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SARAJEVO SCHOOL OF AUTOMATICS

Abstract: The war that led to the break of former Yugoslavia which started in 1992 in Sarajevo, the capital of the state of Bosnia and Herzegovina, ended a blooming production of instrumentation, projecting, development and research related to the control of flying objects, ships, and processing industry. Hundreds of engineers schooled mostly at Sarajevo University were working at up-to-date problems. Moreover, a part of instrumentation was based on a completely new concept, named presently as the sliding mode control. Quite a lot still cited articles were published in that field. The term “Sarajevo School of Automatics” was used in conversation in Yugoslavia.

A country, as Yugoslavia, that did not belong to the developed world was not expected to be the home of such an endeavor. This article has as the aim to try to explain how it happened through the story of its start and rise. The basic ingredients in this success, the author believes, were: the presence of very well educated work force, motivated not so much with salaries, but by interesting jobs; generous state financing of science, and few individuals who were truly passionate about control, and had a comprehensive approach to the development of control area. Of course, a good luck was also on the side of this development, and that makes the story vivid and interesting.

Key words: *control, instrumentation, education of engineers, culture, attitude to work*

The talks at this session are mostly analyses of the present or recommendation for the future. My presentation is a part of the project of ANUBiH which has a task to make a book of memories of its two members: Svetozar Zimonjić and Božidar Matić. It presents the birth and growth of the activities in the area of automatic control systems in the city of Sarajevo in former Yugoslavia. I was actively involved in the activities from 1960 up to 1992. The area of automation in general is conceived as a high technology field. In Sarajevo, it appeared and had grown not as a result of planning

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supported by the government investment, but as an effort of its managers and employees of the Energoinvest company.

This paper was written using interviews with people involved in control area, work related personal documents and contemporary newspapers. It therefore lacks standard reference list. The documents will be available in a mentioned book of memories.

The Bosnian company Energoinvest, founded by Emerik Blum to make projects for the development of electric power sector in Yugoslavia, started as Electroproject in 1951. The range of its activities was gradually broadened to deliver turn-key engineering of the processing plants and hydro and thermal electric plants. A very important task in such plants is to keep at a necessary level various process parameters as voltage, power, temperature, pressure, level, flow, etc. This task is done by control systems, other ways named automatic systems. Diversity of technologies in instrumentation production of control systems is great. Each control system has three main subsystems: sensors produce a signal (electrical voltage or current) proportional to value of the measured quantity. The controller obtains information from the sensor, compares it to the desired value of the measured quantity and makes a decision how to drive the plant in order to move the actual value to the desired value. The controllers' decision is delivered to the actuator in order to make actual changes in the plant. The actuators change their output according to the command of the controller, and so drive the plant to a desired state. Sensor, controller, actuator and plant make so named feedback loop. Many branches of sciences and engineering are involved in the development and production of the control system. At that time, and probably today, control systems development and making were done only in big and technically strong countries such as USA, France, Germany and USSR. It was not expected to be done in small and less developed countries like Yugoslavia.

In Yugoslavia, as in many countries of socialist block some sectors of industry were more advanced than the others. Such typical cases were military complex, electric power production and transmission, water supply, education and health. The main cause of their strength was their importance that channeled financial and material support of the government to these sectors. But, how to explain big ski factory of Elan, high scale cloth factory Mura, and music bands of Sarajevo and others? Their high quality and international success were not a result of the government plans and support. Such was also the development of production and design of control systems in Sarajevo, since the government did not have any particular interest in it. Obviously, only a very passionate entrepreneurship was behind this success.

The people involved in it did not do this to become rich. I consider that it is interesting to say something about their motives and show how it was done.

I came to Sarajevo from Belgrade in 1960 because I had to work in Energoinvest as I received a scholarship from this company. In the era of the shortage of qualified cadre the companies gave scholarships to attract the needed cadre. Energoinvest, for example, gave scholarships for Arabic language students, seeing the business with the Arabic countries in future. I wanted to work in the field of control, since I got passionate about it while taking the control class at the Electrical Engineering Faculty of Belgrade. In Energoinvest I found a group named the Bureau for Automation and Electronics, consisting of its head Svetozar Zimonjić, one electrical engineer, a few technicians and technical drawers. Zimonjić was very passionate about control. Emerik Bloom invited him to develop control sector in Energoinvest after a conversation in Ilijaš steel plant where Zimonjić worked. The future automatic sector would encompass research, development, production, installation and maintenance of control systems for Energoinvest's turn-key plants.

In today's era of globalization, such endeavor sounds absurd. Why one should invest so much effort and money to make something that can be purchased from some established maker. To understand this decision we must remember that in that time autarchy was acceptable, and benefits of local production were considered as obvious.

