Fall-Back Mode Operation on Remotely Controlled Railway Lines

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This paper deals with handling abnormal situations raised on remotely controlled railway lines, in particular how to maintain an automatic operation that is a core function of such systems. Unlike conventional traffic control, in case of remotely controlled stations the operational personnel is not located on the stations, thus nobody can intervene in the railway traffic locally, if necessary. In addition, replacing staff with technical devices and automatism makes the number of potential failure modes even higher. The most critical event happens when the data connection between the control centre and the station is lost, so that the human supervision of the traffic terminates. This paper presents the human, technological and technical aspects of treating such failures and offers some potential solutions in order to maintain railway traffic and minimize disturbances.

Keywords: railway, CTC, remote control, operational control centre, fall-back mode.

1. REMOTE CONTROL OF RAILWAY LINES

Conventionally, the railway traffic is handled manually by the local operators at the stations. Usually there is a hierarchical operational organization above them that consists of dispatchers with different roles and responsibilities. This staff organizes and optimizes the traffic of the entire network. Its role is highly important in case of discrepancies of the planned schedule (due to the track of rolling stock, wayside equipment failures or human errors). The dispatchers try to avoid disturbances by forecasting train movements, planning and ordering the local operators how to control the traffic. These orders are executed by handling the following:

- signalling system (e.g. points, signals, level crossings, interlocking, power supply),
- overhead line system (e.g. power switches, grounding),
- communication system (e.g. data network, engine driver radio system),
- passenger information system (e.g. displays and speakers),
- operations information system (e.g. schedule management, moving authorities),
- wayside vehicle monitoring system (e.g. hot box detection, load measuring)
- alarm system (e.g. infrastructure security, fire detection).

At present the railway infrastructure management companies are pressed to lower their operational costs and improve their effectiveness at the same time. In order to achieve these goals, the state-of-the-art technologies particularly in information and communication technology and in control systems are welcome to use in railway domain. Although local operators have to handle a wide range of systems, in case of small stations their workload is not utilized adequately. In addition, new technologies are capable of not only replacing human resources in certain processes but also optimizing traffic flows with sophisticated automation. Moreover, they can ensure higher safety than former systems. At the highest level of automation the local operators of the railway stations can be replaced by a remote control system that is able to handle all systems listed beforehand.

This system consists of remote control workstations where handling of more stations is integrated thus even a whole railway line could be controlled remotely from one central place. The workstations are usually installed in an operation control centre and each one is responsible for specified tasks over specified stations or lines. Usually for each task there is a single person assigned e.g. for signalling, overhead line managing, passenger information purposes. This modern form of railway traffic operation is called centralised traffic control (CTC).

This centralised system requires technical enlargement and additional devices at the stations. Despite expanding the existing equipment with further elements, a higher availability is expected. It may seem like a contradiction because in case of serial systems the higher the complexity, the higher the possibility of a failure. For that reason many parts of the CTC system are built in a redundant way to minimize the duration of downtimes and allow all the components to operate simultaneously.

The mentioned features of CTC systems like complexity, integrated functionality, availability, redundant architecture, are typical for every implemented system. Apart from this we must take into consideration situations when this system incidentally fails. Maintaining the railway traffic under such circumstances (no local operators at the stations) requires special hardware and software composition and regulation by operational rules. These aspects are discussed in the following section.

2. EMERGENCY SITUATIONS

From the viewpoint of CTC those events are considered emergency situations when the control of the railway traffic and the related tasks cannot be performed from the operation control centre. This partial or total failure can derive from:

- station devices,
- centre of the CTC system or
- communication network between the stations and the centre.

These disturbances can cause traffic congestions, delays and other serious disruptions in the railway traffic. It is necessary to avoid its consequences or at least lower the scale of problem by prompt intervention. However the fact that there are no local operators along the remotely controlled lines and some stations are totally abandoned makes it difficult to accomplish this task. The emergency situations should be treated from technical, technological and human aspects in order to minimize the duration and the territorial scale of the disturbances.

2.1. TECHNICAL ASPECTS

The emergency situations are triggered by the previously listed potential failures considering technical aspects. However it is assumed that besides these types of failures the voice communication between the train personnel and the centre remains available. The communication channels are independent of the data network; their power supply is also independent of the CTC system, as uninterruptible power sources are commonly and easily applied, while mobile devices use batteries. The possibility of the failure of the remote control workstations is really slight because of the applied redundancy concerning both the workstations and the power supply system too. The multiple loop architecture of the data network makes the loss of more stations or an entire railway line also unlikely. Based on the experiences of the existing Hungarian CTC systems only one station loss is so possible that should be taken into consideration in the followings.

