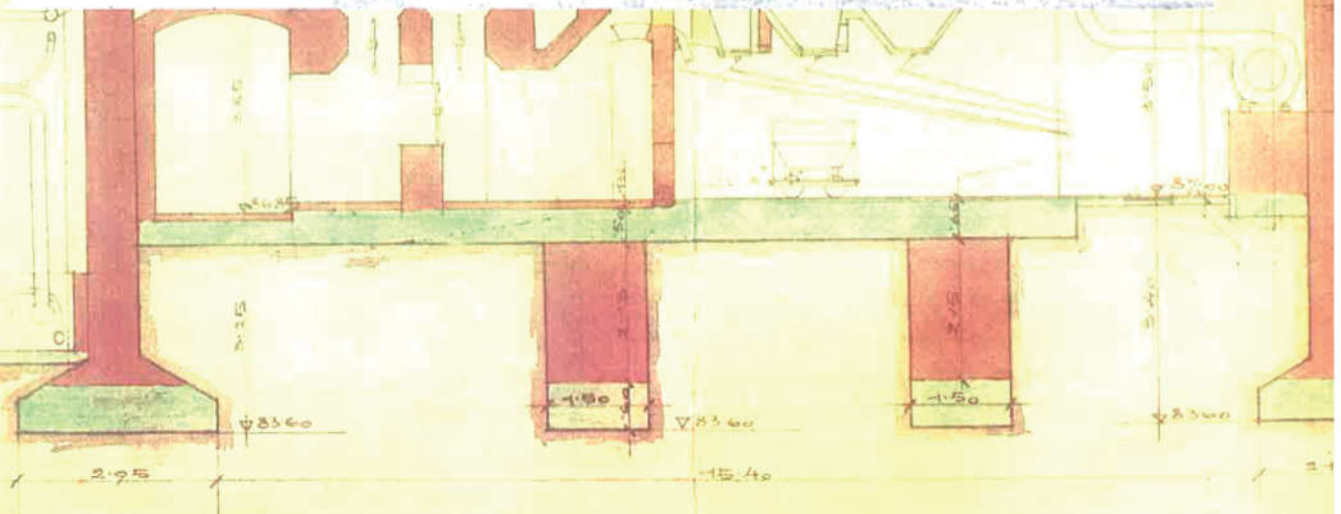
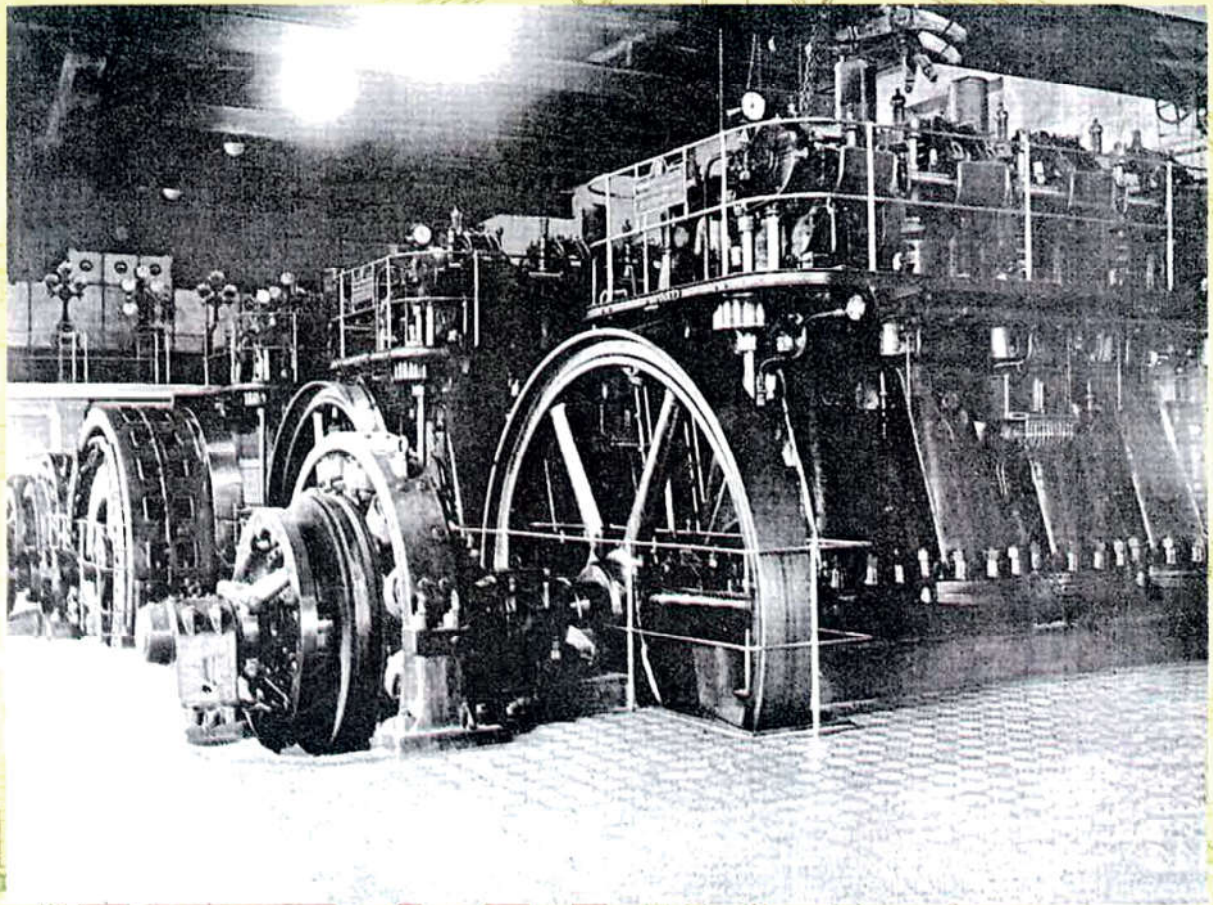
In Vodnjan, from 1883 Pietro Marchesi used two steam locomobiles with DC generators for the needs of his own industry and for workshop lighting. In 1889, he started distributing electricity for street lighting and public restaurants. The name of the company was Electrical Power Plant Marchesi & Company. The power plant generated and distributed electricity until 1928 when the company, still in the power distribution business, started supplying electricity from the Societa Elettrica Istriana from Pula.

Pula, with the city gasworks since 1871, laid the cornerstone for construction of a power plant in 1900 to provide electricity for the public distribution and for operation of electric streetcars. The electric streetcar started service on April 24, 1904 and the first consumers were connected to the network on April 26, 1904. The gas street lighting was maintained in the early period of electrification up to late 1906 when the first electric lamps with bulbs were installed at the Golden Gate. Three gas engines were installed in the power plant for



▷ The Pula diesel power plant design and interior, 1903

1875. 4-10. 1875



A. C. Sullivan

$$\begin{array}{r} 85.20 \\ 2.65 \\ \hline 87.85 \end{array}$$

starting 50 kW DC generators. In 1915 the first additional diesel engine with a 250 kW generator was installed. By 1921 altogether four diesel engines were installed. It is worth noting that the bulbs of the street lighting were connected in series. Such a system was used in Pula up to the end of World War II.

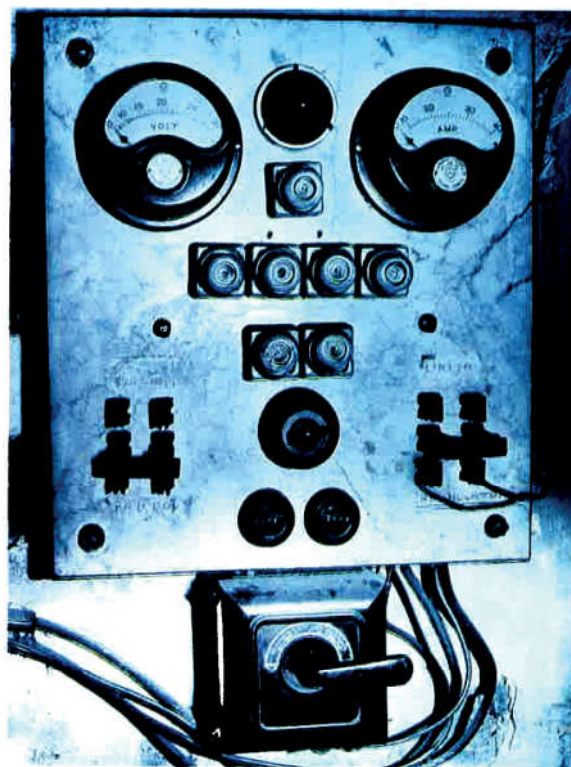
THE CROATIAN SEASIDE

During the Austro-Hungarian Monarchy Rijeka was a detached region under the direct Hungarian authority which had very strong aspirations for access to the Adriatic. In the eighties of the 19th century the Monarchy developed the oil refinery and rice-husking plant, in addition to an existing paper mill, tobacco factory, torpedo factory, tannery, and maritime industry as well as shipbuilding, gradually directing the latter to building steamers. In Gorski Kotar and Lika, within the then Croatia proper, the main economic activities were related to wood and timber processing. There was no public electrification by the time of World War I.

Rijeka has gasworks since 1852 - the first gasworks in Croatia. The gala opening of the theater in 1885 was made even more pompous with the luminosity of the electric lights. In 1890, the first electric power plant was built in Rijeka. It had a 22 kW DC generator for lighting the new railroad station and port facilities. The first proposals for construction of a public power plant for general needs of the city were made in 1886. Finally, in 1892 the power plant with steam engines and three single-phase generators of 120 kVA, 2 kV, 42 Hz was built. The new power plant replaced the first one and took over the lighting of the railroad station, port facilities and the silos. Soon afterwards apartments and offices along the wharf were electrified. There was a single-phase distribution by means of two 2 kV overhead lines with three 2/0, 1 kV substations. From this point energy was distributed to consumers. The power plant did not remain in service long because already in 1897 it was replaced by the Ponsal power plant with three steam engines totaling 400 HP. The fourth thermal power plant,

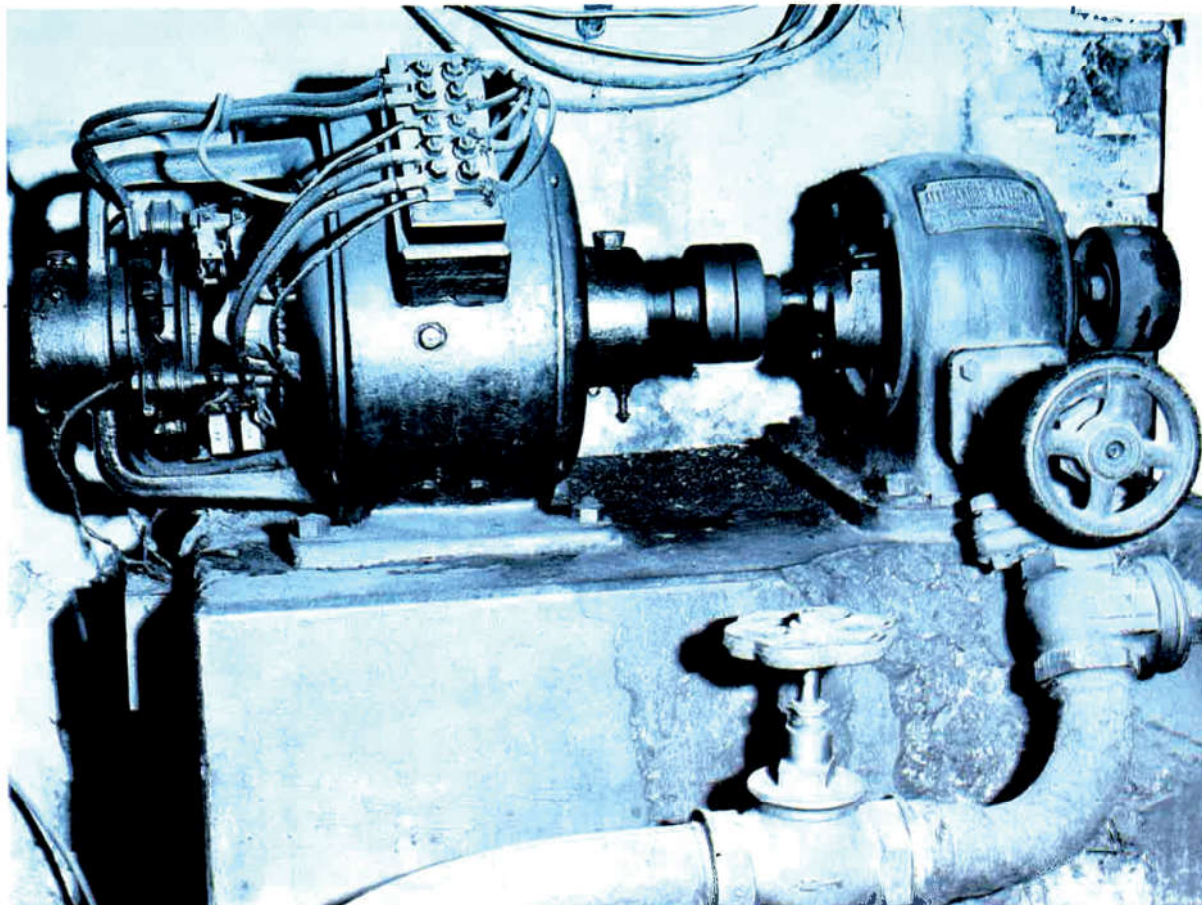
with two turbo-generator sets and three-phase generators of 1,500 kVA, 5 kV, 42 Hz, was built alongside the Zvir well on the river Rječina (1908). This was the first step of a conceptual design of a combined thermal and hydro power plant. The Rijeka thermal power plant replaced the Ponsal power plant which was closed. During the seven years before World War I electricity consumption increased seven times. In 1913 the third turbo-generator set of 1600 kVA was installed. On November 7, 1899 an electric streetcar line was put into service in Rijeka. It ran from Rječina to Torpedo and was 4.4 km long. As from 1904 the waste incineration plant was used for generation of electricity: steam was used to drive a steam engine with 3-phase 150 kVA generator which supplied electricity to one of the pump motors in the water pumping station.

The port in Sušak was connected to the 2 kV high voltage network of Rijeka via two substations which



△ Distribution board in the Rijeka Theater, 1885.

▽ DC power plant for the Rijeka Theater, 1885



supplied electricity to the harbor cranes on Delta and Brajda, 100 V for the lighting and 3x330 V for the motors.

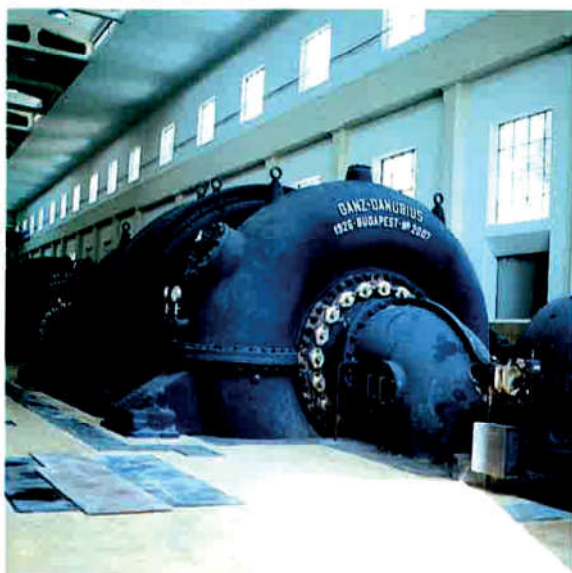
In Bakar, as part of upgrading the Malinice mill, a water turbine was installed to replace the wheels in the old mill, as well as a steam engine as a stand-by in case of water shortage. This hydro power plant was put into operation on June 16, 1894. It had a DC generator of 6.5 kW and 100 V. Public lighting in Bakar had 50 bulbs and private lighting 120 bulbs. Bakar raised the money for construction of the power plant by taking out a loan based on a 50 year mortgage on all its real estates and income.

Opatija and Volosko were electrified in 1896. A

concessionaire from Vienna built a coal-fired thermal power plant at Punta Colova. It had two steam engines and AC generators each of 125 kVA, 5 kV, 50 Hz. In 1897, Opatija got street lighting after a concession for the public lighting was granted. A 12 km long Matulji-Opatija-Lovran electric streetcar line was put into service in 1908. It is interesting that at the end of the thirties generators in Opatija were adjusted to 42 Hz frequency to allow the power plant in Opatija to operate in parallel with the one in Rijeka.

For a long time the only electrified town on the island of Rab was the town of Rab. Electrification started in 1902 and was completed in 1926. The power plant had a diesel generating set with a 27 kW and 2x230 V

▽ The Kraljevac hydro power plant



DC generator. In 1902, the power plant supplied 8,000 kWh of electric power, and 12,000 kWh in 1910.

Electrification on Lošinj started before World War I. The first lamps in Mali and Veli Lošinj were lighted in August 1910 when a power plant with two steam engines of 100 HP and 400 HP each, was put into operation. The engine was to supply power to the electric streetcar running from Mali Lošinj to Veli Lošinj, but, unfortunately, the construction of the streetcar line was stopped by World War I.

DALMATIA

At the end of the last century, crafts production in Dalmatia was transforming into industrial production, though the process was slower than in northern Croatia. Entrepreneurs were concentrated in Zadar, Split, and Dubrovnik. The agricultural and cattle-raising production, viticulture and olive-growing, fish processing were still prevailing, especially on the islands. These products, together with liqueurs, made the largest part of the market supply from Dalmatia. There were more maritime entrepreneurs and merchants than craftsmen.

At the turn of the century some large-scale investments took place in the regions of Split and Šibenik: construction of a cement-mill and carbide-cyanide factory, and a coal-mine.

Zadar started using electricity on the New Year's Eve 1894 when the first electric public lighting was switched on in Široka and other streets. On the Gospodarski Trg a big electric ball equivalent to 1000 candles was lighted. Four 25 kW DC generators in the Zadar's power plant were driven by steam engines. The electricity was distributed at 2x150 V. In 1902 a large steam engine was installed to drive a 160 kW DC generator, and another three diesel generator sets with DC generators were installed by World War I giving the power plant in Zadar the total installed capacity of 515 kW. The electrification was financed by the municipality through Aziende Municipalizzate di Zara, a company established for this purpose.

On August 28, 1895 Šibenik received electric power from the Krka hydro power plant, later called Jaruga and Jaruga I respectively. The power plant had a 2-phase generator of 320 kVA, 3kV, 42 Hz. A four-wire 3 kV transmission line (twice single-phase) was laid to the city. The electricity in the city was transformed to the 110 V by means of five transformers installed at the top of buildings and on poles. At the beginning, electricity was supplied to 216 public lighting places and to some private houses. The next year the theater was connected to the network. In the years to come the first industrial consumers were connected and subsequently households too. Soon afterwards a tariff rate system was developed. The entire project - establishment of our first integral electric power system - was implemented by Ante Šupuk & Son, a company from Šibenik.

At the end of the 18th century Dubrovnik introduced public lighting with paraffin lanterns. Already in 1821 there were 45 lanterns. Hotel Imperial had its own power plant by 1896, and the Marija Mill in Župa Dubrovačka introduced electrical operation in 1898 using the water of Zavrelje. In 1898, the municipal administration signed a contract with Gesellschaft für Elektrische Industrie, a company from Vienna, under

▽ Miljacka (Manojlovac) hydro power plant, constructed 1906

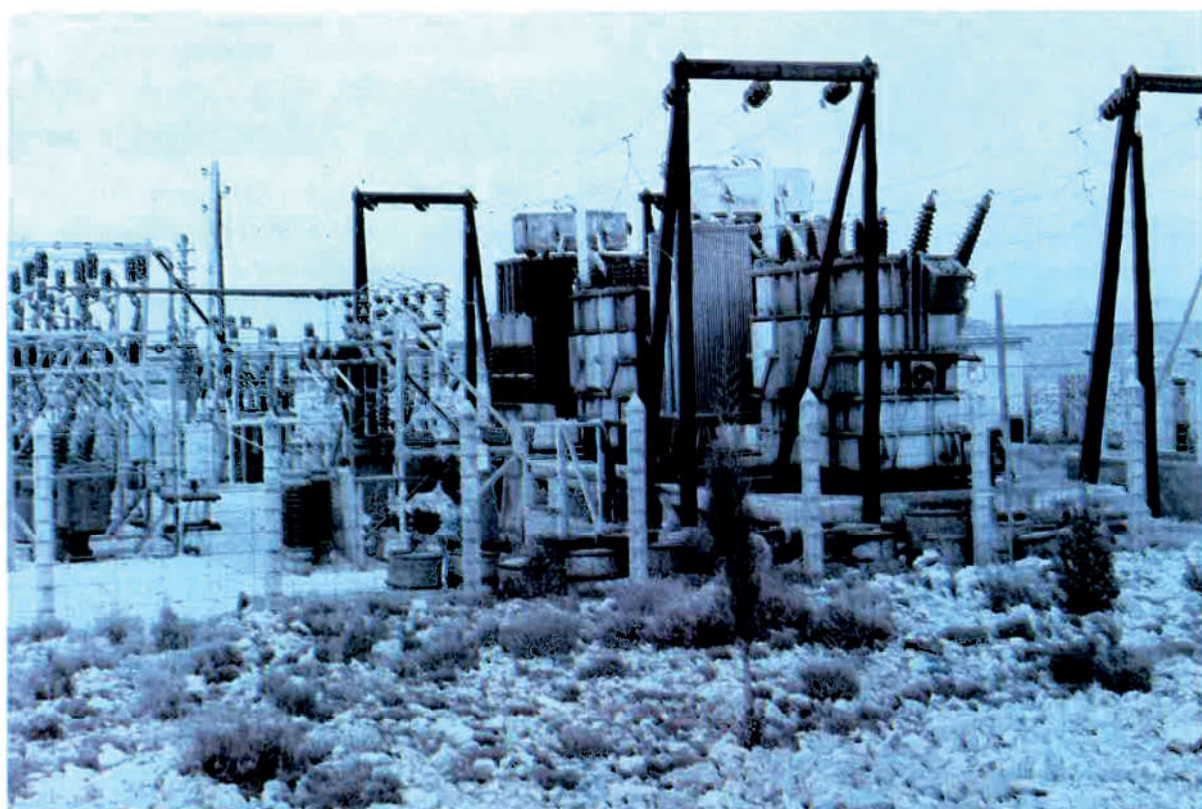


which they were granted a 45 year concession for public and private lighting, for any working use of electricity, and to supply power to the streetcar once the streetcar-line was established. The municipality undertook to install electric bulbs in all public lighting lanterns - 314 bulbs and 13 arc lamps. The electricity tariff rates for lighting and motor-operating purposes (2:1 ratio) were defined in advance. A building site for a power plant was chose, in Gruž on Batali. The electric light was switched on in Dubrovnik, Pile, on June 1, 1901. The power plant used steam engines of 150 HP and three-phase generators of 3 kV, 42 Hz. At first, it was used for night service only, but five years later when 24-hour operation was introduced electricity was distributed to other consumers too. In 1910, the Electric Railroad of Dubrovnik began to operate - a streetcar-line from Pile to Gruž.

