The charging logistic of pusher furnaces VSŽ a.s. Košice

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Logistika zavážania narážacích pecí vo VSŽ a.s. Košice

Narážacie pece Oceľ s r.o. VSŽ a..s. Košice, zabezpečujú ohrev brám pre širokú teplú válcovaciu trať TŠP 1700. Súčasný spôsob organizácie toku brám cez narážacie pece spočíva v cyklickom zavážaní po jednej brame do každej zo štyroch narážacích pecí. Tento postup má za následok, že v druhej zóne narážacích pecí, v ktorej sa bramám dodáva väčšina tepelnej energie, vzniká ich nevýhodná kombinácia a tým aj veľké straty tepla, ktoré zhoršujú ekonomiku spoločnosti. V článku je popísaný nový spôsob zavážanie brám do jednotlivých narážacích pecí v dynamických dávkach, ktorý zabezpečí lepšie podmienky na ohrev brám. Skupinové zavážanie brám súčasne umožňuje riešiť rôzne situácie v riadení materiálového toku v okolí narážacích pecí.

KEY WORDS: Situation control, operative plan, slab, pusherer furnace (PF), wide-strip mill (TSP 1700) , PF charging flow sheet, sequence problem, batch, standard batch

Introduction

Pusherer furnaces (PF) provide slab heating to required rolling temperature for hot wide-strip mill (TSP 1700) according to the rolling program - TSP flow sheet (Fig.1). They are at the same time a flexible coupling between devices for continuous slab casting (CSC I, CSC II). The current mode of charging (i.e. pushing) of slabs into PF1 to PF4, exactly in the order they will be rolled on TSP 1700 one slab at once, cyclically to all four PF, does not enable to effectively solve various situations ocurring on the section of PF - TSP 1700. These situations result in defects from the viewpoint of material flow control, most often to be seen in failing to follow the TSP production schedule . This system does not allow the significant decrease of the cost of slab heating in PF. A model of material flow situation control before and in PF, based on operative plan of PF charging - PF production schedule (PFPS), flexibly created according to one of algorithm set according to the situation on PF, is described below.

Pusherer furnaces role in production process of hot rolling mill plant

Slabs of required dimensions are casted on two casters for continuous casting (CSC I and CSC II). Casted slabs can go to slab cleaning shop or by "direct sequence" to heating into one of the four pusherer furnaces (PF3, PF4, PF5, PF6), if they suit to PFP; if not, they go either to the hot slabs store (they will be suitable for PFPS in a short time) or to the cold slab store (Fig.1).

When the request for a slab arrives, a slab is taken from the respective store and transported together with the direct sequence slabs (hot slabs without previous storing) to the heating in the pusher furnaces. Slabs are pushed out of the pusher furnaces after heating by slabs, which has just been charged, and after that they are transported for rolling on TSP 1700 in accordance with the delivery timetables.

The slab motion on PF section is controlled from operator cabins 1PU, 3PU, 4PU, MKP. Slabs are transported from the cold or hot slab store on the delivery table before PF in order according to the TSP production schedule. 1PU operator transports them in front of the respective pusher furnace. Charging into the PF is performed by operators in cabins 3PU and 4PU by means of "pinchcocks" T2,T3,T4,T5 (Fig.1).

A signal to push for 3PU and 4PU is given by operator in MKP, who makes decisions according to the rolling program, from which pusher furnace (and to which PF) the slab will be pushed out (pushed in). In case of slab charging from the "direct sequence" the slabs will come on delivery

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tables just before PF. The whole PF system has a large inertia from the viewpoint of material flow, because there are usually about 100-120 pieces of slabs in PF. (The slab width is 800-1540 mm, length 6 or 8 m, thickness 180-200 mm, PF length is 32.5 m). Since the pushing speed (interval between two slabs pushed one after another out of the PF) is 60 to 120 seconds, operative modification can be done only with the time delay of 200-240 minutes.

