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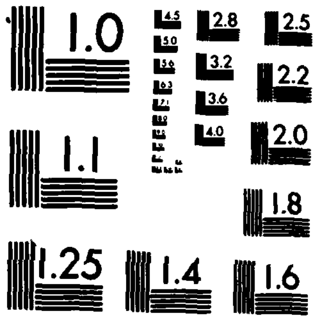

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FOREIGN TECHNOLOGY DIVISION

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by

Tadeusz Flisek and Ryszard Lewandowski

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COMMUTATION PROBLEMS OF POLISH TELEGRAPH NETWORK

Tadeusz Flisek and Ryszard Lewandowski

The Polish telegraph network, both the telex and cablegram network, is fully automated. However, the commutation equipment used is technically very obsolete. It allows users to establish only so-called ordinary connections without providing any facilities. The multiaddress telegraph equipment developed in the Gdansk branch of the Communications Institute does not change the situation since first, this equipment (although it is very necessary) handles only a part of the wide-ranging assortment of needs and second, so far only its prototype has been produced (in the District Posts and Telecommunications Workshops in Lublin), which is servicing only the Lublin District in Provincial Administration-Local Administrations relations.

To modernize the telegraph network, new commutation equipment must be introduced and old commutation equipment must be modernized. Work is being conducted along these lines on electronic (computerized) telegraph and data transmission centers, which has been initiated and is being conducted in the Telegraph Establishment of the Gdansk Branch of the Communications Institute with the participation of the TELKOM-TELMOR Electronics and Telecommunications Plant in Gdansk. Systematic introduction of these centers in the network will transform the presently used imperfect telex and cablegram network into a modern network integrated for all telegraphy and noncyclic data transmission services. The complexity of the problem also requires intensified work on modernization of exchanges in the TW-55 system. Below the article presents in a concise manner the results of an engineering-cost analysis justifying the usefulness (or even necessity) of such an undertaking.

State of Telegraph Networks

Two telegraph networks of the communications sector exist in the country: the telex network and the cablegram network. Each of these networks has separate functional links and commutation exchanges. However, their equipment is installed next to each other--exchanges in the same building, links in the same trunk routes. The reason for separation of the networks is the shortcomings of the commutation equipment in the TW-55 system, on which automation of both telegraph networks is based. Subscribers of the cablegram network can establish connections with subscribers of the telex network. Message traffic in the opposite direction is forbidden (also technically).

The telex network is larger and also undergoing faster development. Mainly because of the inflexibility of the commutation system, the network was divided into two numbering zones: "0" (five tandem central offices) and "8" (one tandem central office). The network has a two-plane structure. The tandem central offices forming the higher plane are interconnected in a full polygon system ("each to each"). Each of about 40 substations forming the lower plane is connected to two tandem central offices, of which one is closest to the tandem central office of zone "0" and the other, to the tandem central office in Warsaw.

The topological layout of the cablegram network differs from the layout of the telex network mainly by the number of exchanges, both tandem central offices offices as well as substations. In addition, in some localities, the cablegram substation is connected to a different tandem central office (zone"0") than the telex substation.

The numbering of subscribers in a network, in principle, is neither completely secret nor uniform. In connections within the area of the same tandem central office, one need not select, for example, the directional number of the tandem central office. Connections in the telex network are metered, depending on the distance of subscribers, according to one of two rates. Connections in the cablegram network are not metered by equipment in the tandem central office.

The TW-55 commutation system, as an operational system without a register, does not provide subscribers with many required basic services, and does not allow one to optimize the organization of the network. The essential systems shortcoming of TW-55 exchanges are:

- lack of a register, and therefore lack of the possibility of storing and processing the number of the called subscriber, which does not permit flexible establishment of connections in the network;

- lack of identifier of category of subscriber, which does not allow one to differentiate subscribers in the area of services and selective introduction of facilities;

- low directional availability (k = 10), which entails small throughput capacity of links and hence higher cost of the network;

- use of electromechanical biased relays introducing great signal distortions, not allowing the introduction of data transmission at rates exceeding 50 bits/s.

