

# Train Control on French Railroads

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The French National Railways' (SNCF's) first high-speed line has been in service between Paris and Lyon for 10 years now. A second high-speed line came into revenue service in September 1989, bringing with it substantial improvements to passenger services to the west and southwest of France. At the same time, SNCF is engaged in construction work for the Northern Train à Grande Vitesse (TGV) line, which will link Paris, Brussels, and London via the Channel Tunnel in less than 2 years' time. A loop line around the eastern outskirts of Paris will link the Northern and Southeast high-speed lines. The Southeast high-speed line will be extended southward (initially as far as Valence). High-speed electric multiple units (emus) will be operated on the new lines at 300 km/hr (187 mph), whereas train speed on the Southeast high-speed line is currently limited to 270 km/hr (168 mph).

For the French National Railways (SNCF), the highest speed at which drivers can be sure of properly observing lineside signals, especially under difficult operating conditions (e.g., fog), is in the 200/220 km/hr bracket. For higher speeds, it is necessary to design a system that does not depend on correct observance of lineside signals because signaling information is transmitted directly to the driver in the cab. In addition, SNCF works on the principle that trains should be driver operated, with drivers responding to the information provided in the cab and adapting tractive and braking forces accordingly. It is, of course, common knowledge that, however reliable, human beings are more error prone than sophisticated automatic systems, whence the need to protect against driver failure.

A continuous speed-control system has therefore been installed in conjunction with the signaling system. This comes into action to generate braking should train speed differ too greatly from the curve set by the speed-control system.

## SIGNALING ON THE SOUTHEAST AND ATLANTIC HIGH-SPEED LINES

The signaling system designed in relation to line throughput, vehicle braking characteristics, and specific operating conditions consists of the following:

- A continuous data transmission system (18 data items), and
- An intermittent data transmission system (14 data items), with track-to-train transmission.

The type and technical characteristics of the transmission systems selected were the result of recognition, early in the research phase, of the fact that it always takes time to design

a signaling system because of its vital safety function and the many and serious environmental constraints (interference, wide-ranging temperatures, atmospheric agents, vibrations, etc).

In addition, SNCF considers it necessary to have a continuous control system for detecting broken rails, whence the choice of track-circuit-based signaling technology.

## Continuous Data Transmission

Under the circumstances described, the continuous data transmission system selected consists of an alternating current (AC) track circuit. There are 18 modulation frequencies between 10 and 29 Hz, depending on the data item to be transmitted. To protect against crosstalk, four carrier frequencies are used.

With track circuits of this type, it is possible to use resonant blocking circuits instead of the insulated joints required with most track circuits, which, in turn, means that jointless, long, welded rails can be used with all their advantages in terms of track performance and vehicle stability.

## Intermittent Data Transmission

The intermittent data transmission system consists mainly of a 10-m cable loop laid in the track. Frequencies range between 1,300 Hz and 3,700 Hz, depending on the data items to be transmitted.

Figures 1 and 2 show the braking and stopping sequence for block sections and for protection at mandatory stopping points.

Adaptations have been made to handle cases of access to track changeover points, turnouts, and points contiguous with lineside signaling when the high-speed line connects with conventional lines.

## SIGNALING ON THE NORTHERN HIGH-SPEED LINE

Line throughput requirements for traffic expected on the Northern high-speed line, which will begin revenue service in 1993, are incompatible with the signaling used on the new Southeast and Atlantic high-speed lines. Whereas trains operated at 270 km/hr on the Southeast line have 5-min headway, it has been cut to 4 min on the Atlantic Train à Grande Vitesse (TGV) line for trains operated at 300 km/hr. The objective on the Northern high-speed line is a 3-min headway (in practice) for an operating speed of 300 km/hr.