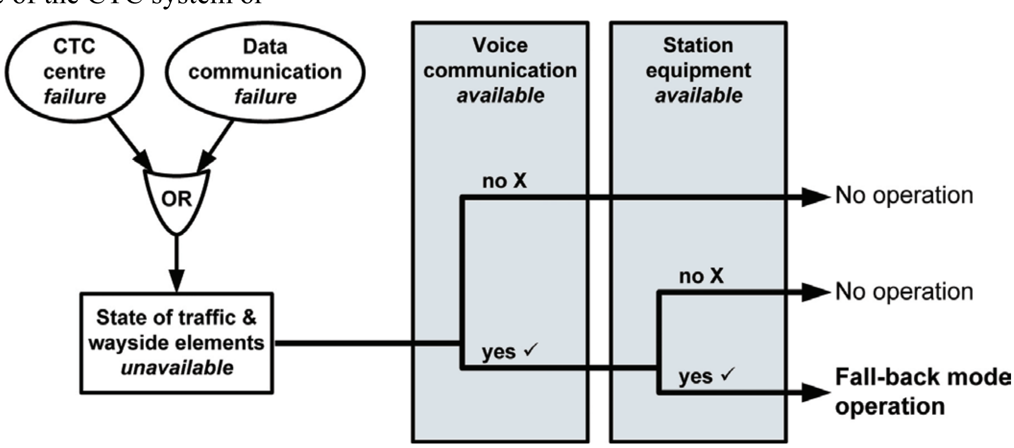

Fig. 1. Combined fault and event tree for fall-back mode operation.

The potential failures and subsystem availabilities taken into consideration regarding the fall-back mode operation are depicted in a fault and event tree (see Figure 1.). From operational aspects the failure of the data connection and the failure of the remote control workstation can be examined together as the consequence of both events: the actual state of the traffic and that of the wayside elements is not transmitted to the CTC personnel. This can be regarded as a critical situation, since the computer aided traffic control becomes disabled. This is the result of the fault tree and the initiation of the event tree. The only way to control the railway traffic is to order the train personnel by voice communication, as we assume that communication remains available. However many parts of the CTC system cannot accomplish their tasks in this situation, because their functionality is partly or totally related to the remote control workstation e.g. logging, train identification, train controlled route setting, automatic passenger information. Note that station devices generally are able to continue their work properly even in such situations, as their possibility of failure is independent on the centre and on the data network.

2.1.1. Suitable system architecture

Based on the general technical aspects mentioned before, potential system architecture will be described in this section that is able to operate under abnormal circumstances too. The signalling, operation information and passenger information systems will be emphasized, because their outage causes immediate effect on railway traffic, while the overhead line control, wayside monitoring and alarm systems are usually not continuously used, so their fall-back mode operation is not an essential requirement. The structure of a potential CTC system with the correspondent human participants, signalling and operation information system is depicted in Figure 2.

Considering the technical aspects the figure shows the relations between the operation information system and the signalling system that consists of the remote control workstation and the interlocking devices of the stations involved. In normal operational this composition ensures high level automation in the traffic control due to the train controlled route setting. The input of this function is the schedule that is determined by the allocated train paths. These schedule data are transmitted to the operational information system and stored in a database. The traffic technologist reviews the received schedule, fixes the bugs, if there are any, and fits it to the operational technology, for example he creates the connection options for passenger trains. These disposition criteria mean that the conditions of the train controlled route setting are on the planning level.

While the trains run, the CTC-dispatchers and the CTC-operators (see section Human aspects) can modify this database according to the actual traffic situation if necessary. The train numbers are assigned to the track occupancies at the remote control workstation. This safety related system and the information system is strictly separated, however the communication between them is ensured. The remote control workstation gives the actual train positions, while the information system sends the route setting orders with the related conditions back. The train controlled route setting is a built-in function of the remote control workstation, practically an interface between the information system and the station interlocking, which processes and evaluates the route setting orders and their conditions. When all requirements are fulfilled the route setting order is transmitted to the interlocking of the appropriate station. The station interlocking executes this route setting as usual. This operation is similar to other CTC systems applied in Austria and Germany (see [1], [2]).

The potential architecture of the passenger information system follows the same as the signalling system. The distributed system consists of a control computer connected to the remote control workstation and speech machines at the stations. Although the control computer controls the speech machines by sending the train numbers and trigger conditions, the speech reported at the stations via loudspeakers is stored in the speech machines locally.