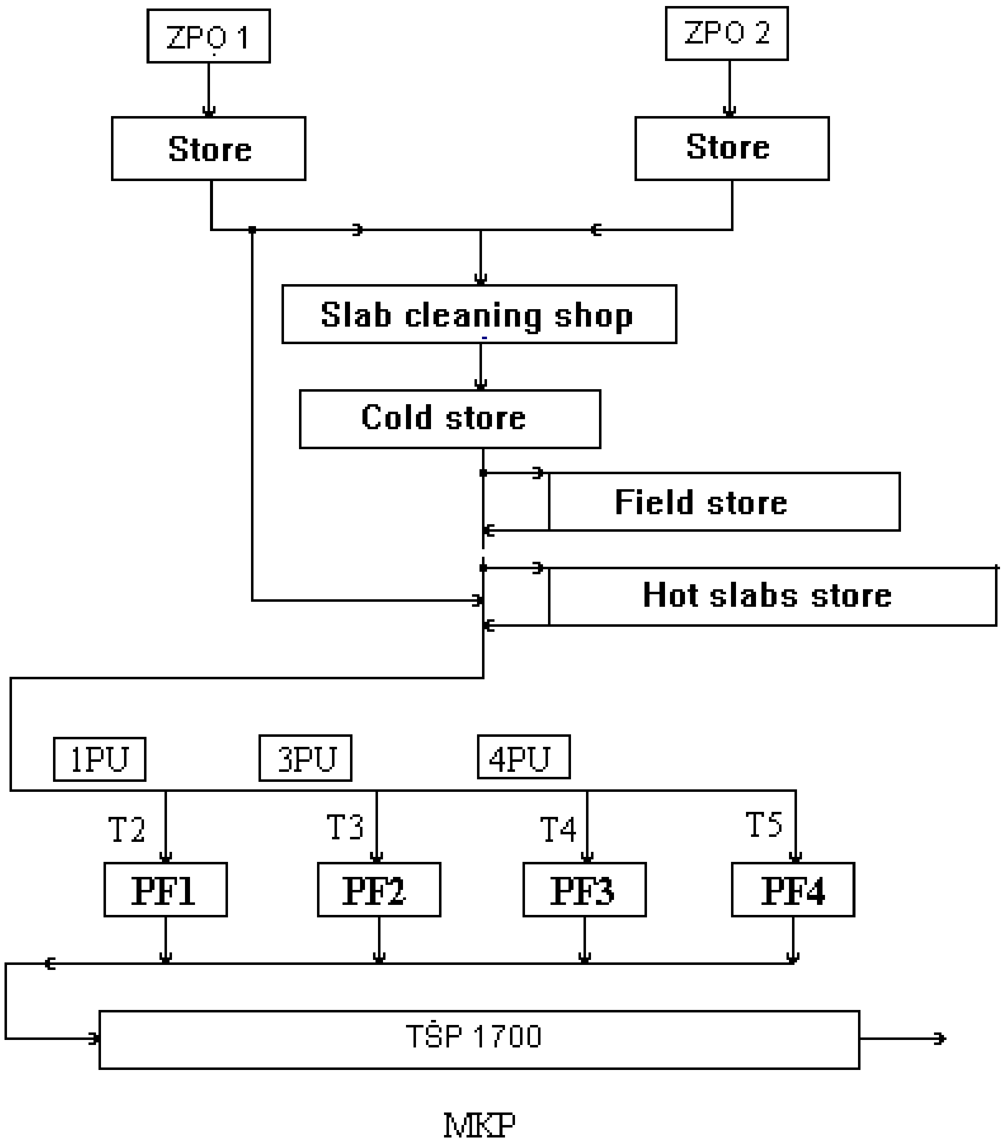

Fig. 1. Material flow scheme around PF.

Information feedback of the section PF and TSP 1700 is through the TSP 1700 flow sheet, created with 4 hour advance manually, and is given to computer KA-10, wherefrom it is utilized in the cabins MKP and 1PU, 3PU, 4PU at charging and pushing out the slabs from PF. TSP flow sheet indicates the order of rolling of the individual slab types and their number.

The current approach to the control and charging of PF has the following main disadvantages:

- Slabs of various qualities are often in PF for heating, with a need of heating to different rolling temperature, and they have often to be heated to the higher temperature, so thatsome of slabs are overheated and energy loss and metal overfiring occurs.
- Slabs are of various input temperature (e.g. 10°C from the cold slab store or 500°C from the direct sequence). The situation on the market forces the manufacturer to confirm incoming orders monthly and weekly. This causes the decrease of average number of same slabs pieces (items) coming to the pusher furnaces. Therefore, often 2 or 3 types of slabs can be in one zone (Fig.3) of the pusher furnace.

- Firm coupling PF input-output limits the possibility to adapt to the situations, when the slabs from the direct sequence delay or come earlier, what causes the TSP flow sheet modification and failing to meet the optimal rolling rules. Heat losses occur at the same time by slabs cooling, because they were not charged in the moment of the arrival to PF.
- There is a different quality of heating at one type of slabs by reason of heating in more PF and this results in different rolled sheet quality for the same order.
- Cyclic slab charging one at the time causes ivery notable heat dynamics of PF, what has an adverse effect on the control of PF.
- The TSP flow sheet does not take into account neither the slab position in the stores nor special conditions for slab heating in PF.
- Large inertia gives a small chance of operative modifications, especially in the case of TSP 1700 shut down and various failures on PF section.

Pusherer furnaces charging control

Pusherer furnaces Control System Idea

Disadvantages described in Section 2 are usually solved by the following model of the situation PF control. The situation control model (Fig.2) is a part of a three-level control systém (Dorčák et al., 1990; Koštial et al., 1991; Malindžák, 1990).

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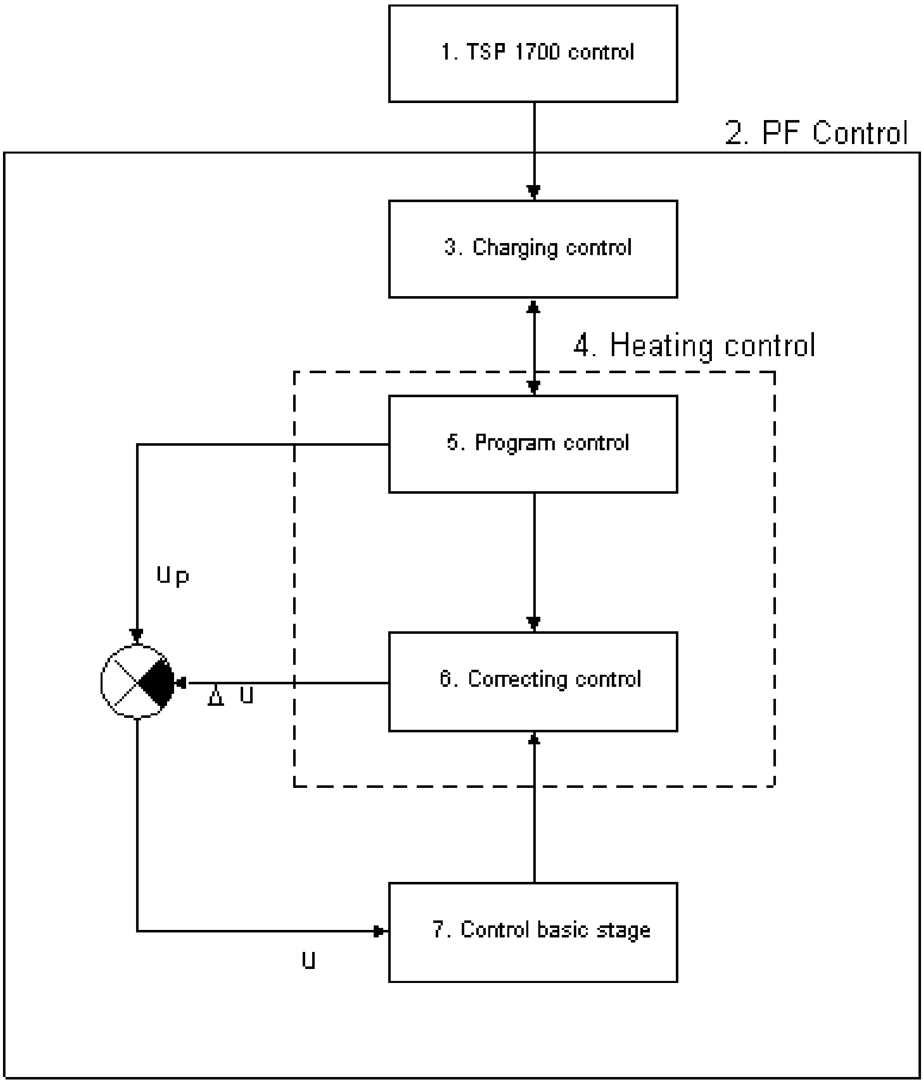

