FUNDAMENTAL PROBLEMS OF CROSSBAR EXCHANGE DESIGN

By

P. Molnár

1. Introduction

In the following chapters some fundamental problems of crossbar exchange design are treated in short, in connection with the system development being in progress in Hungary.

A considerable amount of publications may today be found in the literature concerning crossbar exchange systems, since, — especially of late years — quite a lot of new crossbar systems were designed or invented. The designers of the systems are generally influenced by local conditions, by the already existing network, and restrained by numerous patent limits. As none of these can be taken out of consideration, and the conditions are different in almost every country, a wide scale of crossbar exchange systems exist, most of these having his own character not only in appearance, but more or less in principle too. Even if there is no essential difference in price between the different solutions, they may be ranked as to their up-to-date features, simplicity of maintenance and adaptability for different exchange types. These characteristics are of more importance than it seems at the first moment. It seems namely to be not sufficient to make efforts to gain exchanges of better quality or lower price. The different solutions have a value with respect to the further development, which although a perspective value, can already now be estimated. It is highly probable, that the up-to-date solutions have a better chance for producing technical and economical advantages in the future, even if for the present conditions they do not seem the best solution.

The up-to-date character of a crossbar exchange may be judged from the method of control applied, this being the most characteristic field, where the new system may show an essential difference in principle related to the older machine systems. The simplicity of maintenance depends mostly on the reliability of crossbar switch and other connecting elements used, meanwhile the adaptability of the system is determined by the possibility of a uniform structure of the exchanges for different purposes.

These characteristics are generally connected together, switching devices, method of control and method of switching can in most cases be chosen only together.

Designing a new system our first aim was that beside the well-known advantages of the crossbar system the requirements with regard to the above-mentioned characteristics should also be met.

2. Dimensions of contact-field and crossbar switch

The economical realisation of crossbar contact-field determines the dimensions of the crossbar switch. The high-speed connections with precious metal contacts necessitate the use of more expensive contacts than these of the rotary switches, so that a great part or the whole of the price of the switch is composed by the price of contact-points, or cross-points. This means that on the contrary as in rotary systems, not the number of switches but the number of cross-points should be a minimum. The total amount of cross-points in the exchange may be expressed as

$$C = a \cdot b$$

if "a" is the number of contact-points of a selector, and "b" the total amount of selectors. It is a well-known fact that the number of selectors is a function of the contact-point capacity "a", in case of a greater contact-point capacity the number of selectors needed decreases. Under such circumstances, to obtain a minimum value for C, only a compromise is possible as regards to the values "a" and "b".

In order to analyse the optimal solution, the general junction diagram of an exchange may be chosen, where "n" connections may exist at given time between the subscriber lines N, on the condition, that whichever of the N subscriber lines can be connected to any of the n connecting circuits (see Fig. 1). Assuming that the same number of stages are needed for line-finder and for selecting purposes, the total number of stages is determined by the equation

$$a = \sqrt[k/2]{N}$$

With the presumption that in every stage of the exchange the same quantity of selectors are needed, that is, the whole concentration takes place in the first stage, the total amount of cross-points in the exchange is

$$C = \sqrt[k/2]{N \cdot k \cdot m}$$

where m is the number of selectors in every stage. Both k and m are functions of the contact-point capacity "a". For the case of the above simplifying assumptions the Diagram 2 shows the values C for different values of the contact point capacity "a". It may be seen that within fairly wide limits ($N = 10^3$—10^4) the selectors having ten contact-points are the most economical. These results will somewhat be modified, when the magnets of the switches are also taken in account, since contact-fields of greater dimensions have relatively a smaller amount of magnets and the most economical dimensions will be changed into greater values. It is, however, to be taken in account that contact-fields with greater dimensions want more expensive magnets.

Similar results were obtained by CH. CLOS, P. RIORDAN and J. O. RICE (Bell System Techn. Journal) who have found for arrangements without inner congestion that in cases of practical use selectors with 5—20 contact-points are most economical.

The crossbar switches generally used today have 10 · 10 or 20 · 10 cross-points. There are although efforts today to the effect to use contact-fields of greater dimensions, these will, however, be economical only in the case, when the contact-point will have lower price. In this respect the solutions with wire-springs have a perspective, which — with a suitable technology — may be rather cheap.