Considering the mentioned signalling and passenger information systems, a fall-back mode operation can be defined, since their operation is partially independent of the outage of the CTC centre. The executive devices (interlocking and speech machine) and the trigger elements (track occupancy sensors) operate at the station level. In case of the outage of the centre or losing the data connection the train detection still works, but the train identification by the train number fails, as this function is accomplished at the CTC centre. Thus the control messages (about the route settings and the reported speech) are not transmitted to the stations. However activating the fall-back mode operation described in the following section the operation of the signalling and passenger information systems can be maintained.

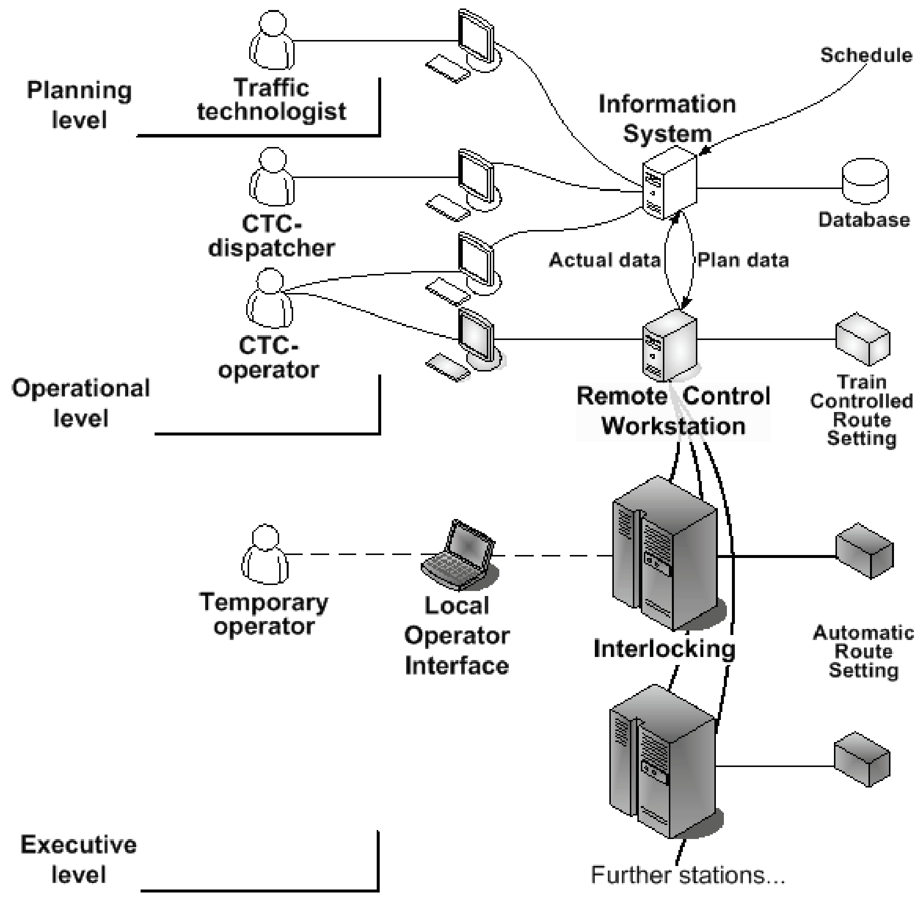

Fig. 2. Potential CTC architecture.

2.1.2. Fall-back mode operation

The fall-back mode operation means a fixed automatic function built in the interlocking, and the speech machine that always executes the same commands when any train approaches the station, as the trains cannot be identified individually. In case of the interlocking this function is called automatic route setting and depicted in Figure 2. Passing a train through the station, handled by this function, is performed in two phases (see Figure 3.). For example, for every train arriving from direction A an entry route is set to platform I., and then an exit route is set to the direction B (dotted arrows). For the trains coming from the opposite direction another platform should be appointed for passing (dashed arrows). If any condition necessary for performing the route setting is missing, the process is suspended until it is fulfilled. Thus trains incidentally depart from both adjacent stations will not cause a deadlock situation; moreover this solution enables even train crossings to be accomplished at a station out of remote control. Both tracks appointed for fall-back mode railway traffic should be provided with platforms in order to be able to serve passenger trains.

