The Influence of a Preceding Selector Stage on the Loss of Gradings

Dieter Bazlen[x] and Wolfgang Lörcher[xx]
University of Stuttgart, Stuttgart, Federal Republic of Germany

ABSTRACT

This paper deals with investigations on the influence of a preceding selector stage on the loss of gradings. Several models of preceding selector stages are considered which differ with respect to the size of the preceding stage, the wiring mode between the outlets of the preceding stage and the inlets of the grading and the hunting mode of these outlets, resp. These investigations were performed by extensive simulation. Recommendations are given for practical applications how to interconnect consecutive selector stages in step-by-step systems.

1. INTRODUCTION

Exchanges in step-by-step telephone systems consist of several consecutive stages. These selector stages are one-stage connecting arrays. They are characterized by their structure and operation mode. For traffic analysis the incoming traffic is usually assumed to be Pure Chance Traffic of Type 1 (PCT1) or Pure Chance Traffic of Type 2 (PCT2), respectively [1].

In systems (without alternate routing) the traffic analysis is usually done in the following way:

Consideration of the loss of a single selector stage. The selector stage can be dimensioned for a certain traffic load by calculation. For PCT1 it holds for instance: In case of full accessibility the Erlang-Formula [4] can be applied; in case of gradings (one stage connecting arrays with limited access) the MPJ-Formula can be used [2,3,5,6].

Consideration of the total loss. The total loss of the traffic flow through all serial selector stages (excluding subscriber busy) is estimated under the assumption of independent loss probabilities per stage.

Thus, the influence of a preceding stage on the loss of a "considered" selector stage is usually neglected.

This paper deals with the influence of a preceding selector stage on the loss of a considered stage with limited access (grading). Up to now, some investigations dealing with this influence were published. In Chapter 2 these publications are briefly reviewed.

Now, these investigations are extended. The considered configuration consists of preceding selector stage and grading. It takes into account the structure and the operation mode of the preceding stage, the wiring between preceding stage and grading and different grading types. This general configuration is presented in Chapter 3.

Different grading types and grading sizes with a large number of different preceding selector stage models were investigated by means of simulation. Results of these investigations are described in Chapter 4.

2. FORMER INVESTIGATIONS

The influence of a preceding stage on the loss of a following (considered) stage was already subject of some investigations.

For consecutive full accessible trunk groups a calculation method was developed in [7]. It takes into consideration mean and variance of the traffic offered to the considered selector stage.

For special structures and operation modes of a preceding stage further investigations were done [8,9,10].

In [8] 4 models of a preceding stage are considered which are used for the simulation of two-stage link systems. Three models have full accessibility in the preceding stage; these models are included in the models CH,PH and PR, respectively, which are presented later on (cf. Section 4.3). The fourth model has a very simple grading in the preceding stage.

In [9] the influence of the preceding line finders on the dimensioning of AT&T gradings is investigated. The complex structure between line finders and grading is replaced by an approximate model. It is introduced as model PRO (cf. Section 4.3).

In [10] a preceding stage with full accessibility followed by full accessible groups or a special grading or a link system (2 or 4 stages) is considered. This model is included in the model SR of this paper (cf. Section 4.3).

3. CONFIGURATION OF THE TWO CONSECUTIVE STAGES

3.1 GENERAL

Figure 1 shows the general structure of the two consecutive selector stages of a step-by-step system: preceding stage and considered stage with limited access (grading).

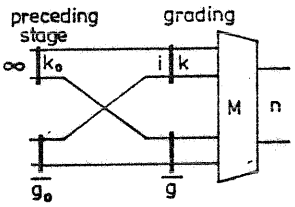

Fig.1: Structure of preceding stage and grading

The preceding stage may consist of g_0 multiples to which PCT1 is offered. Gradings in the preceding stage are not considered for reasons of simplicity and to avoid complex interdependencies between gradings in the preceding and considered stage.

A certain mostly small congestion in the preceding stage results in a clipping of the original offered traffic A_{or}. As many simulations have shown, the influence of this small clipping effect is negligible with respect to the statistical properties of the traffic A offered to the grading. The probability of loss B of the grading is related only to the traffic A actually offered to the grading.

3.2 STRUCTURE

The structure is formed as follows (cf.Fig.1):

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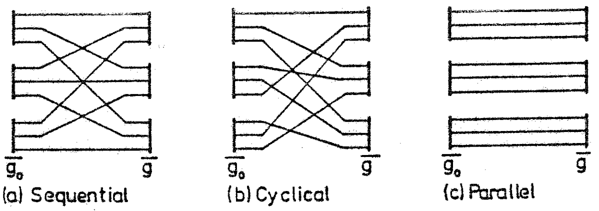
x) D. Bazlen is now with IBM Germany, Böblingen
xx) W. Lörcher is now with Polytechnic Institute of Esslingen, Esslingen/N.

Beitrag des Instituts für Nachrichtenvermittlung und Datenverarbeitung der Universität Stuttgart zum 8th International Teletraffic Congress Melbourne vom 10.-17. November 1976

The preceding stage consists of g_o multiples ($g_o \geq 1$) with k_o outlets each ($k_o \geq 1$). The $g_o \cdot k_o$ outlets of the preceding stage are wired to the g·i inlets of the grading in different modes [11] : Sequential, cyclical, parallel. Examples for these wiring modes are shown in Figure 2.