Off the record, Zimonjić did not want to employ me. He thought that I would be most of the time on a sick leave, bearing and raising children. I got the job anyway when my husband pulled some strings. Zimonjić initiated the research and development of basic instrumentation elements: sensors for pressure, temperature, flow, etc, electronic controllers, and converters which use electric signal to generate needed pressure in pneumatic and hydraulic actuators. Pneumatic actuators were used for security reasons and hydraulic actuators for huge force that they can deliver.

In that time the internet did not exist, technical books and journals were too expensive and complicate to acquire. Moreover, they did not had the necessary information. We gathered ideas form commercial leaflets. Of course, we wanted to establish cooperation with big producers and research institutes. The Germans flatly rejected our offer for cooperation. The Russian did not even bother to respond. We had to do it ourselves using basic engineering, common sense and trial and error. The prototypes of various devices we made worked properly, but the quality and their appearance were sometimes poor. Energoinvest was very supportive, but financing was scarce. A random encounter brought a change to our isolation.

A group of Russian scientists from the Institute of Automatics and Remote Control of the Academy of Sciences of USSR was on their way from Moscow to a conference on control in Dubrovnik via Belgrade and Sarajevo. In that time this Institute was the world's top place for control theory. Energoinvest was asked to host the group for one day. Zimonjić gathered a small group of Russian speaking engineers to welcome and entertain Russian scientists. He threw a dinner party at nearby mountain Trebević. A member of this group was Stanislav Vasiliyevitch Emel'yanov, the director of one of the Institute's laboratories. Zimonjić and Emel'yanov talked all evening and thus a long and fruitful friendship began.

The next morning, Russians visited Energoinvest control laboratory and control production unit. They saw our budding research and production of control instrumentation. Probably they noticed a very qualified working force and use of components from Western countries, which were unavailable in Russia. Emel'yanov invited Zimonjić to visit the Institute. Zimonjić mentioned the unanswered letter proposing cooperation. Emel'yanov got red in face and said that the letter was sitting on his desk. In this way the cooperation between the Institute and the Control group of Energoinvest started.

For starters, several members of automatics sector made study visits to the Institute. Russians visited us too. They liked Yugoslavia and Sarajevo. We had some trappings of Western culture, there was much more freedom, the food and wine were good and the Adriatic seaside attractive. The attitude towards Russians was traditionally much friendlier than in the countries of Soviet block.

The Emel'yanov laboratory worked on a new, unknown to the West, way of control named Variable Structure Control (VSC). It had some very important beneficial features, that other conventional approaches to control did not have. The area of VSC looked very promising. After a while, the situation became ripe for more formal and substantial cooperation. Two big and important projects were completed. The first one was the development and production of a process control system based on VSC approach. The second one was development of VSC for induction motor control.

The control instrumentation for the first project was successfully developed, produced and implemented in Yugoslav and Russian plants. The control of the induction motor had a different outcome. The induction motor was invented by Yugoslav scientist Nikola Tesla. This motor is cheap, simple, non-polluting, durable and reliable. Also it can develop a large torque. Probably 95% of all the electrical motors in world are induction motors. However, their speed is not easily adjustable and therefore they are not suitable

for actuators. The project on the VSC induction motor speed control design has been completed by developing a prototype system of 40kW power machine (1980). The test on the Sarajevo street car (1984) demonstrated the feasibility and the needed technological improvements. The prototype has been tested on smaller servo drive and served as a starting point for the later work in power electronics.

The Automatics sector of Energoinvest did not stay on process control instrumentation only. Other kinds of instrumentation production units, based on similar know-how, were started one by one. These were Measurement systems, power lines protection, high power electronics application, etc. Two institutes for research and development were formed. One was named IRCA (Institute for Automation and Computer Science) and dealt with control, and other named IRIS (Institute for Computer and Information Systems) dealt with computer based applications in industry. Some examples of these institutes' accomplishments were sale of computer networks and SCADA to China, sale of a patent for flow sensor to USA, complete software for control and planning of Electrical power networks etc. Gradually IRCA mastered control of moving objects as ships, airplanes, tanks, and robots. Note that the control of moving objects is much harder than control of plants. The automatics sector employed more than thousand workers, mostly highly qualified engineers and technicians.

The question one may pose is how it was possible to attract and keep so many brilliant engineers whose skills and knowledge were in demand. To explain this, we have to go back to 1960. Emerik Blum was a man with a vision. In present terms he behaved as owner, not as a hired CEO considering his job as a tool to get a better position. As a matter of fact, many lower level employees had the same attitude.

The labor law at that time made very difficult to fire anyone. This fact had two opposing impacts on work culture. On one hand some employees avoided work pursuing some other interests, and some were, simply lazy. On the other hand, talented and industrious employees thought that they will probably spend all working life in the same company. The slogan was that a factory belongs to workers. Their owner's attitude originates from that law. They were devoted to their jobs, willing to tolerate low salaries that even were not paid in time. Today most of them say that they could not wait to start interesting tasks in the morning.