Considering the question of the size of contact-field prospectively, one cannot feel sure that the present crossbar switches are the perfect and best solution of the contact-field problem. It is sufficient to refer to the circumstance that the switches at present have two magnets to operate for a cross-point one after the other, which means a considerably long time especially when related to electronic control circuits. It is possible, that already in the next future simple relay or electronic cross-points can be provided without common magnets. In such a case the small contact-fields having 10 · 10 cross-points will only be economical.

Another important question of the contact-field is the multiple of cross-points. A contact-field having 10 · 10 cross-points may be used as 10 independent selector, or as a multiplied group of 10 selectors.

In this later case the contact-field has a multiple in both, — horizontal and vertical directions. The multiplied contact-field has many advantages with respect to the construction of the switch as well as to the structure of the exchange. If the construction of the switch enables a multiple in both directions, a great number of soldings and a considerable amount of wires can be spared (about 2—400 000 soldings in an exchange of 10 000 lines). This multiple secures further an equable load for the horizontals and verticals of the switch, allowing only one (or two) cross-point to operate at a time in a horizontal and vertical row. This is very important of point of view of the magnets and other moving parts of the switch, as in this manner all parts of the switch are equally loaded. A further advantage of the common multiple is that the contact-field has the same number of inlets and outlets. This circumstance allows a simplifying of the control system. It is doubtless that the stages without concentration or expansion are the most simple to control, and the contact-fields which have no concentration or expansion and are connected together according to fixed rules, allow the control device to establish a connection through several stages with a very small set of information.

The multiplied 10 · 10 contact-fields besides have the perspective value that in case of an electronic contact-field no change in the control system should be needed.

Designing a new crossbar switch, the above considerations were taken in account in Hungary. The new crossbar switch is suitable for contact-fields having 10 · 10 cross-points multiplied in both directions.

3. The marker principle

The question of contact-field-size is in connection with the questions of group building and of control system. On account of the small-size contact-field an entirely new method of control and group building is necessary. The method of control is to be chosen in that manner that the traffic handling-capacity of small groups may attain the standard wanted in telephone exchanges. A new control system suitable for this purpose is based on the so-called marker principle.

The marker principle is a developed form of the by-path common control principle with new idea that the switches of the subsequent stages in a connection can be set not only one after the other, but all in the same time, if the control device is capable to examine all possible routes in question. In that manner not only the working time of the marker diminishes, but the traffic handling capacity of the selectors increases, a smaller amount of selectors and stages are needed in the exchange, than in case of stage-by-stage control.

Let us examine at first the effect caused by the common control system to the number of stages necessary. Fig. 1. shows the general junction diagram of an exchange with N subscriber lines and n connecting circuits. There are a number of k_H line finder and of k_v selector stages. According to the conditions mentioned in Chapter 2, the minimal number of stages is determined by the expressions

$$a/ = \sqrt[k_H]{n} \text{ and } a = \sqrt[k_V]{N}$$

if whichever of the connecting circuits i. g. subscriber lines may be reached from the starting point through only a single route. If in the selector stages a number of "a" possibilities are needed to reach a subscriber line, the number of stages wanted is determined by the expression

$$a = \sqrt[k_v - 1]{N}$$

In case of 10 point selectors

$$k_H = \log n \text{ and } k_V = \log N + 1$$

Since $N \gg n$, more selector stages are needed than line finder stages.

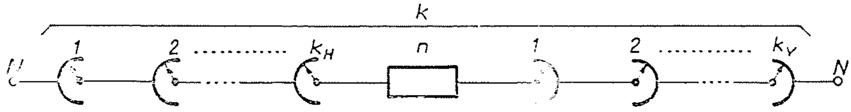

Fig. 1

In case of a stage by stage control system (f. i. Ericsson system) the number of selector stages needed is determined by the expression

$$a = \sqrt[\frac{k_v - 1}{2}]{N}$$

if every group selector stage has ten routes, so that

$$k = 2 \log N + 1$$

The marker- or common control-principle enables a further possibility to lessen the number of selector stages. As shown in Fig. 4, it is possible to use the line-finder stages as selector-stages. When after the line-finder operation the selection starts not from the connecting circuit, but from a line-finder stage beforehand, several line-finder stages may be used as selector stages. If a number of $k—1$ line-finder stages are used as selector stages, the total number of stages is

$$k = k_H + k_v - (k_H - 1) + 1 = \log N + + 1 = \log N + 2$$

The following table can be drawn up to show the difference between the stages needed