(a) Sequential (b) Cyclical (c) Parallel

Fig.2: Different wiring modes

The parameters of the grading are (cf. Fig.1):
- g multiples with accessibility k
- n outgoing trunks
- mean interconnection number (grading ratio) $M=(g \cdot k)/n$
- grading type acc. to Section 4.2 (cf.Fig.3).

Usually the gradings have a mean interconnection number $M \geq 2$. To investigate the most critical case a uniform mean interconnection number M=2 is chosen for all gradings [2] .

3.3 HUNTING MODE

In the preceding stage different hunting modes are considered [11] :

- Sequential hunting with home position: The outlets of a multiple are hunted in sequential order, starting from the first outlet.
- Sequential hunting with random start position: The outlets of a multiple are hunted in sequential order, starting from a randomly selected outlet j , i.e. the hunting sequence is $j, j+1, \ldots, k_o, 1, \ldots, j-1$.
- Random hunting: One out of all idle outlets is chosen at random.

Only gradings with progressive commoning are investigated. Therefore, the outlets of the grading multiples are hunted in sequential order with fixed home position (first outlet).

3.4 MODEL SIMPLIFICATION

In a decimal step-by-step system the traffic flows from the preceding stage (e.g. 1st group selector) to the following stage (2nd group selector), where it is distributed via individual gradings to a maximum of ten directions. To get best distinguishable results of the different wiring and hunting modes only one outgoing trunk group of the considered stage is regarded in the simulations discussed below.

Consequently, the traffic carried from the preceding to the considered stage has exactly the same value as the one outgoing group behind the grading. In other words, the additional traffic which actually flows from the preceding to the considered stage to at most further 9 outgoing groups has not been simulated. Therewith it was possible to clearly recognize the influence of the different wiring and hunting modes on the loss of the outgoing graded group.
It is obvious that these "differences in quality" are softened if the neglected traffic to the other 9 directions will flow also via the connections of preceding to considered stage. Furthermore, it should be noted that also boundary cases have been considered, e.g. $i < k$, or models with random hunting, resp., which are seldomly realized in practice.

4. INVESTIGATIONS ON THE INFLUENCE OF THE PRECEDING STAGE

4.1 GENERAL

In this chapter the results of the investigations are presented regarding different preceding selector stage models as well as different grading types and grading sizes. The investigations were performed by means of extensive Monte Carlo simulations. A large variety of different configurations was studied for a range from 0.01 up to ≈ 100 percent for the probability of loss. All simulations were performed with a confidence interval of 95 percent, which is shown in the figures by Ɨ .

In Section 4.2 the different grading types are characterized.

The investigated models of the preceding stage are presented in Section 4.3. Hereby, models with $g_o \geq 1$ are considered to cover the whole range of possible configurations. In practice, $g_o = 1$ can be found in case of line finders [9] , whereas $g_o > 1$ if several trunk groups form the inlets of the considered selector stage.

It is shown that the traffic analysis which usually neglects a preceding stage and assumes PCT1 is implicitly based on some special models.

The main result of the investigations is that the influence of a preceding stage is similar for all grading types and grading sizes except of some special cases. Therefore, in Section 4.4 the results for the large variety of parameter combinations are mainly discussed for a Standard grading with k=10 and n=45.

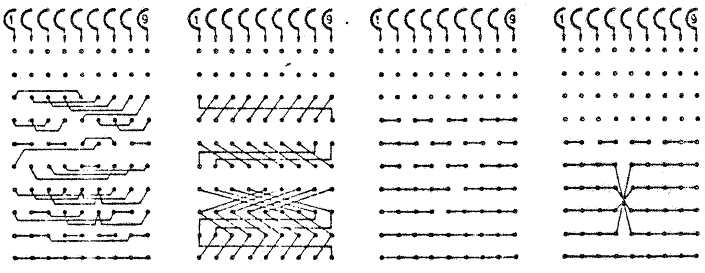
In Sections 4.5 and 4.6 different grading types and grading sizes are considered. Thereby, the above mentioned special cases are discussed, too.

The following diagrams show simulation results of the loss B versus the carried traffic Y/n per outgoing trunk of the grading. For comparison, the following curves are drawn additionally:
- Erlang [4] (full accessible trunk group with offered PCT1)
- MPJ [1,2,3,5,6] (grading with offered PCT1). The Fitting-parameter F(taking into account the various grading types) is indicated in the figures with F=0 for Perfect, F=0.3 for Standard, F=1.1 for O'Dell and F=2.4 for Simple.
- FST [2,12] (finite source traffic, loss formula for gradings with offered PCT2). The FST-loss bases in each case on the corresponding MPJ-loss with a certain Fitting-parameter F.

In addition, some diagrams contain also results of PCT2 simulations without a preceding stage. Hereby, the number of traffic sources per multiple is equal to the number i of inlets. These results are also drawn for reasons of comparison.

4.2 GRADING TYPES

A large variety of different grading types is in use. The investigations were mainly performed with four typical grading types which are shown in Figure 3. These grading types have all progressive commoning.