Planned Development of Telegraph Network

The planned development of the telegraph network, more accurately, the telegraph-data transmission (noncyclic) network, constitutes the main theme of the studies of the Telegraphy Establishment in the Gdansk Branch of the Communications Institute. The studies encompass both the concept of the network as well as modern equipment, both commutation and transmission equipment (multiplex telegraphy and multiplex systems).

The engineering-cost analysis that was made confirms the results of earlier studies [6] that in the case of a complete polygon system (each tandem central office connected to every other tandem central office) the domestic network is optimal with six tandem central offices. From the curve presented in Fig. 1 it follows that a system with six tandem central offices is optimal both for the existing state ($N \approx 30,000$ NN), as well as from the long-range standpoint ($N \approx 200,000$ NN).

Despite the fact that the network system with six tandem central offices is optimal, from the long-range standpoint, another solution must be taken into account, namely, the possibility (and usefulness) of integrating the telegraph network with the telephone network, for which 12 tandem central offices are envisioned, must be taken into consideration.

With 12 tandem central offices in the domestic telegraph network, connections according to the "each to each" principles become cost-inefficient as a result of the great breakup of the structure of message traffic. Therefore, the 12 tandem central office telegraph network does not anticipate many direct connections between tandem central offices, for example, the tandem central office in Szczecin with the tandem central office in Rzeszow or with the tandem central office in Bialystok.

Because of reliability considerations, a tendency exists to connect every substation to two exchanges. In view of the great connection flexibility of electronic exchanges, the second tandem central office (to which the substation should be connected) does not have to be (like now) a tandem central office in Warsaw. The second exchange does not even have to be a tandem central office. It can be the nearest substation, provided that other considerations allow it (for example, the degree of distortion).

The Telegraphy Establishment is also conducting studies on a determination of the character of equipment in the lower plane of the network (substation centers). At the present time, the latter are substations. In the future, both substations as well as line concentrators and also multiplexers only can be used. The preliminary results of these studies are presented in Fig.2, which allow us to fomulate the following general conclusions:

- a system with a multiplexer ($E_{c,1} = 0$) gives the lowest cost only in cases of small capacities of substation centers ($A_0 \leq 7$ Erl) and short substation center-tandem central office links (to about 40,000 zlotys);

- a system with a concentrator ($E_{c,3} = 0.6$) is less costly than a system with a substation exchange for lower substation center capacities and for cheaper links, e.g., for $A_0 \leq 45$ Erl, the concentrator is cheaper with tandem central office-substation center links, which do not cost more than 100,000 zlotys.

- the volume of local message traffic in the substation center (traffic between subscribers of the same substation center) influences considerably the mutual relationship between the cost of a system with a concentrator and a system with a substation. The curves in Fig. 2 were plotted for local message traffic, which is greater than the average traffic (for example, for $A_0 =$ = 30 Erl, the local message traffic amounts to about 11% of the generated message traffic).

Characteristic Features of Electronic and Data Transmission Centers

In the 1973-1975 period two teams of specialists were entrusted with the task of conducting an analysis of initiating the production and introducing in operation telegraph commutation systems for the public network in the communications sector of the Polish People's Republic. The final conclusions of the studies conducted by the teams included the statement that the development of the domestic telegraphy network must be based on commutation equipment produced in the country. The Communications Institute was entrusted in 1976 with the development of an electronic system of commutation centers for telegraphy and data transmission to 300 bits/s. A user model of such a center with a capacity 2x256 terminals was developed and produced in 1976-1980 as part of theese studies.

After analyzing the available literature on electronic telegraph exchanges and taking into account in 1976 the existing program for the production of computer equipment and components and subassemblies, the concept of a center was developed whose functional diagram is presented in Fig. 3.

The following basic assumptions were adopted in this concept:

- application of a minicomputer adapted to operation in a real-time mode as the central control unit;

- ensuring transparency of the center in the range of modulation rates and codes;

