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DEVELOPMENT OF THE TELEMECHANICS INDUSTRY IN THE USSR

M. A. Gavrilov

Telemechanics is one of the young branches of electrotechnics which has been developed only recently. In the USSR the first practical and efficient telemechanic installations for industrial purposes appeared in 1932-1934. Despite the short time, the technique of telemechanics has reached a highly-developed state, and Soviet specialists have obtained important results both theoretically and in the practical development of telemechanical installations.

The necessity for a wide application of telemechanics is explained, first, by the fact that telemechanical installations, for remote control, long-distance signaling and telemetry, are becoming more necessary organically in directing and controlling modern industrial enterprises and systems. The progressive use of automatic production processes, connected with reducing or completely eliminating man power by industrial machinery, has increased the demand for centralized control and direction. To accomplish this, considering the enormous extent of present-day industrial enterprises, telemechanical methods must be applied.

Wide application of telemechanical installations is also necessitated by the progressive introduction of continuous-production methods which require employment of centralized control and direction to coordinate joint operations in individual units or plants. Telemechanical installations are also necessary in directing and controlling systems covering a large territory, such as power and water supply systems, long oil and gas pipe lines, etc.

Moreover, the use of telemechanical installations makes it possible to safeguard workers by enabling them to carry on direction and control at a distance, from machinery which must be installed in places where a worker could not be stationed.

The technical and economic effect of the application of telemechanical installations has been of great importance in their development. As a result of the elimination or reduction of man power and the economies thus effected in

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workers' wages and accommodations, the introduction of telemechanical methods of directing and controlling now, more efficient technological procedures, the additional expense involved in telemechanical control usually pays for itself within a year or two. This makes such installations very profitable.

The greatest use of telemechanical apparatus is in power installations. At present, the great network of electric power stations and substations for parallel operation, the creation of a great number of huge net power systems serving areas covering thousands of kilometers, require extensive utilization of telemechanical installations which form complex systems for remote control and telemetry. The use of telemechanics, moreover, is practical for smaller municipal networks as well. In the USSR during the war, plans were made for extensive application of telemechanics in centralizing and directing power systems in many large metallurgical plants. Telemechanical equipment should be extensively employed in municipal water and drainage systems and in trolley track networks to direct traction substations, in street-lighting systems, etc.

Telemechanical installations are also extensively used in rail transport to direct the traction substations of electrified railroads and underground railroads, to control switches and road signals and to transmit signals to locomotives (cab-signaling and autoregulation). The present tendency is to run substations without attendants, under full telemechanical control and direction from a central point. There are now many such automatic, remote control traction substations in the USSR.

Finally, telemechanic apparatus began to be employed recently in air transport for remote control of numerous landing and take-off signals at large modern airdromes.

The great expansion of functions of telemechanics and the increased complexity of telemechanic systems characterize the present state of the technique. Whereas such installations were previously used in individual, isolated plants to carry out comparatively restricted functions, they are now often employed to combine individual industrial units and plants in complex cooperative systems.

An example of such a complex system is the telemetric integrating instruments which regulate the work of individual installations forming part of a system and which depend upon the total amount of work of all the systems as a whole. Other examples are instruments for the automatic (remote) regulation of power distribution. At present the operation of huge combined power systems is based largely on these instruments. As an indication of the scale on which such appliances are used, we might point out that, to have long-distance regulation in one of the huge combined power systems in the US, it was necessary to install more than 60 telemetric setups.

Telemechanical operations in the USSR were conducted at first on a purely practical basis and were directed toward working out telemechanical setups for various industrial uses. These operations were carried on in a number of industrial and scientific research organizations. As a result, domestic remote control and telemetric systems were created to equip a large number of plants and systems.