Fig. 2. Structure of PF control system (Dorčák,L.. and Terpák,J., 1990).

- up - program control (Dorčák et al., 1990)
- ∆u - correcting control
- u - resulting control

- Pusher furnaces group control (charging control)
- Heating optimization
- rrecting control.

Pusher furnaces group control is performed through charging production schedule, situation creation and material flow monitoring. It calculates, for a given charging production schedule, from which the lengths of time periods of a slab stay in the PF zones result, the optimization control level, optimal temperature field and inputs for each pusher furnace zone to provide the heating for required rolling temperature. This ensures heating with minimal cost of fuel and minimal metal overfiring losses.
Correcting control compares actual temperature mode and the calculated optimal mode, computed in advance, and in the case of significant difference it performes interventions into heating control in real time with aim of maximal heating to the calculated optimal heating trajectory.

Pusherer furnaces charging situation control

Idea of changing the current way of charging arose from the PF slab heating model idea (Koštial,I. et al, 1991) which supposes that is given to the slabs maximum energy amount in the 2nd zone (cca 60% of energy). (Fig.3).

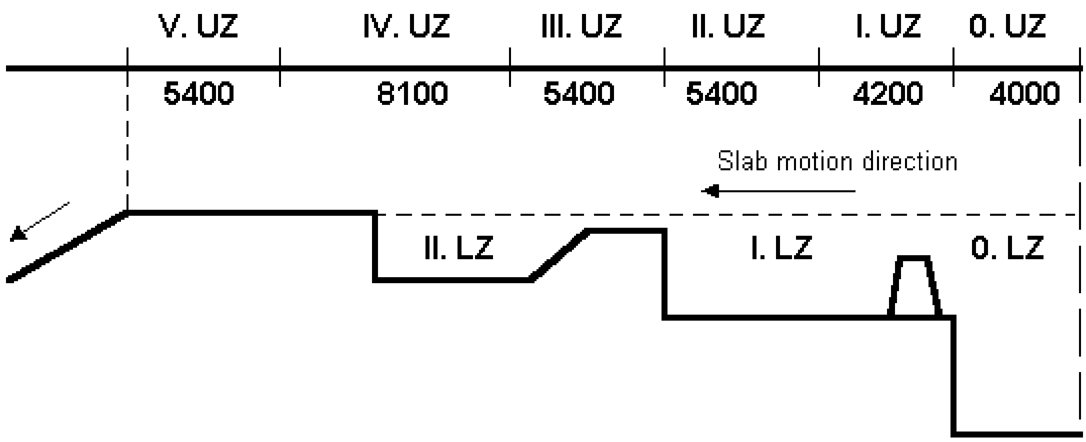

Fig. 3. Pusher furnace (UZ - Upper zone   LZ - Lower zone).

The current PF charging mode, when slabs are cyclically charged into 4 PF one piece at the time, is typical by the fact that slabs of several different qualities (material, dimensions, temperature, thickness) are very often in the same zone at the same time. This led us to the idea of the batch "homogenization" in the second zone, which should also save energy used for heating slabs. Further aspects of this idea were discovered during the charging control system design. As the result, the following aims were formulated.

Pusherer furnaces charging control system aims

The basic aim is to provide the required number of slabs in required order, speed and temperature for the 1700 TSP:

- suitable conditions for the slab heating control in PF are provided by the batch charging, what will provide heating energy saving,
- percentage of hot slabs charging with respect to the total number of charged slabs will be increased, what will also save energy necesssary for heating,
- batch charging allows creation of the PF charging situation control system. This will solve non-standard situations, such as premature arrival of hot charge, delay of hot slabs etc., and these situations will not be failures but, on the contrary, a part of situation control,

- keeping of TSP 1700 production schedule and keeping the optimal rolling conditions will be improved.

Pusherer furnaces batch charging

A batch is a group of slabs of the same quality (dimensions, type of material, temperature) or of two similar qualities, with equal requirements for heating, which are delivered to one PF in the speed interval.

Batch length, i.e. sum of slab widths in one batch is calculated from the PF dimensions.

The batch length is calculated from the PF dimensions and from the PF zones length. PF has 6 zones, the total length is 32.5 m and most of zones have length of 5 m. Heating from gas torches can be regulated separately for each particular zone. The 0th upper zone and the IV-th and the V-th upper zones are not heated. That is why we decided to form the slab batch dynamically basing on the state of the PF and width of charged slabs in the interval 4.5 m to 6.5 m. This is the so-called *standard batch*. Charging is performed using standard batches, if no interference occurs. PF operation mode is changed from the continuous mode to the batch mode. Due to this, the PF operation is divided into 2 periods:

a) Charging - i.e. when several pieces of slabs of one batch are charged into the corresponding PF and the slabs are heated (the position of all slabs in PF is changed at the time).

b) Heating - slabs stand in the furnace, no charging is being performed, slabs are heated and batches for other pusher furnaces are charged.