(a) (b) (c) (d)

Fig.3: Typical grading types (k=10,n=45,g=9)
(a) Perfect, (b) Standard,
(c) O'Dell , (d) Simple

The main characteristics of these grading types are:
a) Perfect: Grading with skipping (and sometimes also with slipping). These gradings have comparatively small losses.

b) Standard : Grading with skipping and slipping. These gradings are regularly constructed and therefore economical for their manufacture and extension, respectively. This grading type is used by the German Post Office.

c) O'Dell : A straight inhomogeneous grading without skipping and slipping.

d) Simple : Grading without skipping and slipping. Compared with the O'Dell grading the Simple grading (e.g. AT&T) has a more simplified structure and a more progressive commoning.

The losses increase from a) to d), i.e. for normal load conditions, the simpler the grading the higher the losses [2].

All gradings shown in Figure 3 have
- g = 9 selector groups (multiples)
- k = 10 outlets per multiple (accessibility)
- n = 45 outgoing trunks
- M = 2 for the mean interconnection number
- i $\gtreqless$ k inlets per multiple.

4.3 PRECEDING SELECTOR STAGES

In practice there is a large variety of structures and operation modes for preceding selector stages. Therefore, for a general investigation it is necessary to consider a large variety of models. Table 1 shows the abbreviations for models with different wiring and hunting modes.

Wiring mode	Hunting mode sequential hunting with	
	Home position	Random start position
Sequential	SH	SR
Cyclical	CH	CR
Parallel	PH	PR

Table 1 : Abbreviations for models with different wiring and hunting modes for the preceding selector stage

Additionally, the parameters g_o and k_o are varied as follows : $g_o = 1,2,\ldots,i\cdot g$, $k_o = i\cdot g,\ldots,2,1$.

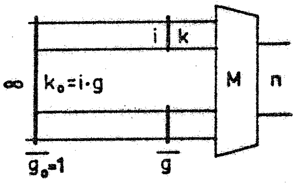


Fig.4: Structure of the special models

Furthermore, two special models are considered : These models have both $g_o = 1$ multiple in the preceding stage. The outlets are wired parallel as shown in Figure 4.

The models differ with respect to the hunting mode :

Model PRM : Parallel wired, the outlets of the preceding stage are hunted sequentially, where the start position is the first inlet of a randomly selected multiple.

This model is normally used to investigate gradings or link systems, respectively [11].

Model PRO : Parallel wired, at random one out of the free outlets is selected.

This model is used in [9].

For both models it is not necessary to simulate the preceding selector stage explicitly.

4.4 STANDARD GRADING WITH n = 45

This Section shows the results for Standard grading with g=9, k=10, n=45 (cf. Fig.3).

4.4.1 $g_o = 1$, i > k

Figure 5 shows the results for a preceding selector stage with $g_o = 1$ and $k_o = 180$, i.e. i = 20 (i > k).

The different models have the following characteristics :

PR ≈ PRM : The values of the loss for these models are in good accordance with the MPJ-Formula.

PRO : These results are slightly below the PRM results. One outlet out of all free outlets is selected at random. Therefore, with respect to the multiples of the grading the offered traffic is more equally distributed than in the PRM model, since a multiple of the grading with a large number of free inlets is selected with higher probability than a highly occupied multiple. This yields an effect similar to PCT2 and therefore the losses tend to PCT2.

SR ≈ CR : According to the sequential or cyclical wiring mode these models yield smaller losses than PR and PRO.

Regarding all models two boundaries exist, given by the following models:

PH : Since all outlets of the one multiple of the preceding stage are parallel wired and sequentially hunted and since i > k only the k=10 outlets of the first multiple of the grading can be occupied. Therefore, the results for this model are the results of a full accessible trunk group with k = n = 10.

SH : It can be shown from Fig.3 that the outlets are occupied in the following sequence : 1st-hunted oulets of the multiples 1 up to g, 2nd- 3rd-, 5th- and 7th-hunted outlets, i.e. all 45 outgoing trunks are fully accessible.

If an outlet becomes free, it is always occupied from the same inlet of the same multiple. E.g., if the outgoing trunk wired with the 3rd outlet of multiple 2 becomes free then the inlet 3 becomes free, too. If a new call arrives the first free inlet of the grading is selected. This inlet is again the 3rd inlet of multiple 2 and therefore the new call occupies again the outlet 3 of this multiple.

CH : The same considerations can be made as for model SH, all outgoing trunks are fully accessible.

Except of the two boundary cases, all results for the different models are on the MPJ curve or between MPJ and FST (PCT2) results.