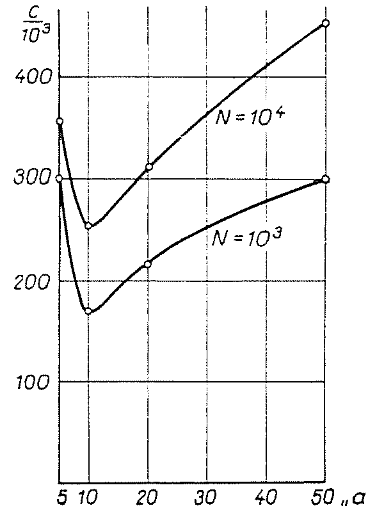

Fig. 2

in case of common control and of stage by stage control.

$n = N/10$

	$N = 10^3$			$N = 10^4$		
	k_v	k_H	k	k_v	k_H	k
Common control	4	2	6	5	3	8
Stage by stage contr.	7	2	9	9	3	12

Fig. 3

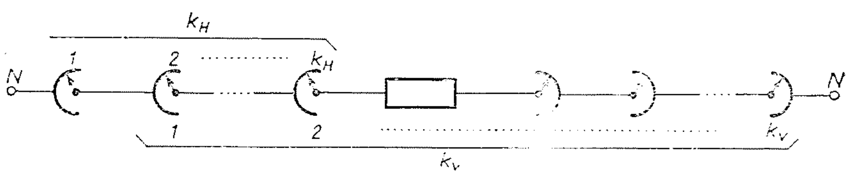

Fig. 4

4. The effect of common control to the traffic handling capacity

To display the effect of common control to the traffic handling capacity of circuits or links, may be chosen the five-stage selector system drawn on Fig 4. Fig. 5 shows the possible routes for the connection between two preselected lines. It may be seen that the number of possible routes are 10 in the first and in the last stages, much more, however, (100) in the intermediate stages. This means, that the intermediate stages have hardly any influence to the grade of service, or the loading in these stages can be much higher as in the first and last stages. In the intermediate stages the links or circuits are grouped in large boundles in spite of small contact-fields.

A similar diagram can be drawn for stage by stage control system as shown on Fig. 6. As it seems in every stage only a number of routes depending on the contact-point capacity can be used, so that the traffic-handling capacity of the system is determined by the contact-point capacity of the selectors used.

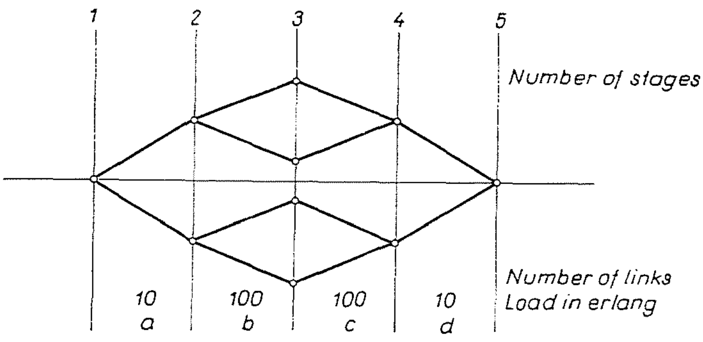

Fig. 5

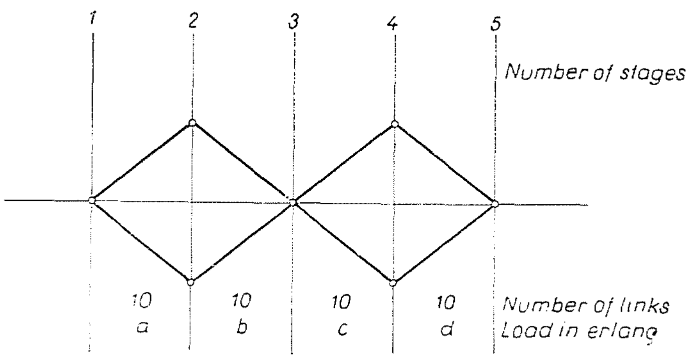

Fig. 6

If the load of links between the different stages are denoted with a, b, c and so on, the grade of service may be expressed as follows ; In case of common control, for the total connection

$$p = f(a^{10} + b^{100} + c^{100} + d^{10}) \cong (a^{10} + d^{10})$$

in case of stage by stage control

$$p = f(a^{10} + b^{10}) + f(c^{10} + d^{10})$$

which gives a considerable greater probability of loss as the expression for common control.