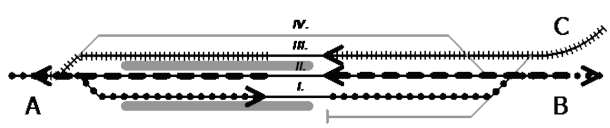

Fig. 3. Potential route settings in fall-back mode operation

In case of junction stations train movements are ensured only at one way considering the branch line (direction C in Figure 3.). While routes can be set from direction C to A (stroked arrows), the exit routes of the opposite direction have more potential endpoints. Without train identification the fixed automatic function cannot find out the correct direction. In such cases a potential solution is to set the direction used more often as a default endpoint, and the trains that might intend to run to another direction should be stopped at the previous station. Considering larger stations this solution would mean significant capacity limit, so it should be ensured that the control of the station fallen out from remote control is temporary taken over by a local operator as fast as possible. Since these large stations are usually not totally abandoned, it does not seem to be an impracticable requirement.

The fixed automatic function must work at every station in the same way; the only configuration parameter is the platform number and the main direction in case of junctions. Keeping this principle in mind, the CTC personnel will always know which route should be set if a train approaching a station has fallen out of remote control, and he can notify the train personnel about it if necessary.

For passenger safety reasons, the passenger information system should be also maintained in course of emergency situations. A potential way is to inform the passengers about the railway traffic by speech directly from the CTC centre, if the communication system is available. Another way is to define a fall-back mode operation considering the automatic passenger information system. Without train identification there is no chance to give detailed schedule information to the passengers about the trains. Moreover it is also impossible to detect whether the approaching train is a freight train or a passenger one, and if it is the latter whether it is going to stop at the station. The primary goal is to draw the passengers' attention to an approaching train by automatic warning speech, thus ensuring their safety. It is feasible since track occupancies are processed locally, and the concerned platform can be also retrieved from the automatic route setting function of the interlocking. This architecture can be improved by enabling the speech machines to inform the passengers about the fall-back mode operation and let them know that detailed schedule information is not available. This can be completed by the ticket inspectors if the platforms are equipped with communication boxes that allow direct connection to the loudspeakers. Note that these boxes are also essential to ensure redundant communication on remotely controlled lines by enabling the connection to the dispatchers' phone network.

The defined fall-back modes in signalling and passenger information systems allow maintaining train traffic on stations fallen out from the remote control. A great advantage is that during this mode of operation the CTC personnel still knows what kind of automatic processes are executed at the stations. However this solution can only work properly in emergency cases, if the voice communication, the interlocking devices at the stations and the railway track remain available (see Figure 1.).

Despite all efforts put into fall-back mode operation the railway traffic cannot be maintained permanently and in case of large stations disturbances appear quite soon. Besides starting troubleshooting, the handling of station loosed connection with the centre should be taken over temporary by a local operator. The related technical requirement is to ensure local operator interface at every interlocking. This HMI can be:

- a conventional desk (in case of relay interlocking),
- an installed computer (in case of existing electronic interlocking or relay interlocking equipped with electronic control board) or
- plugging facility for a portable emergency control computer.

The last option is depicted in Figure 2. This additional relation of the interlocking system is marked with dashed line. Every kind of emergency computers should be capable of controlling the interlockings at all stations that were defined previously. This operating area is only restricted by the performance features of the computer; however only those interlockings are included that do not have local HMI. At larger stations an ordinal HMI must be left, because handling them through a portable machine is quite cumbersome due to heavy traffic and ergonomic aspects. For security reasons the emergency computer must be used only for HMI purposes, all kind of media devices are forbidden to connect as input device.

The failure of station devices can occur independently of the CTC system. State of different types of station devices (e.g. interlocking, communication, overhead line and power systems) are monitored from the CTC centre. Their failures are indicated at the workstations of the CTC centre in a similar way as it is implemented at conventional stations without remote control. The railway traffic can be maintained with safety critical signalling commands, however these commands cannot be ordered automatically, so the train controlled route setting function should be disabled in the area of the faulty element. In this situation the workload of the CTC-operator suddenly increases, in addition it has to give safety critical commands without the supervision of the interlocking and including the possibility of human error. That is why the fast troubleshooting and appropriate specialist crew re essential. That can be ensured by organizing the duty services of the troubleshooting personnel.

2.2. TECHNOLOGICAL ASPECTS

The procedures to be applied in case of failures of station devices have been already discussed. However sometimes it is necessary to identify the failure locally or inspect the faulty element. As there are no local operators, the personnel of trains or other railway co-operators should be involved depending on the seriousness of the failure. Thus the origin of a failure concerning e.g. a track occupancy detector, a signal or a point can be easily and quickly determined before the troubleshooting staff arrives. For example a point failure can be eliminated just by removing the obstacle from the track.