Moreover, provision has been made for working the line at 320 km/hr (200 mph). To achieve these objectives, SNCF

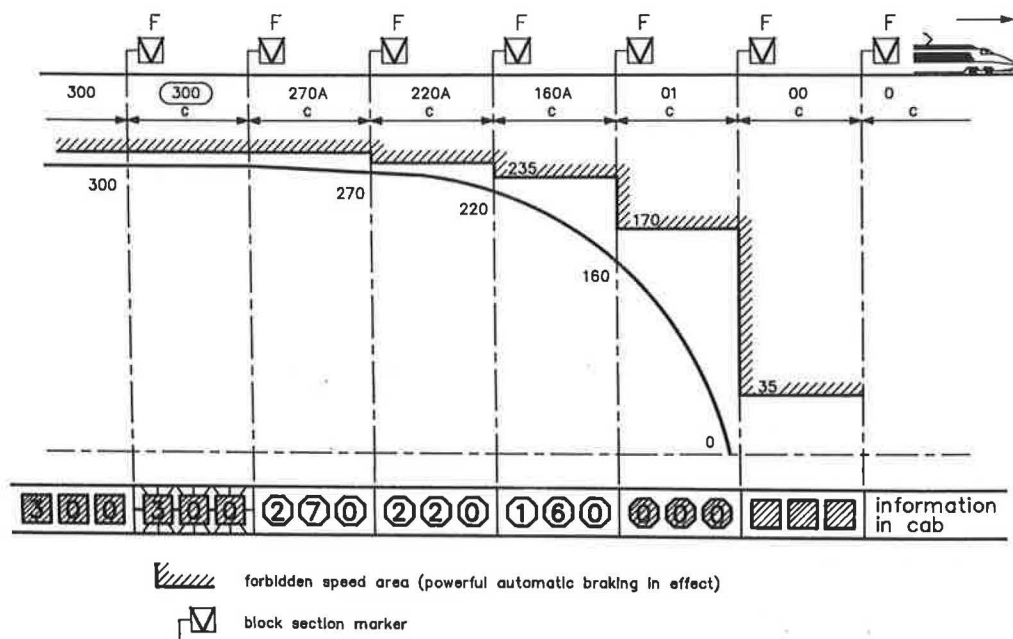


FIGURE 1 Stopping sequence for block sections.

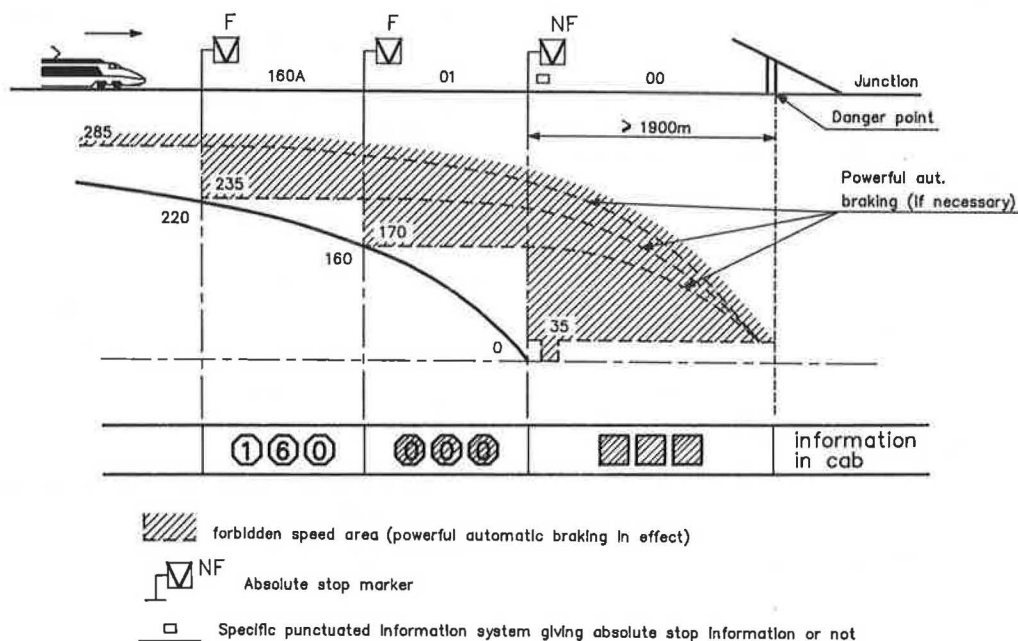


FIGURE 2 Principle of braking before an absolute stopping point.

has developed a new signaling system called TVM 430, derived from the system in operation on the Paris Southeast and Atlantic TGV high-speed lines (called TVM 300), but with better performance levels.