According to unreliable data, in 1907 Benkovac

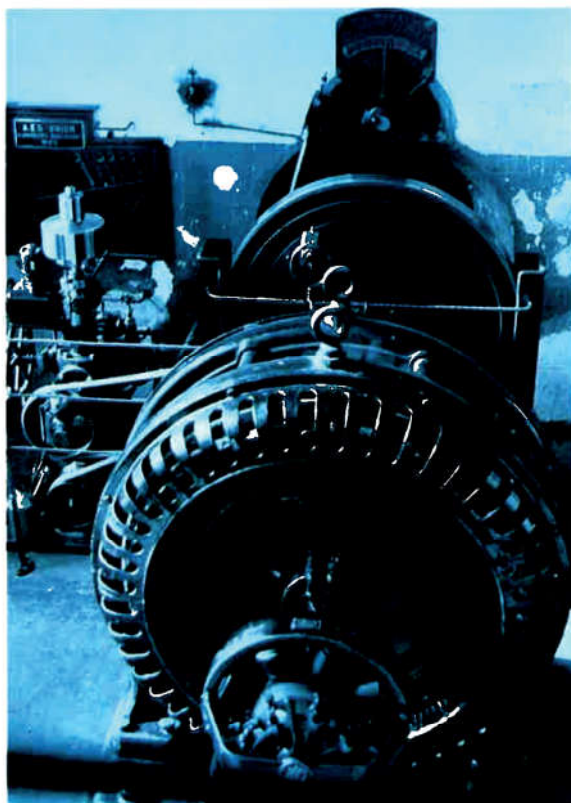
received public electrification from the Novaković mill with a water turbine as the prime mover.

In 1915 the municipality of Drniš was connected to a 15 kV transmission line from the hydro power plant of Roški Slap thus allowing public electrification of the town by its own 15/0.4 kV transformer of 50 kVA. This is the first example of using electricity in Dalmatia for public needs from a formerly constructed industrial hydro power plant.



Δ A 50/30 kV Lozovac substation

INDUSTRIAL POWER PLANTS AS SOURCES OF PUBLIC POWER SUPPLY



△ Roški Slap power plant, 1906

Some of the first hydro power plants in Dalmatia, big at that time, were originally intended for industrial use only. Only later, frequently much later, did their multi-purpose use start taking place and, eventually, they were included into the electric power system in order to balance their utilization with other power plants in the system and to participate in public electricity supply. These bigger hydro power plants were as follows:

- Jaruga II HPP, 2x2,625 kVA, in operation since 1904 to supply electricity to the calcium carbide factory in Crnica near Šibenik. As from 1914 it fully replaced the Jaruga I HPP (built in 1895). Since then it has been supplying electricity to the city of Šibenik;

- Miljacka (Manojlovac) HPP, 4x5,200 kVA, in operation since 1906 to supply electricity to ferro-alloys factory in Crnica near Šibenik.

- Roški Slap HPP, 2x500 kVA in operation since 1906 to supply electricity to the coal-mines in Siverić and Velušić. It has been supplying Drniš too, since 1915.

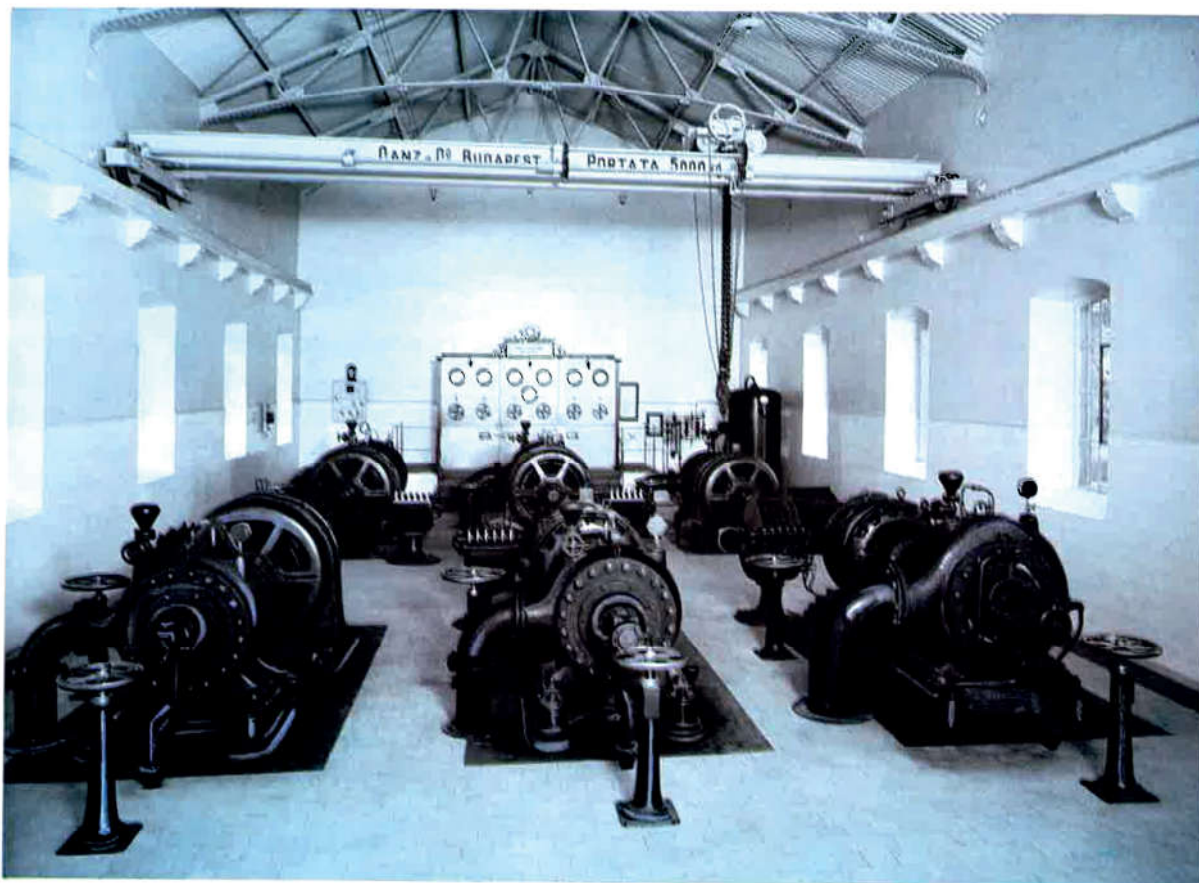
- Vriilo HPP (Majdan), 2x600 kVA, in operation since 1908 to supply electricity to the cement mill in Solin. From 1920 it was also used for public electrification of Split;

- Kraljevac HPP, 2x16,000 kVA in the first phase, in operation since 1912. It supplies power to the carbide and cyanide factory in Dugi Rat. Only in 1927 did it start supplying electricity to Split.

- Jaruga I HPP destiny is shocking (originally Krka HPP, 1895). It was shut down because its equipment and the connecting transmission line was dismantled by the Austro-Hungarian Monarchy in 1914 to use copper as a military and strategically important material.

The inclusion of the above power plants in the electric power system enabled them to be more economically utilized and their consumers to be provided with a more reliable and stable supply of electricity.

The circumstances in which industrial thermal power plants and hydro power plants built for the needs of industry operated were distinct; the former were located within the industrial circle, and as a rule operated in a combined cycle to provide necessary heat for that particular industry. Sometimes they used produc-



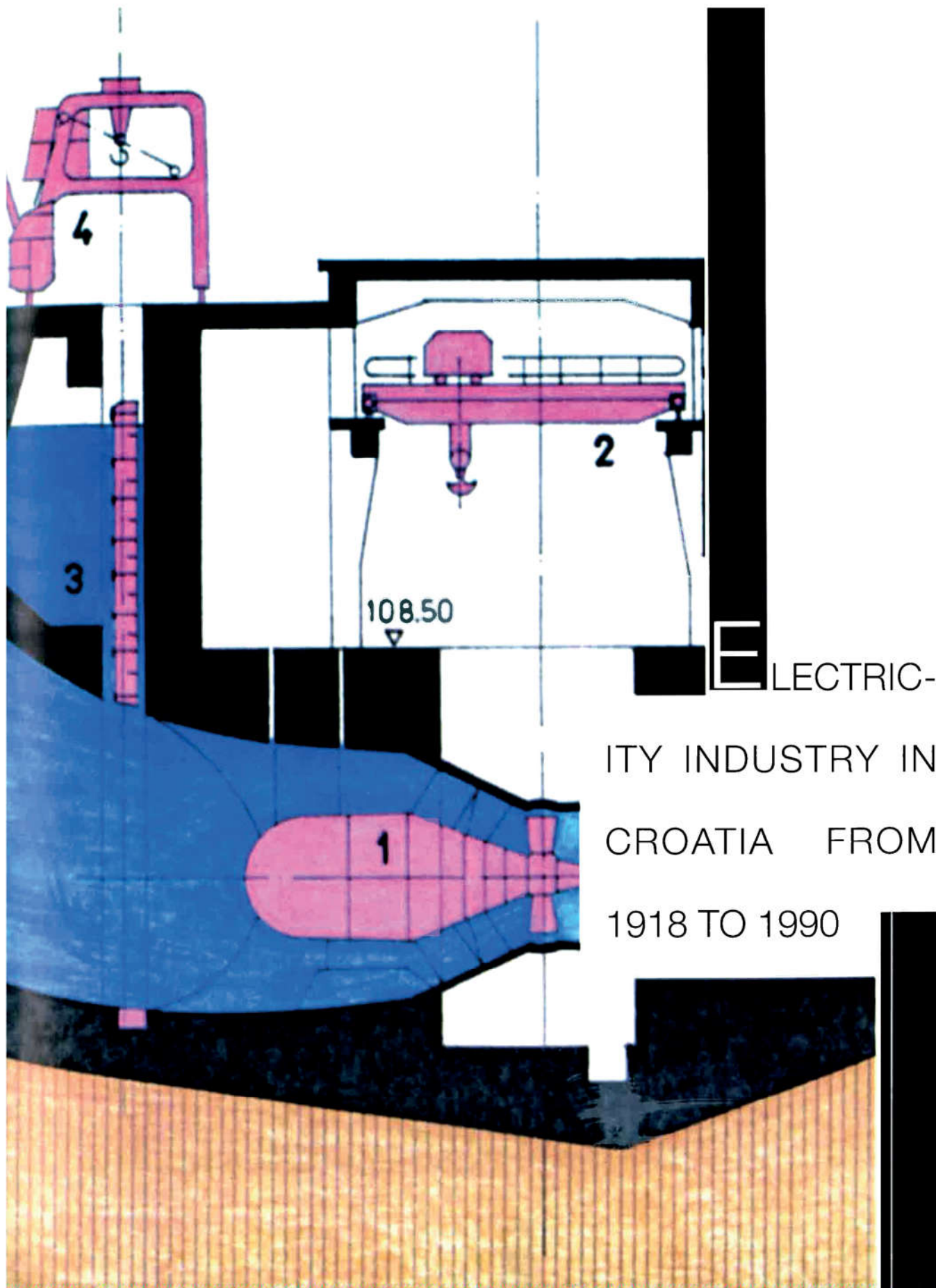
Δ Electric motor driven pumps, the Rijeka Water Supply System

▽ Electric streetcar in Pula, 1904



tion waste as fuel. Such power plants have never become public power plants.

When the electric power system was formed, they were included into it in order to ensure a more reliable supply and to make available their surplus electricity to the system. In the period until and after World War I, a strong relationship was established between such industry and towns, for continuous supply of electricity for public needs. The first such examples are Marchesi & Comp. in Vodnjan, hemp-spinning mill in Vukovar, Brewery in Daruvar, and the Central Dairy in Beli Manastir. ■



ELECTRIC-
ITY INDUSTRY IN
CROATIA FROM
1918 TO 1990



△ Construction of a hydro power plant

CONSTRUCTION OF INDIVIDUAL ELECTRIC POWER SYSTEMS

After World War I and the disintegration of the Austro-Hungarian Empire, the territory of present-day Republic of Croatia became a part of a new state - the Kingdom of Serbs, Croats and Slovenes, except for Istria, Rijeka and Zadar which were occupied by Italy. Due to its location on the outskirts of the former Empire, Croatia was economically underdeveloped which affected its electrification. Data on power plants and electrification from that period are scant, especially as regards capacity. It is estimated that the installed capacity of all power plants could have totaled a maximum of 65 MW in which hydro power plants in Dalmatia participated with 53 MW. Most of the plants, about 70%, were constructed solely for the needs of industry. Besides industrial consumers, 9% of the power plants provided power supply connection for industrial and private consumers. The remaining 21% met only public demand, so that they could be considered public electric power plants. These plants supplied electricity to a very limited area in which they were located.

In Dalmatia, which was at that time the richest part of Croatia in terms of electricity sources, public con-

▽ Laying of a 3 kV cable in Osijek, 1926



sumption was connected only to the Jaruga HPP which supplied electricity to the city of Šibenik. The fact that Split did not have electric lighting in 1918, illustrates how rare public electric power plants were at that time. By far the largest part of generated electricity in Dalmatia was for the electrochemical industry. Electric lighting was brought to the city of Dubrovnik in 1901, but the power plant was in such a bad condition after World War I that it was put out of operation for a short period of time in 1919. Only two power plants of a larger capacity existed in continental Croatia: a thermal power plant in Zagreb and the Ozalj hydro power plant which supplied electricity to the city of Karlovac. The number and types of power plants per region of Croatia are presented in Table 1.

Table 1: Number of Power Plants in Croatia per Prime Mover at the End of World War I

AREA	TOTAL	NO. PER PRIME MOVER		
		TPP	HPP	DPP
Zagreb	45	27	3	15
Rijeka	4	3	1	-
Osijek	18	13	2	3
Split	9	2	5	2
Croatia	76	45	11	20

TPP thermal power plant DPP diesel-driven power plant
HPP hydro power plant

Central Croatia was the region with the greatest number of thermal power plants. In Slavonia, the greatest number of generators were installed in the wood processing industry. Public electrification was poorly developed and the largest city in Slavonia, Osijek, was without electric lighting at that time. Generators with the capacity exceeding 1000 kVA existed only in seven power plants in Croatia (Table 2). Transmission lines were used solely for electricity transmission from the hydro power plant to consumers. The 50 kV Kraljevac HPP -

Dugi Rat line and the 30 kV Miljacka HPP - Carbide Factory Šibenik line had the highest transmission voltage. In central Croatia, the Ozalj HPP - Karlovac transmission line operated at the highest voltage level of 20 kV. Naturally, at that time an integrated electric power system did not exist.

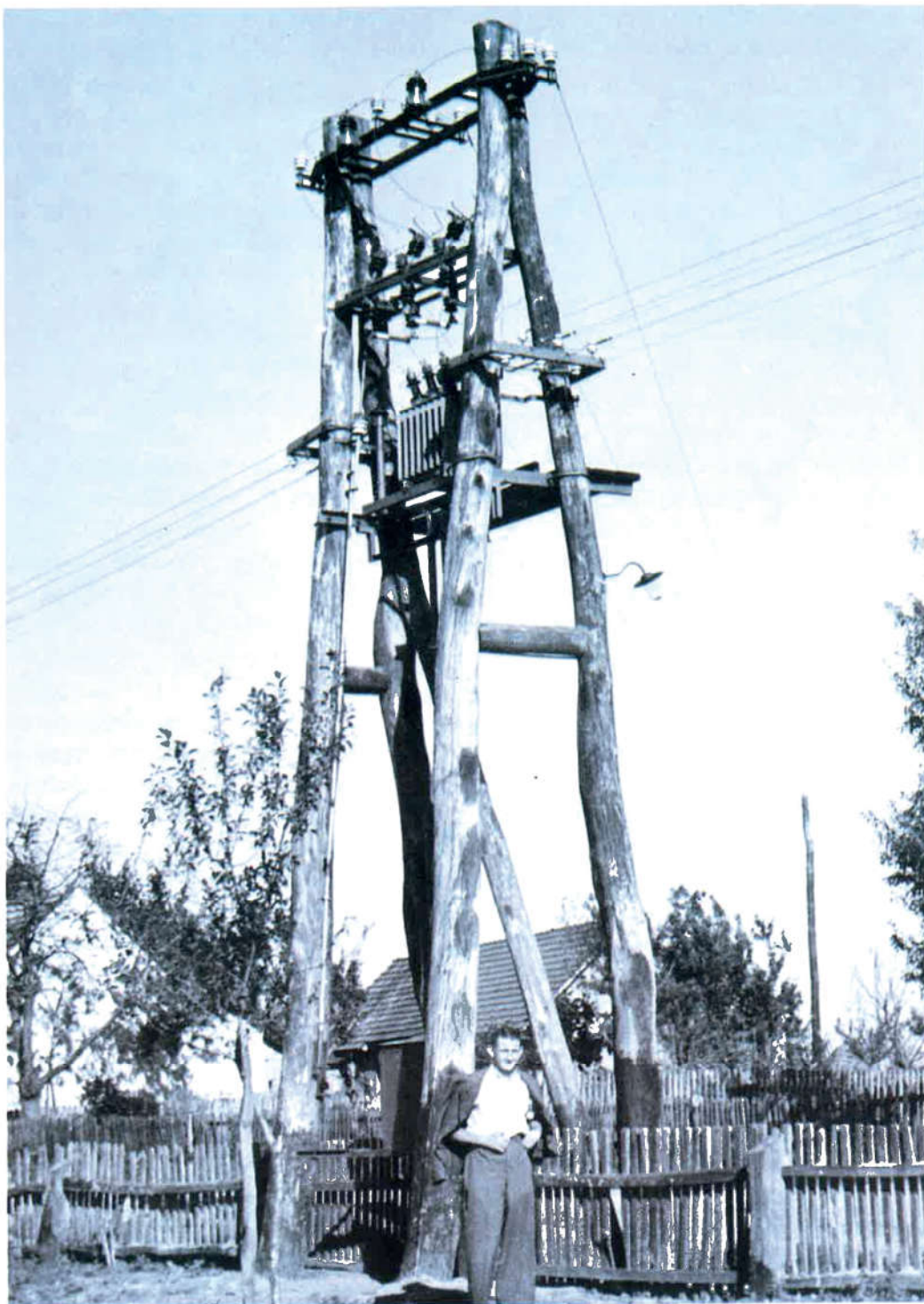
Table 2: Larger Power Plants in Croatia in 1918

PLANT NAME	TYPE	INSTALLED CAPACITY	
		PRIME MOVER HP	GENERATOR kVA
Kraljevac	Ind.HPP	36,000	32,000
Miljacka	Ind.HPP	24,000	20,800
Jaruga	Comb.HPP	7,000	5,250
Zagreb GEC	Pub.TPP	6,400	5,980
Karlovac-Ozalj	Pub.HPP	2,700	2,250
Majdan-Split	Ind.HPP	1,765	1,310
Roški slap	Ind.HPP	1,320	1,000

Ind. - Industrial power plants Comb. - Combined power plants Pub. - Public power plants

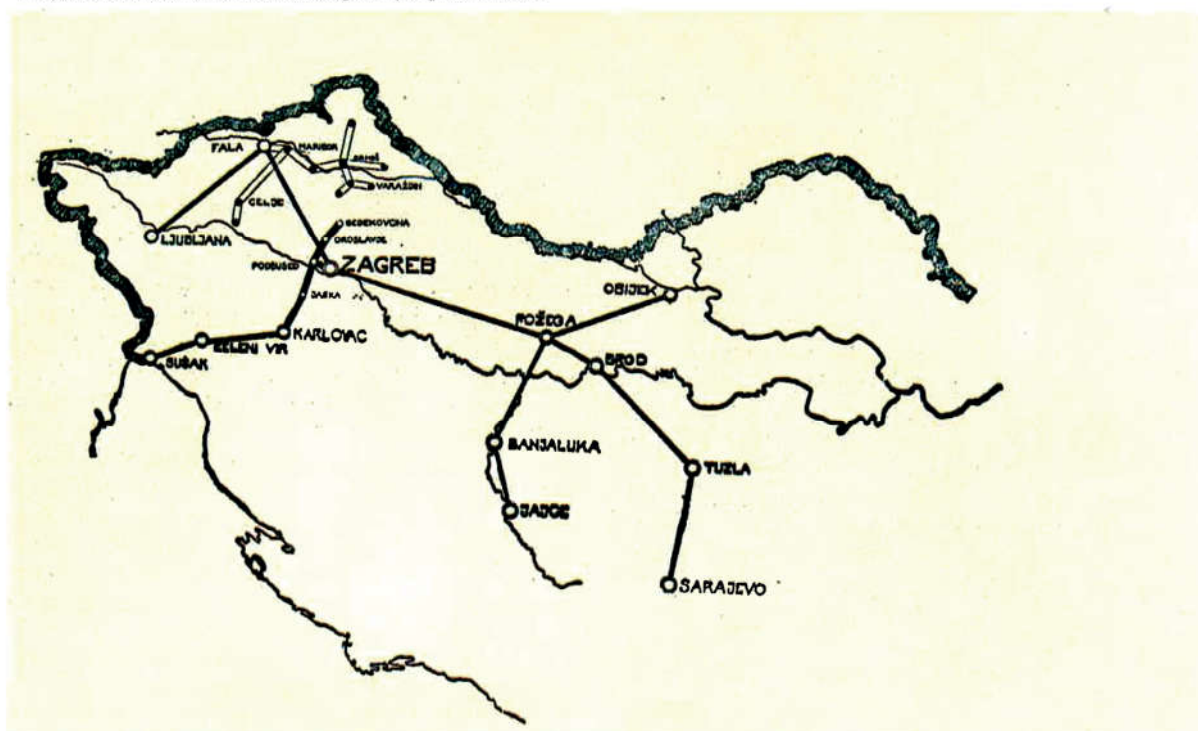
The regions which came under Italian rule - Istria, Rijeka and Zadar, were also poorly electrified. Besides the larger cities, Pula and Rijeka, only a few smaller settlements had electricity supply. The installed capacity of public diesel power plant's generators in Pula was 640 kW, and the installed capacity of Rijeka's coal-fired thermal power plant was 4,600 kVA. In Zadar, a diesel power plant of 300 kW was in operation. The above regions developed separately from the rest of Croatia until the end of World War II.

After World War I, a market boom occurred which influenced the construction of power plants. The new state encompassed the territory of several former states, with seven judicial regions, neither of which had legislation regarding electrification and its advancement. In the early twenties, the Draft of the Electrification Act was prepared in the Kingdom of Serbs, Croats and Slovenes, according to which the activities connected



Δ A 10/0.4 kV pole-mounted substation from the period of extensive electrification of Slavonia

Layout of the electrification network designed by engineer Visković



with electrification were to be administered exclusively by the state. The Association of Yugoslav Engineers and Architects disapproved of such a solution and proposed franchises with the possibility of foreign capital engagement, i.e. a competition of economic forces. All the attempts to make any progress in this regard failed to be realized, and the Act was never passed. Electricity industry was not instituted as a branch of economy and was excluded from state responsibility. The problem of electrification was regulated only in one article of the Company Law dating from 1931. Despite unsettled legislation and absence of any support from the state, the use of electricity spread. It would have been logical that, due to abundant hydro power sources, widespread electrification should have begun in Dalmatia. Unfortunately, this was not the case. Besides Šibenik, which was supplied with electricity in 1895 from the Jaruga HPP built on the river Krka, hydro power plants brought electricity to Drniš in 1915 and Omiš in 1924. The larg-

est city in Dalmatia, Split, which was supplied with electricity from the Majdan HPP, was connected to the largest hydro power plant of that time - the Kraljevac HPP - as late as 1927.

In northern Croatia, the cores of electrification expansion were created in 1908 around the Ozalj HPP near Karlovac and in 1922 in Gorski Kotar by the commissioning of the Zeleni Vir HPP. The greatest possibilities for electrification existed around Zagreb, where the largest thermal power plant in Croatia was constructed in 1907. The then ruling tendencies as regards electrification could be well illustrated by one article which was published in a daily paper and written by the manager of the Zagreb electric power plant, engineer Visković, concerning the electrification of the western part of the country. This was an attempt to spur a wide range electrification in north-western Croatia. The author spoke in favor of a modern concept, proposing the construction of an electric power system which would connect larger

power plants and consumption centers of that time by way of high voltage lines. He gave a hint that a number of settlements were in the habit of constructing their own power plants without actual benefit and contemplation and at higher costs, although a cheaper solution would be to establish a connection with some neighboring power plant. Such power plants used to meet only local needs, without a wider prospect or the possibility of connecting neighboring rural areas.