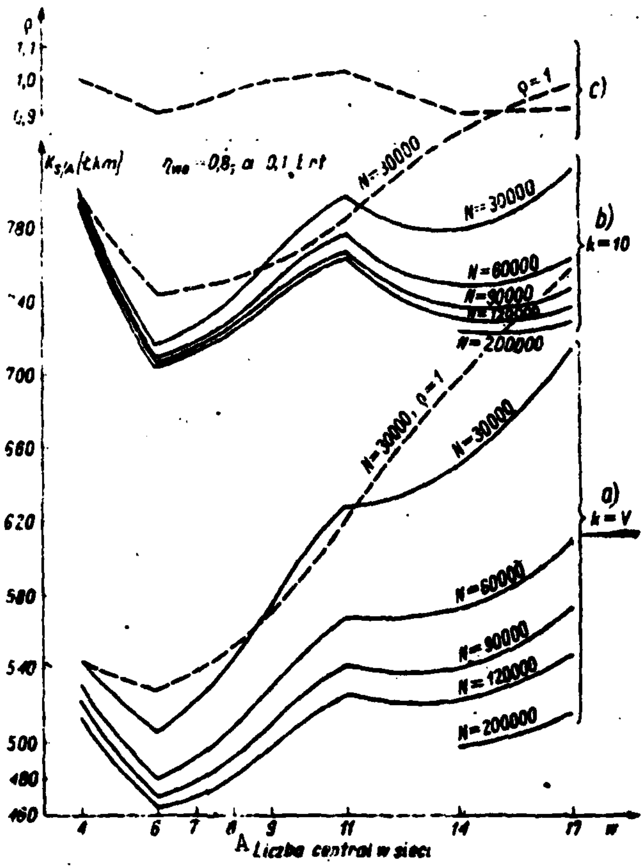

Fig. 1. Cost (expressed in terms of the number of link-kilometers) of servicing message traffic units in the domestic telegraph network versus the number of tandem central offices in this network: a) during full availability of link groups, k = V (V = number of links in group in a given direction); b) during limited availability of group of links, k = 10; c) deviation (expressed as a percentage) of real distances between tandem central offices from mean calculated value, equal to 410.5 km. The irregular graph of the curves is due to the change in the mean distance between tandem central offices (for different numbers of tandem central offices) resulting from the actual location of tandem central offices.

η_{wo} = share of interstation message traffic in message traffic arriving to tandem central office

α = traffic on substation exchange-tandem central office sector per subscriber

ρ = coefficient determining deviation of real distance between tandem central offices from mean distance

Key: A. Number of tandem central offices in network

- realization of characteristic (rated) telegraphy modulation instants by exchange;

- application of commutation field with time-sharing (asynchronous);
- doubling of all group and exchange equipment;
- utilization of structural base of E10 licensed exchanges;
- modular structure of exchange with 256 terminals for each module (a module need not be complete);

The functional diagram of the user model of the telegraphy and data transmission center distinguishes the following:

- equipment servicing single links;
- doubled equipment servicing a group of 256 links, which comprise: identifier, demultiplexer, linear data processor, commutation storage, commutation call buffer storage, and transmission call storage;

- doubled equipment servicing the entire center, which includes: the central control unit, the internal memory, the commutation signal path, the transmission signal path, a set of interacting data processors, and peripheral equipment;

- control-measurement and monitoring equipment (not shown in Fig. 3).

Telegraph links terminating in repeaters can be in one of the following states : rest, establishment of connection, message exchange, disconnection, and failure. These states of the link are represented in the memory of the linear data processor and in internal memory.

Every change in the electric state of the link detected by the repeater causes generation of a "Request for Service" associated with this link. Two types of Request for Service are distinguished. The first is associated with detected changes in the following states: rest, establishment of connection, disconnection or failure. This commutation type request is directed to the linear data processor, where, after preliminary processing, it can be transmitted to the central control unit. The second type of Request for Service is associated with changes detected in the link in the message exchange state. This transmission type request is directed to commutation storage bypassing the linear data processor and the central control unit.

Establishment of a connection takes place as follows: the change in the electrical state of the link detected by the repeater is transmitted to the identifier, which after confirming the Request for Service of the commutation type, transmits it to the linear data processor for the purpose of preliminary processing. The information stored in the linear data processor consists of the physical number of the link and its logic state (0 or 1). If additional processing of the Request for Service is requested by the central control unit, the corresponding information is directed to the central control unit via the commutation call buffer and the signal commutation path.