In the remote control field, two special trends should be noted in the work accomplished by various groups of specialists. The first group worked on distributive-type remote control appliances, on the basis of the standard telephone apparatus. The first remote control installation made by this group, and the first set up in the USSR, was developed in 1934 under the direction of Engineer M. A. Gavrilov in the industrial laboratory of one of the large power systems. This installation used polar signals and was set up in a power system to act as a signal transmitter from a 110-kilovolt-network substation to the central dispatching center. Later improved remote control appliances using time signals were developed in the same installation by Engineer R. L. Raynes, M. I. Paretskiy and B. K. Kornetsov. These appliances are now widely used. This type, in particular, forms part of [illegible] equipment [illegible] dispatching (control) center of one of the great USSR water supply systems, a vast telemechanized center. From this center, control is exercised [illegible] including [illegible] pumping stations and one hydrostation, supplied by long-distance signaling and telemetry. The number of installations under remote control is comparatively small, but an increase in this number is planned soon. The telemechanic apparatus installed in this system was put in operation in 1938 and in a short time gave reliable service.

This type of apparatus was also installed in a USSR power system as a transmitter at a dispatching center for oil cut-off signals. At present this apparatus in a slightly modified form, under direction of Engineer V. F. Ronzhin, has been installed to transmit signals in one of the huge hydrostations in this system. Later, with the aid of this apparatus, remote control will be put in operation here for hydro-aggregates. Signal transmission will be carried on in this station by high-voltage lines.

Another great telemechanized center in the USSR is the dispatching center of the USSR transport systems. In this system in 1941 a few automatized traction substations operated without man power under the sole control of a dispatching center. Both the designing and assembling department (under Engineers L. G. Rashkovskiy and R. L. Raynes) and the operators of the system (under Engineer A. G. Mel'nikov and Ye. A. Kaminskiy) took part in planning and assembling the apparatus for this work. During the war telemechanical installations were dismantled. In 1943, however, work was resumed on telemechanization and by 1945 a new dispatching center was equipped, and the substations, which had been telemechanized earlier, were again put in operation without man power and with remote control of all aggregates from the dispatching center. The new remote-control apparatus with amplitude selection, which had been developed by the operators of the system under Engineer Ye. A. Kaminskiy, was installed in these centers. Remote control will soon be introduced into other substations.

Work was also done in telemechanizing the traction substations of one of the large city trolley lines. Here one of the designing and assembling departments under Engineer L. C. Rashkovskiy with the aid of the operators under Engineer N. A. Zagaynob equipped a substation with an experimental remote control installation which operated quite successfully under practical conditions.

Another group of remote-control specialists developed appliances of the distributor and combiner-distributor types for use with coding apparatus. Out of all the remote-control appliances developed by this group only the RTU-type (Engineer B. K. Shchukin) relay-distributor system of remote control is in actual use. This type remote-control apparatus, produced partly by the scientific research department, but largely by the operators under Engineer V. N. Borisov, was installed before the war in one of the great power systems to control oil cut-off and to transmit signals about such cut-offs from stations and substations of a high-voltage system. The apparatus operated in a thoroughly reliable manner both in this and in other systems.

Among the remote-control appliances developed by the above group of specialists we should also note types KRP and KPV (combination-distribution polarized and combination-distributor auxiliary remote control apparatus), developed and turned out as efficient installations immediately after the war (Engineer R. I. Yurgenson). These appliances, equipped with the best indicators for that time of any appliances developed in the USSR as to time of transmission and specific number of contracts and relays, were tested by a special committee and recommended for industrial production. Unfortunately, this could not be realized because of the outbreak of World War II.

To conclude the description of remote-control developments, we should mention the appliances developed for remote control of street lighting systems and centralizing apparatus for dispatching relay-coding. The most modern street lighting appliance was developed for one of the large USSR cities under the

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direction of Engineer A. A. Veprintsev. Centralized dispatching relay-coding, used for remote control of railroad switches and signal lights, was put in operation in 1936 and now serves track sections with an approximate length of 90 kilometers. After a short time it operated satisfactorily.

In the telemetric field, three trends in the work accomplished in the USSR should be noted. One of the first started was the development of various types of rectifiers and photo-compensators. These appliances, developed in a scientific research institute branch in 1931-1934 (Engineer A. V. Mikhaylov), were manufactured on a small scale and, after installation in a number of power systems, proved very reliable.