In the period of prosperity, i.e. till the beginning of the thirties, a number of new electric power plants were built but, as stated above, without a uniform plan. At that time, no statistical record was kept which would have shown the status of electrification. The first attempt to do that was made in 1925, when the Club of Mechanical and Electrical Engineers, Zagreb, issued an inventory of electric power plants in the Kingdom. In 1931, the company Siemens issued its private inventory of public power plants. The most significant and comprehensive publication is the statistics of Yugoslav power plants dating from 1933, and issued by the Association of Electrical Power Plants of Savska Banovina, which recorded all power plants exceeding 15 kW. This publication provides interesting and useful data on the status of electrification in Croatia in the early thirties. Table 3 has been drafted in accordance with those statistics and presents data on the number, capacity and type of power plants in four Croatian regions.

Table 3 Number and Capacity of Power Plants in Croatia in the Early Thirties

AREA	Total No./kW	HPP No./kW	TPP No./kW	DPP No./kW	GPP No./kW
Zagreb	113 / 37,588	7 / 2,836	68 / 30,261	26 / 3,892	12 / 599
Rijeka	19 / 2,355	2 / 1,210	3 / 335	12 / 670	2 / 140
Osijek	40 / 9,123	4 / 287	25 / 7,357	8 / 1,317	3 / 162
Split	24 / 94,162	5 / 86,400	2 / 4,200	16 / 3,522	1 / 40
Croatia	196/143,228	18/90,733	98/ 42,153	62/ 9,401	18/ 941

Dalmatia had the largest capacities in hydro power plants, and the industrially most developed central Croatia in thermal power plants. Hydro power plants accounted for 63%, thermal power plants for 29% and diesel motor driven power plants and gas motor driven power plants only for 8% of the total installed capacity in Croatia. The situation in continental Croatia was completely different: thermal power plants accounted for 77% of total installed capacity, diesel power plants and gas power plants 14% and hydro power plants only for 9%. As for the purpose of power plants, there were 58% of industrial plants which met only proper needs, and 7% of combined power plants which met not only proper demand but supplied public consumption as well. The 35% of public power plants supplied electricity only to mass consumption. By 1931, direct current was almost entirely pushed out of use. Nevertheless, 39% of power plants still operated using a direct current system, their total capacity accounting for only 4% of the total installed capacity in Croatian power plants. Their average output was only 73 kW.

According to post-war estimates total electricity generation on the territory of present-day Republic of Croatia, excluding Istria and Rijeka, could have amounted to 300 GWh. Although the setting up of an energy system was still a long time off, its outlines could be seen. The construction of high voltage networks started close to the mentioned electrification centers. Since 1922, the 5 kV network had started to develop in Gorski Kotar. In Dalmatia, after 1927 when Split was connected to the Kraljevac HPP, wider surroundings of Split were also connected. The Kaštela Riviera was connected to Trogir via a 10 kV line. In 1928, Varaždin was connected to the Fala HPP in Slovenia via a 35 kV line and Čakovec in 1932. The 10 kV lines enabled electrification of several other settlements, but a widespread rural electrification was not carried out.

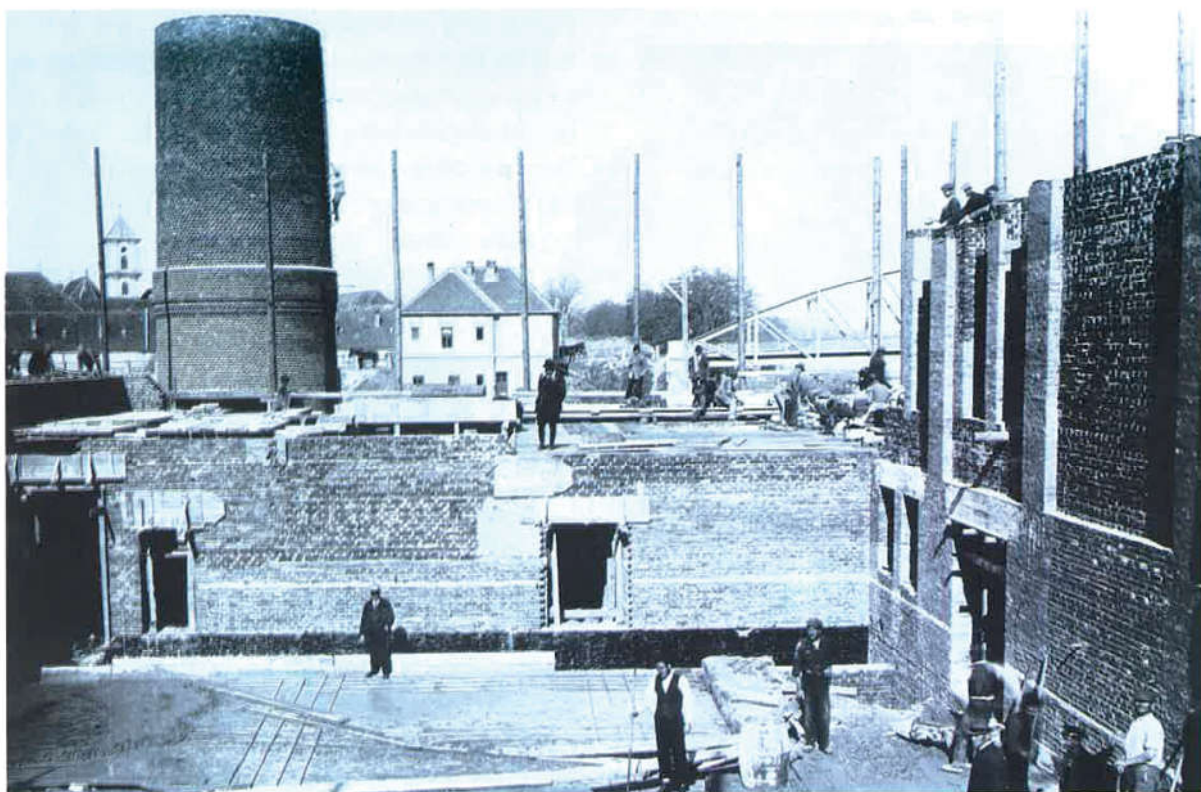
An important step in the electrification of north-western Croatia was taken in 1930, when Zagreb and Karlovac were connected by a 30 kV line. The first modest electric power system in Croatia was established. The Zagreb power plant (18,750 kW), the Ozalj HPP

(2,690 kW) and diesel generating set in Karlovac (720 kW) were connected in parallel. When the water level of the river Kupa was low, the thermal power plant in Zagreb supplied energy to Karlovac, and during favorable water level the energy would flow, mainly during night, towards Zagreb. The efficiency of the power plants' operation and reliability of supply were considerably increased. In addition to the above advantages, this link was the basis of further development of high voltage network and expansion of electrification to surrounding areas. Two 30/10 kV substations were constructed on the line route during line construction, one in Kerestinec and the other in Cvetković near Jastrebarsko. These were the first supply points for the electrification of wider surroundings of Zagreb. The area supplied by the Zagreb electric power plant extended beyond city limits. Samobor and Jastrebarsko were connected by 10 kV lines to these supply points. Thus, the external network of Zagreb started to evolve. The Zagreb City Power Plant (CPP) became the agent of electrification for this part of Croatia. In 1929, a separate company was founded - Allied Electrical Power Plants (AEPP) - for the purpose of electricity purchase and sales and the maintenance of the Zagreb - Karlovac transmission network. The development of high voltage network started in the region of Karlovac. In 1931, Metlika (Slovenia) was connected via a 20 kV line with the Ozalj hydro power plant. The factory in Duga Resa was connected by the line of the same voltage level with the Ilovac substation near Karlovac.

In the observed period up to the beginning of the thirties, the completion of the second phase in the construction of the Kraljevac HPP in Dalmatia represents an important event. Two hydro generating sets were installed with a generator of 26,000 kVA output. However, this great increase in output had no impact on wider public electrification. A significant step in the electrification of Slavonia was made by the construction of a thermal power plant in Osijek. In 1926, when the plant was put into operation, it had the installed capacity of 2,200 kVA but did not extend its area of supply outside city limits until 1938.

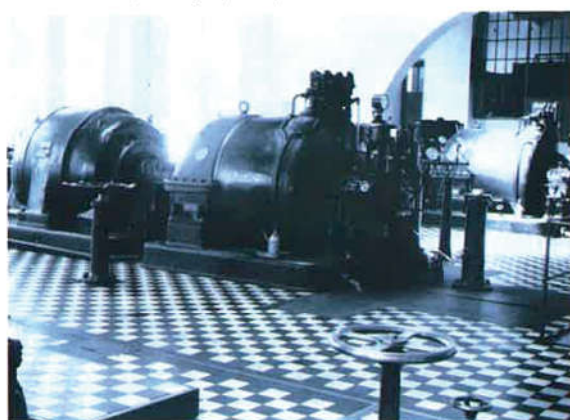
The Great Depression affected our country in the early thirties, and the development of electrification was slowed down. Still, despite difficulties, the enthusiasm for further development was not affected. In 1930, the Association of Electrical Power Plants of Savska Banovina was established, with the aim to affiliate electric power plants, promote electric power management and spread technical and economic interests of its members. In 1934, this Association organized the First Congress of Electrical Engineering in Zagreb with a specialized exhibition under the Zagreb Autumn Gathering (today's Zagreb International Fair). The aim of the Congress was to enable the attending representatives of electric power plants from the entire state to pinpoint the best and the fastest method of implementing planned electrification of the country, taking into account prevailing economic, financial and political conditions. Numerous interesting facts illustrating the electric power engineering of that time were heard. A significant indicator of industrialization and electrification of a certain country is the average annual electricity generation per capita. In 1931, it amounted to only 56 kWh country-wide, and as regards Zagreb - industrially and culturally one of the most advanced cities, 128 kWh. In the period from 1918 to 1931, installed capacity of power plants increased three times, but extensive electrification progressed very slowly. On the Congress, as well as on similar gatherings before and after the Congress, the abiding topic was the improvement of electricity industry which took a step back at the beginning of the thirties: some areas saw a drop in electricity generation of up to 20%.

In addition to difficulties caused by the Great Depression, the state tried to increase its budget in 1932 by prescribing an excise tax on electricity of 70 para per kWh, considering it a luxurious good. On average, this represented 10 to 20% of electricity price for households and up to 50% and more for engines and larger consumers. The municipalities did not lag behind as regards various additional taxes on electricity. Furthermore, significant state fees were set for meter calibration and difficulties arose in the procurement of electric



Δ Izgradnja strojarnice Munjare Osijek

Power house, the Osijek power plant



Construction of the Kraljevac hydro power plant

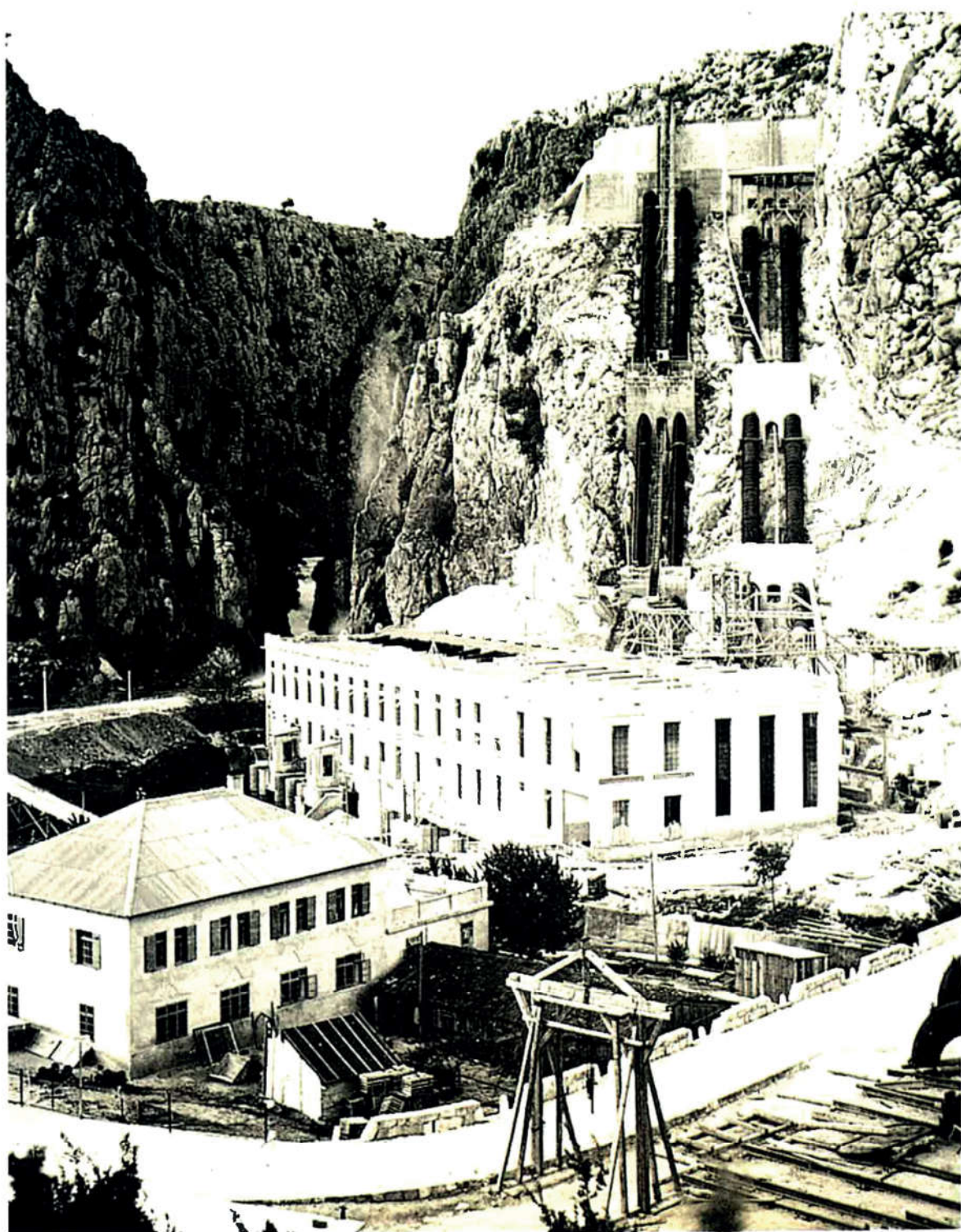


material from abroad due to the repeal of tariff benefits. Especially high excise taxes were imposed on bulbs. The excise tax made the introduction of a modern tariff system difficult, although it would have stimulated the consumers. Due to excise tax, the industry started to use mechanical force instead of electrical one since it was not subject to the excise tax. A great obstacle to intensive electrification was the lack of capital in the country: if it existed, the financiers reluctantly invested in the electricity industry. Due to underdeveloped industry and a small consumption area, electricity consumption was low which offered little prospects for profitable business operation for invested capital. Electrification of rural areas seemed especially unfavorable, so that its profitability and usefulness was a topic of dis-

cussion until the breakout of the war. Experts thought that the electrification of railways could create a basis for extensive electrification of the country. But, it had not yet started during the existence of the Kingdom. The state did not provide support. On the contrary, in 1934 the situation was made more difficult by introducing a new charge on newly-erected buildings in the electricity industry. The owners of electric power plants, on the other hand, tried to increase profitability by increasing consumption. Annual operation of the Zagreb thermal power plant at that time was only 2,500 operating hours; while the state average for public power plants was 1,270 operating hours. In 1935, average consumption of a two-room apartment in Zagreb was 5 kWh per month, which asked for a more stimulating tariff system. Nothing was done as regards legislation in the field of electricity industry, except that the Building Department regulated by law the issue of approvals and land expropriation for the construction of electric power lines in 1937.

Despite these difficulties and obstacles, extensive electrification experienced a slow development in Croatia, especially as of the mid 1930s. The external network of Zagreb spread at a slow pace. Up to the year 1935, the settlements at the bottom of Medvednica Mountain were electrified as well as its summit Sljeme. The supply area spread out to the east of Zagreb in 1934, by the construction of the 30 kV line up to Božjakovina, where a 30/10 kV substation was built. The 30 kV transmission line was extended in 1938 from Božjakovina to Križevci. Bjelovar, which was without electric lighting at that time, was electrified by way of a 10 kV line from Križevci.

There were no significant developments in the field of electrification in other regions of Croatia. It should be mentioned that the Osijek power plant started extensive electrification of Baranja in 1938 by means of a 15 kV line and connected several larger industrial organizations outside narrow city limits via a high voltage line. As the need for electricity increased, it was ascertained that progress could not be realized without sufficient quantities of electricity available to every citizen at a fa-



avorable price. However, all endeavors connected with planned electrification on a general basis remained unsuccessful, although some regional developments took place.

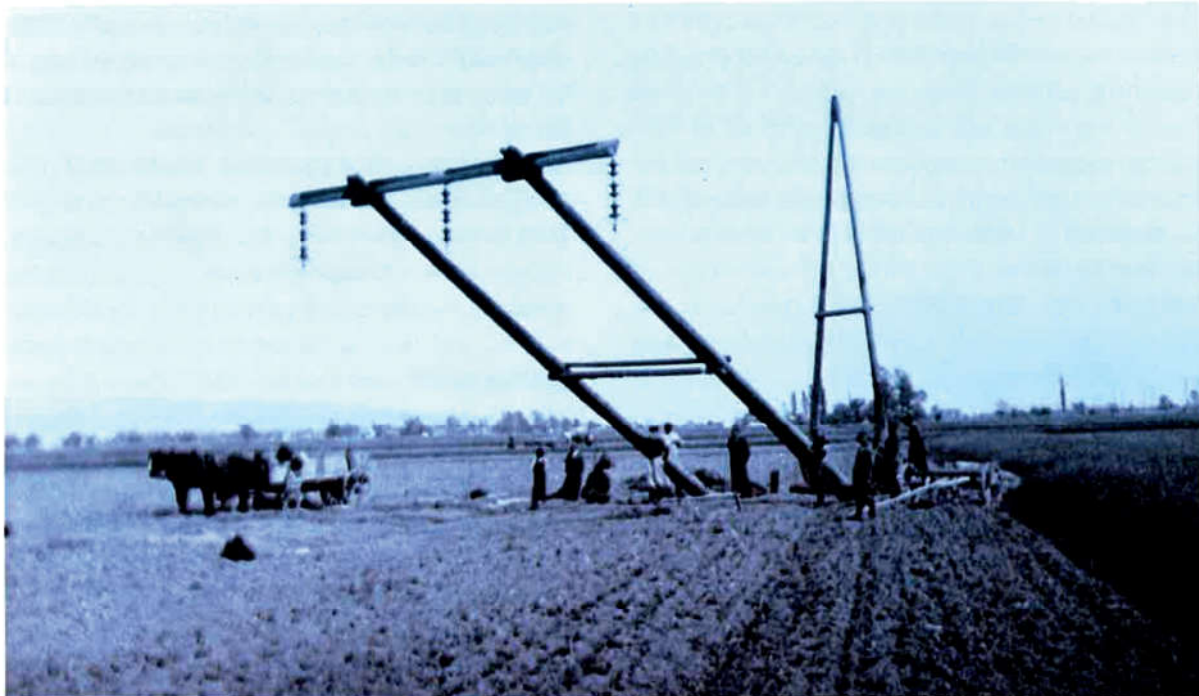
In 1937, the Electric Company of Banovina (ECB) was established in Zagreb and electrification was given a greater spur. At the beginning, the company operated on the territory of Savska Banovina, and extended its operation to the entire territory of Croatia by the establishment of Banovina Croatia. The intention of Banovina Croatia was to render public electricity supply and, with this aim, to take upon itself electricity generation, transmission and distribution on its territory and to entrust the electrification to someone who could assess individual factors decisive for planned electric power economy in the best possible way. At that time, there was nobody who would or could implement planned large-scale electrification. Individual problems related to electric power economy were resolved partially, for more or less limited area which gravitated towards the existing city- or municipal power plant. The establishment of ECB, with the task to implement planned electrification of the whole of Croatia, represented the origin of the electricity industry as an integral organization which could fully effectuate its role only by acting on the entire territory of Croatia.

Although Istria and Rijeka were not at that time a part of Croatia, something about the electrification of this region ruled by Italy should be said. In the early period after World War I, the electrification of Istria was based on small local power plants and there were no significant changes with relation to the pre-war period. Expansive electrification started in 1924, when a 50 kV double system line was constructed, connecting the 132/50 kV Opicina substation near Trieste with Pula. Two 50/10 kV substations were built on the line route, in Karojiba and San Vincent. This line, which was connected to Italian electric power system by 42 Hz, was the keystone of Istrian electrification. It fed the 10 kV distribution network rendering extensive electrification. The west littoral part of Istria was electrified by means of a 27 kV one-system line from Opicina, with transfor-

mation to 10 kV. The Raša coal basin was connected to one branch of the 50 kV line from San Vincent. During the war, when the 132/50 kV substation in Matulji near Rijeka was constructed, Istrian high voltage network got a new supply point. The construction of the 50 kV Matulji - Labin line closed the Istrian 50 kV ring. The Rijeka supply network was then connected to the substation Matulji via the 50 kV line, which since 1931 has been supplying electricity to the entire Kvarner Riviera, and occasionally Sušak.

As of 1938, when the first field works organized by the Electric Company of Banovina started, and especially since 1939 when Banovina Croatia was established, ECB initiated electrification works in the entire Banovina taking electrification into its own hands. Electrification in Croatia from 1938 to 1945 is tied to the activities of ECB and NEC (National Electric Company, as it was called in the Independent State of Croatia - ISC). The main task of the Electric Company of Banovina was to electrify the country by constructing electric power sources on the one hand, and to create consumption regions by electrifying rural municipalities on the other. From the very beginning, ECB devoted itself to the resolution of actual problems of electrification, so that there was no time to contemplate general issues or to develop a general plan of electrification. The most important true problem was electricity supply to Zagreb. The possibility of utilizing the Lika and the Gacka water potential was considered. Soon, it was concluded that there was neither money nor time for the realization of such a project. A more simple and easier solution was accepted, i.e. the utilization of the Ličanka and the Lokvarka waterflows in the Vinodol hydro power plant. Project engineering works started immediately. The general plan was completed in mid 1939. At the same time, the main part of the electromechanical equipment was ordered from Switzerland: four 18,000 HP Pelton turbines; two 32.5 MVA generators; two 35 MVA transformers and a penstock. At the end of 1940, on-site works began, but were stopped in mid 1943 due to the war. Simultaneously with the construction of the Vinodol HPP, preparatory works and tracing of the 110 kV trans-

▽ Construction of the 110 kV Zagreb - Brestanica transmission line, 1943



mission line began. The line was to connect the hydro power plant with a distribution and transformer substation located in Sv. Klara near Zagreb. The route was 150 km long, and two systems of conductors were to transmit 60,000 kVA at power factor 0,8. It was anticipated that, besides Zagreb and its wider surroundings, the surroundings of Vrbovsko and Karlovac would be supplied from two substations constructed on the line route. Regretfully, the works were stopped in the spring of 1941; only 5 km of the line was fully constructed. When it became obvious that there was no realistic possibility of completing the Vinodol HPP, two more attempts were made to construct a larger power source. Three 15 MVA generating sets with 60 t/h boilers were ordered from Germany for the thermal power plant located on lignite deposits in Oriovac near Nova Gradiška, as well as the pertaining switchyard with transformers. It soon became obvious that the delivery would not be realized. Following the cancellation of the Oriovac TPP project, the idea of the construction of a thermal power

plant on the site of the Zagorje coal mines near Konjščina was started again in 1943. The equipment purchased and paid for the Vinodol HPP was traded for equipment to be installed in that thermal power plant. The investigation of terrain around the village Turnišće began, but the exact site was not determined until the end of the war. Although nothing was done on the site, the equipment which was paid for and ready for installation proved to be precious in the post-war construction.