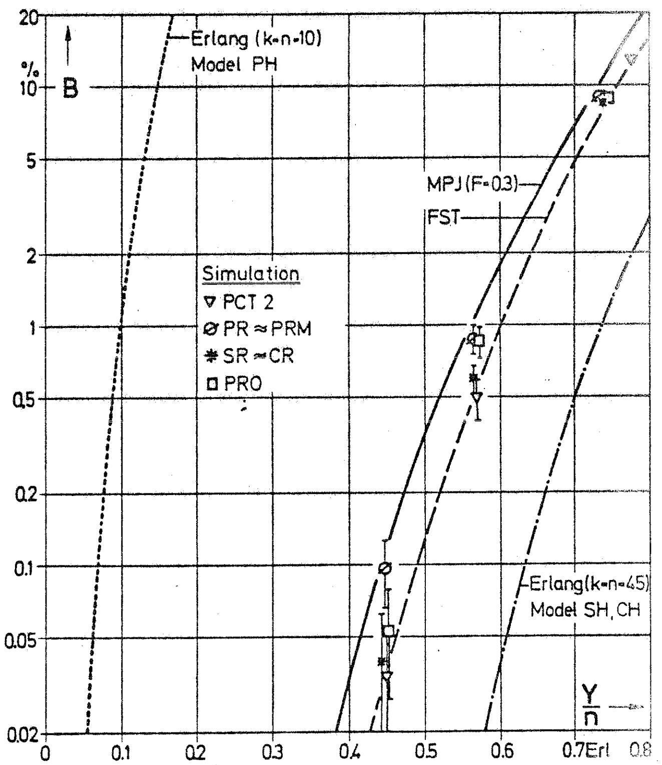


Fig.5 : Standard grading with i = 20, k = 10, n = 45 and $g_o = 1$

4.4.2 $g_o = 1$, $i = k$

Figure 6 shows the results for a preceding selector stage with g_o=1 and k_o=90,i.e. i=10 (i=k).

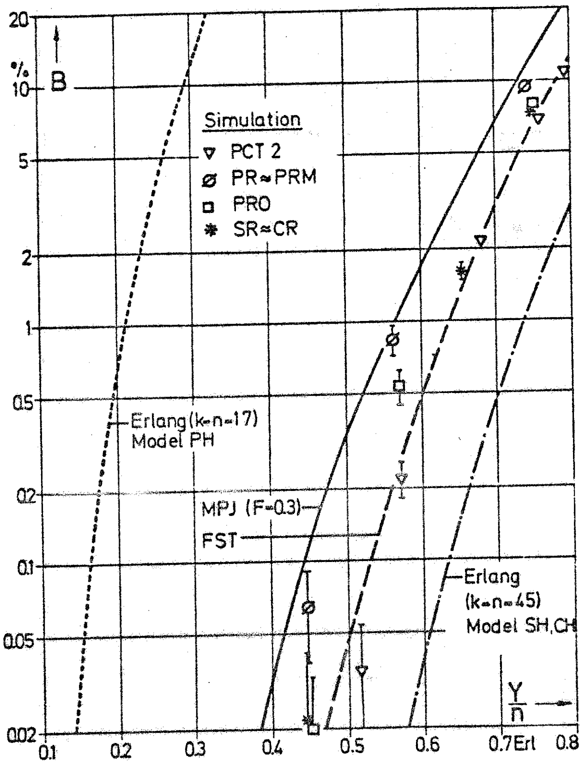


Fig.6 : Standard grading with i = 10, k = 10, n = 45 and g_o = 1

The results for the PRM model are unaffected. The PCT2 losses decrease and accordingly the losses for the models SR, CR and PRO. The lower boundary remains the Erlang curve for k=n=45 (models SH and CH). The upper boundary is obtained for model PH. Since i=k, only a maximum of 17 outgoing trunks can be occupied. (It can be shown from Fig.3 that three outlets of multiple 2 are interconnected with outlets of multiple 1. If 17 outgoing trunks are occupied, 3 inlets of multiple 2 are free. However, the three not occupied outlets of this multiple are blocked via multiple 1.)

4.4.3 $g_o = 1$, $i < k$

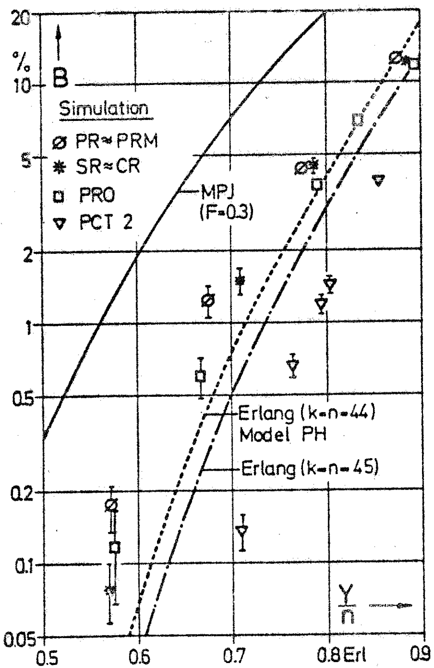


Fig.7:Standard grading with i=5,k=10,n=45,g_o=1

In Figure 7 the results for a preceding selector stage with g_o = 1 and k_o = 45, i.e. i = 5 (i < k) are shown.

For all models the probability of loss decreases compared with i=k. Since the Standard grading has progressive commoning the first 5 outlets of each multiple are only little interconnected, therefore the losses tend to the losses of k=n=45 (models PRM,PR,SR,CR, PRO).

For model SH and CH the 45 inlets have full access to the 45 outgoing trunks, i.e. no loss occurs.

In case of model PH only 44 of 45 outgoing trunks are accessible. It can be shown that one outgoing trunk cannot be occupied (cf. Fig.3).

(In this case no FST results are presented since the FST-Formula was developed for practical configurations, i.e. for gradings with i·g/n ≥ 2.)