Another organization developed a frequency-impulse type of telemetric apparatus. Many modifications were made in its design by Engineer M. I. Paretskiy, S. A. Ginzburg and O. K. Kvitzinskiy. However, only the frequency-impulse appliances with condenser transformers (Engineer O. K. Kvitsinskiy) were put into practical use. These appliances now form part of the equipment of the largest integrating and telemetric plant in the USSR in one of the power systems which has many appliances for integrating the active power of station generators, measuring from a distance the cumulative power at a dispatching center and establishing the total active power of all the systems as a whole. The system also includes some sets of appliances for remote measurements of separate quantities.

The third trend in this field, which has brought practical results, is the development of photo-impulse appliances for telemetry in one branch of the laboratory for measuring instruments (Professor M. L. Tsukkerman, Engineer Lukyanskiy, Candidate in Technical Sciences A. V. Fremke, V. O. Arutyunov). The dispatching center of one of the great USSR power systems was equipped with several of these appliances. This laboratory also invented several individual parts to be combined in telemetric appliances (in particular, rectifiers and inductors). These parts are very simple forms of telemetric systems, but in combination they can form more complicated installations which will fulfill almost any conditions of practical use.

A frequency-type telemetric appliance (Engineer Minin) was recently developed by a research and exploitation organization. A test model was set up early in 1947 to work under the power-system operating conditions and performed well.

Beside these practical developments, Soviet specialists in telemechanics have accomplished a great deal of theoretical work. Some of it represents a considerable advance over similar work abroad.

First, a great amount of basic work was accomplished by Soviet specialists in analyzing telemechanical appliances, examining their working principles and generalizing the present state of the technique. Among such works are: "Centralized Control of Electric Installations and Systems" by Professor B. I. Daranskiy (1933); "Selector Elements" (1936) and "Theoretical Bases for Estimating and Constructing Remote Control Apparatus" (1936); by Professor N. A. Livshits; "Telemechanization of Dispatcher Control in Power Systems" (1938) by Engineer M. A. Gavrilov; and "Remote Control" (1940) and "Bases of the Technique of Remote Control" (1945) by B. K. Shchukin.

The work of Soviet specialists on various problems in the theory of telemechanical appliances is also extremely important.

The most important questions in the theory of telemetric apparatus are those on the dynamics of telemetry and the theory of error. These problems have not as yet been finally solved either here or abroad. Moreover, their study involves difficulties related to the fact that telemetric appliances usually are combinations of various gauge and transformer elements working together, and themselves have interconnections. Consequently, in studying their transitional processes and errors, it is necessary to deal with complicated dynamic systems for which no satisfactory method or research has been worked out.

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The first efforts along the lines of dynamic telemetry were research on dynamic properties and on a method for calculating definite types of telemetric appliances. Here mention should be made of the work of Engineer A. V. Mikhaylov and Yu. G. Kornilov on the theory of telemetric appliances with current-compensation and the work of Engineer S. A. Ginzburg on methods for calculating the dynamic qualities of receivers for frequency-pulse telemetry. The work of A. V. Fremke is more general in character. In his thesis for a doctor's degree, he made a general investigation of the dynamic properties of telemetric appliances and found a method of calculating their parameters to obtain the minimum damping time, by studying the coefficients of a differential equation characterizing the dynamic properties of the appliance under examination in comparison with the coefficients of a standard equation. He also studied the action of interconnections on the dynamics of telemetry.

Engineer G. M. Zhdanov and V. O. Arutyunov studied error in telemetric appliances. The former furnished a method for calculating additional errors in connecting lines and a method for calculating the parameters of telemetric appliances by summing up the voltages. The latter studied general problems in the theory of summation. The work of B. E. Berdichevskiy, who studied error in integrating appliances to carry out additions over connecting lines, should also be mentioned.