The sequence charging is typical for pusher furnaces. In such a case, the charged slabs order is determined by the rolling program. This solution is optimal when the furnaces have equal temperature characteristics and work close to steady-state mode. The batch charging mode has the following advantages:

- it allows to utilize of PFs with different productivities. Optimal output distribution for particular furnaces is achieved when all the furnaces work with equal efficiency.

- it enables to collect slabs with similar requirements for heating in one batch.

Requirements for the pusherer furnaces charging control system

They can be written in the following points (Malindžák, 1990):

1. To keep the TSP production schedule and the speed of slabs pushed out of the PF.
2. Slabs will be charged to PF in batches and will enter the PF in speed intervals of slabs just pushed out.
3. Slab need not to be pushed out in the same sequence as they were charged in.
4. Batches need not to be pushed out of PF in the same order as they were charged in.
5. The item entirety must be kept (an item is a set of all slabs of the same quality in all PFs, which can be limited by a contour so that there are no slabs from another item in it). This means that slabs from different items must not be mixed at pushing out.
6. It is important to create such a combination of slabs, which is suitable for heating, already at the furnace entrance, because the 2nd heating zone with the maximal energy supply is situated between 4.5m and 10 m from the PF beginning.
7. Maximizes utilization of hot slabs from the direct sequence and reduce their "mixing" with cold slabs.
8. To prepare algorithms for the solution of situations on the principle of advance control for the situations that caused "failures" in the pusher furnaces charging system and in TSP flow sheet, production schedule,

Generations of PF charging model

We know the "real image of furnaces" i.e. the slab sequence in furnaces during the charging flow
schedule preparation. The whole process (continuous) will be discretized because of planning it for the furnaces image.

Charging flow schedule is a slab sequence for PF, which, when delivered to PF, pushes real image slab sequence out of it. The real image of furnaces is designated FI(N) (Actual composition and sequence of slabs in PF).

Charging flow schedule (1 st. future image of furnaces, FI(N+1)) will be created so that the furnace image FI(N+1) will push the image FI(N) from PF to keep the TSP flow schedule. If we want to know the times of slab transition from the image FI(N+1) through PF, i.e. times of slab stay in

particular zones before entering PF, it also is necessary to create the furnace image of the third generation FI(N+2), because only the last slabs of the image FI(N+2) will push the last slabs of the image FI(N+1) from the furnaces.
For the charging system it is necessary to create and to know the following sequences (see Fig.5):
1. Slab sequence from PF to TSP (TSP flow schedule).
2. Slab sequence in PF (real image FI(N)).
3. First future slab sequence in PF, namely FI(N+1).
4. Second future slab sequence to PF, namely FI(N+2).
5. Sequence on the delivery table before PF with the determination of the time of slab pushing and the number of furnace.