Rules (programs) for servicing individual links are stored in internal memory. These rules define unambiguously the set of admissible intermediate and terminal states of individual links in successive phases of establishing a connection, where decisions made by the central control unit are based on control-check information contained in the call from the linear data processor. Methods for servicing successive calls are defined. The effects of servicing are: generation of the appropriate response to the link, storage in linear data processor memory, and commutation memory. For example, the response of the central control unit to depressing the calling button in a teletypewriter is transmission to the subscriber via the commutation signal path, commutation call buffer storage, commutation storage, and conversion of the signal actuating the teleprinter, and also transmission of the appropriate information to the linear data processor.

In the case when message exchange has been established between links in the same group, the bias change and the physical number of the link are directed to the multiplexer and via the repeater to the link (subscriber). In the case when the analysis of the read out number shows that the interacting links belong to another group, data containing the change of state and destination address are directed via transmission call buffer storage to the signal transmission path. This

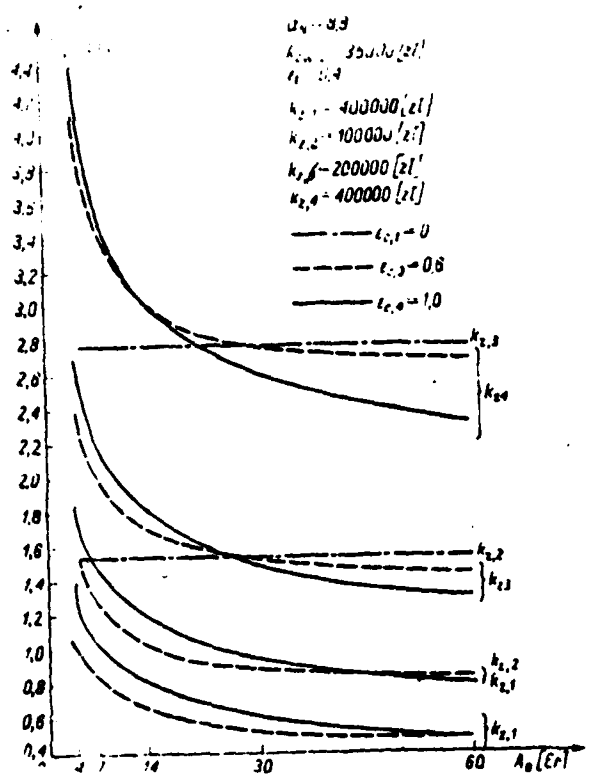

Fig. 2. Cost of servicing unit message traffic (K_0) in lower plane of network versus capacity of substation center expressed in terms of quantity of generated traffic A_0 by subscribers of tandem central office

$a_N = 1/a_0$, a_0 = mean traffic generated by one subscriber

k_{cw} = unit cost of tandem central office (cost of single terminal in tandem central office)

k_c = unit cost of substation center

k_z = cost of link on tandem central office-substation center sector

s_c = ratio of unit cost of multiplexer ($s_{c,1}$) or concentrator ($s_{c,3}$ = 0.6) to unit cost of substation center

s_1 = ratio of cost of subscriber link to cost of tandem central office-substation center link

Capacity of substation center: $N = a_N \cdot A_0$

Cost K_0 takes into account:

- cost of subscribers' lines
- cost of links on tandem central office-substation center sector (for both directions of message traffic)
- cost of substation center;
- cost of tandem central office

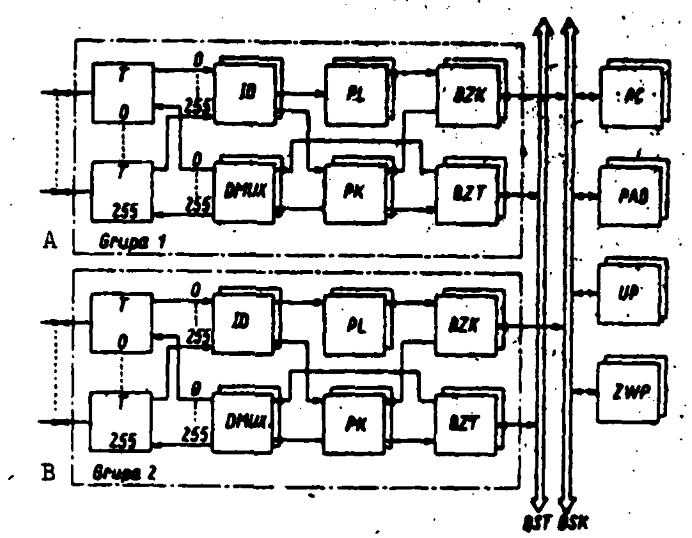

Fig. 3. Functional diagram of user model of Electronic Telegraph and Data Transmission Center