4.4.4 $g_o > 1$, $i \geq k$

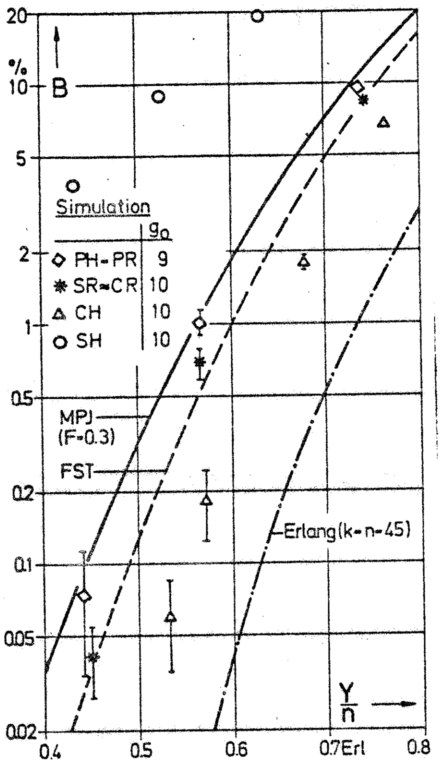


Fig.8 : Standard grading with i=20, k=10, n=45 and g_o=9 or 10

Figure 8 shows the results for preceding selector stages with g_o=9 and g_o=10, respectively. The number of inlets per multiple of the grading is i=20 (i > k). (Similar results were obtained for i=k).

In all models with parallel wiring g_o=g=9 is chosen, thus all outlets of a multiple of the preceding stage are wired with the same multiple of the grading (cf. Fig.2c). In all other models the number of multiples in the preceding stage is slightly modified (g_o =10). Thus the same number of lines leads from one multiple of the preceding stage to each multiple of the grading (k_o=18=2·g).

Compared with g_o = 1 (Section 4.4.1) different results are obtained :

SH : This model yields unbalanced offered traffic for the grading since all first hunted outlets of the multiples of the preceding stage are wired to the first multiple of the grading, etc. Therefore, high losses are obtained.

PH = PR : With respect to the structure the models PH and PR differ from model PRM (cf. Section 4.4.1). But since i > k, the multiple of the grading to which a call is offered is randomly selected in all models. In model PRM the randomly selected outlet (g_o = 1) determines the multiple of the grading, in models PH and PR the multiple is determined by the randomly selected preceding stage multiple (g_o = g). Thus, all three models yield identical results, which are in good accordance to the MPJ-Formula.

SR ≈CR : The results for these models are between MPJ and FST and tend to FST for decreasing number of inlets (e.g. i = k). This behaviour can be explained as follows (cf. Figure 9).

The arrival rate λ per multiple of the preceding stage is constant and equally distributed on all free outlets. Thus the arrival rate per inlet of the grading varies between 0 and λ (cf.Figure 9).

As long as no multiple of the preceding stage is fully occupied (cf. occupation pattern in

Figure 9) the total arrival rate for the grading is $g_o \cdot \lambda$ = constant. Thus, the loss must be greater than for PCT2, although the arrival rate per inlet varies between 0 and λ.

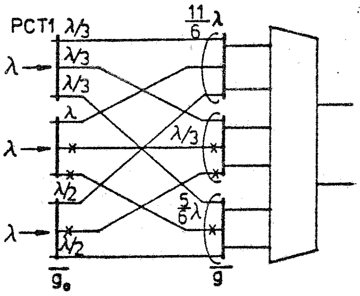


Fig.9 : Example of an occupation pattern between preceding stage and grading (x occupied line)

As shown in Figure 9 the arrival rate per multiple of the grading is such that a multiple with small number of occupied inlets has a greater arrival rate than a highly occupied multiple. Thus the traffic is very equally distributed among the multiples of the grading.

CH : This model yields the smallest losses, even smaller than PCT2. The reason is the extreme balancing of the traffic offered to the multiples of the grading. Due to this balancing the results are approximately independent of the number of inlets i, if i ≥ k. Whereas for model SR the arrival rate per inlet varies between 0 and λ here the arrival rate is either 0 or λ; i.e. as long as each multiple of the preceding stage has at least one free outlet, only g_o trunks (inlets) have an arrival rate λ each, all other inlets have the arrival rate 0.

4.4.5 $g_o > 1$, $i < k$

For all models with, e.g., i = 5 (i < k) all losses are slightly smaller than the losses for a full accessible trunk group with PCT1. The reasons are

1) traffic truncation caused by a smaller number of outlets k_o.
2) small interconnection between the first 5 outlets of the grading.

Since all models yield nearly the same losses a presentation of these results is omitted.

4.5 COMPARISON OF VARIOUS GRADING TYPES WITH n = 45

Here the grading types Perfect, O'Dell and Simple are considered (cf. Figure 3) and their results are compared with Standard grading.

Extensive simulations have shown that the characteristics for the different models of preceding selector stages found for Standard gradings (cf. Section 4.4) are usually also valid for the other grading types. Therefore, only results for the three models PH, SH and CH are presented for g_o = 9 or 10, respectively and for i = 10 (cf. Figures 10 and 11). Additionally one special case with g_o = 5 and i = 5 is shown in Figure 12.

In Figure 10 the results for the model PH = PR for the 4 grading types are presented. The results confirm the good accordance with the MPJ-Formula.