But the works mentioned above cover only some aspects, however important, of error. From a more general standpoint, still to be studied, the problem of determining error in telemetric or integrating appliances is as follows: given the amount of error in the parts forming the telemetric appliance, to determine the amount of error in it as a whole, or given the error in each of the telemetric appliances forming part of the integrating appliance, to determine the total error of this appliance as a whole. One complication in this problem is that, in general, especially in designing telemetric and adding appliances, only the type or degree of accuracy of the elements composing the appliance may be known, while the concrete amount of error is not known. Such errors can, therefore, be determined only by their distribution curves as incidental quantities showing the degree of precision in the given element. There are similar difficulties in determining the error in adding appliances where the share of error in each of the telemetric appliances is determined by the distribution of the sum, at any given moment, of the various components and is, consequently, itself an incidental quantity.

In addition to works of a general character, Soviet specialists in these fields (Professor K. S. Karandeyev, Professor M. L. Tsukkerman, A. V. Fremke, Candidate in Technical Science, S. A. Ginzburg, V. O. Arutyunov, N. F. Gatkurha and others) have published a number of studies on the theory of action and calculating methods, and descriptions of the construction of various telemetric appliances in the USSR.

The most essential points in the theory of remote-control appliances are work on the problem of the theory of selection and structural synthesis and analysis of the setup of appliances for remote control.

Various Soviet specialists (Professor N. A. Livshits, Doctor of Technical Sciences M. A. Gavrilov, Candidate in Technical Sciences B. K. Shchukin and R. N. Yurgenson, Engineer R. L. Raynes, M. I. Paretskiy, and others) have devoted themselves to problems of the theory of selection. These problems are in large part solved theoretically, although additional study is required for some aspects.

The theory of structural synthesis and the analysis of remote-control appliances are much less advanced. Usually such appliances are complicated, multiple-duty relay-contact systems. Until recently they were designed on the basis of the experience and intuition of the designer. Hence, the development of a theory for the construction of relay-contact systems has been of major importance in the development of the theory of remote-control appliances. Until recently, the work accomplished by Soviet specialists (Engineer A. K. Kutti, M. M.

Tsimbalistyy, V. A. Rosenberg) only touched on various special problems in constructing relay-contact systems, and no practical application was made.

Impetus to the development of the theory of relay-contact systems was given for a time by proof of the applicability to them of algebraic logic supplied in particular, by the work of Candidate in Physico-Mathematical Sciences V. I. Shestakov. Further essential development was given this theory by Doctor of Technical Sciences M. A. Gavrilov, who worked on the general theory of structural synthesis and on an analysis of relay-contact systems which would be valid for all classes and types. The establishment of this theory permitted its present extension to developments in constructing remote-control appliances themselves. The essential difference between the theory of remote control and the theory of relay-contact systems is that, whereas in the latter the problem consists of constructing a setup which will satisfy definite conditions, composed of separate elements (contacts, reactive relay organs and active mechanisms, valve parts, etc.), fulfilling simple functions and possessing simple properties, in the theory of remote-control appliances the problem is complicated by the fact that the very elements of which they are composed are complicated relay-contact systems. It is essential to establish definite criteria which will permit objective comparison both of the remote-control appliances as a whole and of their various connections. It is also essential to work out methods of selecting and combining the latter to obtain remote-control appliances with definite parameters.

Besides the aforementioned general works, Soviet specialists have published many works on the theory and principles of action and on descriptions of the construction of various type remote-control appliances developed in the USSR (M. A. Gavrilov, R. L. Raynes, L. G. Rashkovskiy, I. V. Shavlovskiy and others).

This summary of practical and theoretical developments in the field of telemechanics shows that much has been accomplished and telemechanical apparatus is sufficiently perfected in the USSR. It has operated reliably under working conditions, and needs only some modernization along the lines of recent improvements and of present theoretical ideas. In the field of theoretical developments in many basic problems of the theory of telemetric and remote-control appliances, the work of Soviet specialists is far in advance of similar work abroad. These conditions guarantee a rapid development in the industrial production of telemechanical apparatus and the extensive employment of such apparatus in the Soviet economy, corresponding to existing demands.

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