T = repeater   ID = identifier   DMUX = demultiplexer
PL = linear data processor   PK = commutation storage
BZK = commutation call buffer storage   BZT = transmission call buffer storage   DSK = commutation signal path   DST = transmission signal path   PC = central control unit   PAO = internal memory   UP = peripheral equipment   ZWP = set of interacting processors

Key: A. Group 1   B. Group 2

information is analyzed in transmission call buffer storage on the basis of an analysis of the most significant bits of the destination address (physical number of link interacting in transmission) and the change of state is transmitted via the multiplexer to the appropriate link.

The software of an electronic telegraph center constitutes a specialized real-time operating system. The latter is characterized by processing of a very large number of short, highly time-dependent tasks. The system must also ensure high reliability of the center, even in the case of failure of some system in the center. The functional structure of the system includes the following program modules: data management module, commutation call service module, administrative module, diagnostic and testing modules. All operating system programs are stored on disc memory, while data management module programs, commutation call service programs, and the diagnostic module programs determining malfunctioning of systems in the commutation part of the center are permanently stored in internal memory. The remaining programs of the operating system are read into internal memory if needed. The capacity of the center is basically determined by two parameters:

- number of calls per unit time which the control unit can process;
- number of bias changes which can be transmitted over the signal transmission path, taking into account the fact that a portion of the message traffic is locked out within groups.

The number of calls which can be processed by the central control unit within one sector depends on its operating speed, the sharing of tasks in the central processing unit and the linear data processor, and the efficiency of the software that is used. Overloading the central control unit can cause deterioration of signal parameters (for example, an increase in telegraph signal distortions) transmitted via the central control unit in the direction of subscribers or links between centers. To avoid these inconveniences, the linear data processor was equipped with the necessary mechanisms which allow it to calculate corrections and thus neutralize possible delays in the response on the part of the central control unit.

The capacity of the exchange for connections in the transmission phase is determined by the signal transmission path operating cycle. In the user model, this cycle is about 0.5 μs. Therefore, in 1 s about $2X10^6$ bias changes can be transmitted, which gives on the average, assuming 4 bias changes per character in alphabet number 2, 500,000 telegraphy characters per s. This is equivalent to the simultaneous operation of about 70,000 teletypewriters at full speed (about 400 characters per min).

The result of an analysis of the operation of individual systems in the center and the results of measurements that were obtained showed that a model of the electronic telegraphy and data transmission center operates with very high traffic and time redundancies and that delays in servicing individual requests (calls) are negligible.

Basic Technical Data of User Model of Electronic Telegraphy and Data Transmission Center

Supply - 220 V, 50 Hz, ±60 V, -48 V

module capacity: 256 terminals

signaling--type B in conformity with CCITT recommendations (different if necessary)

Number selection method: teletypewriter keyboard or dial

Number of categories: at least 100

Services and facilities

- closed group of subscribers with exit right
- closed group of subscribers without exit right
- abridged selection
- multiaddress calling
- conference connection
- private branch exchange (PBX)
- transmission of information pertaining to rates
- identification of subscribers
- limitation of range of established connections

Service stations:

- intermediate station
- operator station
- order stations

Link diagnostics:

- station for automatic tests of subscriber lines
- station for automatic tests of links between centers according to recommendation R.79
- test text station
- automatic distortion measurement stations
- manual measurement station

Problems Involved in Modernizing Network

Transformation of the existing, very imperfect domestic telegraph (telex and telegram) network into a modern telegraph-data transmission network requires the solution of many problems and surmounting many difficulties. The data transmission network is such an extensive, complex, and important system that it cannot be modernized all at once. It is a gradual transformation process in which the transformations must take place during full availability of the network (with message traffic). Specific features of the Polish telegraph network include the fact that from an operational standpoint the commutation exchanges are new (the utilization time of about 70% of the numbers does not exceed 5 years) and technically very obsolete (design from the 1930s). Every modernization of this network must be based on these characteristic features. The latter implies the following conclusions: simple replacement of TW-55 exchanges electronic telegraph and data transmission centers is not justified from an economic standpoint; TW-55 exchanges must still be used for a long time; however, leaving the TW-55 exchanges unchanged would deprive subscribers connected to them of the possibility of taking advantage of new services and facilities for a long time.