#### Functional Description of the TVM 430 System

Three measures have been adopted to meet throughput requirements. First, the block sections are shortened and have

a length of 1500 m on the flat. Second, to limit system reaction time if necessary, the driver receives continuous advance warning information according to the following principle:

- If information is displayed continuously (not flashing on and off), the speed to be enforced in the next block section is not more restrictive,
- If the information displayed flashes on and off, the driver knows that the speed applicable in the next block section is more restrictive.

Third, the speed-control mechanism features a higher degree of precision than that possible with TVM 300. At any moment, the train data in the plan (distance, speed) are compared against a speed-control graph in the train-borne computer, this graph being based on the characteristic parameters of the train and information from TVM. Emergency braking is triggered when the curve on the graph is exceeded (Figure 3).

## Technical Description of the TVM 430 System

Continuous transmission of 18 data items has proved to be insufficient; it is therefore necessary to enhance the system to transmit more information. With the new approach, the frequency modulated UM71 track circuit still acts as carrier, but from the very low frequency a signal is worked out from which 27-bit messages can be established. The structure of the message (Figure 4) gives the following information:

- **Railroad address:** This allows the train-borne system to determine the operating mode (North TGV, Channel Tunnel, etc.).
- **Speed:** This enables the train-borne computer to determine speed indication to be shown on the cab display; whether

that indication should flash; maximum speed limit allowed in the block section; and automatic train protection (ATP) speed limit at the end of the block section.

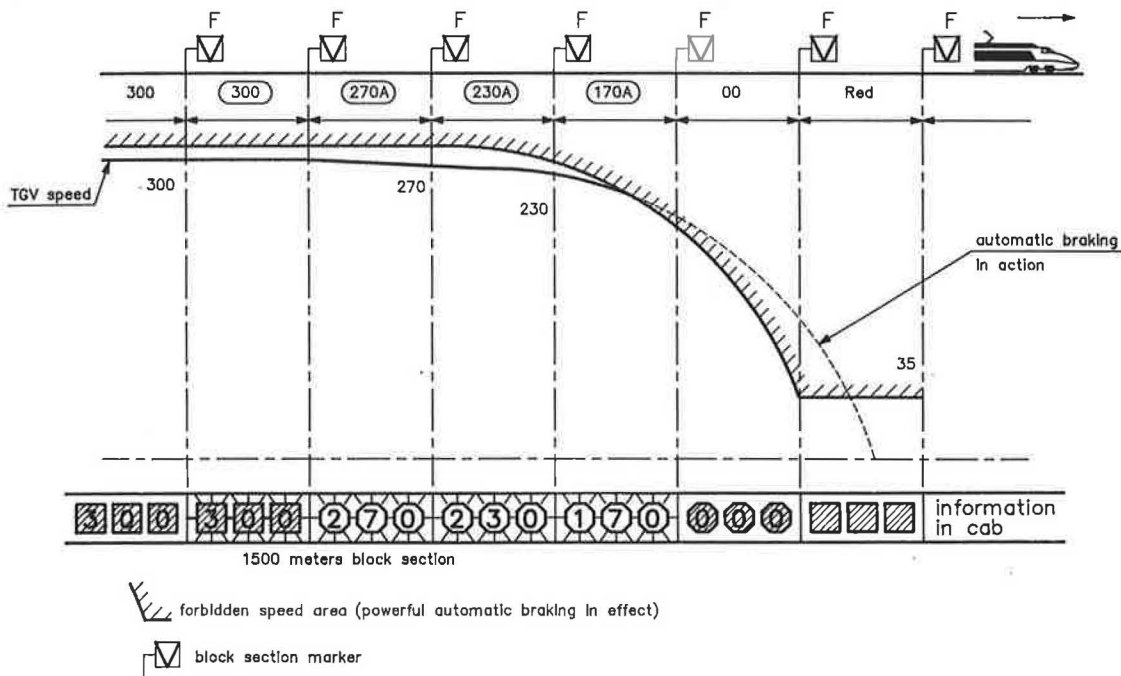
- **Distance:** The distance between the start and end of a block section is called the “target distance.” This distance is quantified and the data are transmitted to the moving vehicle for use in speed-control graph compilation.
- **Coding:** The message coding ensures data integrity.