During World War II, electric power supply conditions were especially unfavorable in Zagreb due to the difficulties in fuel supply. Since in Brestanica, Slovenia, a thermal power plant with one 15 MVA generating set was commissioned in 1942, NEC concluded a contract with this power plant for energy supply to Zagreb. A 110 kV line on wooden poles was constructed in the length of 40 km. In the fall of 1943, the voltage level of this line was changed to 30 kV. This line represented a great aid to Zagreb and met about 40 % of Zagreb an-

nual electricity demand in 1944.

ECB or NEC accomplished much more in the field of extensive electrification than in the field of providing new energy sources. Since, due to the lack of time and start of the war, it was unable to construct its own sources of electricity, it connected its electrified regions to existing power plants. Križ was the first settlement to be electrified in 1939, and became an electrification center of Moslavina. The entire high voltage network of Moslavina was connected to the substation of the Zagreb City Power Plant (CPP) in Božjakovina by way of a 30 kV (at the beginning 10 kV) line. The line terminal was in the 10/6 kV Križ substation, and it was stretched later up to Novska which was connected in 1943. A very diversified 6 kV network was connected

to this line, and by the end of war about 90 settlements with 70 substations were connected to this basic transmission line. To the west of Zagreb, a high voltage 10 kV network connected to CPP was extended up to Savski Marof.

Gradually, electrification works started in other parts of Croatia. On-site works on the electrification of Međimurje started in 1939, but were stopped due to the war and Hungarian occupation. Hrvatsko Zagorje, Oroslavlje and Donja Stubica were first to be electrified in 1940, and were connected to the Oroslavlje textile factory's power plant. In 1941, NEC extended the existing 35 kV line network of the Fala HPP company, and purchased its plants all over the territory of ISC. The 30(35) kV section of the Lepoglava - Oroslavlje line was constructed, as well as the Varaždin - Novi Marof line and the Mirkovec - Bedekovčina branch line. The last two lines were temporarily loaded with 6 kV. The mentioned 30 (35) kV lines with pertaining substations should have served as centers for the connection of 6 kV distribution lines. By the end of the war, about 40 settlements and 20 industrial plants, mainly coal mines, were connected in Hrvatsko Zagorje. ECB expanded the high voltage network near Karlovac and connected it to the Karlovac electric power plant. Near Krašić, 7 settlements and a mill were electrified, as well as 17 settlements near Duga Resa.

The activities of ECB in Gorski Kotar started in 1939, when it took up the local network in Fužine fed by electricity from a saw mill. Further expansion of the electric power network and increased load mainly due to the Vinodol HPP construction site, resulted in the connection of the entire area to its own electric power sources. In 1940, the construction of high voltage and local network started in Hrvatsko Primorje, in the wider area of Crikvenica and Novi Vinodolski. Due to the war, all on-site activities were stopped in 1943. By that time, a total number of 23 settlements were entirely electrified, via 16 substations and 5 substations for the Vinodol HPP construction site. To provide supply to the Gorski Kotar - Hrvatsko Primorje network, ECB constructed power units in Drvenik (145 HP) and Fužine (400 HP)

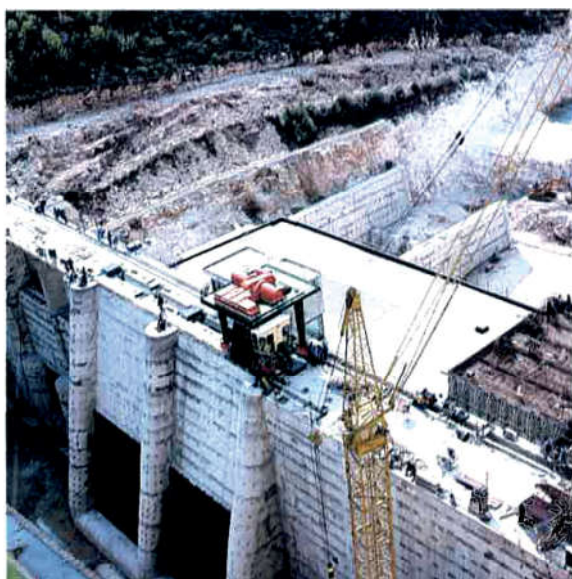


△ War damage to the Osijek power plant, 1944

and connected the Crikvenica power unit (236 HP), which it had purchased. In 1942, NEC purchased all units of the Zeleni Vir power plant (1,185 HP) and connected them to the Primorje network via the 5/6 kV substation constructed in Kupjak in 1944.

To the west of Osijek, NEC constructed its own 6 kV network, which was fed from the Osijek power plant. The settlement Čepin was connected, as well as three private substations. In Donji Miholjac, ECB started electrification works in 1940, but the municipality took it upon itself in 1944.

In the mid 1940's, the Technical Directorate was founded in Split. It had the task to execute planned electrification of central Dalmatia and its islands. On-site works on the construction of the 15 kV line on the island Brač and a local network on the island Vis started at that time. NEC planned to construct the 15 kV network on the island Brač, which should have been connected to the electric power plant of the ferrous metal factory in Dugi Rat by means of a submarine cable, thus being fed from the Kraljevac HPP. By the beginning of 1942, only 12 km of the line were constructed, since the works were stopped due to the war. NEC tried to urge public electrification in Dalmatia, since it stagnated between the two wars: small power plants were constructed exclusively for local needs. A similar situation was present in other parts of Croatia. During World War II, due to the damaged transmission lines and plants, the Kraljevac HPP and the Miljacka (Manojlovac) HPP were out of operation. The integration of the most abundant Dalmatian hydro power plants into a common electric power system was accomplished after the war. In 1945, Electric Company of Croatia (ECC) was founded with the aim to carry out planned electrifica-



△ Construction of the Bale hydro power plant

FOUNDATIONS OF THE PRESENT ELECTRIC POWER SYSTEM

tion, and it took possession of all electric power plants within the borders of the then Socialist Republic of Croatia.

When considering the development of electricity industry in Croatia after World War II, two facts should be taken into account. First of all, this development took place under a socialist political system. Secondly, Croatian electricity industry operated within Yugoslav electricity industry of that time, with more or less freedom as regards development, depending on a particular period of time.

THE PERIOD FROM 1945 TO 1965

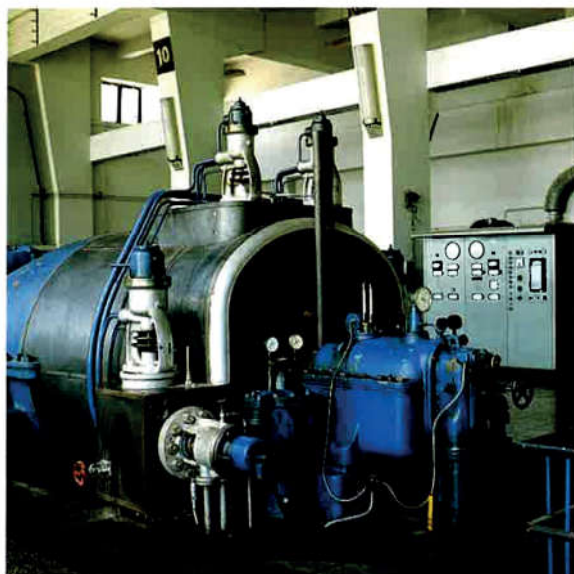
After the war, Croatia did not have an integrated electric power system, but isolated small thermal power and hydro power sources for local consumption. Only on the territory of Dalmatia, Zagreb and Rijeka, the ori-



▷ A 30 (35)/10 kV substation

gins of electric power system could be perceived. Total installed capacity of power plants was 178 MW and annual consumption in 1945 was 224 GWh. Since numerous generating sets were damaged or destroyed in the war, only with their restoration the consumption in 1948 reached the pre-war level of 543 GWh. After the war, only 13% of settlements and about 26 % of house-

▽ Power house, the Jertovec thermal power plant



holds were electrified. This was a period of centralist planning system and general investment funds which, despite the Workers Self-Management Act passed in 1950, lasted until 1965. The general climate, which influenced electricity industry of that period, can be most appropriately depicted by the slogan "Electrification plus industrialization equals socialism". Streets and squares were flooded by similar slogans. Unfortunately, the wishes and sincere efforts made by experts regarding more efficient electrification were slowed down by continuous reorganizations, changes in economic conditions and indistinct governmental decisions on Federal and republican levels. If we want to emphasize basic factors in the development of Croatian electricity industry in the observed period, it might be done as follows: electricity industry and its main business partners - Energy Institute, Dalekovod, Elektroprojekt, Končar and some others, attained a high professional level and were able to deal with very complex tasks of electric power system planning, construction, operation and maintenance; decisions essential for the existence of electricity industry were made outside the electricity industry; managers in the electricity industry were more governmental representatives than businessmen; unresolved

economic standing of the electricity industry and constant changes meant the loss of energy, time and money. Two facts played a positive role in the development of electrification, which was despite everything an explosive one. Degree-granting educational institutions and secondary schools created very good experts of all profiles required for the successful operation of an electricity industry and the working conditions in the electricity industry were relatively stimulating, so that there were no personnel related problems.

Besides the expansion of a distribution network in the post-war period, up to the year 1950, a significant event was the commissioning of the 110/30 kV Sv. Klara substation and the Sv. Klara - Brestanica TPP transmission line. The first production-transmission and distribution companies were founded at that time. In 1950, the installed capacity of power plants was in the order of 188 MW, and consumption reached 666 GWh. 21% of settlements and 32% of households were electrified.

In the period between 1950 and 1955, the explosive growth in consumption started resulting partly from an unprofitable electricity price. Energy demand asked for new energy sources. The idea to catch the mountain creeks of Dinaric karst in the region of water impermeable Paleolithic sediments of Lokvari and Fužine into a storage basin was conceived even before World War I. In 1939, the Electric Company of Banovina reached the decision and elaborated the project on the use of water potential of the Ličanka and the Lokvarka. The Vinodol HPP with an output of 76 MW was constructed as late as 1952. The Ozalj II HPP with the output of 2.2 MW was commissioned in the same year, on the left bank of the old dam of the Ozalj HPP on the river Kupa. The first connection with the electric power system of Bosnia & Herzegovina was realized by the construction of the Kraljevac - Mostar transmission line. An especially significant event of that period was the creation of the first electric power system which included Slovenia and western Croatia. This was realized by the construction of the 110 kV Sežana - Matulji - Vinodol - Rakitje - Nedeljanec - Maribor transmission line. The first experi-



△ Cooling towers, the Jertovec thermal power plant



Δ The Zagreb West combined heat and power plant

ences in the operation and management of electric power system were gathered and the significance of a dispatch service grew. Since the electricity industry could not keep pace with the consumption growth, the first reductions in electricity supply were introduced and reached 3.2% of total consumption in 1953.

The idea to construct a thermal power plant on the location of Zagorje coal mines was conceived in 1943 and realized in 1954: the first kWh came from the Jertovec TPP of 39.8 MW output which was at that time our largest and most advanced thermal power plant. At the end of this period consumption reached 1,076 GWh and installed capacity of power plants 327 MW. There were 36% of electrified settlements and 46% of households. In the period up to the year 1958, consumption annual growth rate was 9.6%.

Household consumption experienced an especially rapid pace of growth, and reached annual growth rate exceeding 31%. Such a growth of consumption, with appropriate development of distribution networks, was enabled by self-organization of villages and settlements which established electrification councils taking care of project engineering, construction and financing of rural networks, with expert support provided by distribution companies. Regretfully, the first networks were built for very low loads, from 50 to 150 W per household, which later on caused numerous problems in operation and induced the need for reconstruction. As an oddity of that time we could mention that wooden poles applied in electrification were so raw that they sometimes used to put forth leaves in the spring. Impregnated poles were very rare at that time.

In the period between 1955 and 1960, the tendency of consumption growth continued and the shortage of electricity, especially in western Croatia, caused frequent reductions. The lack of energy sources was somewhat mitigated in Dalmatia in 1956, when the refurbished Miljacka HPP was put into operation. Due to significant electricity surpluses in the electricity industry of Bosnia & Herzegovina, it was decided that the 110 kV Zagreb - Jajce double circuit transmission line be constructed. This line was commissioned in 1957. In

1957, the Fužine pumped storage plant, 3.8 MW, was put into operation. It was located within the Vinodol HPP system on the tunnel connecting the Lokvarka and the Bajer storage basins. During 1956 and 1957, Slavonia was connected to the Bosnia & Herzegovina network by the construction of the Dobož - Slavonski Brod - Osijek transmission line and the 110 kV Slavonski Brod and Osijek substations. The first parallel operation of the entire Yugoslav electric power system was realized in December 1957. Thus, Croatian electric power system was integrated for the first time, although via the Bosnia & Herzegovina network. Intensive development of the 110 kV transmission and distribution network was characteristic for that period. The Nedeljanec - Söjtör transmission line, a significant facility, was commissioned in 1958, together with the extended Nedeljanec substation including the 120/110 kV transformation. This was the first international link of Croatian electric power system. This significant investment, which required larger works in the field of protection, measurement and telecommunication, was realized during the four winter months on the turn of 1957 into 1958.

Intensive construction of hydro power plants in the second half of the fifties reduced the shortage of energy sources in Croatia. Two underground rivers, the Gojačka Dobra and the Ogulinska Mrežnica sink on the Ogulin - Oštarije karst plateau and pass the height difference exceeding 100 meters during their underground flow, springing as permanent waterflows - the Gojačka Dobra and Zvečajska Mrežnica rivers. The Gojak HPP of 48 MW output was constructed and commissioned in 1959 on that very location.

The greatest construction challenge in the period from 1956 to 1960, was the construction of the Peruća HPP with gravity rockfill dam and storage basin of total volume 541 hm³ built on karst terrain. This was the first step towards energy utilization of the Cetina river wider catchment. The Peruća HPP of 41,5 MW output, with the storage basin for annual discharge leveling of downstream hydro power plants on the river Cetina, would not have been constructed in view of its technical, energy and economic features, had it not been part of a

wider project which gave significant contribution to downstream energy supply, water management and agriculture.

At the end of 1960, the electrification of settlements reached 57% and of households 63%. The Electricity Act passed in 1958 comprised a special part regarding electric power dispatch service organized in the Union of Yugoslav Electric Power Industry and in the associations of republican electricity organizations. The main task of this service was to provide for efficient work of all participants. The Dispatch Service of the Union of Yugoslav Electric Power Industry controlled the exchange among republican associations, defined priorities in case of electricity shortage and coordinated plants' overhaul plans. Since the end of the forties, there have been three dispatch services operational in Croatia: Zagreb, Split and Osijek.

In the period from 1955 to 1960, telecommunication network started to powerfully evolve. It was founded on high-frequency links built on 110 kV transmission lines. The first specialized transmission companies were founded: Elektroprijenos Split for the region of Dalmatia and Elektroprijenos Zagreb for the rest of Croatia. In 1960, installed capacity of Croatian power plants was in the order of 470 MW and consumption 1943 GWh, i.e. 469 kWh per capita. As regards the structure of energy sources, hydro power plants outnumbered other types of sources which remained the characteristics of Croatian electric power system till the end of the seventies.

In the early sixties the development of Croatian electricity industry started which was characterized by intensive construction of energy sources. In 1965, 80% of settlements and 81% of households were electrified. Croatian electric power system significantly improved when the Zakućac HPP, the Senj HPP and the Dubrovnik HPP and the Zagreb East CHPP were put into operation. The installed capacity of power plants in the system was 898 MW and total consumption reached 3,115 GWh. Only a year after the construction of the Peruća HPP, the first phase of the Zakućac HPP construction (216 MW) was completed and put into operation, in



△ Laying of a 110 kV submarine cable

▷ The Zagreb East combined heat and power plant









◁ The Rijeka (Urinj) thermal power plant

△ The Sisak thermal power plant



Δ The Osijek combined heat and power plant

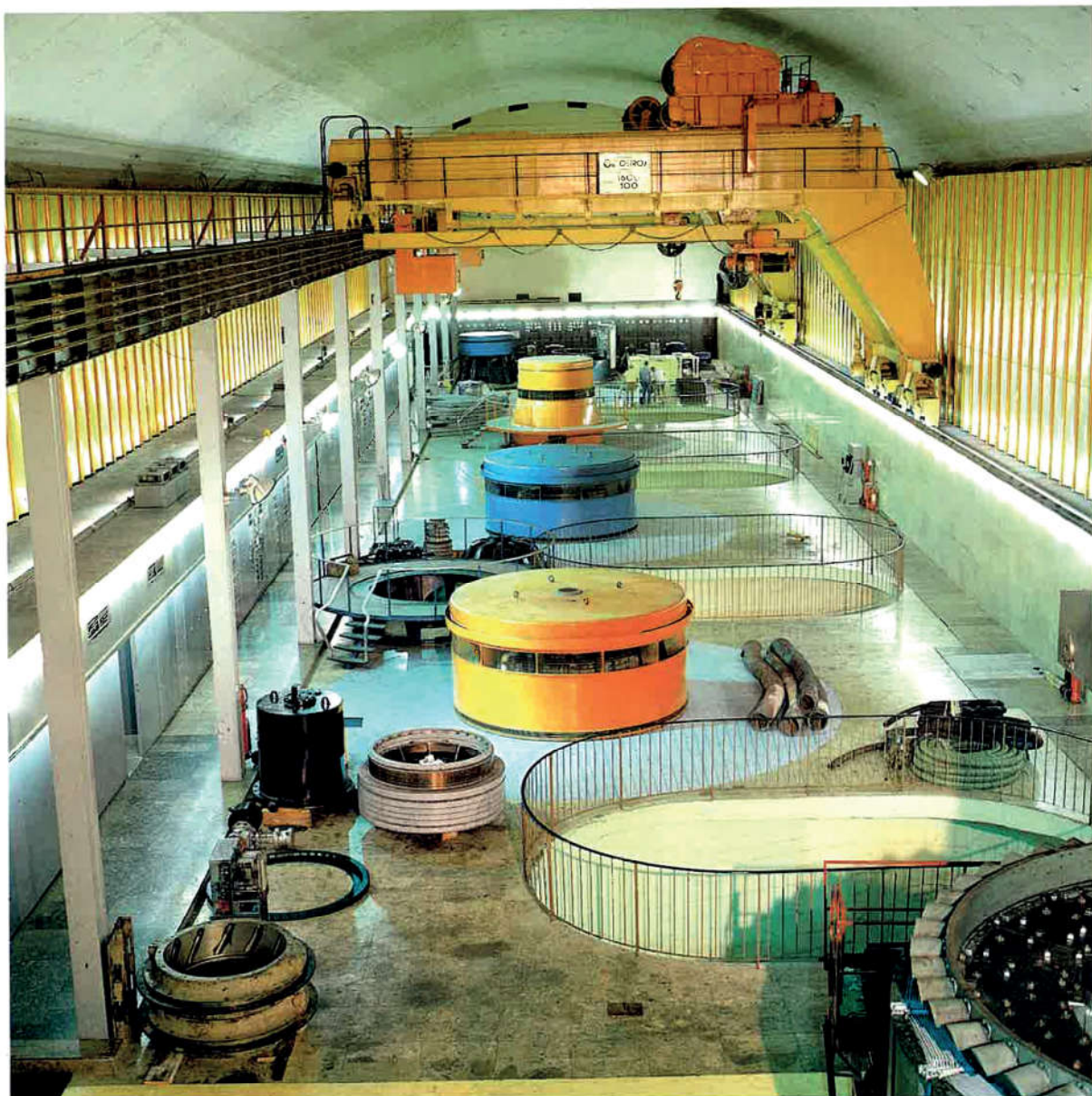
the downstream flow of the river Cetina where most of hydro power potential of the river was concentrated. Together with the upstream Peruća storage basin, energy utilization of this concentrated hydro power potential became meaningful.

At the end of 1962, the Zagreb East CHPP of 64 MW output was put into operation on the left river bank of the Sava, on the border of the Zagreb industrial zone and residential city quarters. Besides a usual condensing plant, it was fitted with equipment for heat supply to consumers. The lignite of the Zagorje coal mines and natural gas surpluses from nearby oil fields offered a possible energy basis for this plant. For this, a railway

siding was constructed for coal delivery, as well as re-loading facilities, inplant transport to the bunker and coal storage. However, three years later, due to the more favorable price of petroleum products with relation to coal prices in the world market, the boiler house was modified to burn crude oil in addition to the existing natural gas fittings. The first unit was modified at the beginning of 1965, and the second one at the end of 1966. Electricity industry at that time was mainly oriented towards the construction of hydro power plants. In 1965, the Senj HPP and the Dubrovnik HPP were included in the Croatian electric power system. When the Senj HPP, of 216 MW output, was put into opera-







△ The Zakućac hydro power plant

◁ The Cetina River canyon with the Zakućac hydro power plant

tion, it was the largest hydro power plant of that time. The water of two underground rivers in the Lika region: the torrent Lika partially caught in the Kruščica storage basin and the more steady Gacka, were diverted by a long diversion system, composed mainly of tunnels, to the water chamber and therefrom by a penstock to the power house located near the sea coast. The planned increase of storage area in the region of the Lika plain, over which the Lika and the Gacka flowed, would enable a significant reduction in overflows and an increase in the Senj HPP generation.

The Dubrovnik HPP of 216 MW was constructed in 1965, in cooperation with electricity industry of Bosnia & Herzegovina. This hydro power plant is located between the river Trebišnjica upstream from Trebinje and the Adriatic Sea and has a head of 270 m. Unfortunately, due to political conditions, the Croatian share in the production of the Trebišnjica system, in which the Dubrovnik HPP operated, was only 22%. Despite the occasional endeavors to increase the proportional share of energy in accordance with the proportionally larger participation of Croatia in the financing of the construction of this system, nothing has changed up to present.

An increase in consumption and new electricity sources surpassed the capacity of the 110 kV transmission network. Simultaneously with the construction of the Zakučac I HPP, the 220/110 kV Mraclin substation and the 220 kV Zakučac - Mraclin transmission line were constructed, so that in 1962, Dalmatia and western Croatia were directly connected for the first time. In 1962, the 220 kV Zakučac - Mostar transmission line was put in operation, in 1963 the 220 kV Mraclin - Cirkovci transmission line and in 1965 the 220 kV Mraclin - Kakanj transmission line. Thus, the connection between western and central part was significantly reinforced and there were no major reductions in electricity supply during that period, except in the year 1964. This does not mean that there were no problems in individual parts of the system. Despite significant development of the 110 kV network and distribution network, this construction was unable to keep pace with consumption growth at that time. Local restrictions and

especially voltage problems occurred frequently.

The economic status of the electricity industry, one of the largest problems in the entire post-war period, remained unresolved. The price of electricity was set in an administrative manner. The imbalance of prices of various fuels was permanently present and attempts to introduce a rational tariff system were never fully realized. Preferential prices of electricity, especially in households and for special consumers, gave rise to uneconomical energy use. The price of electricity did not cover operating expenses of the electricity industry. In order to enable normal operation of the electricity industry, various more or less economically unjustified measures had to be implemented.