Since in 1960 Sarajevo had three technical Faculties of Mechanical Engineering, Civil Engineering and Architecture, Blum initiated and enabled foundation of the Faculty of Electrical Engineering. First lectures were given in 1960 in the cellar of the building of the Faculty for Economics. The

next year regular classes began. First two years were devoted to the fundamental knowledge needed in all fields of electrical engineering and subsequent three were devoted to diverse areas of electrical engineering taught at four departments. The firstly founded was Power Engineering Department, obviously badly needed in Yugoslavia. Then the Department of Automatics and Electronics was established, followed later by the Department of Computer Sciences, and, finally, the Department of Telecommunication.

Department of Automatics and Electronics was the first such department in Yugoslavia, and maybe one of the first in the world as well. One of the most important tasks in Yugoslavia was building of process industry, and when trying to define what to teach automatic control students, an original approach to define curricula for control in processing industry was necessary. The curriculum was made by members of Automatics sector in Energoinvest, using more common sense than copying other control departments. The teaching standards were high. Since fundamentals for STEM were very well covered both in high schools and during the first two years of university education, students hadn't big problems to understand and master courses. It should be noted that some courses were part of MSc and PhD programs at Western universities. Examples are Optimization theory, Identification of systems, Adaptive systems, Artificial intelligence, Theory of organizations, etc. The classes were interesting, jobs plentiful, and employment almost guaranteed. No wonder Automatic and Electronics Department attracted many smart youngsters. It is important to add that a nice percent of students were girls. Students who completed Electrical Engineering Faculty were willing to work long hours, and were very productive and full of initiative at the job. This was probably one of key reasons for the success of the Electrical Engineering Faculty, the Energoinvest Company and Control area.

The other component was the fact that two main persons in the development of Control sector, Svetozar Zimonjić and his remarkable successor Božidar Matić were like Emerik Blum people of passion and vision. They were willing to take administrative positions where decisions concerning science and development were made. Zimonjić became a member of the Central Committee of the Socialist Party, faculty dean and the president of the Academy of Sciences and Arts of Bosnia and Herzegovina. His remarkable achievement was the change of the law which funneled a lot of money to research at universities and in industry. This had very beneficial influence to the science in Bosnia and Herzegovina. (When I, in early '90, taught at the University of Urbana and AM University in Texas, I found in my office computers far inferior to the ones I left on my desk in Sarajevo.)

Young people were employed in research. Some branches of research were equal, and even more advanced to the ones in the West. No wonder that engineers who left when the war in Bosnia started got jobs easily in the advanced countries.

Božidar Matić did wonders for Automatics sector. He raised IRCA to a high level. Later Matić became Energoinvest director, Rector of Sarajevo University and Secretary for Science and Technology in former Yugoslavia. The law, about financing the science and research in Yugoslavia was named Matić's law. After the war he was shortly a Prime Minister of Bosnia and Herzegovina, and a long time president of the Academy of Sciences and Arts of Bosnia and Herzegovina.

There was one more important factor for Automatics sector success, i. e. the cooperation with Russians and inclusion in starting years of research of VSC with sliding modes. The invention about of this kind of nonlinear control is attributed to famous Russian rocket scientist Boris Nikolayevich Petrov. Emel'yanov was his PhD student and follower. He founded the Laboratory for VSC. Automatic Sector in Energoinvest and Electrical Engineering Faculty got very much involved in research, devices development and production of VSC systems. Dozens of PhD, MSc and BSc theses were defended at the Electrical Engineering Faculty. It should be noted that until 1990 very few control researchers outside of USSR and Yugoslavia knew what it was about. Some fundamental advances of VSC as State Space approach, Discrete VSC systems, and VSC converters were originated in Sarajevo. Two VSC workshops were held in Sarajevo. The first took place just before the begging of the War in Bosnia. The term Sarajevo School of Automatics came into use.

The end here is not a happy one. The War in Bosnia started in 1992. Sarajevo was under the siege for four years. Many engineers and other professionals left and started new professional lives abroad. The ties with customers were severed. The production was impossible. The other companies now make control systems. A few factories that are now built do not need control systems. Today, automatics lives through departments of Automatics and Electronics at Electrical Engineering Faculties in Sarajevo and East Sarajevo.

What can be a conclusion of this story that can be relevant for the future in Bosnia and Herzegovina? I am ignorant in economics. I am just an electrical engineer devoted to the Control theory and still doing research in this field. I wonder whether the story of Sarajevo School of Automatics can be repeated nowadays? The globalization pushes us to concentrate on the production where we are strong. Such are healthy food, tourism, forestry,

Electric power production for export, etc. These are the fields where highly educated young people in STEN area do not find enough of jobs. If this path is followed, the brain drain will be worse and worse. Young bright people do not want high-paying jobs. They also need interesting and meaningful jobs, the one they would be proud of. Maybe a direction to high technology jobs would be a solution to the brain drain that runs down our most precious resources.