The difference between the two systems is apparent from the table as well as from the above expressions.

This is the cause, why selectors with small contact-point capacity cannot be used economically in systems control led stage by stage, and in order to get a better grade of service, the contact-point capacity of switches is to be increased above the economical limit. In case of common control the 10 point selectors may also be used with good results, as the inner congestion in most of the stages does not depend on the capacity of selectors.

5. Switching methods in common control system

The economical advantages treated in the foregoing chapters can only in the case be used in whole extent, if the common control circuit is not too complicated, and works safely. The first aim is therefore in case of common control to make the marker circuit as simple as possible.

The most simple solution can be reached if only a single control circuit exists in the exchange. In this case the complications can be eliminated which occur if two or more control circuits are working at the same time, and there is no possibility of two or more connections to be mixed. Since the traffic-handling capacity of the marker — assuming a suitable large amount traffic offered — depends on the working time of the circuit, it is important to make efforts to the effect that a minimum working time be reached. The working time of marker circuit consist of two parts, first to make the plan of the connection, then to set the selectors of the different stages.

There are several ways to shorten the time needed for the plan of connection. First by the analysis of the different functions of the marker can be determined, which of these can be perfected at the same time. The more are the parallel functions, the shorter will be the working time. The working time may also be lessened if a small set of information is only needed for making the plan ready. This question is in connection with the dimensions of selector groups and the methods of link connections. As it was mentioned before, with respect to the control system, the most simple solution may be obtained by use of selector groups having the same number of in- and outlets. The information set needed diminishes with the use of regular link connections. If the link connections are directed according to fixed rules, the marker — knowing these rules — is capable to build up a connection through several stages only with the information relating to the starting and end-point.

The time needed for setting the selectors can be lessened if the selectors of the different stages are connected in that manner as shown on Fig. 7. In this connection only vertical or horizontal magnets are connected together, so that the whole connection can be built up in two steps, at first to operate the

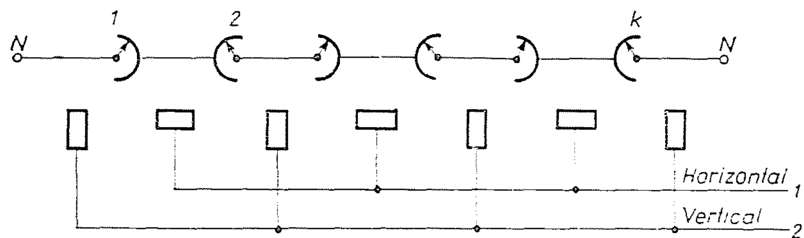

Fig. 7

horizontal, then the vertical magnets of every stage.

A further possibility to shorten the working time of the marker to provide high-speed relays or electronic switching elements. The use of such high-speed elements enables a total working time not much longer than the operating time of selector magnets.

6. Subscriber stage

Special heed is to be paid to the subscriber stage, since the traffic-handling capacity of this stage does not depend on the control system, but only on the contact-point capacity of selectors. Besides, the subscriber stage contains more than half of the whole quantity of switches in the exchange.

According to the two well-known types of subscriber stages in machine systems, the crossbar switches may also be used as line-finders or preselectors, depending on that, whether the subscriber lines are connected to the horizontals, or verticals. Of economical point of view the two methods are fairly the same. The line-finder system wants a smaller amount of selectors, the preselector system enables, however, a more simple line circuit and control system. In case of common control system, therefore the preselector connection seems to be preferable.

The preselector connection — by a given selector-size — enables a greater concentration than the line-finder system. The concentration obtained with preselectors is in most cases sufficient, so that in the other stages no further concentration is needed. This circumstance is important — as it was mentioned before — because of the use of selector groups having the same number of in- and outlets. Besides, it is possible to increase the concentration of preselectors by simple grading, which is much more convenient with respect to the control system, than the mixed or transposed connections in line-finder stages.

The preselector connection has the great advantage that it makes possible the use of selector groups multiplied in both directions in the subscriber stage too.

Finally, the preselector connection is advantageous with respect to the identification of the calling line, this having only one fixed place in the exchange.

Summary

On the basis of the above considerations the new crossbar system designed in Hungary uses crossbar switches with a multiple in both directions. The switch consist of 20 ten point selectors in the subscriber stage, and 2 times ten ten-point selectors in the other stages. A simple common control system is applied for all functions of the exchange.