The Electricity Act passed in April 1965, established the Union of Yugoslav Electric Power Industry as business association of compulsory united electric power production and transmission companies. The new law abandoned a long lasting treatment of the electricity industry as public service and reinstated it as an economic activity. In June 1965, the Union of Croatian Electric Power Industry was dissolved. Production and transmission companies on the territory of Zagreb, Split and Rijeka established a business corporation Allied Electricity Industry of SR Croatia, and the republic dispatch service became inoperative.

THE PERIOD FROM 1965 TO 1975

The subsequent period between 1965 and 1970 was marked by events which influenced the development of the electricity industry. With the transition from centralized to indicative planning, the banks increasingly took over the role of general investment funds.

Together with the economic depression the inflation occurred coupled with a growing unemployment rate. The tendency of development and construction of electric power sources in Croatia was however preserved. In addition to two hydro power plants - the Rijeka HPP of 36 MW output with the Valiči storage basin located on the waterflow of the Rječina and the Sklope



△ The Orlovac hydro power plant

▷ The Dale hydro power plant

HPP of 22.5 MW output located on the Lika along the dam of the Krušćica storage basin - three thermal power plants were commissioned in 1970: Plomin I TPP, Sisak I TPP and Zagreb West I CHPP. In the Plomin TPP of 100 MW output, located on the coastline of the Plomin Bay, local industry still had a significant share in equipment production. In accordance with views on environmental protection of that time, the location of the power plant was chosen because of the topographically and geologically appropriate terrain, vicinity of the Raša coal mine, possibility of sea and potable water supply, low population, possibility of ash disposal, connection to the network and vicinity of roads. This thermal power plant is a conventional plant burning the Raša coal. Due to high sulfur content in the coal (about 9%), special requirements were prescribed for boiler house which, unfortunately, have not been entirely met. The Sisak I TPP of 210 MW output is located in the center of the largest consumption area (Karlovac, Zagreb, Kutina and Sisak) immediately by the Sisak oil refinery and can burn liquid fuels (mazut, low octane petrol and crude oil) and



natural gas. As heat consumption in Zagreb increased, the need arose to extend the boiler house of the Zagreb West CHPP fueled by heavy fuel oil and natural gas on the site where the City Power Plant had been in operation in the period 1907-1960. This was partly carried out in 1970 by the construction of a 11 MW unit.

The construction of energy sources in the period 1965-1970 increased the capacity of Croatian hydro power plants within the electric power system by 58.5 MW, as well as the installed capacity of thermal power plants by 321 MW. In 1970, total installed capacity of



▽ The 400/220/110 kV Konjsko substation, near Split



all power plants reached 1,277 MW, and the consumption was 5,308 GWh. 94% of settlements and 94% of households were electrified.

Significant development was seen in the field of energy transmission. The 220 kV Senj - Brinje and Đakovo - Gradačac transmission lines and the Brinje switchyard were commissioned in 1966. The 220/110 kV Đakovo substation was commissioned a year after that, and in 1970 the 220/110 kV Pehlin substation and the 220 kV Mraclin - Sisak, Sisak - Jablanica, Senj - Pehlin, Pehlin - Divača and Zakučac - Bilice transmission lines. In addition to the development of the 220 kV network and transmission nodes, intensive work was carried out on the extension of the 110 kV transmission network and distribution network. No significant reduction in electricity supply occurred in the period 1965-1970.

The period 1970-1975 could be called a dramatic period as regards the development of electricity industry. Depression and inflation continued and reached their peak in 1973 during the oil crisis. The oil crisis in Croatia had a special significance as regards the use of mazut as fuel in Croatian thermal power plants. On the insis-

tence of the coal mining lobby from Serbia and Bosnia & Herzegovina, the price of mazut for thermal power plants was burdened by high taxes in order to give preference to coal and lignite fired thermal power plants.



△ A detail of the 220 kV network



△ The 400/110 kV Tumbri substation



Due to such policy, the price of 1 kWh imported from Italy was lower than the price of mazut required for the production of 1 kWh in Croatia. In 1973, the aluminum electrolysis started its operation in Ražine - a typical political investment despite the warning from experts that Croatia would be unable to sustain such technology from an energy point of view. In late 1973, dramatic reductions in supply, in the order of 512 GWh or 7.85% of annual consumption, clearly demonstrated electric power supply conditions in Croatia. Although the conditions did not considerably improve until the end of 1975, Croatian electricity industry was not defeated since it introduced the Orlovac HPP, the Tuzla IV TPP, the Varaždin HPP and the reconstructed Jertovec TPP into the system in order to meet consumers' demand.

The Orlovac HPP and the Buško Blato storage basin were constructed. In this way the water in the Livanjsko Polje - Buško Blato catchment, which properly flows into the Cetina through subterranean pas-

sages, were retained in the storage basin at the elevation of 716.4 meters above sea level. The water was directed towards the left affluent of the Cetina, the Ruda, by means of a tunnel through Kamešnica and a penstock. The power house is located on the Ruda and uses the head of 380 m to generate 237 MW. The Buško Blato storage basin has the volume of 800 hm³ and enables controlled discharge towards the largest hydro power plant - Zakućac - located downstream. Other plans for water intake from the north-western part of the Livanjsko Polje have not been realized until now. Since the exploitation of coal from Zagorje coal mines was very expensive, Croatian electricity industry completed the reconstruction of the Jertovec TPP in 1974 adjusting it to burn liquid fuel.

Unable to construct coal fired thermal power sources in Croatia, Croatia began to finance the construction of such plants outside Croatian territory in the early seventies. For the needs of Croatian consumers, one unit of the Tuzla TPP in Bosnia & Herzegovina of



210 MW output was commissioned in 1974. In line with its energy strategy to exploit its own resources, in energy terms inexhaustible water potential, Croatian electricity industry started the construction of the Varaždin HPP in the early seventies. The plant rated 86 MW, is located on the river Drava between Ormož and Varaždin and was commissioned in 1975. This was our first hydro power plant built on the territory of an alluvial valley, which represented a big challenge as regards construction works.

The 220 kV network expanded in the first half of the seventies. During 1972 and 1973, the Đakovo - Tuzla and the Orlovac - Bilice transmission lines were constructed, together with the 220/110 kV Bilice substation.

The turning point in the work of electric power system is marked by another two events. In 1972, analogous device for frequency - power of exchange control was put into operation. Control requirements were conveyed from the dispatch center of the Union of Yugoslav Electric Power Industry to control sub-centers. The sub-center West was located in the Zagreb dispatch center and it controlled the operation of the Zakučac HPP, the Senj HPP, the Vinodol HPP and the Orlovac HPP, and later on the operation of several power plants in Slovenia. This control was a prerequisite for parallel operation with West European interconnection UCPTE (Union for the Coordination of Production and Transmission of Electricity), which was realized on September 16, 1974. This event had significant influence on the operation and reliability of Croatian electric power system and forced other participants within Yugoslav Electricity Industry to operate in accordance with UCPTE regulations. In 1975, 98% of settlements and 97% of households were electrified.

THE PERIOD FROM 1975 TO 1990

At the end of 1975, the installed capacity of power plants was 1,922 MW, including the capacity of the Tuzla IV TPP constructed in Bosnia & Herzegovina for the needs of Croatian consumers. Electricity consumption

was in the order of 8,225 GWh.

The most prosperous period of construction of energy sources for the needs of Croatian consumers, especially thermal power plants, was between 1975 and 1980. The capacity of hydro power plants increased by 270 MW, and that of thermal power plants, including the facilities outside Croatia, by 1,084 MW. Consumption grew by more than 3,000 GWh. Rapid growth of consumption in the seventies asked for rapid action in order to provide sufficient quantities of power and energy. In 1973, the idea to construct a gas fired power plant which would serve as a stand-by in the system was conceived. In 1976, two gas turbines were commissioned on the Jertovec TPP location, extending in fact the existing plant: these turbines with two heat recovery steam generators and two steam turbines with pertaining auxiliary engines formed two combined cycle units each of 44 MW output. The boilers of the third turbo-generating set of 14.8 MW, which was retained in the existing plant, fired heavy fuel oil. In addition to the gas fired thermal power plant Jertovec, the construction of the Osijek GTPP of 47 MW was started and completed in the course of 1976. Both plants were constructed pursuant to the special decree as emergency power plants. The second unit of the Sisak TPP, firing liquid fuel, was commissioned in the same year. It was fitted with equipment mainly originating from Russia and had the output of 210 MW. The Kakanj V TPP was commissioned in Bosnia & Herzegovina at the same time. This was a coal fired thermal power plant with an output of 93.5 MW, and 46 MW of that amount was available to the Croatian electric power system. The following power plants were commissioned in the period 1978-1980: the Zakučac II HPP, 270 MW; several thermal power plants which fired liquid fuel such as the Rijeka TPP, 320 MW, the Zagreb East II CHPP, 120 MW and the Zagreb West II CHPP, 30 MW and the Obrenovac VI TPP, 310 MW constructed in Serbia for the needs of Croatian consumers which burnt coal.

Thanks to new sources, the period 1975-1980 was not burdened with reductions in electricity supply. The most significant event from the point of view of elec-



△ The Dubrovnik hydro power plant

tric power system was the construction and commissioning of the 400 kV network. It was designed to connect all significant production and consumption regions in former Yugoslavia and enable the connection with neighboring energy systems. After the oil crisis, world experts were of the opinion that energy shocks should be mitigated by a strong network which would enable the management of available energy without difficulties. In order to reach optimum solutions and guide local equipment producers, comprehensive preparations were made as regards the systematization and standardization of the 400 kV equipment and plants. Several 400 kV facilities were commissioned in the period 1977 - 1979: the Ernestinovo substation, the Tumbri substation, transmission lines Ernestinovo - Tumbri, Tumbri - Krško, Konjsko - Mostar, Ernestinovo - Obrenovac, Ernestinovo - Tuzla, Konjsko - Melina and Melina - Divača. The 400 kV network offered new possibilities for energy exchange, increased operational reliability and lower transmission losses. This network brought about some operational problems, as well, especially concerning overvoltage during low loads, e.g. on the south main line Konjsko - Melina which was commissioned somewhat later. Another event to influence the life of electricity industry was the passing of the Associated Labor Act in 1976, which led to the extreme decentralization of Croatian electricity industry. Until 1980, installed capacity of power plants, including facilities constructed outside Croatia, reached 3,276 MW and consumption grew to 11,226 GWh. The degree of electrification kept the same level registered as in 1975. Consumption growth was more moderate and there were no reductions in electricity supply.

In the period 1980-1985, Croatian electricity industry was organized in four generation and transmission companies and seven distribution companies as well as more than hundred basic organizations of associated labor. Inflation grew at a rapid rate and a planned economy demonstrated the lack of power. Decision making in the electricity industry was more and more difficult. Although decentralization made some routine works related to plant maintenance easier to carry out,

in the field of investment it gave negative results which heavily burdened Croatian electricity industry. The Obrovac pumped storage hydro power plant was constructed, a very complex and expensive power plant which was premature since the need for such a plant occurred only after the construction of one or two nuclear units in Croatian system. The start of insufficiently prepared Plomin II TPP project resulted also from a disorganized and decentralized electricity industry, as well as the decision to connect the Rijeka TPP to the 'local' 220 kV network instead of the 400 kV network. Such management resulted in the scarcity of financial means and postponement of the 400 kV Tumbri - Melina transmission line construction which would have considerably increased the reliability of the western part of the electric power system. The events which followed proved these assumptions.

In 1981, Croatia in cooperation with Slovenia completed and commissioned the first nuclear power plant on this territory - the Krško NPP. The generator output is 664 MW, of which Croatia is entitled to one half of energy and the available capacity of 316 MW.

Besides the small hydro power plant Golubić, 6.5 MW, located in the Krka catchment to the north of Knin, our second hydro power plant on the river Drava - the Čakovec HPP - was commissioned in 1982, its output is 79.3 MW. In the same year, the Gacko TPP was completed in eastern Herzegovina. It has the output of 300 MW and Croatian electricity industry participated in the construction of this plant with one third of total investment, thus obtaining the right to one third of energy with available capacity of 92 MW. This was the last power plant outside Croatia to be financed by Croatian electricity industry. For Croatian consumers, power plants were built outside Croatia in a total capacity of 1,099 MW of which 916 MW are available. Electricity supply from the Tuzla TPP, the Kakanj TPP and the Obrenovac TPP was warranted by the electric power system of former socialist republics Bosnia & Herzegovina and Serbia, while the contracted electricity supply from the Krško NPP and the Gacko TPP depends on operating status and availability of these



△ The Obrovac pumped storage hydro power plant



△ The Varaždin hydro power plant

plants.

Croatian electricity industry entered high risk investments by participating in the financing of construction of energy sources outside its territory. Making an error on its own territory in 1984 by constructing a useless and expensive project of pumped storage hydro power plant Obrovac of 276 MW output, it gained from this experience. Instead of constructing a CHPP in Rijeka of 42 MW output, it decided to relocate this plant in Osijek where significant heat consumption existed. Thus, in 1985 Osijek got a new energy source. In addition to the construction of energy sources, two substations were put into operation in the 400 kV network during this period: the Konjsko substation in 1981 and the Melina substation in 1984.

At the end of 1985, the electrification of settlements and households was practically completed. Installed capacity of power plants, including the capacity of power plants outside Croatia, amounted 4,130 MW and annual electricity consumption reached 13,759 GWh. An important investment was realized in the electricity industry at that time: the remote control system was put into operation which included Republic dispatch center and four regional control centers for transmission network control. This project was conceived in the early seventies, but its realization was prolonged due to permanent organizational changes in the electricity industry. Through commissioning the remote control system, Croatian electricity industry made a significant step towards modern technology. A number of young experts were trained in the electricity industry and in the company Končar which was the main contractor. In parallel with this project, dispatch centers were created in distribution organizations, increasing total reliability of Croatian electric power system.

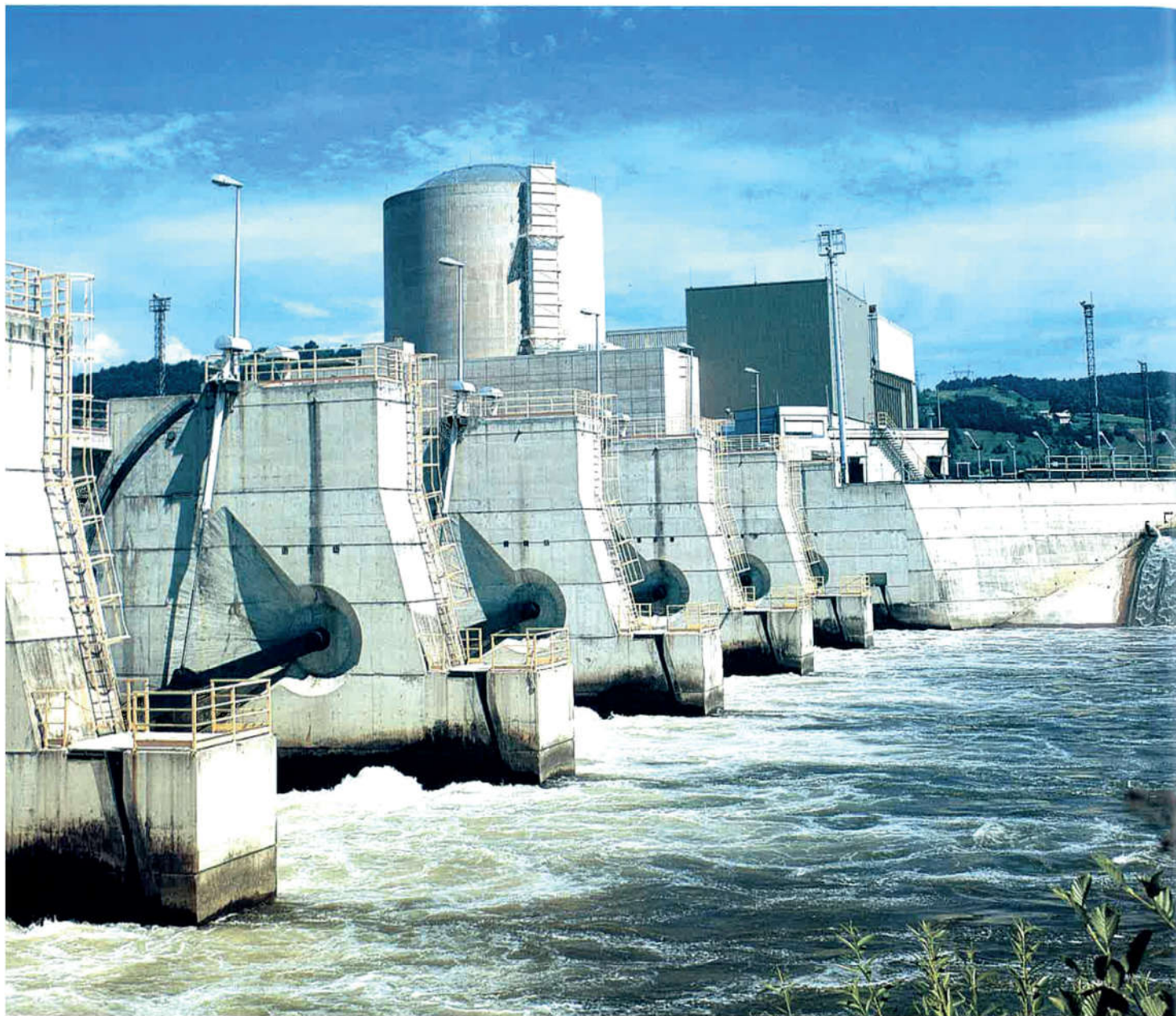
In the period 1985 - 1990, the construction of three hydro power plants and the Plomin II TPP were under way. Two hydro power plants were completed in 1989: the Dubrava HPP on the Drava with 80.6 MW output and the Đale HPP on the Cetina with 40.8 MW output. Due to difficulties in construction, the Lepenica pumped storage hydro power plant was commissioned



△ Power house, the Varaždin hydro power plant

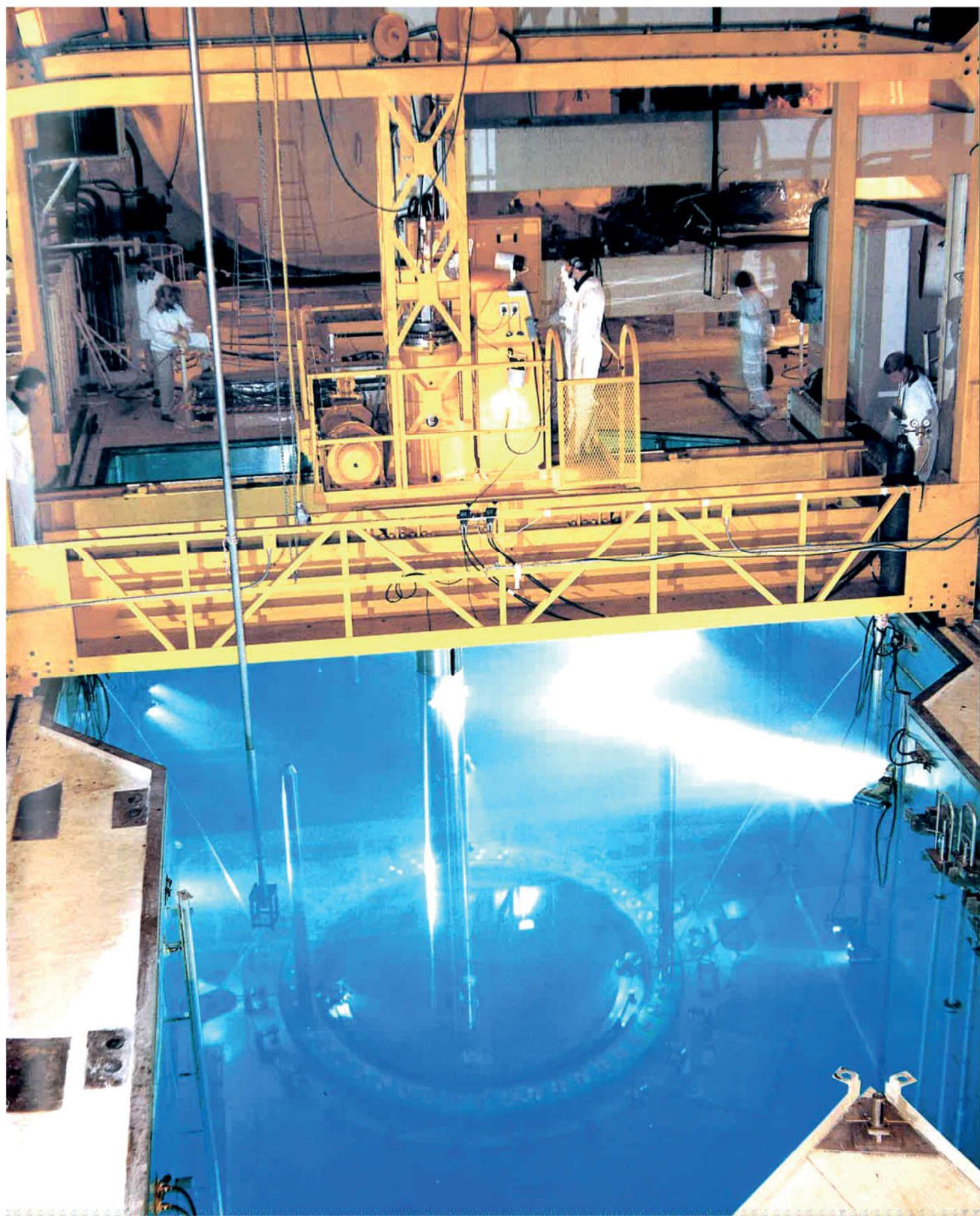


▽ Access tunnel of the hydro power plant



△ Dam for cooling water intake in the Krško nuclear power plant

▷ Nuclear reactor, the Krško nuclear power plant



in 1995. Its output as motor is 1.33 MW and as generator 1.10 MW. The construction of the Plomin II TPP of 210 MW is still in progress.

The activities related to the construction of transmission and distribution network in this period mainly included extension and interpolation of new substations in the existing lines. At the end of this period, 24 substations of 110/10 kV were operational in the distribution network, their capacity totaling 935 MVA, 341 substations of 35/10 kV with a total capacity of 3,626 MVA and 19,113 substations of 10/0.4 kV with a total capacity of 4,634 MVA were also in operation. The total length of overhead lines and power cables rated 35 kV was 4,488 km and of 10 kV lines 27,206 km. Low voltage network reached the length of 58,006 km. The quoted data relate only to the plants owned by distribution organizations, while a part of the plants is owned by business organizations. It has to be mentioned that regional dispatch centers were put into operation in numerous distribution organizations at that time, which significantly increased the reliability of the distribution network operation.

At the end of 1990, total installed capacity of generators in all power plants constructed for the needs of Croatian consumers was 4,247 MW and annual electricity consumption reached 14,749 GWh. The capacity of hydro power plants was 2,024 MW, thermal power plants 2,223 MW in which thermal power plants constructed outside Croatia, including the Krško NPP, participated with 973 MW. Furthermore, installed capacity of industrial power plants in Croatia was about 276 MW.

The main characteristic of the period 1985-1990 was a pronounced inflation and slowdown of consumption growth. The economic position of the electricity industry in the conditions of raising inflation became more and more difficult. Total number of employees constantly increased pursuant to the requirements of local authorities. The efficiency of Croatian electricity industry expressed in terms of the number of employees per kWh constantly dropped with relation to developed European electricity industries.