The ground-based computer compiles messages for each track circuit several times per second. The information given is fail-safe.

## Ground-Based TVM 430 Equipment Architecture

Two central units guarantee backup. One central unit is operational and receives input, processes information, and generates output. The other is on standby; it is initialized and is ready to take over if the central unit in use fails. A switching unit transfers from one central unit to the other if a failure occurs or in response to an external command.

Each unit is structured around two processors that process information in parallel. A single coded processor compares



**FIGURE 3** North TGV: automatic braking in case of excessive speed.

	TVM 430	North TGV			TVM 430
Field name	Operation	Speed	Distance	Gradient	Coding
Length (number of bits )	3	8	6	4	6
Safety information	YES	YES	NO	NO	

**FIGURE 4** Message structure.

the results and cuts the power controlling the output if there is a disparity (Figure 5).

### On-Board Equipment Architecture

The message received is decoded several times per second. The computer checks the display units and establishes the speed-control graph. This calculation is initialized each time a track circuit joint is passed; in particular, another target distance is then set.

Figure 6 shows the architecture of train-borne equipment.

Sensors are located over rails and have two windings (each linked to a digital receiver). The signal processing chain is

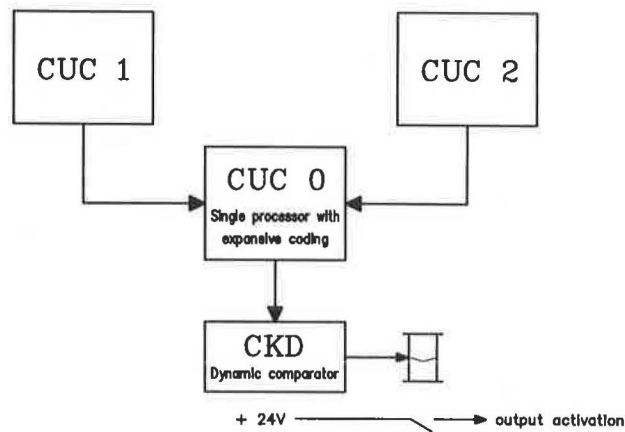


FIGURE 5 Safety data processing.

made up of two identical units (digital receivers) each of which receives the signal sent by the sensors.

Although processor software is based on the same algorithm, it is different because the two data-capture chains are nonsynchronous. The central unit compares the results given by the two digital receivers and validates the message. A signal-processing chain is associated with each central unit. The two central units are structured around a single coded processor and operate simultaneously. Only one of them is selected by the switching unit and supplies the power needed to light the displays to which it is connected.

### Safety

For both train-borne and ground-based equipment, data are constantly safeguarded in the capture stage by coded information, and, in the processing stage, either by coded information or duplication and by rereading at the output stage. The single coded processor system is based on use of a single processor and a single program for data processing. Safety is ensured by the very high level of data coding. The code dedicated to each variable has its own signature that relates to the previous process and the exact date of that process. For each cycle, an electronic fail-safe control unit compares all the signatures obtained from codes against a given word.

### Intermittent Transmission

The carrier for the intermittent transmission system is a loop placed in the track carrying current modulated by phase jumps.