Figure 11 shows the results for the 2 models SH and CH, respectively.

SH : Since this model yields unbalanced offered traffic the results are above the MPJ results (cf. Section 4.4.4). The losses for Perfect and Standard gradings are in the same range but considerably below the losses for O'Dell or Simple gradings. This is due to skipping.

It is astonishing that the O'Dell grading yields greater losses than the Simple grading. This effect is caused by the larger number of single outlets per multiple for Simple gradings (cf. Figure 3). E.g., all 10 outlets of the first hunted multiple are occupied, then the second hunted multiple has 4 free outlets in case of the Simple grading but only 3 free outlets in case of the O'Dell grading.

CH : All results are below the MPJ results and slightly below the FST results (cf. Section 4.4.4). For reasons of clearness the results for FST are not drawn in the Figure.

The differences with respect to the loss between the 4 gradings are small, because the good balancing of the offered traffic caused by the preceding selector stage diminishes the importance of the quality of the grading type.

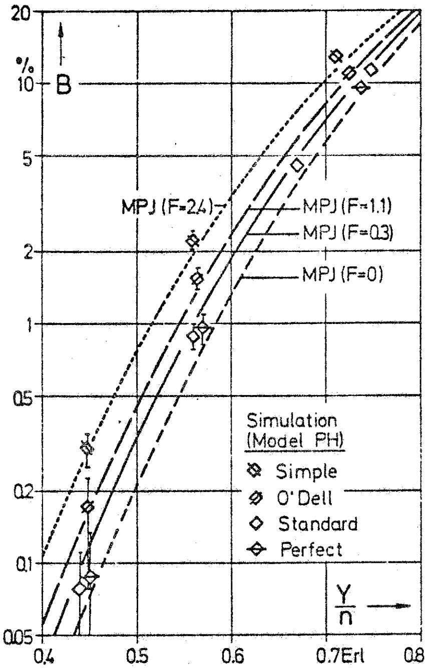


Fig.10 : Different grading types with i = 10, k = 10, n = 45 and g_o = 9

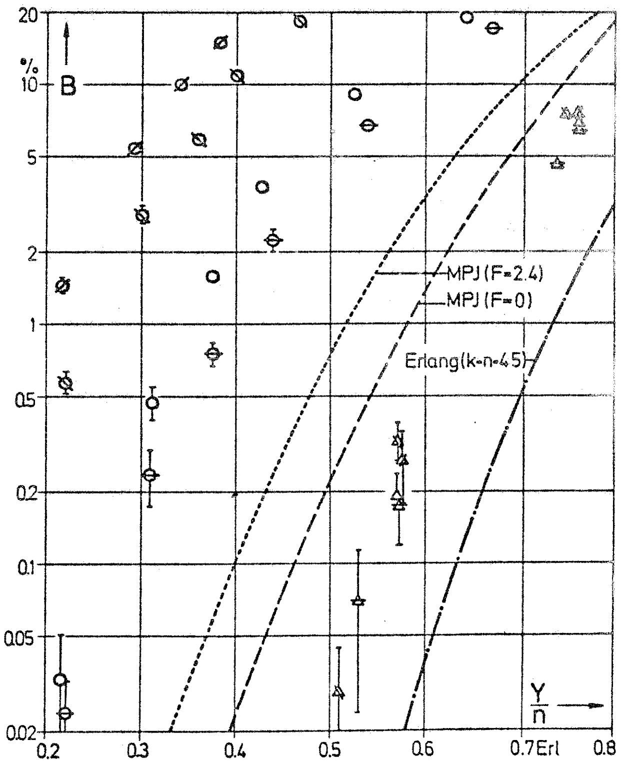


Fig.11 : Different grading types with i = 10, k = 10, n = 45 and g_o = 10

Simulation :

	SH	CH
Standard	○	△
O'Dell	⊘	△̸
Simple	⊗	⟁
Perfect	⊖	△̶

In Figure 12 a special case for model SH with g_o= 5, i = 5 is shown. The small number of inlets i = 5 has no practical importance, but for principal reasons it was considered, too.

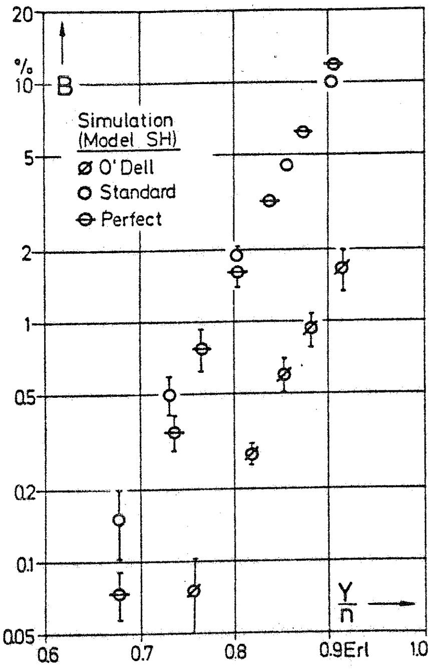


Fig.12 : Different grading types with i = 5, k = 10, n =45 and g_o = 5

The result for this special case is that the simpler the grading structure, the smaller the losses. The Simple grading has no loss, and the O'Dell grading has significant smaller losses than the Standard and Perfect grading. For Simple grading each free inlet can be connected with a free outlet for all possible occupation patterns. This is mainly because there are 4 single outlets together with 5 fully interconnected outlets (cf. Figure 3). However, for O'Dell grading already a larger number of partially interconnected outlets exists which cause a mutual congestion of the outlets.