If we summarize the total accomplishment of the

electricity industry in the period 1945-1990, we could say that Croatia made its way from the country on the threshold of electrification after World War II, to a moderately electrified European country. A strong professional personnel was formed. Croatian electric power system was connected on the 400 kV level with the UCPTE interconnection. A very modern control system has been developed and electricity was one of the safest commodities on the market. Unfortunately, the unprofitable price of electricity and social and political conditions have had negative consequences: certain bad investments, inappropriate maintenance of plants due to the lack of financial means and the problem of special consumers. Since the problem of the price of electricity became a political issue, the electricity industry gained a wrong image in the public without being to blame. Besides a relatively solidly constructed system, the strength of the electricity industry was seen in the experience of its experts at all levels demonstrated at the beginning of the nineties during Serbian aggression on the Republic of Croatia.

Finally, here is the list of managers running the electricity industry in the period when it operated as a business enterprise:

Miloš Damjanić, from October 1952 to June 1965

Anđelko Marušić, from July 1965 to November 1973

Ivica Pavelić, from November 1973 to February 1974

Ivo Božin, from March to July 1974

Hakija Hasanbegović, from August 1974 to May 1978 and from June to October 1982

Rade Pavlović, from June 1978 to May 1982

Vojislav Roksandić, from November 1982 to July 1990.



△ The Plomin thermal power plant

PEOPLE MERITORIOUS IN THE DEVELOPMENT OF ELECTRICITY INDUSTRY IN CROATIA

From the very outset of electrical engineering, towards the end of the 19th century and in the early 20th century, there were prominent people in Croatia who contributed to the general development of this science and those who promoted it among the Croatian population.

Vjekoslav Meichsner was one of the first builders of power plants and networks in our cities, while Ante and Marko Šupuk were the first electric power system users and managers. Early developers and promoters of technical sciences, first of all electrical engineers, were educated outside Croatia till the end of World War I when the Engineering College was opened in Zagreb which evolved into the School of Engineering in 1926. From 1927, electrical engineers have been graduating from the Zagreb University together with other students, and some of them have given a significant contribution to the development of this science. Considering a hundred year old history of electricity industry in Croatia, it is worth naming those people who gave outstanding contribution in this period, either through the construction of electric power facilities or through the development and promotion of electrical engineering in general.

One of most reputable power plants' constructors was a municipal engineer of Karlovac, Valerijan Rieszner (Bakar, 1876 - Zagreb, 1949). A civil engineer, he worked in Vienna until 1906, designing and constructing hydro power plants. In 1906, he was entrusted with the elaboration of the project design and construction of the Ozalj HPP on the river Kupa near Karlovac. This plant was successfully completed in 1908. The Kuzmica HPP on the river Orjava near Požega was constructed in 1912 on the basis of his project design and under his guidance as well as the Zeleni Vir HPP near Skrad in 1922. He ended his professional and scientific career in Zagreb as a professor at the School of Engineering, lecturing in Hydro Construction. Engineer Edgar Montina led the construction of the electromechanical part of the Ozalj HPP. Afterwards, he was appointed manager of the city power plant in Karlovac. In 1923, he wrote the first technical study on the electrifi-



cation of Slavonski Brod (at that time called Brod na Savi) He lectured Design of Electrical Power Plants and Networks at the Engineering College.

Two electrical engineers and professors at the School of Engineering, Miroslav Plohl Senior and Juro Horvat, are specially meritorious for the establishment of the Electric Company of Banovina (ECB) in Zagreb, in 1937. They can be considered actual creators of electricity industry in Croatia. Miroslav Plohl Senior (Gorica, 1881 - Berlin, 1939) started his career as navy officer specialized in electrotechnical equipment of warships. He studied alternating current used as motive power and radio technology. In this field, he registered several patents by 1918. After World War I, he retired and devoted himself to the study of electrical engineering. Upon graduation, he became a lecturer at the Engineering College and School of Engineering in Zagreb, for Power Engineering, Electricity Transmission and Shipping Electrical Engineering. He established the Institute for Electromechanical Engineering at the School and actively

participated in the construction and development of Radio Zagreb technology. He was Technical Manager of ECB. It was his idea to electrify Gorski Kotar, Hrvatsko Primorje and North-Adriatic islands. He also conceived the construction of the Vinodol HPP. During inspection of the terrain for this power plant, he lost his life in a car accident.

Juro Horvat (Gospić, 1882 - Zagreb, 1954) graduated from the Engineering College in Graz in 1904. After that, he took part in the Fala HPP construction on the river Drava in Slovenia and lectured for a longer period of time at the School of Engineering in Ljubljana. In 1932, he was employed at the School of Engineering in Zagreb, lecturing in Electrical Power Plants. He published numerous scientific papers in the field of electric power supply and performed the function of Manager of ECB with great enthusiasm. He worked on the electrification of Posavina (Božjakovina, Križ) and on the elaboration of the electrification project of Croatia.

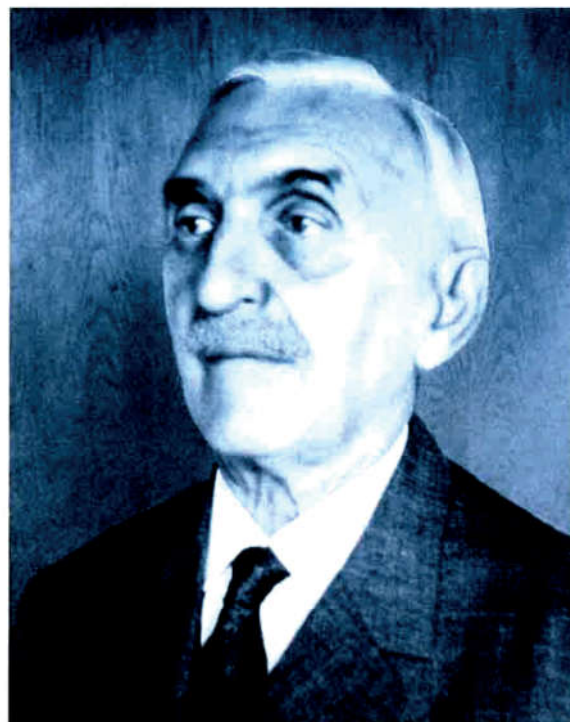


△ Juro Horvat

The name of Josip Lončar (Đakovo, 1891 - Zagreb, 1973) stands abreast with the names Miroslav Plohl and Juro Horvat. He was the third prominent professor at the School of Engineering in Zagreb. He lectured mathematics, which he studied in Zagreb and Paris, and gained his Ph.D. in physics at the School of Humanities and Social Sciences in Zagreb. Since the establishment of the Engineering College in 1919, he was teaching there part-time because the Ministry refused to award him full professorship. In 1932, Lončar was appointed senior lecturer at the School of Engineering, although he had been constantly lecturing *The Basis of Electrical Engineering and Electrical Measurements* since 1919. The field of electrical measurements was of special interest for him. In 1923, he founded the Laboratory for Electrical Measurements, which evolved into the Institute for Electrical Measurements at the School of Engineering. He engaged himself mainly in scientific and educational work and wrote a significant number of scientific papers and several books which become standard and an inevitable source of knowledge in the field of electrical engineering. He was a member of JAZU (Yugoslav Academy of Sciences and Arts) and honorary doctor of the University of Zagreb. His career as a lecturer lasted 50 years.

Special place in the development of electrical engineering as a science take the professors of the School of Electrical Engineering in Zagreb: Antun Dolenc, Božidar Stefanini and Hrvoje Požar. Each of them has left an unforgettable mark in his field of activity. After graduating from the School of Electrical Engineering in Ljubljana, Anton Dolenc (Celovec, 1905 - Zagreb, 1984) worked all his life in Zagreb. He was a project engineer and subsequently manager of the Siemens factory in Zagreb which evolved into the Končar factory after World War II. Dolenc designed, constructed and built large energy plants, especially large synchronous generators which were constructed in the factories in Croatia and worldwide. He won recognition with his original designs and a great number of patents. Since 1939, parallel with his practical work, Dolenc lectured in Zagreb in the field of electromechanical engineering, and in his later years

▽ Josip Lončar



in Ljubljana. He published numerous professional and scientific papers and books on transformers and rotating electrical machines. He can justly be considered the founder of electromechanical engineering in Croatia.

Božidar Stefanini (Split, 1913 - Zagreb, 1991) was employed in ECB in 1937 as project engineer and constructor of substations. After 1945 he worked on the construction of transmission lines and switchyards and was the builder of the first 110 kV networks in Croatia. Later on, he took active part in the planning of the 220 kV and 400 kV transmission lines, by which the interconnection network on the entire territory of former Yugoslavia was realized. He also participated in the planning of the first interconnections towards Italy, Austria and Hungary. From 1950 he was lecturing at the School of Electrical Engineering in the field of electrical networks, electricity transmission, high voltage technology and, towards the end of his career, information science. Stefanini kept pace with all developments in electrical engineering and was the first to introduce computers in

▽ Anton Dolenc



Croatia, educated the first information system experts and organized the University Computer Center where he was manager. Besides his high merits in the high voltage network technology, Stefanini is greatly meritorious for leading Croatia and its experts into the computer age.

Hrvoje Požar (Knin, 1916 - Zagreb, 1991) was a distinguished lecturer at the School of Electrical Engineering in Zagreb. After carrying out practical work as the head of electrical networks, head of power plants and dispatcher, he became a lecturer in Electricity Production and Basis of Energy Supply at the School of Electrical Engineering. His lectures, professional and scientific work and books in the field of electrical engineering have raised numerous generations of electrical engineers. His book titled *Power and Energy in Electric Power System* is of special significance and has had several editions in the German language. He laid the foundations for professional organization of power plants' operation in the system and foundation of tech-

▽ Božidar Stefanini



nical and economic analysis of energy system operation. He was a member and General Secretary of JAZU for a number of years, and Editor in Chief of *Technical Encyclopedia* published by Lexicographic Institute "Miroslav Krleža" in Zagreb.

Numerous distinguished Croats contributed to the development of Croatian electricity industry, some of them devoting their life to the development of electric power supply and electrical engineering as science. Vlatko Dabac (Nova Raša, 1902 - Zagreb, 1988) compiled the first *Dictionary of Electrical Engineering*, German-Croatian and Croatian-German and the *Technical Dictionary* comprising the terms from all basic fields of technology. Vladimir Žepić (Osijek, 1894 - Zagreb, 1971) designed the first 50 kV transmission line Dugi Rat - Split by which Split was connected to the Kraljevac HPP and, thus, completely electrified. Later on, he was the head of the City Power Plant in Zagreb and head of technical service of NEC in the period 1942 - 1945 and the manager of ECC, Zagreb. Božidar Filipović (Petrinja,

▽ Hrvoje Požar



1894 - Zagreb, 1977) dealt in particular with economic problems related to electricity and was an outstanding expert in the field of tariffs.

Božidar Ribić (Varaždin, 1895 - Zagreb, 1986) engaged in the electrification of railways, especially the railway Zagreb - Rijeka. Being a chief electricity industry's inspector for a number of years, he initiated the elaboration of technical standards and regulations for the construction of electric power plants in Croatia. Đuro Švarc (Koprivnica, 1901 - Zagreb, 1980) also dealt with the problem of railway electrification, as well as with oscillatory circuits. Egon Najman (Osijek, 1915 - Zagreb, 1972) worked in Končar and constructed our first electrical locomotives. He also lectured in Electric Traction. Zdravko Hukavec (Požega, 1905 - Zagreb, 1994) devoted himself to the problem of meter calibration. He established and lead the National Office for Meter Calibration. He wrote a book titled Induction Meters in three volumes. Blaž Uzelac (Smiljan, 1906 - Zagreb, 1985) dealt with high voltage technology and testing of electrical material and equipment. He was the founder of

the first high voltage laboratory in Croatia. Mladen Dokmanić (Šćitarjevo, 1908 - Zagreb, 1980) dealt with project engineering and wrote scientific and professional papers on electrical networks and transmission lines, especially distribution networks. He wrote an extensive book titled *Electric Power Supply Networks*.

These distinguished experts which gave significant contribution to the development of electricity industry in Croatia, and those who earned this attribute but are not mentioned here, are meritorious for the current high level of electricity industry and electric power supply. They have educated new generations of experts who lead Croatian electricity industry into the 21st century, i.e. into the second century of its operation on this territory. ■



▷ Hydro generator shaft

MAPS OF ELECTRIC POWER PLANTS AND FACILITIES OF HRVATSKA ELEKTROPRIVREDA

CONSTRUCTED POWER PLANTS

Hydro Power Plants		
Name	Year of Commissioning	Capacity (MW)
1. Varaždin HPP	1975	86.0
2. Čakovec HPP	1982	79.3
3. Dubrava HPP	1989	80.6
4. Ozalj HPP	1908/1952	5.1
5. Gojak HPP	1959	48.0
6. Vinodol HPP	1952/1957	79.8
7. Rijeka HPP	1968	36.0
8. Sklope HPP	1970	22.5
9. Senj HPP	1965	216.0
10. Kraljevac HPP	1912/1932	67.2
11. Peruča HPP	1960	41.5
12. Zakučac HPP	1961/1980	486.0
13. Orlovac HPP	1973	237.0
14. Dale HPP	1989	40.8
15. Miljacka HPP (Manojlovac)	1906/1956	24.0
16. Jaruga HPP	1904/1937	5.6
17. Golubić HPP	1982	6.5
18. Obrovac HPP	1984	276.0
19. Dubrovnik HPP	1965	216.0 (108*)

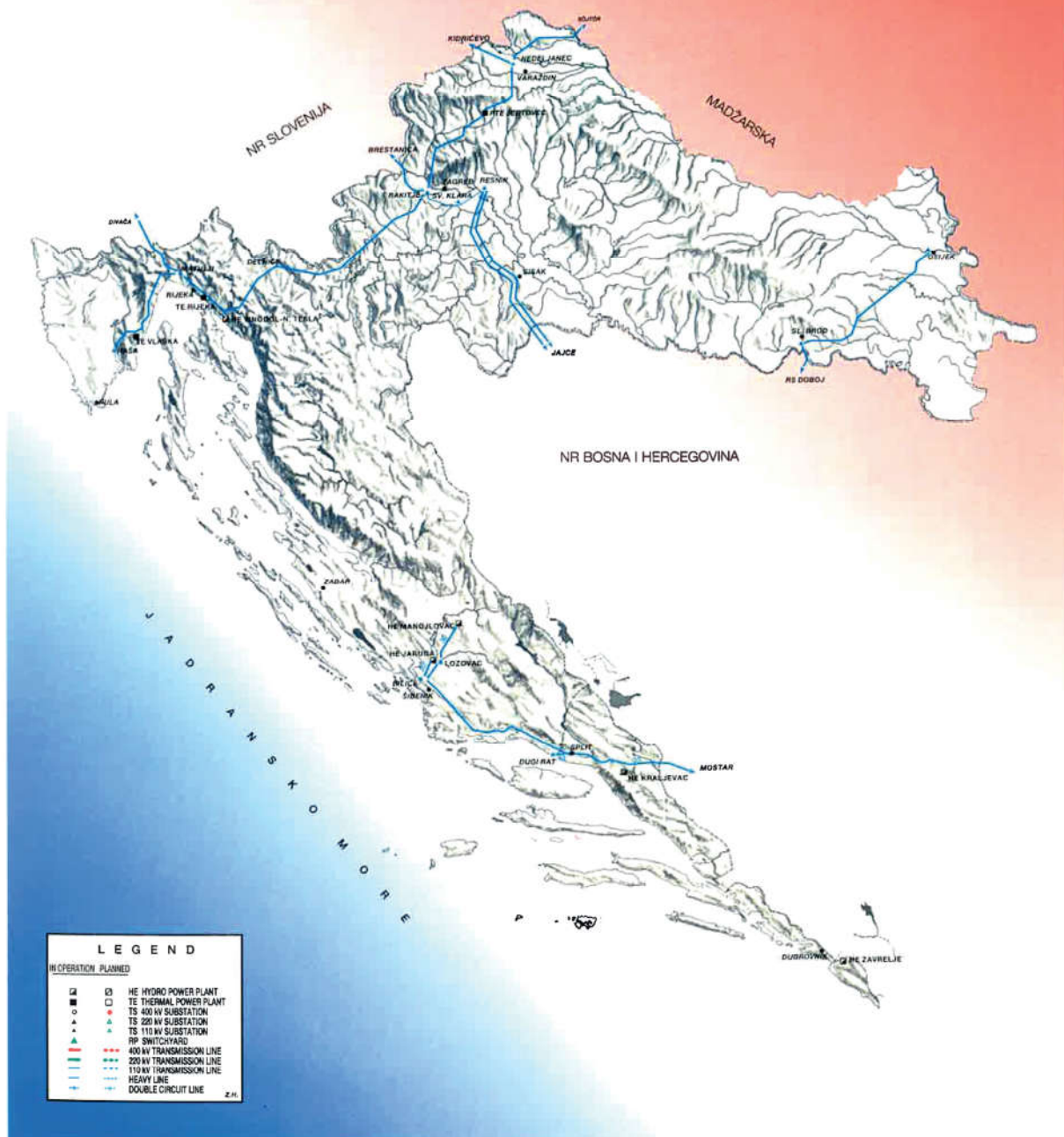
Thermal Power Plants and Combined Heat and Power Plants		
Name	Year of Commissioning	Capacity (MW)
20. Sisak TPP	1970/1976	2x210
21. Plomin TPP	1970	100
22. Zagreb East CHPP	1962/1979	2x32+120
23. Zagreb West CHPP	1970/1980	11+30
24. Rijeka TPP	1978	320
25. Jertovec GTPP	1954/1976	2x44 + 14.8
26. Osijek CHPP	1976/1985	2x23.5 + 42
27. Krško NPP	1981	632 (316**)

LEGEND

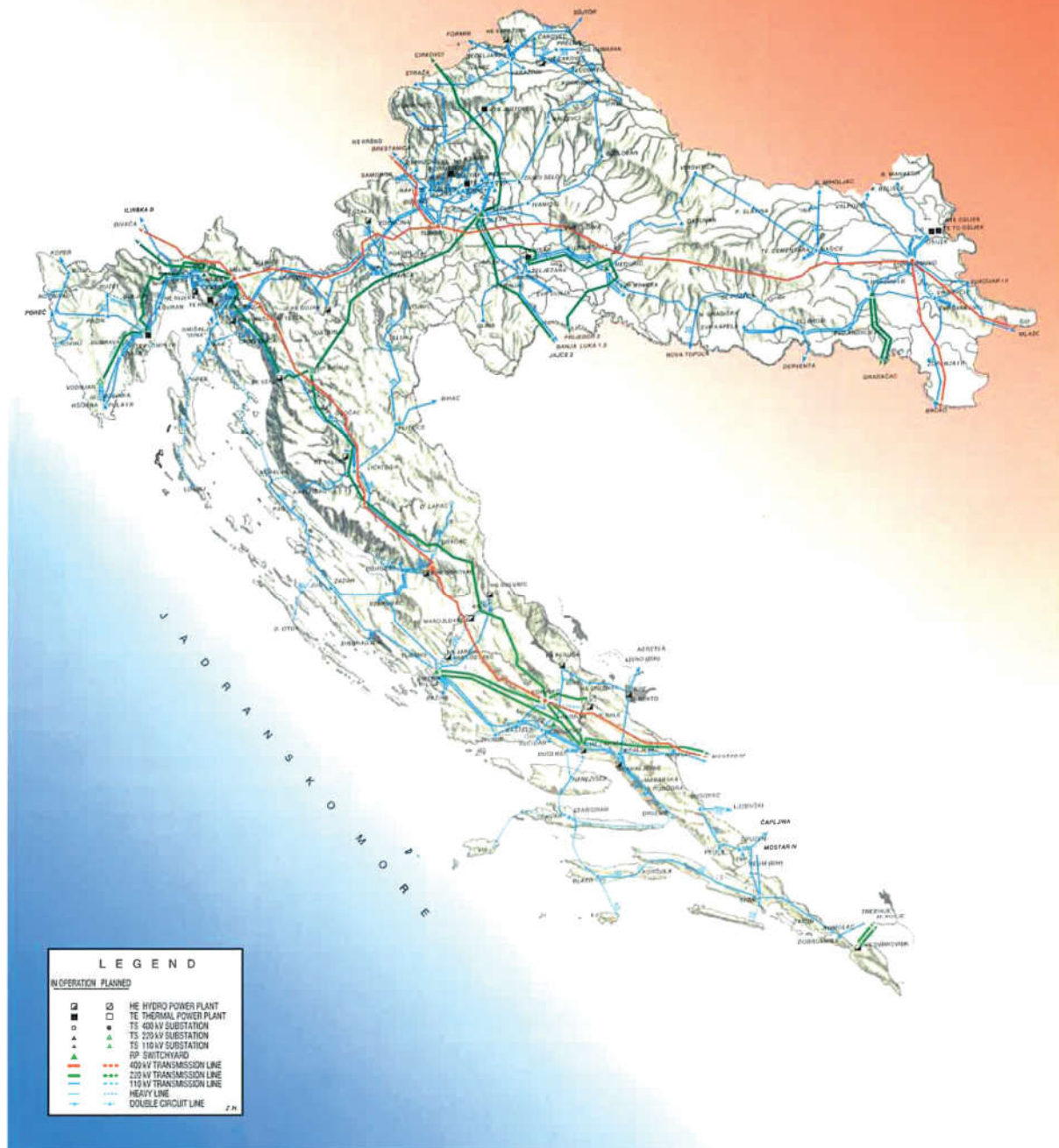
HPP	-	Hydro Power Plant
TPP	-	Thermal Power Plant
GTPP	-	Gas Thermal Power Plant
CHPP	-	Combined Heat and Power Plant
NPP	-	Nuclear Power Plant

*currently used by Croatia

MAP OF 110 KV ELECTRIC POWER FACILITIES IN CROATIA IN THE YEAR 1958



MAP OF 400-220-110 kV ELECTRIC POWER FACILITIES IN CROATIA IN THE YEAR 1990

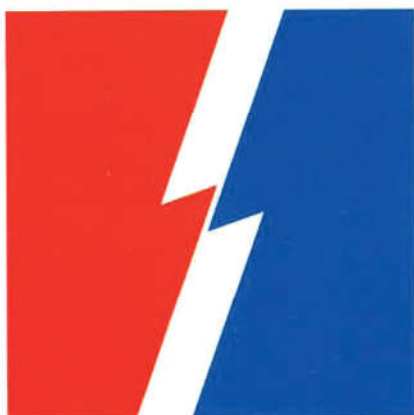




△ Headquarters of Hrvatska Elektroprivreda in Zagreb

THE FOUNDATION OF HRVATSKA ELEKTROPRIVREDA

▽ The company logo - a symbol of integrated
Hrvatska Elektroprivreda



The period from 1990 to date is of particular significance in the hundred year tradition of electricity industry in Croatia. In May 1990, a historical turning point put Croatia on the democratic road to sovereignty and independence. Following its first multiparty general elections the Republic of Croatia declared independence on June 27, 1991, gained international recognition on January 15, 1992 and was admitted into the membership of the United Nations the same year on May 22.

Immediately following the declaration of independence Croatia took full responsibility for the overall functioning of its energy sector, including electric power supply within its borders. Changes in the electricity industry commenced after July 26, 1990 when the Parliament of the Republic of Croatia passed the Electricity Act. Under this Act the Government of Croatia founded a state owned public enterprise named Hrvatska Elektroprivreda (HEP). Hrvatska Elektroprivreda joined together 119 previously independent electricity organizations which only formally constituted the Union of Croatian Electric Power Industry. All of these organizations were integrated into a single public enterprise, organized on functional and territorial principles, covering all of Croatia's state territory, with clearly defined delegation of responsibility, accountability and managerial authority. With this Act the former inefficient self-management system was wiped out.