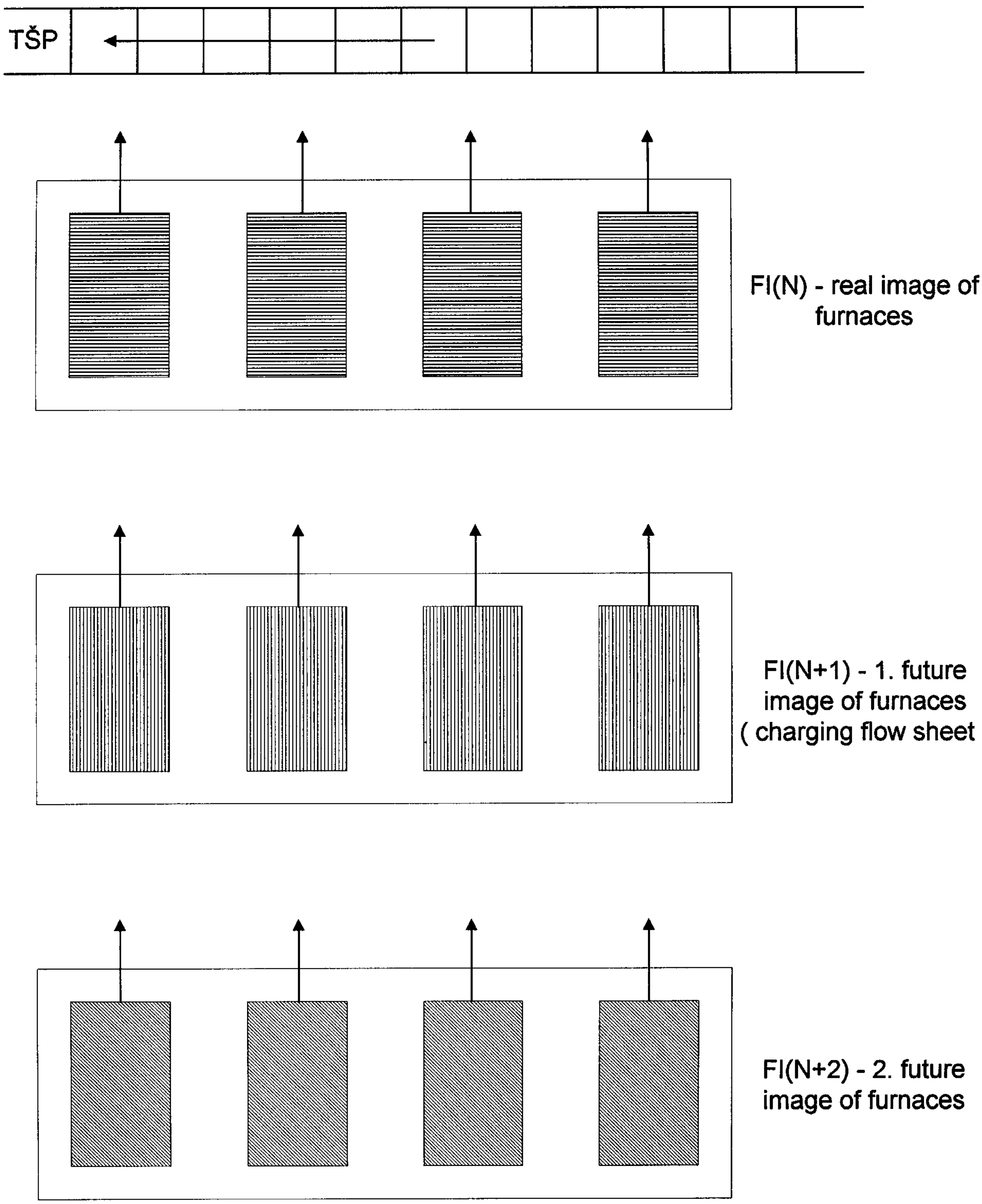

Fig. 4. Charging models generations.

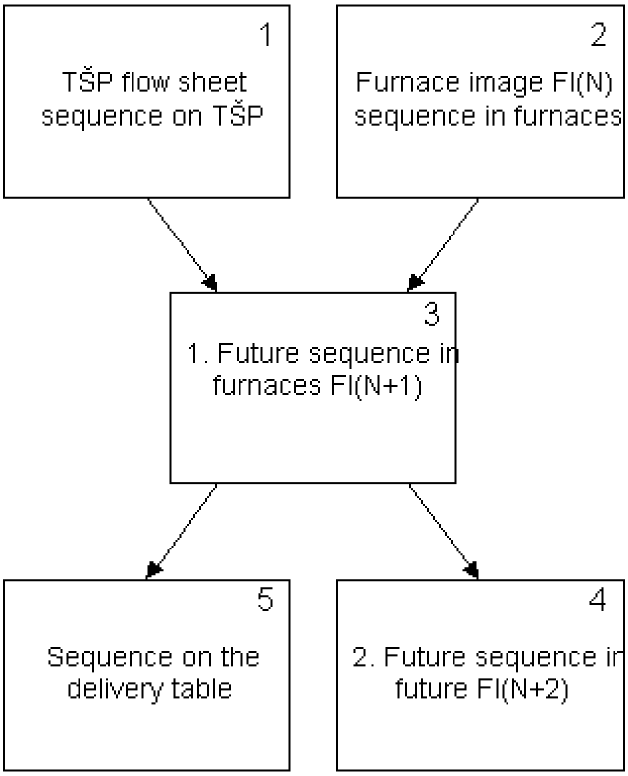

Fig. 5. Slab sequences at the stage of creation of the PF charging flow schedules.

Structure and principles of the pusherer furnaces situation control

Charging flow schedule FI(N+1) and FI(N+2) will be created based on the TSP flow sheet, system operator data (MKP cabin), furnaces condition FI(N), i.e. according to the situations S(N) on PF. FI(N+1) will be calculated with regard to time, and information will be transported to the heating control system, which calculates the optimal heating strategy. FI(N) is gradually updated based on the signals about slab falling out of the PF and the information about pushing into PF. In the moment when FI(N+1) becomes FI(N), new generation FI(N+1) and FI(N+2) is created. FI(N+1) and FI(N+2) are created according to the situation S(N). Situation control consists of the algorithms for solving the following situations:

- Standard situation (PF charging by a standard batch - (SB).
- Utilization of non-standard batch (Non-standard batch is a batch created from slabs of equal quality, length from 5 to 10 m - double length of standard batch) (NSB) .
- Transition from charging of one slab to the batch charging (1 - B).
- Transition from the batch charging to charging of one slab (B - 1).
- Charging of one slab at the time (1S).
- Late arrival of hot charge (LAHC).
- Premature arrival of hot charge (PAHC).
- Transition from 4 pusher furnaces operation to 3 pusher furnaces operation (4 - 3).
- Transition from 3 pusher furnaces operation to 4 furnaces operation (3 - 4).
- Furnace shut down.
- Interactive way of creation of the PF charging flow schedule (IPF).

In the case when no information from the system operator comes in on-line mode, creation of FI(N+1) and FI(N+2) is performed by an algorithm based on standard batch (SB). In the moment of solving any other situation S(N) the system operator recalls the menu of the above situations. He will choose the type of situation and therefore also a module for solving the chosen situation. The called module will generate a mask on the terminal, where information for the chosen situation is depicted, for example:

- time delay of hot slabs

- item number
- number of slabs, etc.