4.6 GRADINGS WITH n ≠ 45

In this Section two different grading types are considered:

- Standard as an example for a grading with skipping and slipping,
- O'Dell as an example for a grading without skipping and slipping.

These gradings are chosen to show the principal behaviour which is similar for Perfect and Simple gradings, respectively.

Furthermore, out of the large variety of parameters two examples are presented:

- k = 10, n = 30 , i = 10
- k = 10, n = 120, i = 10 or i = 20.

(Other grading types and parameter combinations (k,n) have also been investigated, which yield similar results.)

4.6.1 GRADINGS WITH k = 10, n = 30

In Figures 13 and 14 the results for O'Dell and Standard gradings are shown for the same models. Comparing both Figures it is obvious that the differences between the different models are larger for a simple grading as O'Dell than for a better grading as Standard.

The results for the different models:

SH : For this model two structures of the preceding stage are compared:

- g_o = 10, k_o = 6 : Hereby, an extreme unbalanced traffic is offered to the multiples of the grading. E.g., the first multiple of the grading has only first choice inlets. Therefore, the results are above the MPJ results as in the previous examples.
- g_o = 5, k_o = 12 : Here, the first multiple of the grading has only 5 first choice inlets. Therefore, the multiples of the grading are loaded more equally. Thus the losses decrease remarkably.

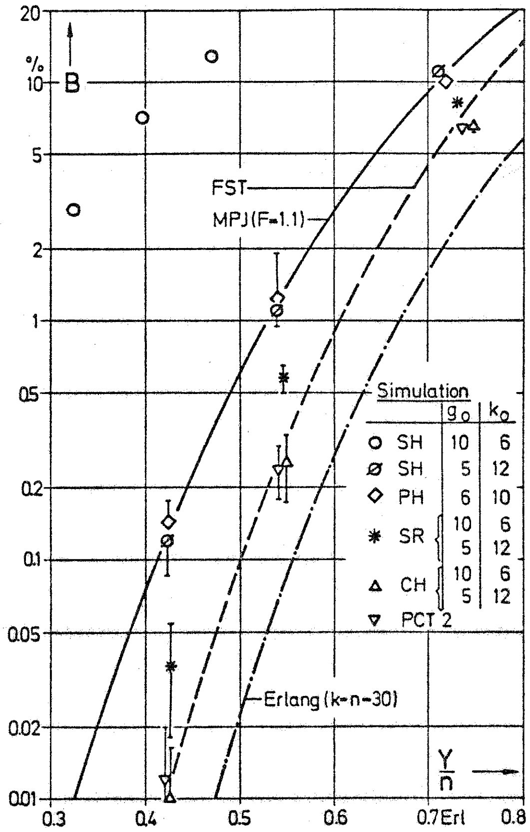


Fig.13 : O'Dell grading with i = 10, k = 10, n = 30 and g = 6

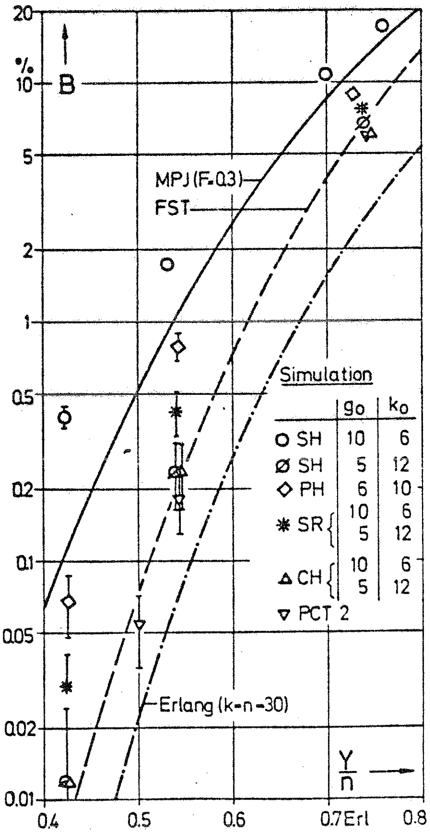


Fig.14 : Standard grading with i = 10, k = 10, n = 30 and g = 6

PH : It is g_o=6, k_o=10. The results are in good accordance with the MPJ-Formula.

SR : Caused by the hunting mode, a balanced traffic is obtained. This yields the same small losses, independent of the parameters of the preceding stage (e.g., g_o=10, k_o=6 or g_o=5, k_o=12).

CH : This model yields the smallest losses (cf. Section 4.4.4). Hereby, the losses for g_o=5, k_o=12 and g_o=10, k_o=6 are nearly the same.

4.6.2 GRADINGS WITH k=10, n=120

In Figure 15 the results for Standard as well as O'Dell gradings are shown.