Taking into consideration the above conclusions, several concepts have been proposed for modernizing the Polish telegraph network. These concepts are based on satellization or hybridization of substation centers or microcomputerization of TW-55 exchanges. Replacement of tandem central offices by electronic telegraphy and data processing centers is assumed in the case of satellization or hybridization of substations.

Satellization of a substation involves subordinating it in all analytical and logic processes to the superordinated tandem central office. A subscriber connected to the substation exchange becomes in fact a subscriber of the tandem central office, which is equipped with suitable capabilities for servicing the former (memory, programs), etc. The conditions for satellization are:

- possibility of transmitting to tandem central office the complete number of the requested subscriber;

- possibility of determining number by tandem central office (and possibly category) of calling subscriber.

The substation must be appropriately adapted to meet these conditions. In the case of complete satellization, the local message traffic in a substation realized between subscribers connected to the same substation is handled via the tandem central office.

Hybridization of a substation involves equipping the latter with an electronic "separation" stage in the form of an electronic telegraph and data transmission center, which takes over all analytical-logic functions of a substatiion. At the same time, local as well as external traffic is serviced by the electronic telegraph and data transmission center, which also locks out local connection paths. The tandem central office "sees" such a substation as an exchange of the electronic telegraph and data transmission system. In the simplest case, the TW-55 substation interacts with "its" electronic telegraph and data transmission substation center similarly as in the case when they are separated by territory. The TW-55 substation must also be suitably adapted in the hybridization case.

Microcomputerization of the TW-55 exchange involves introducing in it, between the WW and WGI stages, a register (known as a register complex) designed according to microcomputer technology. This register complex, depending on the hardware and software, can fulfill the function of a register proper, specialized computer, transmitters, and receivers of various codes, analyzer of category of subscriber, etc. It also allows one to increase availability of trunk groups in the TW-55 exchange [5]. Microcomputers can also be introduced both in substations as well as in tandem central offices. Microcomputerization, which imparts to tandem offices the characteristics of computer centers (see Table 1), also requires a suitable adaptation of TW-55 exchanges.

The following concepts for modernization of the telegraph network were developed on the basis of the very general characterization of the above concepts for modernization of TW-55 exchanges:

- concept WS: replacement of tandem central office by electronic telegraph and data transmission center, satellization of substation;

- concept MS: microcomputerization of tandem central office, satellization of substation;

- concept H: replacement of tandem central office, hybridization of substation;

- concept WM: replacement of tandem central office, microcomputerization of substation;

- concept M: microcomputerization of tandem central office and substation.

The qualitative effect of a modernization of the telegraph network according to the analyzed concepts are presented in Table 1. On the other hand, the quantitative effects are presented in Fig. 4.

The curves in Fig. 4 were plotted under the following assumptions:

a) in view of the great number redundancy in TW-55 exchanges, two states of the network are distinguished: "installed" state and "occupied" state. The cost of switching from the "occupied" (state) to the "installed" state of the network is calculated. This corresponds to an increase in message traffic by about 70%.

b) One substation is used as the basis. The cost takes into account the following costs: cost of modernizing substation, the portion of the modernization cost (replacement) of the tandem central office for the analyzed substation, the cost of increasing the number of links on the substation-tandem central office sector, and the portion of the cost of increasing the number of links between tandem central offices for the analyzed substation.

Modernization concepts (M, WM, H, and E) ensure full (or nearly full) availability of groups of links in all circuits and provide great economy (savings) of the number of links. These economies (savings) are so large that, for example, in concept M, in exchanges with generated message traffic to about 85 Erl, they are greater than expenditures incurred in modernization of commutation equipment.