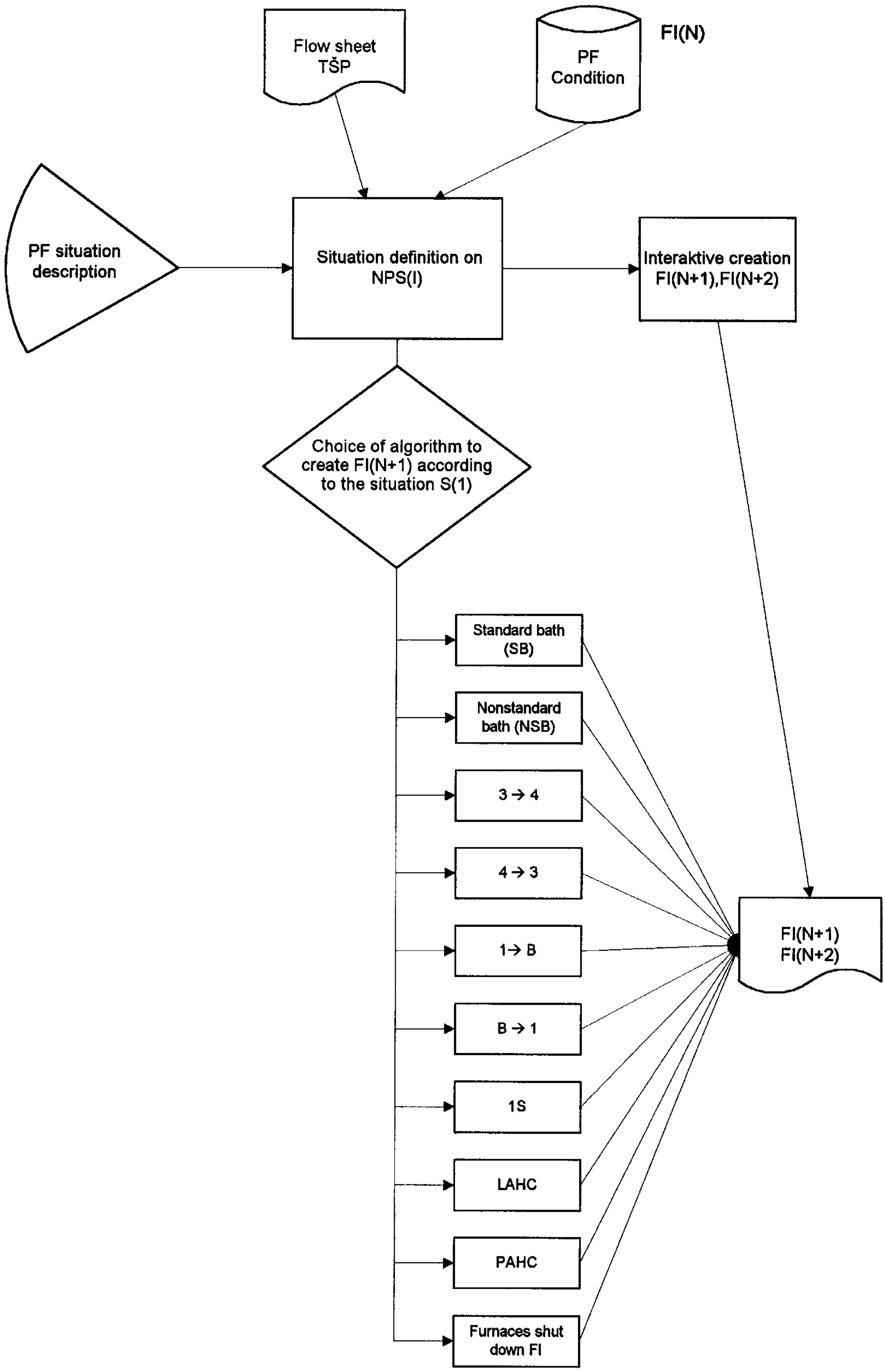

Fig. 6. Structure of the situation control of PF.

Each module calculates the possibility of solving the situation with regard to the system inertia. If the problem can be solved, the furnace images FI(N+1) and FI(N+2) are created.

The situation solution may be in arbitrary time. In the case when the system cannot solve the situation, this will be reported to the system operator. The operator may choose another module or switch to interactive mode and a logistics will create FI(N+1) and FI(N+2).

Description of the module for the situation solution

<u>Utilization of a standard batch for creating FI(N+1) and FI(N+2).</u>

- Let us introduce an item map: an item map is a shape of the same item slabs arrangement in the pusher furnaces, limit of which is made by a continuous line - contour (MAP(I))

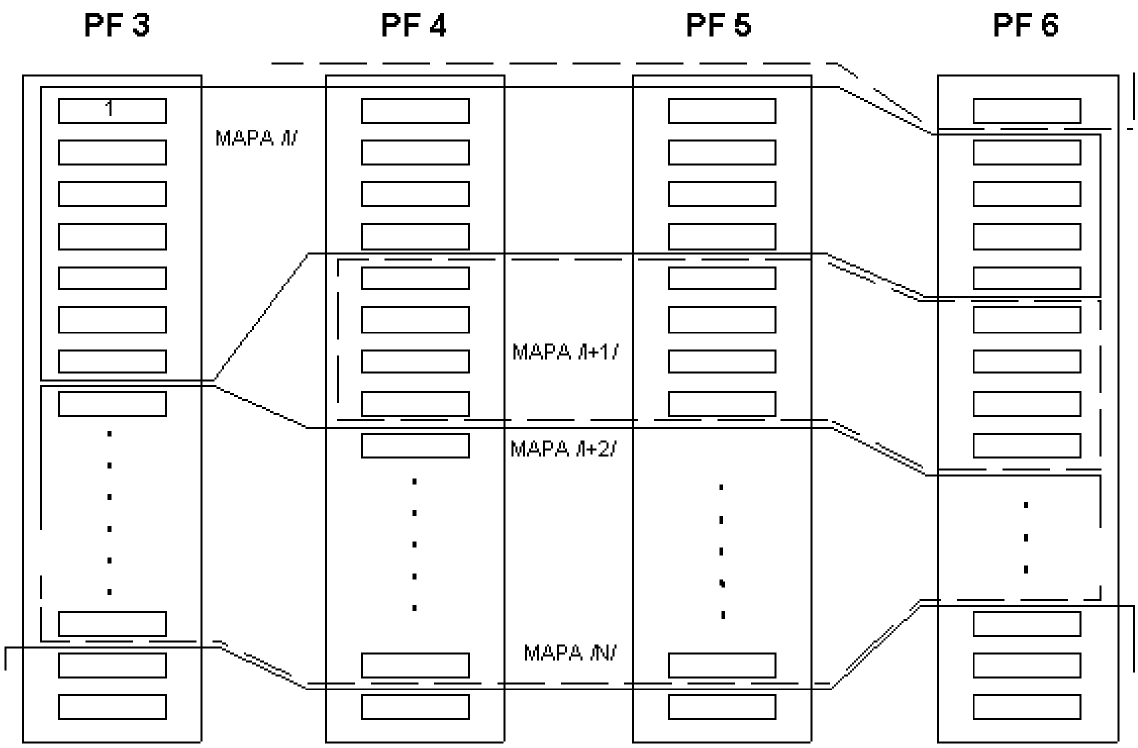

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Fig. 7. Maps of items in the image PF - FI(N).