The procedures applied in case of the outage of CTC centre or data communication, when fall-back mode operation is activated, require special regulation. The most important restrictive factor at junction stations is that the automatic route setting function always sets the exit routes to the same endpoint from every direction. Thus those trains that would pass to another direction have to be stopped at the previous remotely controlled station. The same procedure should be followed in case of those trains that must run on a track different from what the automatic function uses or which terminates at the station. It usually affects mainly freight trains, for example RollendeLandstrasse (Ro-La) cargo.

The most appropriate staff who can take over the control of a station fallen out of remote control is the signalling or communication troubleshooting staff, as these organizations are ready to react immediately to unexpected failures (see duty services). Usually they arrive firstly at the abandoned stations. The takeover of handling a station means activating the local HMI described in previous section. At this point we have to define the limits of roles and responsibilities of the participants. Depending of the regulation issued by the infrastructure manager company the troubleshooting staff can set all potential commands on the HMI in compliance with the CTC-operator's orders, or their role can be restricted only to normal commands, while safety critical commands cannot be performed at all. In case of both solutions the troubleshooting staff should be trained (and re-trained regularly) about the operational rules before they are allowed to handle the interlocking. If the failure of the station is serious or seems to be long lasting then a temporary operator must be assigned. Considering larger stations which are not abandoned totally, the temporary operator should be selected from the remained staff who can take over the control immediately if necessary. However the notified temporary operator always has to act in compliance with the CTC-operator's order.

2.3. HUMAN ASPECTS

The roles and responsibilities of the human participants should be clarified in case of handling a station locally. Under normal circumstances the CTC personnel controls the station. At the moment the CTC-operator is the person who is responsible for a group of stations considering every event that occurs there. However responding these events is not only his duty. As it is mentioned in the section a suitable system architecture and the range of CTC functions is assigned to different workstations. The CTC-operator is responsible for the signalling and operation of information systems, in addition collects and distributes information from other workstations concerning his stations. Generally it is quite rare that a CTC-operator gives commands through the remote control workstation, instead he/she handles the operation information system, plans the train traffic about 1-2 hours forward, while the train controlled route setting function issues the effective commands.

The CTC-dispatcher usually carries out the operational planning. It means that he deals with the track restrictions and trackside works. He logs these events into the operation information system, and communicates with the maintenance staff, if necessary. Through the operational information systems or by speech they inform the CTC-operators and the train personnel about every restriction. With this cooperation between the participants the railway traffic can be organized efficiently under normal circumstances.

In course of emergency situations temporary operators are required immediately at the stations that have fallen out of remote control. This demand on human resource can be satisfied by the troubleshooting personnel or by the railway staff remaining at the station. Whichever is chosen, the potential temporary operators should be trained about the operational rules. Even though they do not control the railway traffic effectively, they can be logically considered as a transmission channel between the CTC-operator and the station devices, therefore a simplified operational training is enough for them.

Besides the temporary operators, the CTC-operators should also be prepared regarding the unexpected emergency situations with numerous restrictions. The train controlled route setting function is disabled even if only one interlocking element fails. The CTC-operator has to temporary tolerate the higher workload and stress. Meanwhile his decisions have got serious effects on railway traffic; greater awareness is required to avoid leading the trains into a deadlock situation under the restricted conditions. Although the fall-back mode automation at the stations partially counteracts this situation, yet it is not absolutely impossible to occur, therefore the role of the CTC-operators is indisputable.

The appropriate education and training system can ensure the preparation of the CTC-operators. During theoretical education the correct procedures and the efficient strategies should be discussed, while applying operation simulation software, the principles can be practised and the workload can be examined by generating emergency situations. Since the availability of modern CTC systems is high enough, and the possibility of emergency situations is quite slight, the efforts into the preventive actions can be questioned. Nevertheless the serious consequences of the failures of the CTC functionality and the potential large scale of damages points at the important role of education and training.

3. CONCLUSIONS

In this paper we presented a complex solution on how to handle railway traffic in case of emergency situations. Since many types of failures can be raised concerning CTC systems, a fall-back mode operation is defined in order to maintain the traffic with less congestion. Considering technical aspects, a suitable CTC system architecture is described that distributes the functionality to different levels of traffic operation and execution. This structure ensures the station devices to work on even when the CTC centre or the data communication falls out. Besides that, the roles and responsibilities of the CTC personnel (centre, stations, train and troubleshooting staffs) are clarified and the proper proceedings under abnormal circumstances are determined. In connection with the human resources the importance of the education and training is emphasized. The main conclusion is that the fall-back mode operation aided by technical solutions has to be harmonised with the concerning technological and human aspects.

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