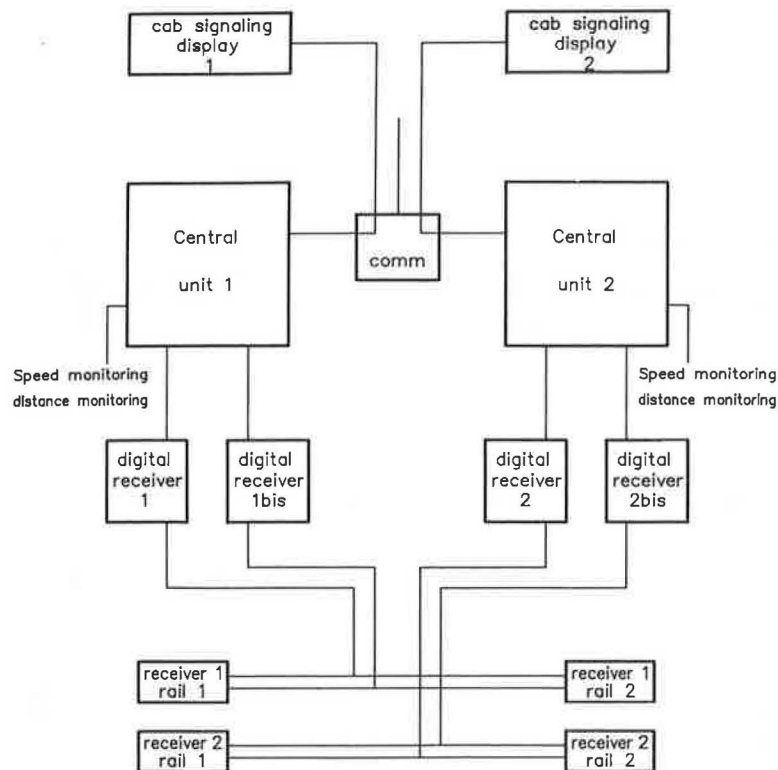


FIGURE 6 TVM 430 on-board equipment.

With this technique, a large number of telegrams can be sent to the train. Among the possible functions that can be performed are the following:

- Activate/deactivate the system,
- Ensure that no absolute stop signals are passed,
- Radio channel and system transmission,
- Cut power, and
- Lower pantograph.

## VERY HIGH-SPEED LINE OPERATING SYSTEMS

High-speed lines connect with the existing network at specific points. In addition, to maintain suitable service standards even if traffic is, for example, stopped at a particular place or on a particular line, crossovers have been provided between the two tracks every 20 to 25 km (12.5 to 15.5 mi) and single-track working is to be possible on each of these sections. To be economically viable, signaling systems in the case of single-track operation must ensure a smooth flow of traffic with a minimum of constraints by comparison with normal conditions.

The maximum speed in the diverging direction on these changeover points is 160 or 170 km/hr. In certain places SNCF also uses points that can be negotiated at 220 or 230 km/hr in the diverging direction.

### Control Center

Each very high-speed line is controlled from a control center that fulfills the following functions for the whole of the line:

- Points operation (remote control of signals and switches),
- Traffic control, and
- Remote control of the substations supplying power to the overhead lines.

Traffic control and power supply control are housed together in the same room. For example, the 280-km (174-mi)

TGV Atlantic line is controlled from a single work station, although at peak periods or in cases of disruptions to traffic, dual manning is possible.

Power supply control facilities are single-manned for the whole line. Both work stations—traffic control and power supply control—have input keyboards and multicolor display screens. Only overall data (and train-describer data) are displayed on the visual control panel.

### Traffic Control Systems

The traffic controller has a wall-mounted visual control panel containing the train describer, signal indications so the controller can be sure everything is working normally, and general monitoring data (warning systems, hot-box detectors, radio).

The traffic controller also has four multicolor screens plus keyboard for interfacing with the computerized control and monitoring systems. The screen's visual control panels display a magnified image of each station for safety purposes. Emergency control data are also displayed. The train describer system indicates remote train-announcing data, train schedule discrepancies as well as hot-box detector data or indications for the devices installed to stop trains automatically if road vehicles fall over bridge parapets. The computer-based, route-setting system also interfaces with the same screens and keyboard.

Route setting is automatically controlled from the control center using a computer-control module of similar design to that used in SNCF's computerized signal boxes.

## CONCLUSION

In conclusion, this description of the systems to be used on very high-speed lines in France shows the factors and developments research engineers took as a basis in their design work to ensure better, even more cost-effective operations than on the Southeast and Atlantic lines. Today's sophisticated signaling techniques, especially those that are microprocessor-based, will be one of the many features underlying the commercial success of the Northern and other subsequent TGV lines.