Table 1. List of Basic Characteristics and Modern Services Provided by Telegraph Exchanges

Characteristic or Service	Modernization Concept WS	MS	M	WM	H
Possibility of discriminating categories of subscribers	1	1	1	1	1
Possibility of flexible direction of message traffic	1	1	1	1	1
Possibility of introducing data transmission (at a higher rate than 50 bits/s)	0	0	1	1	1
Possibility of introducing uniform secret numbering	0	0	1	1	1[a]
Possibility of increasing availability of directions (trunk groups)	0.5[b]	0.5[b]	1	1	1
Possibility of selecting teleprinter keyboard	1	1	1	1	0
Possibility of centralizing metering	1	1	1	1	1
Possibility of using automatic transmission service line for connecting telex subscribers	1	1	1	1	1
Possibility of introducing multiaddress connections	0[c]	0[c]	1	1	0[c]
Possibility of relaying to subscriber information about connection rates	0[c]	0[c]	1	1	0[c]
Possibility of introducing "store and relay" services	0[c]	0[c]	1	1	0[c]
Possibility of introducing abridged selection	0[c]	0[c]	1	1	0[c]
Possibility of introducing direct connections	0[c]	0[c]	1	1	0[c]
Possibility of introducing closed groups of subscribers	0[c]	0[c]	1	1	0[c]

a) Only during dial selection
b) Only in tandem central office-substation point to point circuit
c) Introduction of service is possible during mixed dial-keyboard selection

For comparison purposes, Fig. 4 shows the cost of switching from the "occupied" state to the "installed" state of the network by way of replacement of all TW-55 exchanges by electronic telegraph and data transmission center exchanges (curve E).

From a comparison of the curves it follows that the lowest cost of modernizing the telegraph network is attained in the case of realization of concepts M or WM. These concepts also ensure the greatest qualitative effects (Table 1). Concept WM is of particular interest, since as a rule tandem central offices are most heavily used and for this reason their replacement may be justified. On the other hand, tandem central offices, in view of their superordinated functions in the network, are burdened with many additional tasks (statistics, diagnostics) requiring large memories.

Curve O in Fig. 4 represents the cost of a switch from the "occupied" state to the "installed" state in the case when the network is not modernized. From the graph it is evident that it represents the highest cost. It is the cost of additional links between exchanges used in particularly disadvantageous systems (availability equal to 10). Therefore, not modernizing the network, besides not providing even basic services and facilities to subscribers, is also the most expensive solution.

The present state of the telegraph network that was presented and the commutation problems associated with its development demonstrate the tremendous amount of work required to transform the presently used telex and telegram network into an integrated network for all telegraph and data transmission services.

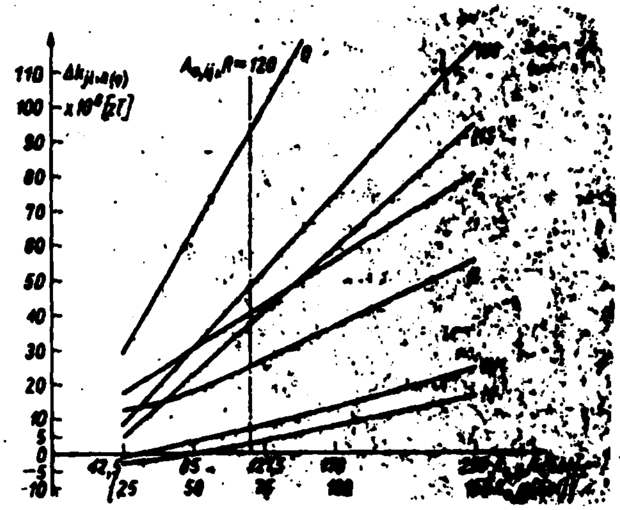

Fig. 4. Cost of switching from "occupied" state to "installed" state versus capacity of substation for various network modernization concepts

$A_{0,ij}$ = message traffic generated in substation in "occupied" state

$A_{0,ij,R}$ = same as above, however, in "installed" state

$\bar{A}_{0,ij,R}$ = average capacity of substation in "installed" state

CZji = i-th substation connected to j-th tandem central station

q = E, H, M, MS, WM, WS = type of network modernization concept

q = 0, nonmodernization network variant

Capacity of i-th substation CZji is expressed approximately by the following relation: $N_{ji} = 8.8\ A_{0,ij}$

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