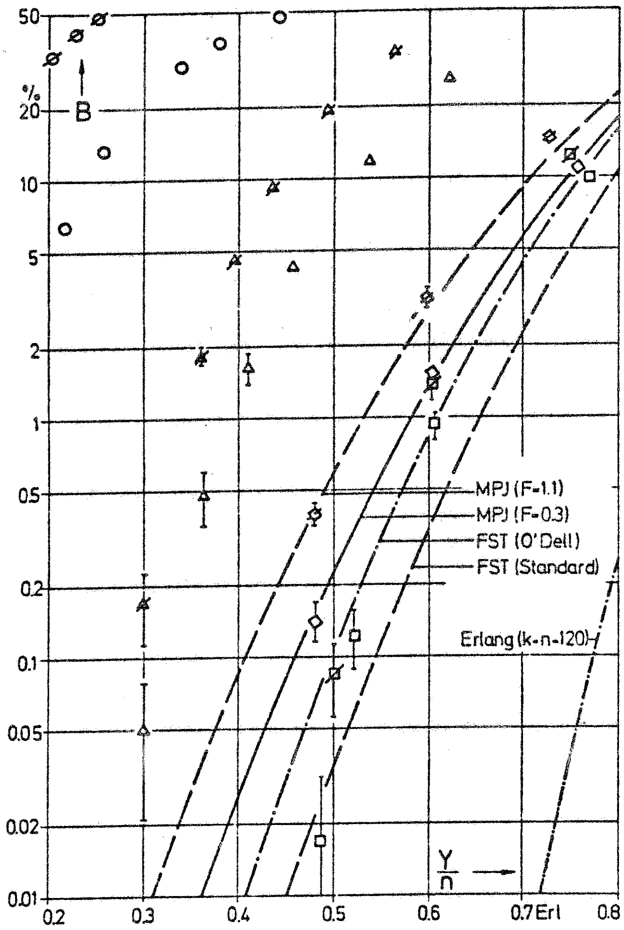


Fig.15: Different grading types with k=10, n=120, g=24 and i=10 or 20 Simulation

	Standard	O'Dell	g_o	k_o
SH	○	⊘	10	24
CH	△	△̸	10	24
PH	◇	◇̸	24	10
CH	□	⧄	20	24

For the models SH, PH and CH (g_o=20) the results are as expected. But the model CH (g_o=10) yields rather high losses. The reason is the small number of multiples of the preceding stage (g_o=10) compared with the number of multiples of the grading (g=24). Thus, unbalanced traffic is obtained in spite of the cyclical wiring.

4.7 CONCLUSIONS AND RECOMMENDATIONS

4.7.1 CONCLUSIONS

From the results of the investigations the following general statements can be given (hereby the usual case $i > k$ is considered):

Model PR : Independent of the parameter combinations similar results are obtained ($g_o \geq 1$), which are in good accordance with MPJ results.

Model PRM: Special case of model PR with g_o=1 only. Results are very close to those ones of model PR.

Model PRO: Special case of model PR with g_o=1 only. The losses are slightly below the PRM losses, because a free inlet of the grading is selected at random (cf. Section 4.4.1).

Model PH : Dependent on the parameter g_o the losses are higher than MPJ for g_o<g and in good accordance with MPJ for $g_o \geq$g.

Model SR and CR: Caused by the hunting mode R, both models have a similar behaviour which is independent of the wiring mode. The losses lie in between MPJ and FST curves.

Model SH : With increasing number g_o the probability of loss increases because the traffic becomes more and more unbalanced. Thus, losses are obtained which are significantly higher than the MPJ results. However, it must be denoted that for g_o=g·i (i.e. k_o=1) FST (PCT2) results are obtained (calls originating from g_o "sources").

Model CH : On the one hand, with this model the smallest losses can be obtained which are even below the FST results. On the other hand, dependent on the parameter combinations high losses are possible because of unbalanced traffic.

4.7.2 CONSEQUENCES FOR FIELD ENGINEERING

For the practical applications follows:

- Whether Perfect, Standard, O'Dell or Simple gradings are applied is a matter of economic balance between trunk costs on the one hand and grading installation costs on the other hand only.
- The influence of the investigated wiring and hunting modes has for all grading types the same tendency. Unsuitable wiring and hunting modes have, however, less influence on more sophisticated gradings.
- The wellknown loss increasing effect of unbalanced offered traffic per multiple of the grading is very striking for all models where unbalanced offered traffic can arise.
- The random hunting models yield comparatively small losses. In practice, these small losses may not be achieved because of the additional offered traffic to the considered stage flowing to the other outgoing groups (cf. Section 3.4). Once again, the consequence for the practice is a carefully balanced offered traffic per multiple of the considered selector stage, i.e. the "random"-models (well balanced traffic) should be closely approximated by suitable wiring between preceding and considered stage.
- The real situation in step-by-step systems is, as mentioned in Section 3.4, that the traffic to all outgoing groups flows from the preceding to the considered selector stage via the same connections. Here the MPJ formula is valid for well-balanced offered traffic, provided the Fitting -parameter F corresponds to the grading in use. In case of extremely well-balanced offered traffic, the MPJ-losses can be slightly on the safe side.

ACKNOWLEDGMENT

The authors wish to express their thanks to Prof. Dr.-Ing. A. Lotze for supporting this work and many valuable discussions. Furthermore, the authors are grateful to the Ministry of Research and Technology (BMFT) of the F.R. of Germany and also to the Federal German Research Association (DFG) for the support of this investigation.

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