Accordingly, Hrvatska Elektroprivreda was organized in six divisions: Production; Transmission and Control; Distribution; Development, Engineering and Information System; Finance and Accounting and Legal, Personnel and General Administrative Services. Hrvatska Elektroprivreda was governed by a Managing Board consisting of nine members, the executive function was appointed to the General Manager.

Organized as such, Hrvatska Elektroprivreda fulfilled its fundamental task of electricity generation, transmission, distribution and Croatia's electric power system control. Besides, Hrvatska Elektroprivreda is re-

▽ A 400 kV network



sponsible for heat generation and distribution through a district heating system in Zagreb and Osijek, and gas distribution in Osijek.

Fundamental business principles of Hrvatska Elektroprivreda are defined by the Electricity Act: rational and efficient functioning, organizational and technological consolidation of all activities within the organization, clearly defined responsibility for the functioning of all parts of the electric power system, open-mindedness towards technological development and changes in the Croatian economic system, and organizational improvements in the interest of consumers and the owner.

After the collapse of Yugoslavia, Hrvatska Elektroprivreda broke off all business connections with the Union of Yugoslav Electric Power Industry (JUGEL), and upon its international recognition, the Republic of Croatia directly became a full and proper member of international professional and business associations such as UCPTE, SUDEL, CIGRE, IAEA, WEC, UNIPEDE, etc.

Following its foundation Hrvatska Elektroprivreda was faced with the war which directly affected the functioning of the system. Due to aggressor's attacks and

destruction of the Croatian power plants, substations, facilities of transmission and distribution network, the years 1991 and 1992 were exceptionally difficult. The forced separation of the Dalmatian area from the rest of the Croatian electric power system created difficult conditions for system functioning. Even in those difficult war days Hrvatska Elektroprivreda successfully performed its fundamental task. It supplied electricity throughout the free territory of Croatia to households and industry.

At the end of 1994, the Electricity Act was amended and harmonized with other legislation of Croatia by the decision of Croatian Parliament. On January 21, 1994 the status of Hrvatska Elektroprivreda was changed from a state-owned company into a joint stock company. Hrvatska Elektroprivreda still operates as a single company on the whole territory of Croatia, under government control. The single and the only owner is the Republic of Croatia. However, in accordance with the restructuring and privatization plan, a gradual change of ownership structure of the company is foreseen within the next five years. An Amendment to the Act enables the Croatian Government to sell off up to 25 percent of company's indivisible part, while the remaining 75 percent are subject to a decision of the Croatian Parliament. This opens the door for investments in and privatization of Hrvatska Elektroprivreda, especially in the field of electricity generation and distribution.

The Stockholder Assembly is at the head of the company, controlled by a seven member Supervisory Board. The company Hrvatska Elektroprivreda is run by the Management Board.

Goran Granić (1950, Baška Voda) was the first general manager of Hrvatska Elektroprivreda, appointed on July 31, 1990. Mr. Granić graduated from the School of Electrical Engineering, Zagreb, in 1972, received his M.Sc. degree in 1976, and Ph.D. in 1979. The subject of his Ph.D. thesis was the issue of energy planning. He is a senior research associate and assistant professor at the School of Electrical Engineering and Computing in Zagreb. Before being appointed Hrvatska Elektroprivreda's general manager, Dr. Granić was the head of Hrvatska Elektroprivreda's Development Department and a member of the Managing Board responsible for the development and construction in ZEOH (Union of Croatian Electric Power Industry). Dr. Granić is the chairman of the Croatian Energy Association and director of the Hrvoje Požar Energy Institute.



Δ Goran Granić

Ivan Putanec (1937, Zagreb) was appointed general manager of Hrvatska Elektroprivreda on January 7, 1991. He graduated from the School of Electrical Engineering, Zagreb, in 1960, where he received his M.Sc. degree in 1970 in the field of high voltage measuring techniques. Following graduation, he joined the Electrical Engineering Institute of the factory Rade Končar, then Westinghouse Engineering in Krško NPP. From 1981 to 1990 Mr. Putanec worked for Elektroprojekt, Zagreb, as chief engineer for electrical components in nuclear and thermal plants. In the fall of 1990, he was appointed Energy and Industry Vice Minister. Mr. Putanec is the chairman of the Croatian CIGRE Committee since its founding in 1992. Since 1993 he is the director of the company KONEL HV in Vienna.



▽ Ivan Putanec

Damir Begović (1948, Zagreb) is the general manager since May 7, 1993. He graduated from the School of Mechanical Engineering and Naval Architecture, Zagreb, in 1973. After receiving his B.Sc. degree, he joined the Design Office of INA-Engineering where he was responsible for designing equipment for refinery plants. He was a member of the construction team and start-up team for the Rijeka TPP. In 1978 he worked as project manager responsible for erection of process furnaces in oil refineries. After that, in the newly-formed INA-Projekt, Mr. Begović participated in preparations for the construction of the University Hospital in Zagreb. In 1985, he joined Elektroprojekt Zagreb as project manager of the Plomin II TPP. From 1991 he held the position of Industry, Shipbuilding and Energy Vice Minister. In 1994, Damir Begović was proclaimed the Manager of the Year within the large company category by the Croatian Managers Association. On the fifth anniversary of the Croatian National Day, May 30, 1995, Mr. Begović was conferred the Order of Danica Hrvatska portraying Blaž Lorković.

▽ Damir Begović



▽ The Peruća hydro power plant



HRVATSKA ELEKTROPRIVREDA IN THE PATRIOTIC WAR

Many workers of Hrvatska Elektroprivreda were soldiers in the Croatian army who, with arms in hand, defended their homeland on the front lines. Many more carried out the day to day repairs and maintenance of electric power facilities and networks. Climbing up poles and towers, entering substations the workers of Hrvatska Elektroprivreda were risking their lives under constant enemy fire. Through their efforts they restored electricity distribution to households thus returning trust in the strong and firm defense of the homeland. It should be mentioned that 21 workers of Hrvatska Elektroprivreda lost their lives and in fact became heroes of the Patriotic War, fighters for a free Croatia. Hrvatska Elektroprivreda has firmly left its mark in the Patriotic War, there where death and destruction were commonplace events and has written the most impressive pages in its hundred-year history.

A heavily destroyed system, a large number of refugees and considerably reduced economical activity have very much contributed to the decrease in electricity consumption in Croatia. In the pre-war year 1990, consumption was 14,750 GWh, i.e. about 3,000 kWh per capita. In the second half of the year 1991 yearly consumption fell by 12 percent, in the war year 1992 a further drop of 15 percent occurred. That decline stopped in the relatively peaceful year of 1993, but not until 1994 did electricity consumption in Croatia rise by 2.8 percent.

From September 1991 to the end of 1993 the war in Croatia escalated. The enemy attacked and destroyed numerous Croatian cities and settlements, from Vukovar, Osijek, Vinkovci, Slavonski Brod, Karlovac, Sisak, Gospić, Zadar, Šibenik, the wider area of Split right up to Dubrovnik and its wider surroundings. Public buildings were bombarded: cultural monuments of world renown (the old city center of Dubrovnik, the theater of Osijek, Šibenik cathedral, Vukovar town center) as well as churches, schools, kindergartens and hospitals in those Croatian cities and settlements which were under aggression. For strategic reasons the enemy attacked with equal intensity many facilities of Hrvatska Elektroprivreda from Slavonia to the south-

DESTRUCTIONS AND DAMAGES DURING THE PATRIOTIC WAR

Electricity generation facilities

1. Osijek CHPP
2. Sisak TPP
3. Peruća HPP
4. Dubrovnik HPP
5. Senj i Sklope HPP
6. Zagreb East CHPP
7. Jaruga HPP

Electricity transmission facilities

400 kV facilities

8. 400/110 kV Tumbri SS
9. 400/220/110 kV Konjsko SS
10. 400 kV Konjsko - Obrovac TL
11. 400 kV Tumbri - Ernestinovo TL

220 kV facilities

12. 220/110 kV Mraclin SS
13. 220/110 kV Bilice SS
14. 220/110 kV Đakovo SS
15. 220 kV Konjsko - Brinje TL
16. 220 kV Mraclin - Brinje TL
17. 220 kV Mraclin - TE Sisak TL
18. 220 kV Dubrovnik - Trebinje TL
19. 220 kV Zakućac - Mostar TL
20. 220 kV Zakućac - Konjsko TL

110 kV facilities

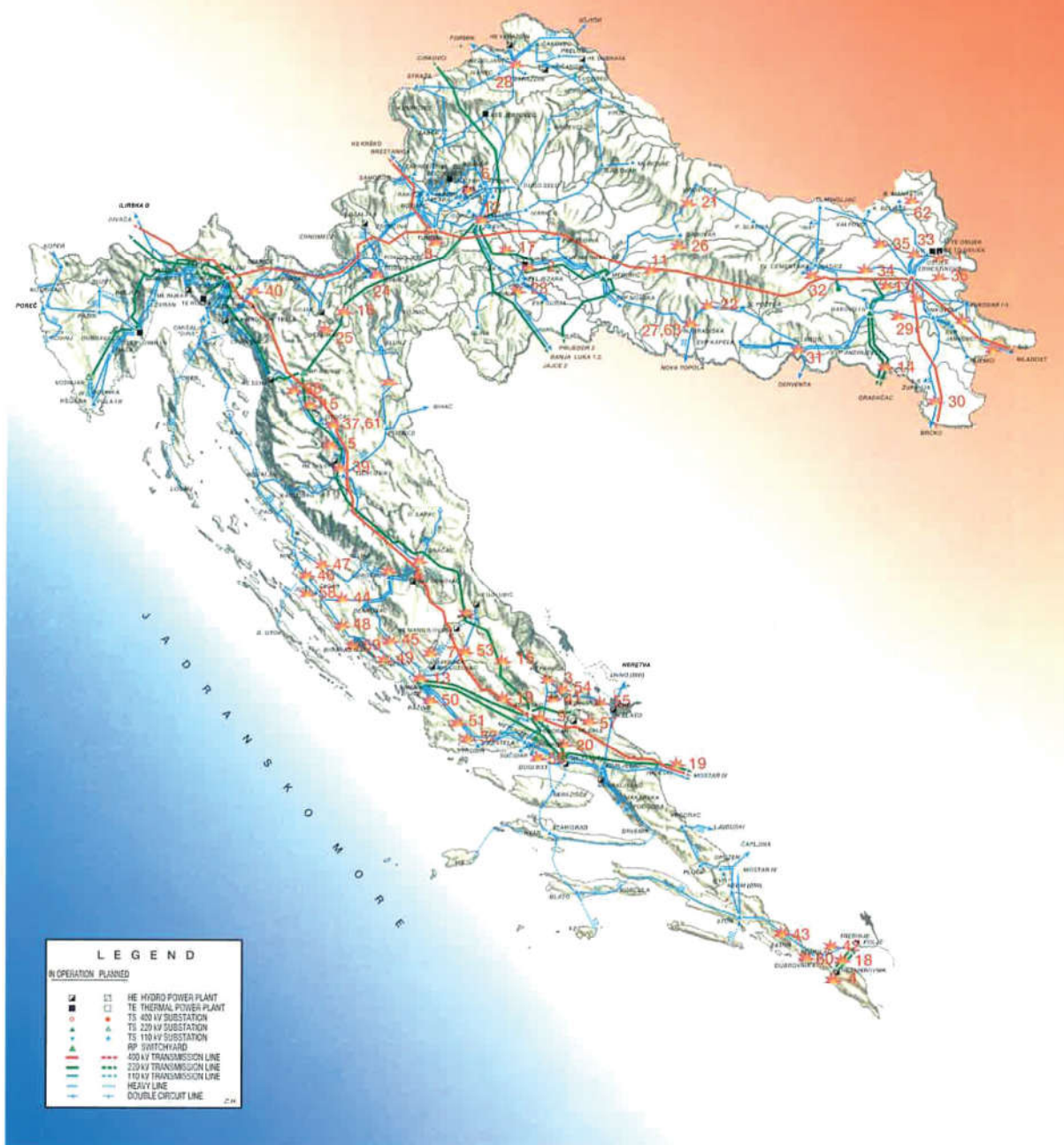
21. 110 kV Daruvar - Virovitica TL
22. 110 kV Nova Gradiška - Požega TL
23. 110/35 kV Pračno SS
24. 110/35/10 kV Švarča SS
25. 110/25 kV Oštarije TS
26. 110/35 kV Daruvar SS
27. 110/35 kV Nova Gradiška SS
28. 110/35 kV Nedeljanec SS
29. 110 kV Đakovo - Vinkovci TL
30. 110 kV Županja - Brčko TL
31. 110 kV Sl. Brod 1 - Sl. Brod 2 TL
32. 110 kV Našice - Cement Industry TL

33. 110 kV Osijek 2 - Osijek 3 TL
34. 110 kV Ernestinovo - Našice TL
35. 110 kV Ernestinovo - Valpovo TL
36. 110/x kV Osijek SS (Osijek 1, 2 and 3)
37. 110 kV Otočac - Lički Osik TL
38. 110 kV Senj - Otočac TL
39. 110 kV Sklope - Lički Osik TL
40. 110 kV Vinodol - Delnice TL
41. 110 kV Sinj - Meterize TL
42. 110 kV Trebinje - Komolac TL
43. 110 kV Ston - Komolac TL
44. 110 kV Obrovac - Zadar TL
45. 110 kV Bilice - Benkovac TL
46. 110 kV Zadar - Nin TL
47. 110 kV Obrovac - Nin TL
48. 110 kV Biograd - Zadar TL
49. 110 kV Bilice - Biograd TL
50. 110 kV Bilice - Ražine 1 and 2 TL
51. 110 kV Bilice - Vodice TL
52. 110 kV Bilice - Vrpolje - Trogir TL
53. 110 kV Bilice - Knin TL
54. 110 kV Peruća - Sinj TL
55. 110 kV Peruća - Buško blato TL
56. 110 kV Zakućac - Meterize TL
57. 110/35 kV Sinj SS
58. 110/35 kV Zadar SS
59. 110/35 kV Biograd SS
60. 110/35 kV Komolac SS
61. 110/35 kV Otočac SS
62. 110/35 kV B. Manastir SS
63. 110 kV Međurić - Nova Gradiška TL

LEGEND

CHPP	-	Combined Heat and Power Plant
TPP	-	Thermal Power Plant
HPP	-	Hydro Power Plant
SS	-	Substation
TL	-	Transmission Line
TS	-	Traction Substation

MAP OF 400-220-110 kV ELECTRIC POWER FACILITIES IN CROATIA DESTRUCTIONS AND DAMAGES





△ The Peruća dam, a day after being blasted, January 29, 1993



△ Initial remedial works on the Peruća dam

ernmost parts of Croatia.

It is difficult to describe in detail all of the destruction, to count all of the heroic actions and all of the efforts which can be attributed to the employees of Hrvatska Elektroprivreda. We will mention, therefore, just a few examples.

WAR DAMAGES

During the Patriotic War the most heavily damaged electricity generation facilities were the following hydro and thermal power plants: the Osijek CHPP, the Peruća HPP and the Dubrovnik HPP. The Sisak TPP, the Zagreb East CHPP and the Senj HPP were somewhat less damaged.

In September 1991, the Osijek CHPP was bombed and all of its vital equipment and facilities damaged, a total of 70 MW. In October the Peruća HPP, Dubrovnik HPP, Obrovac HPP, Miljacka (Manojlovac) HPP, Golubić HPP and Krčić HPP were occupied, a total installed capacity of 347 MW. Besides, Croatia remained also without the thermal power plants built for Croatian needs in Serbia and Bosnia and Herzegovina, a total installed capacity of 650 MW.

The fuel tanks in Osijek CHPP were destroyed. On the site of this thermal power plant, the gas-fired thermal power plant was heavily destroyed by bombardment. The switchyard was also destroyed as well as nearby auxiliary plants. This damage seriously reduced the capacity of electricity and heat generation for the city of Osijek.

During two attacks on October 1 and 17, 1991 the Dubrovnik HPP was damaged and occupied. The power house, warehouses, toolroom and workshop were ransacked, 220 kV transmission lines knocked down, and the access tunnel filled and mined. Fortunately, due to a mistake in planting the mines they did not activate. In 1993, the Dubrovnik HPP was liberated and the damage repaired. The previously mentioned power plants were liberated in August 1995, during the military operation Oluja (Storm) and their repair is

▽ Slavonski Brod - destroyed substation in the Masarikova Street



presently in progress.

The blasting of the Peruća dam on January 28, 1993 was one of the most serious crimes committed by the enemy during the war. The explosion destroyed the closing gate, overflow bridge, the inside gallery of the dam was heavily damaged, the switchyard flooded and filled with mud and the plant's power house also flooded. This 32 year old dam withstood the explosion holding back a mass of 470 million cubic meters of water which would have endangered more than 20,000 inhabitants in downstream settlements along the river Cetina.

Due to the enormous dam damage the storage basin had to be emptied, which reduced or completely stopped production in the remaining four downstream hydro power plants in the Cetina catchment. Dalmatia remained without its major source of electricity supply. If we additionally mention that the connections of high voltage lines with other parts of Croatia's system were broken, it is understandable why during the summer months of 1993 there was a big shortage of electricity in Dalmatia requiring considerable reduction in supply.

Hrvatska Elektroprivreda again proved to be capable of doing its job. This was especially evident in the case of the Peruća HPP and power reductions in Dalmatia. The workers of Hrvatska Elektroprivreda started repairing the Peruća dam and an emergency power supply program was introduced. In November 1991, the experts of Hrvatska Elektroprivreda devised



the operation plans for the case of extreme emergency which were embodied in the study titled *Dan poslije* (The Day After). Consequently, it was possible to form a crisis coordination team the very same night when the dam was mined to monitor developments on the dam and quickly commence repair work and rehabilitation of the power plant. By 1993, the power house was repaired, the remaining damage by the end of 1994 and in September 1995, during the celebration of one hundred years of Hrvatska Elektroprivreda, the greatest part of the storage basin dam repair was completed. For this achievement Hrvatska Elektroprivreda received numerous recognitions from well known Croatian and foreign experts in this field.

On the eve of the Patriotic War the transmission network of Hrvatska Elektroprivreda operated at 110, 220 and 400 kV and covered the whole of the Republic of Croatia. This network enabled the import and export

of electricity to foreign countries as well as neighboring electric power systems. Because of its integrating role in the whole system, war hostilities were directed at the transmission network, the first tower of the 400 kV Konjsko - Obrovac transmission line near Žegar, was mined in November 1990. During 1991 there was not a single part of the 400 kV network or 400, 220 and 110 kV substation that was not attacked, destroyed or damaged. Emergency actions and repairs of this network were frequent, often daily.

The bombardment, destruction and occupation of the 400/110 kV Ernestinovo substation near Osijek, a very important supply point for the entire Slavonia region, is a typical example. With its destruction almost a quarter of Croatia's consumers remained without electricity. However, through reconnecting a 110 kV network and numerous improvisations amongst which should be mentioned a 220/110 kV substation without

▼ Damaged and destroyed Ernestinovo substation



switching devices and appropriate protection equipment, placed on a meadow, the eastern part of Slavonia remained connected to the network in the most difficult war days.

The distribution sector of Hrvatska Elektroprivreda experienced great difficulties. Its performance in war conditions was, in spite of this, impeccable. All areas which were not directly affected by the war e.g. Zagreb, Rijeka, Pula, Varaždin, Zabok, Koprivnica, Čakovec and Bjelovar helped the war hit areas with material, equipment and people.

Section Vukovar of the distribution zone Vinkovci holds a very special place in the history of Hrvatska Elektroprivreda during the Patriotic War. The single remaining power supply connection between Vukovar and other parts of Croatia was broken on October 21, 1991 when the town was besieged up to its fall on November 19, 1991. The town Vukovar, its defenders and inhabitants remained in complete darkness, but not for long! Employees of Hrvatska Elektroprivreda had already by the end of September prepared and put into opera-

tion a small electric power system using generators available in the town and its surroundings. This enabled important town services to be regularly supplied with electricity and to function: water supply, kitchens, bakeries, a plant for the production and repair of weapons, town hall, police station, territorial defense headquarters, radio Vukovar, shelters for the local inhabitants and, particularly, the town hospital. At times the hospital cared for more than 400 wounded. Right up to the fall and surrender of the city into enemy hands the improvised electric power system functioned well. Afterwards a large number of these employees were to experience six months of insufferable captivity.

The example of Vukovar is just one of many. The employees of Hrvatska Elektroprivreda defended and repaired distribution facilities in many towns and villages from Slavonia to Konavle. Every area was destroyed in a specific way. It should be particularly mentioned that the employees of Hrvatska Elektroprivreda through their work in all regions during the Patriotic War gained the respect and admiration of the consumers.

The destruction of Croatia's electric power system, plants, network, substations and other facilities mostly stopped by the end of 1993. It is, therefore, possible to estimate, up to December 31, 1993 inclusive, the total direct damage at 2,100 million DM, and the indirect damage, caused mostly through lost profits and business losses created during the period 1991 through 1993, at 1,900 million DM. Out of stated amounts, applying World Bank methodology, the damage to generation, transmission and distribution facilities in Croatia amounts to 210 million DM; the damage due to Hrvatska Elektroprivreda's property losses in former Yugoslav Republics amounts to 1,550 million DM and the costs of the intervention program in Dalmatia amount to 340 million DM. These amounts do not, however, include the estimates for the areas liberated in 1995 and will be adjusted subsequently.

For the defense of the Republic of Croatia, in particular for the requirements of the Croatian army, and

for industrial and residential needs in the war, the activities of Hrvatska Elektroprivreda during the period 1991 - 1993 were exclusively directed to repairing war damage and building substitute facilities (intervention program), subsequently all available financial means were used for these activities.

Members of the European Union for the Coordination of Production and Transmission of Electricity (UCPTE) helped in the repair of war damaged facilities, following an appeal for technical help at the end of 1991. Electricity industries from Germany, Italy, Switzerland, Slovenia, France, Norway, Austria and Hungary offered their help. Together they delivered by the end of 1993, 10 million DM worth of technical help in the form of equipment.

The chronicle of Hrvatska Elektroprivreda during the Patriotic War would be incomplete if we do not mention that following liberation of the larger part of the occupied territory of Croatia in 1995, the employ-



△ Temporary substation built in 1992 after the destruction of the Ernestinovo substation

▽ Damage to the Osijek combined heat and power plant



ees of Hrvatska Elektroprivreda went into action re-establishing the electric power system. With the liberation of the 307 MW in hydro power plants in Dalmatia, transmission and distribution network full capacity was once more secured enabling effective management of the whole system. Thus, Hrvatska Elektroprivreda would provide for the start of economic activities in Croatia and restoration of normal living conditions on these territories.

RECONSTRUCTION OF ELECTRIC POWER PLANTS AND FACILITIES



△ Switchyard of the Sisak thermal power plant after enemy attack

At the beginning of 1993 a program for the reconstruction of facilities and plants of Hrvatska Elektroprivreda was already prepared. It included the repair and rehabilitation of war damaged electric power facilities on the free area of the Republic of Croatia as well as the proposed future repair of facilities in occupied regions after the liberation of these areas. The reconstruction program consisted of 32 projects: 5 for generation facilities (the Osijek CHPP, the Sisak TPP, Peruća HPP, Dubrovnik HPP and Senj HPP); 15 for transmission facilities and 12 for the reconstruction of distribution networks. The repairs of damaged facilities during the war were mostly carried out by the employees of Hrvatska Elektroprivreda alone, or in cooperation with the employees from the company Dalekovod. Enormous commitment was often called for during these repairs which were carried out under difficult conditions,



△ Gas fired thermal power plant Dujmovača, Split, 1994

almost invariably during or immediately following military actions. Some of these repairs had to be repeated as the facilities were being continually damaged through ceaseless enemy attacks. However, the employees of Hrvatska Elektroprivreda performed their tasks quickly and to a high standard, enabling all facilities to be as soon as possible once more used within the single electric power system of Croatia.