- We know the order in which batches are pushed out of FI(N).
- We know the shape MAP(I) of the image FI(N), which must be pushed as a first one; therefore, we know the number of slabs and the batches lengths, which are occupied by the item (I) in a particular PF.
- We will find out whether no other situation occured in the charging moment S(N).
- If no other situation is defined, standard batch of slab item (SD) will be created as to push them out from the MAPA (I), batch from the PF "J", where the batch from the item (I) was delivered first.

We will push out the batches from the item (I) by the most recently created batches from the map MAP(I) of the image FI(N+1) in the same order as they were charged into the PF. The batch consisting of the slabs of two items will be pushed out as the last one (if any). Maps are of various shapes depending on the slabs width and sill.

If there is an insufficient number of slabs for creatiing a batch of required length, we fill it using the slabs of the next item to obtain SB. This is repeated (in simulation) untill all FI(N) image maps are pushed out of the PF and the image FI(N+1) is created.

The process for creating the furnace image FI(N+2) is the same - image FI(N+1) is pushed out from PF during the simulation.

Late arrival of a hot charge

There can be situations, when at the time T an operator obtains the information that the hot slabs of direct sequence scheduled for charging to PF in time T_o will not come at the time $t \leq T_o$, but at the time $T_o + \Delta T$. The aim is to charge such delayed slabs to the PF as soon as possible, to accelerate their transition through the PF to push them out approximately at the scheduled time according to the TSP flow schedule.

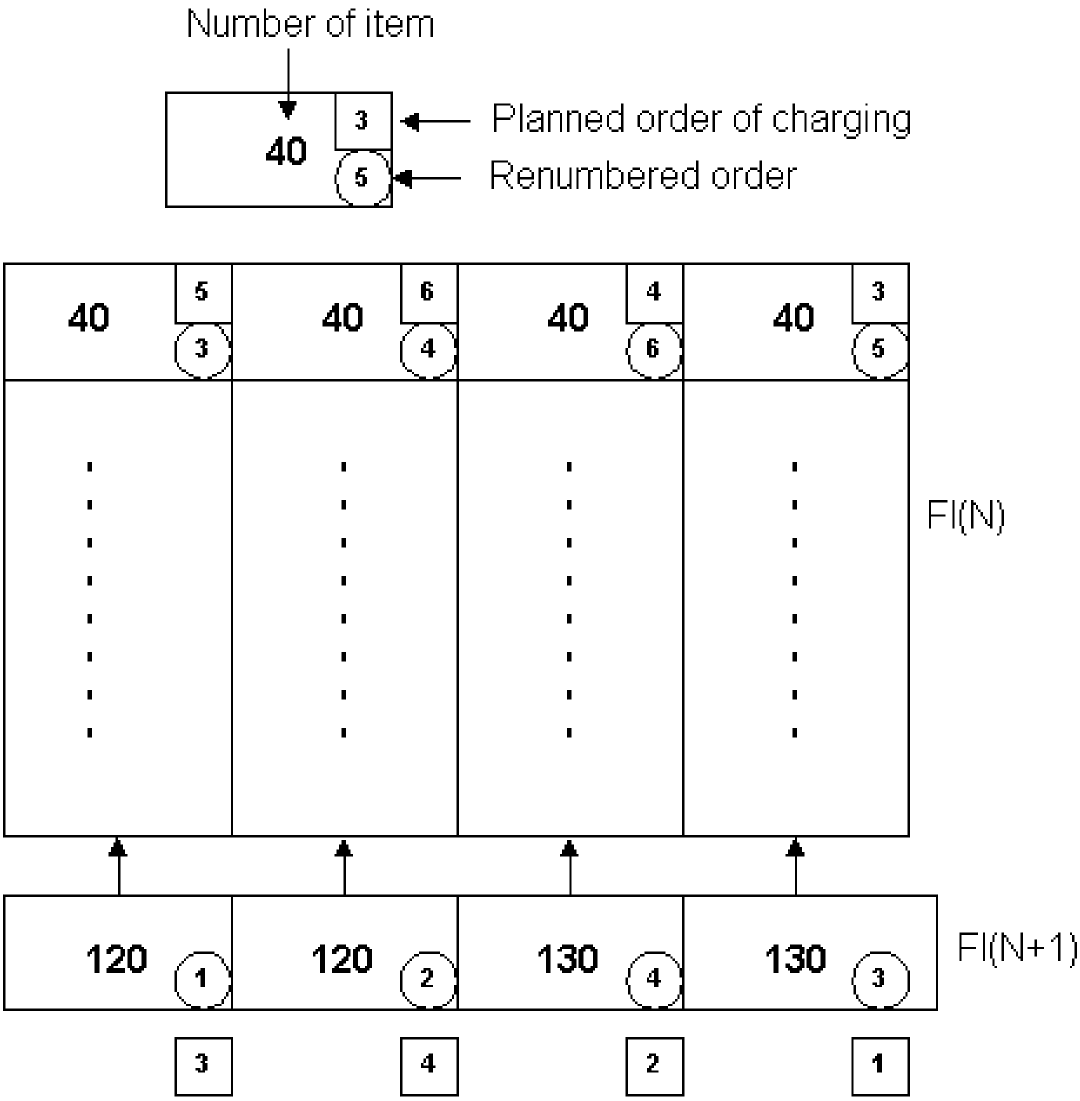

Fig. 8. Solving the delay by renumbering the batches.