As a part of reconstruction of generation facilities of Hrvatska Elektroprivreda, new fuel tanks were built for the Osijek CHPP and its gas-fired plant has also been repaired and reconstructed. New fuel tanks have been built for the Sisak TPP, and one generator has been connected to the 110 kV network of the Dubrovnik HPP, the water intake was repaired in the Senj HPP, and the Peruća dam has been repaired and a freeboard constructed.

The Dalmatian area remained completely separated in energy terms from the remaining electric power system in 1993. An emergency program through substitute plants was implemented. These were mostly substitute diesel and gas-fired power plants which were erected on nine different locations in Dalmatia. They offer a total of 168 MW installed capacity partly generated by purchased and partly by leased plants. These plants very much improved the electricity supply conditions in Dalmatia from September 1993 onwards. Within this action, electricity supply to Dubrovnik and its surroundings has been re-established, and the Dubrovnik HPP directly connected to the Croatian transmission network instead of using the switchyard Mokro Polje in the neighboring country Bosnia & Herzegovina.

The first phase of the project Otočna veza (Cross Island Interconnection), to meet the energy demand of Dalmatia, was started and completed in 1994. Cross Island Interconnection represents a combined 110 kV overhead line and cable connection from the 400/220/110 kV Melina substation near Rijeka via the islands of Krk, Rab and Pag passing through Zadar and Šibenik to the 400/110 kV Konjsko substation near Split, as well as the 110 kV connection from Novalja on the island of Pag through Karlobag to Lika. As the intercon-



△ ▽ Cross-island interconnection, 1994.



nection Melina to Rab was completed beforehand, the link from Rab via Pag to Zadar was realized by overhead lines and submarine cables as a part of the first phase. Presently, the second phase, connecting Lika, is under way.

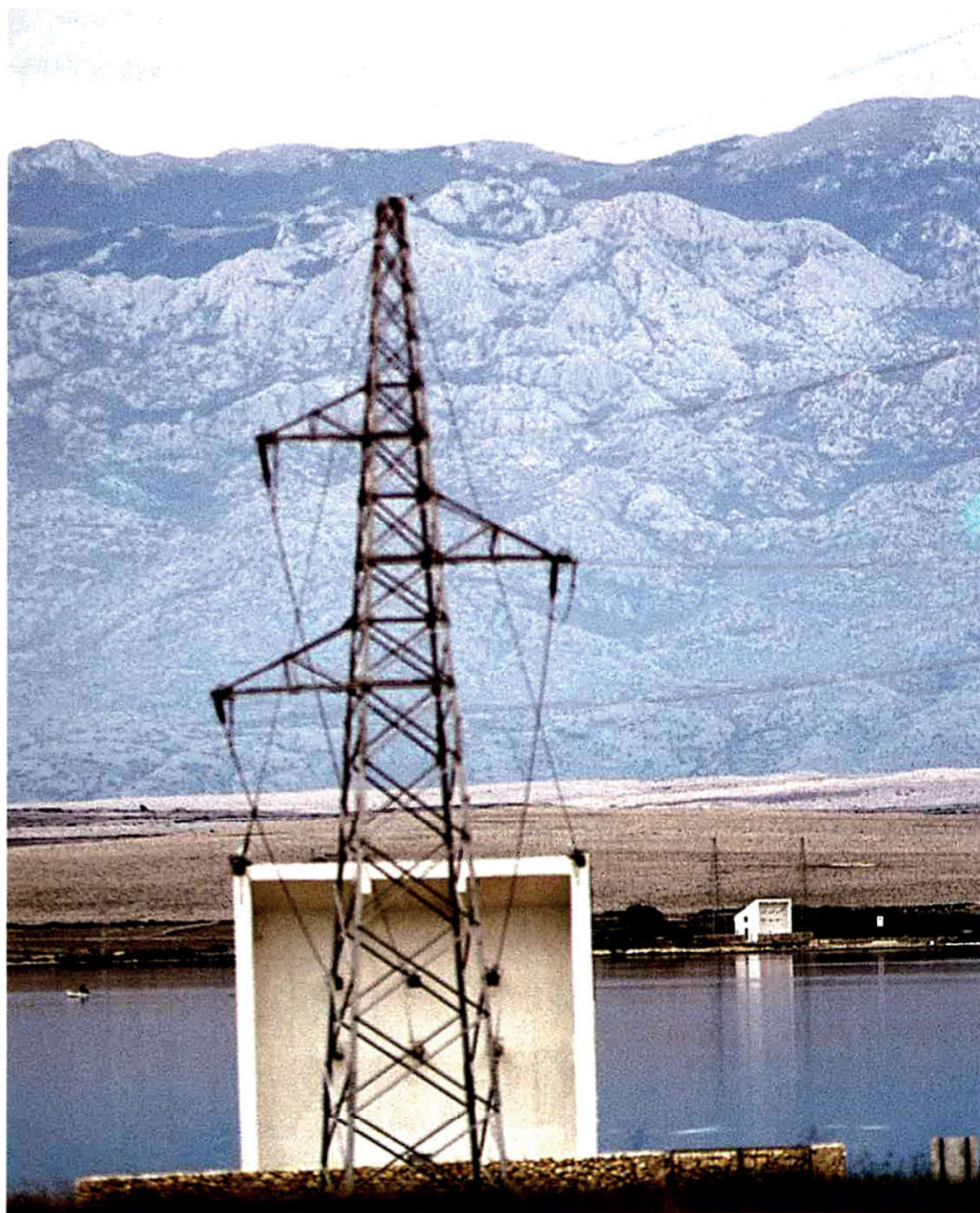
During the war besides the repair of damaged transmission networks and other electric power facilities stable and final solutions were implemented. For example the 400 kV transmission line from Tumbri near Zagreb to Melina near Rijeka was built and put into operation in 1992, the 110/20 kV substations Rab and Novalja on Pag in 1993, and the 110 kV transmission line from the Dubrovnik HPP to Komolac. Within the execution of the project Cross Island Interconnection the 110/20 kV Zadar Centar substation and 110/20 kV Pag substation, as well as numerous complementary facilities, are under construction.

In Slavonia, the eastern part of Croatia, the existing conductors were replaced in 1994 with 'black' conductors for the 110 kV Našice - Đakovo transmission line. This allows greater capacities to be transmitted from the temporary 220/110 kV substation built to the west of Đakovo. At the beginning of 1995, the 110 kV Valpovo - Donji Miholjac transmission line was built, extending beyond the Hungarian border. This connection with the Hungarian electric power system enabled an interchange of electricity between the two countries. The 110/35 kV Donji Miholjac substation is also being built as a part of this project.

In the liberated area of western Slavonia the 110 kV transmission line between the 220/110/35 kV Međurić and Nova Gradiška substations has been repaired and once again made operational. Thus another direction for electricity supply to Slavonia has been secured.

At the same time projects are being formed for several 400 and 220 kV transmission network facilities which will permanently solve the electricity supply in eastern Croatia and considerably improve the difficult electric power supply condition in this area.

▷ Cross-island interconnection, 1994



EMERGENCY WORKS AND NEW FACILITIES CONSTRUCTED DURING THE PATRIOTIC WAR

Temporary facilities

1. 220/110 kV "1505/2" SS - Slavonija
2. 110/35 kV "505" SS - Slavonija
3. 110/10 kV "Kava" SS - Dalmacija
4. 220 kV "1505/3" TL - Slavonija
5. 110 kV "505/1", "505/2", "505/3", "505/4" and "505/5" TL - Slavonija
6. 110 kV "2000" TL - Slavonija
7. 110 kV Bilice - Biograd TL
8. 110 kV Biograd - Zadar TL, branch to "Kava" SS

Temporary operation

9. 400 kV Tumbri - Ernestinovo TL at 220 kV
10. 400 kV Ernestinovo - B&H TL at 110 kV
11. 400 kV Konjsko - B&H TL at 220 kV
12. 110 kV Ernestinovo - Đakovo TL at 220 kV
13. 35 kV Lozovac - Zadar TL at 110 kV
14. 400 kV Melina - Obrovac TL at 220 kV

New facilities built during the war

15. 400 kV Tumbri - Melina TL
16. 110/20 kV Rab SS*
17. 110/35/10 kV Novalja SS*
18. 110/20 kV Zadar - Centar SS (under constr.)*
19. Rab - Novalja TL-CB*
20. Novalja - Nin TL-CB*
21. Nin - Zadar TL-CB*
22. Novalja - Karlobag TL-CB (under construction)*
23. 2x110 kV Dubrovnik HPP - Komolac TL
24. 110 kV Komolac - Ston TL
25. Connection of Dubrovnik HPP to 110 kV
26. 110/35 kV Komolac SS-new facilities 110 kV
27. 2x110 kV Vrboran - Dujmovača TL
28. 110 kV Valpovo - D. Miholjac TL
29. 110 kV D. Miholjac TL
30. 110kV Našice - Đakovo TL

* Cross-Island Interconnection

** Leasing

Facilities liberated during the military operation "Oluja"

31. 400/110 kV Obrovac SS
32. 110/35 kV Obrovac SS
33. 110/35/10 kV Lički Osik SS
34. 110/35 kV Gračac SS
35. 110/35 kV Knin SS
36. 110/35 kV Benkovac SS
37. 110/25 kV Knin TS

Facilities in eastern Slavonia

38. 400/110 kV Ernestinovo SS
39. 110/35/10 kV Vukovar SS
40. 110/35/10 kV Nijemci SS
41. 110/25 kV Jankovci TS
42. 110/35 kV B. Manastir SS

Emergency electricity sources in Dalmatia

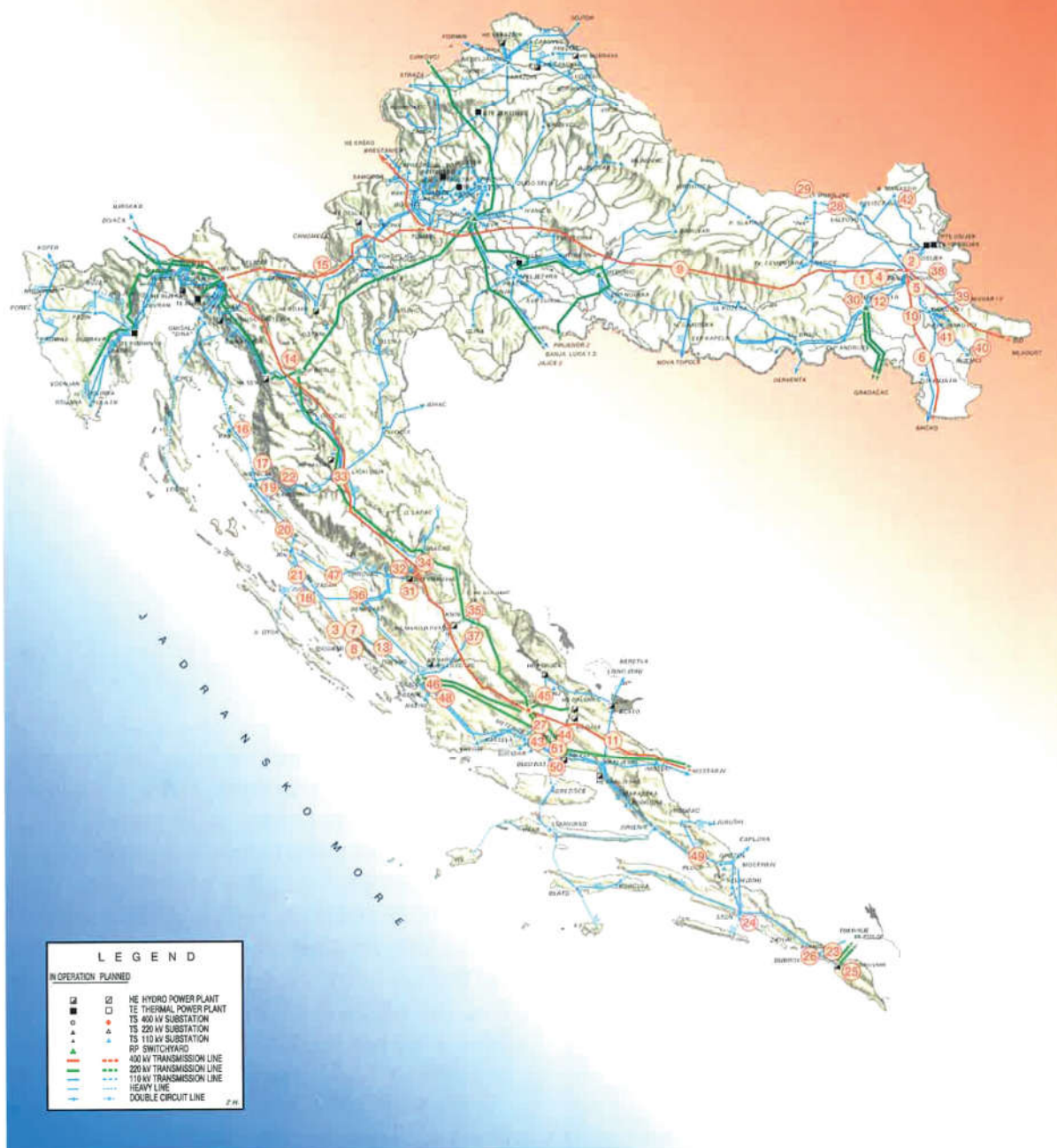
- | | |
|---------------------------|---------|
| 43. Dujmovača GTPP | 52 MW |
| 44. Split DPP | 15 MW |
| 45. Sinj DPP | 13,7 MW |
| 46. Šibenik DPP | 7,9 MW |
| 47. Zadar DPP | 15,6 MW |
| 48. Šibenik GTPP | 12 MW |
| 49. Ploče DPP** | 20 MW |
| 50. Omiš DPP** | 10 MW |
| 51. Dalmacijacement DPP** | 22 MW |

T o t a l: 168,2 MW

LEGEND

CHPP	-	Combined Heat and Power Plant
GTPP	-	Gas Thermal Power Plant
HPP	-	Hydro Power Plant
DPP	-	Diesel Power Plant
SS	-	Substation
TL	-	Transmission Line
TS	-	Traction Substation
CB	-	Cable

MAP OF 400-220-110 kV ELECTRIC POWER FACILITIES IN CROATIA EMERGENCY WORKS AND NEW FACILITIES



HRVATSKA ELEKTROPRIVREDA TODAY AND TOMORROW

▽ The illuminated Split



Hrvatska Elektroprivreda today owns a total of 4,396 MW installed capacity in power plants of which hydro power plants account for 2,075 MW (47%), thermal power plants 1,349 MW (30%) and nuclear power plant 332 MW (8%). The installed capacity of 650 MW (15%) in lignite fired thermal power plants constructed by Hrvatska Elektroprivreda and located outside Croatia's territory are presently unavailable.

Reconstruction and technological improvements of the existing power plants are absolutely essential due to their obsolescence, and in order to improve the utilization of energy potential of hydro and thermal power plants and provide for better environmental protection.

The total existing generating capacity of the power plants, respecting standard safety criteria, is approximately 17,000 GWh given an average yearly rainfall. Not using its unavailable capacity, Croatia's power plants are capable of generating about 14,000 GWh. As annual consumption in Croatia in 1994 totaled 11,039 GWh, which was 2.8 percent more than the previous year, and expecting a consumption increase in the following years, it is anticipated that existing capacity will meet annual electricity demand over the next five to six years.

At the end of 1994, Croatia had 1,734,530 consumers of electricity. Of these, 11 big consumers are directly connected to the high voltage network, and the remaining consumers to the distribution network. Industrial consumers totaling 1,780 are connected at different voltage levels (110, 35, 20 and 10 kV). Other individual consumers totaling 141,093 and household consumers totaling 1,591,646 are connected to the low voltage network.

Hrvatska Elektroprivreda uses a high voltage network of 400, 220 and 110 kV, its total length is 6,721 km (903 km of 400 kV voltage, 1224 km of 220 kV voltage network and 4,594 km of 110 kV voltage network). It has 106 substations with a total installed capacity of 9,635 MVA. The following period will be directed towards developing a high voltage network with increased transmission capacity and more reliable facilities. New technology and maintenance methods for



plants and networks will be introduced, and special attention will be given to live work.

The total length of Croatia's distribution network is 101,595 km, out of which 73,490 km is a low voltage 0,4 kV network (more than 70 %), 24,099 km is of 10 or 20 kV voltage, and the remainder 35 or 110 kV voltage. Total installed capacity of distribution transformers is 10,063 MVA, out of which 4,925 MVA is in seventeen thousand eight hundred and two (17,802) 10 or 20/0.4 kV substations. In three hundred and fourteen (314) 35/10 kV substations a total of 3,243 MVA is installed, and a remaining 1,895 MVA is installed in forty-three (43) 110/35 or 20 kV substations.

Due to economic and financial limitations the de-

velopment of the distribution sector has lagged behind that of production and transmission. This development was not consistent throughout different periods and individual segments of the network. It was especially slowed down after 1980 when for organizational reasons the investments in this sector of electricity industry were considerably reduced. It can be anticipated that, due to aging distribution networks, the repair and reconstruction of a third of today's total overhead network will be necessary, as well as approximately 10% of the present cable network. The 0.4 kV voltage network and accompanying 10/0.4 or 20/0.4 kV substations are in a particularly bad shape.

The distribution sector is gradually introducing

the so called direct transformation, meaning that the 110/35/10/0.4 kV four-level-voltage distribution system is to be converted to a 110/20(10)/0.4 kV three-level-voltage system. The introduction of new overhead power lines and cable conductors, new equipment and maintenance technology and live work is expected in the next development period.

Croatian electric power system is managed from a national dispatch center in Zagreb and four regional centers in Rijeka, Split, Osijek and Zagreb. Electricity distribution to consumers is effected through twenty-one distribution zones in the Republic of Croatia, controlling the belonging distribution network.

Democratic changes in 1990, put Croatia on the road of social and economic adjustment to a free market. As the war was imposed upon Croatia, the time required for the political settlement and the time essential for the restoration of Croatian economy will represent two fundamental determinants of the future economic development. The growth of electricity consumption in Croatia will depend on this. We can, however, with certainty say that it will increase, the fastest in the area of services, next in households and finally in industry.

Expecting an increased electricity consumption, a study of medium and long term development is presently being carried out. According to present estimates Croatian electric power system should meet 17 to 20 TWh of electricity demand by the year 2010. Besides building new sources of electricity Hrvatska Elektroprivreda must develop a reliable electric power network as a prerequisite for gaining power supply independence and a firm connection with Europe. An integrated transmission network will secure the distribution of high quality electricity to the consumers. Croatia's interconnecting transmission network will be of great importance in the European context. It is anticipated that Croatia's network would be able to take over some 25-30% of total electricity exchange between eastern and western Europe and thus become an important energy transmission factor in the direction northwestern-southeastern Europe. The connection to the re-

gional electricity groups of central European countries, interconnection with Greece and Turkey, and eventual realization of the so called Mediterranean Ring represents technological, economic and political challenges which face Hrvatska Elektroprivreda tomorrow.

Hrvatska Elektroprivreda's fundamental future task is to become a profitable and highly productive electricity industry up to the world standards, which can guarantee reliable and high-quality electricity supply to Croatian consumers at lowest possible costs.

This is the path that Hrvatska Elektroprivreda has chosen for the second century of its existence. It will enable Hrvatska Elektroprivreda to crown one hundred years of tradition and take a prominent place in the energy map of Europe, the place where Croatian pioneers and visionaries led it a century ago. ■



△ Transmission network of Hrvatska Elektroprivreda - connection to the world

The Publisher and Editorial Board are grateful to a number of people who have helped us with this publication.

Our thanks for exceptional contribution to:

Prof. Dr. Thomas Bohn, DIGE, Essen
Istvan Dénes, Ganz Ansaldo Ltd, Budapest
Rizah Hercegovac, ELIN, Vienna
Helmut Holzinger, ELIN, Vienna
Karl Hönigmann, Verbund, Vienna
Dr. Sándor Jeszenszky, Magyar Elektrotechnikai
Múzeum, Budapest
Klaus Mayr, ELIN, Weitz
Dr. Zoltán Reguly, MVM, Budapest
Dr. Michel-François Simon, EDF International, Paris
Dr. Antal Tombor, MVM, Budapest
Slavica Barta-Koštun, M.Sc., HEP, Zagreb
Milivoj Blažević, Šibenik Archive Centre
Nenad Bubrić, HEP, Šibenik
Jakša Bučević, Zagreb
Gustav Červar, Šibenik City Council
Vojmir Dvornik, HEP, Split
Krunoslav Galić, Elektroprojekt, Zagreb
Zdravko Kedžo, Šibenik City Council
Gojko Lambaša, Šibenik City Museum
Dražen Ninić, HEP, Šibenik
Karlo Ožegović, Split
Vinko Radić, HEP, Zagreb
Ante Sekso, IE, Zagreb
Ante Šupuk, Mayor of Šibenik
Gojislav Zubović, Šibenik

for textual contribution to this publication:

Nikola Dellavia, HEP, Zadar
Ivica Deranja, Pula
Damir Karavidović, HEP, Osijek
Božidar Kolega, HEP, Zagreb
Gordana Lučić, HEP, Zagreb
Riko Pera, HEP, Zadar
Zdravko Plander, Rijeka
Damir Pešut, IE "Hrvoje Požar", Zagreb
Božidar Radmilović, HEP, Zagreb
Marin Vilović, HEP, Split

the following persons and organizations for providing us with photographs appearing in this publication:

Archives of Elektroprojekt Zagreb
Archives of ELIN, Vienna and Weitz
Archives of GANZ, Budapest
Archives of HEP Public Relations, Zagreb
Petar Čerina, Split
DUC-Foto, Zagreb
Julije Huremović, HEP, Osijek
Mario Javorčić, Split
Lexicographic Institute "Miroslav Krleža", Zagreb
Hrvatske Željeznice Museum, Zagreb
Karlo Ožegović, Split
Ivan Perišić, Rijeka
Ivo Pervan, Split
Ante Sekso, Zagreb
Davor Šarić, Šibenik
Lav Šupuk, Šupuk Family Collection, Šibenik
Technical Museum, Zagreb
Frane Fantulin Collection, Šibenik

for administrative and technical services:

Višnja Bošnjak, Zagreb
Katica Jančić, HEP, Zagreb
Goran Penić, HEP, Zagreb
Marica Rak, HEP, Zagreb
Mario Rukavina, HEP, Zagreb
Neda Štos, HEP, Zagreb
Lidija Viher Papeš, HEP, Zagreb

<i>Published by:</i>	Hrvatska elektroprivreda d.d.
<i>For the Publisher:</i>	Damir Begović
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<i>Maps:</i>	Zlatko Huss
<i>Photolithography:</i>	Skaner studio, Zagreb
<i>Printed by:</i>	Tiskara "Kačić", Šibenik
<i>Printing Run:</i>	1500 copies

CIP - Katalogizacija u publikaciji
Nacionalna i sveučilišna biblioteka, Zagreb

UDK 621.31(497.13)

STOLJEĆE hrvatske elektroprivrede / [skupina autora ;
glavni urednik Milivoj Zenić]. - Zagreb : Hrvatska
elektroprivreda, 1995. - 166 str., {4} lista s kartama : ilustr.
; 30 cm

ISBN 953-96312-9-7

ISBN 953-96312-9-7

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