This can be done in the following way:

a) Let us suppose that the delayed slabs belong to the item I.

b) If we want to achieve the above aim, then at least the item I+1 will be charged to PF before the item I.

c) Because the slabs cannot outrun each other in the same PF, the item I+1 cannot go to the pusher furnace before the item I, as the item I will be pushed out before the item I+1.

d) We shall "shift" FI(N) into the condition at the time $T_o + \Delta T$ by simulation (until the time of arrival of the item I to PF).

e) Let the situation at the time $T_o + \Delta T$ be the following:

In such a case, the situation can be solved only by renumbering the batches I=120, I+1=130. Order of charging is changed so that the corresponding number of batches of the item I+1 (number of batches I+1 = number of furnaces - number of batches I), will be charged before the item I. At the moment of charging, the batches will be renumbered in the furnace image FI(N). Time of acceleration

of the delayed item will be equal to

$$T_a = (\sum_{i=1}^{NB} N_i)^* S$$

where: NB - number of batches, which will outrun the item I
N - number of slabs in the batch i
S - charging speed.

A necessary assumption for this solution is the occurence of the same item batches in the PF output.
f) If it is not possible to solve the situation by means of the algorithm according to (e), the following algorithm is used:
- we create a non-standard batch (NSB) from the item (I), if the sum of slabs width in the item I is in the range of 5 to 10 m,
- we find the PF, say with the number J, at the time T_o+delta T, from which the length of batches, the item K batch and the item K+1 batch (or K) is larger or equal to the length of the non-standard batch of the item I, NSB(I).

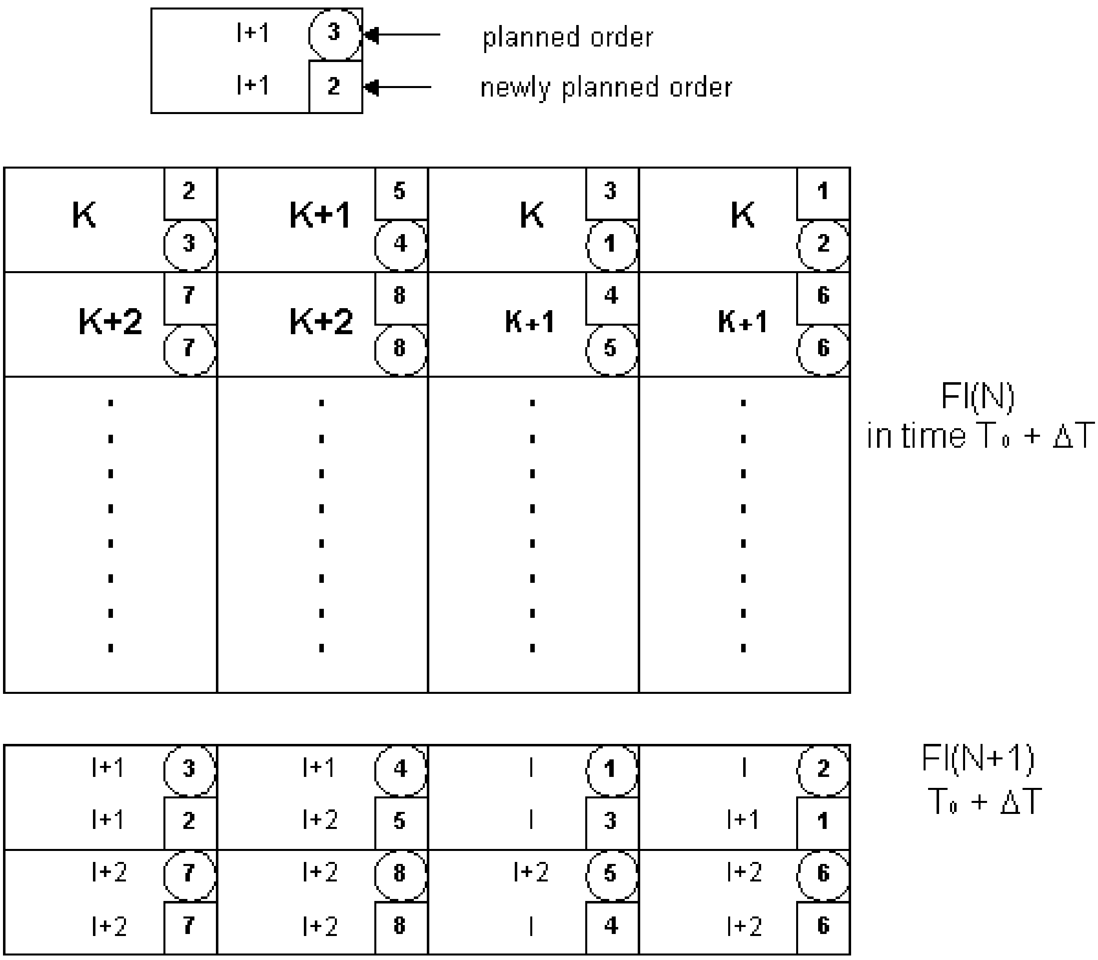

Fig. 9. Solving the delay by a non-standard batch.

For example, let it be the PF5. We cannot charge the slabs of the item I+1 into this PF. We solve it as shown in Fig. 8.

Modules for the solution of other situations are not described because of the paper length limitations. The reader can find them in Koštial,I. et al.(1991).

Conclusion

A new approach to the pusher furnaces charging control, which has been successfully applied in VSŽ a.s. Košice, is described in the paper. This approach is based on pusher furnaces charging by slab batches. A control system for the control of charging is created as the situation-based control, so with the majority of situations, which created failures on PF and TSP 1700, becomes a natural part of advance situation control system.

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