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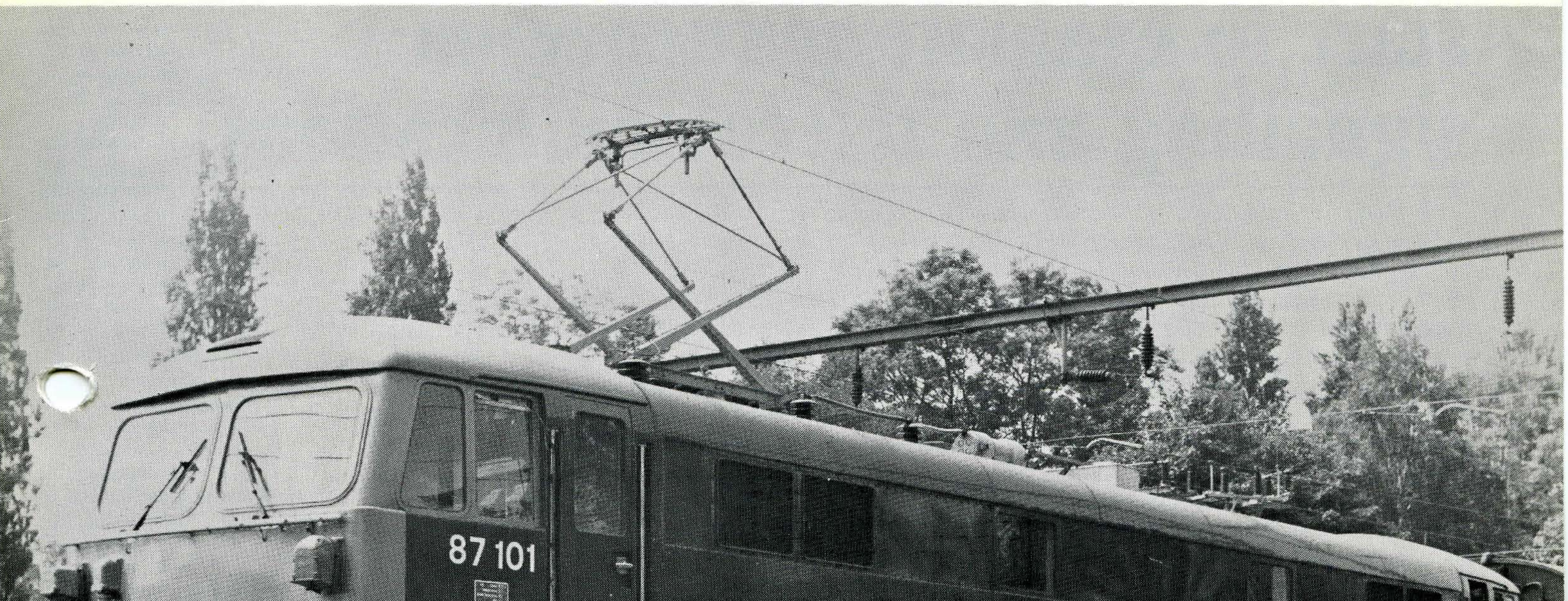

THYRISTOR CONTROLLED

25 kV locomotive

British Rail Class 87/1

GEC Traction Limited

Superior tractive effort characteristics including wheel-slip control obtained by stepless power-control induce BR to go ahead with the 36th of its 3,750 kW 176 km/h locomotive design built with thyristorcontrol which also introduces weight-saving possibilities

Prototype thyristor-controlled BR Class 87 25 kV introduced and trials start to evaluate influence on signalling and telecommunications

Problems arising with telecommunications because of electrical interference brought about by chopper and thyristor techniques in traction control and other circuits on rolling stock have forced British Railways to be slow in approach to their adoption, which, from the point of view of the home manufacturing industry's interest in export markets, has been somewhat of a handicap. Nevertheless, the General Electric Company Limited introduced chopper-control on the Netherlands Railways (NS) and Thyristor-control on South African Railways some time back and which have met with entirely satisfactory service operation (1).

It was an important step forward therefore when BR was able to decide to go ahead with prototype service trials using thyristor control on a Class 87, 3,750 kW 25 kV Bo-Bo, the series production version of which was described in detail in our September 1973 issue (2). British Rail Engineering Limited (BREL)'s Crewe works has now turned out this prototype locomotive which is numbered 87101 and which has started preliminary service trials. We look forward to report the experience gained in a future issue but at this stage we can only mention that the trials have indicated that the interference problem has not presented those of gravity as was first feared in some quarters.

The locomotive closely follows the basic Class 87 design of the 35 now in service which are geared for 176 km/h running and working Anglo-Scottish expresses on the London Midland West-Coast main line between Euston and Glasgow. Besides evaluating the tractive effort performance of No. 87101 which is superior to that of normal tap-changer controlled locomotives, investigations will be made into aspects such as power factor and general harmonics as well as those of electrical supplies and signalling equipment already indicated. It will also provide a further full sized test-bed for the development of thyristor power equipment for rail traction, in addition to the experience gained with thyristor equipment operating at the power levels normal with multiple-unit trains.

Transformer and rectifiers

The elimination of the h.t. tap-changer and its associated 25-kV auto-transformer greatly reduces the weight of the transformer so there was no need to achieve a low transformer specific weight for this locomotive in the context of the specified axle loading. Nevertheless, it was considered desirable to produce a light transformer as general policy for the future, and a reduction from 11 tons for standard Class 87 locomotives to about 6 tons was achieved for the transformer of the thyristor locomotive (6,110 kVA primary at continuous rating) including the integral oil pumping equipment, radiator, oil conservator and usual fittings. Use of an aluminium tank would further reduce weight, but except for "advanced control" demonstrations, No. 87101 will normally operate with notches as for Class 87 and, if any lighter than that class, must be so only by a small amount. Also, some of the saving is offset by other apparatus additional to Class 87 including power factor correction apparatus, but even so, the design weight is well within the specified 80 tons. The "flat" design for Class 87 is superseded by a "tall" design avoiding a tall turret to the h.t. bushing and allowing minimum dimensions in plan view.

Each motor armature circuit is fed from two rectifier bridges in series, the composition of any one bridge being two thyristor arms each with four devices in parallel and two diode arms each with four devices in parallel. This gives totals of eight thyristors and eight diodes per bridge; 16 thyristors and 16 diodes per motor armature circuit, i.e. a total of 64 thyristors and 64 diodes for all armature circuits, as against an equivalent figure of 64 diodes (plus a tap-changer) for the standard Class 87 locomotives.

(1) Latest SAR electrical equipment for multiple-unit includes 24 chopper sets, D. A. Hawkins, Rail Engineering International, June 1974

(2) Bo-Bo 176 km/h 25 kV electric locomotive design for BR West-Coast main line to Scotland. Rail Engineering International, September 1973

Locomotive Class 87 No. 87101 equipped with thyristor control undergoing evaluation trials which include both 'manual' and 'advanced' control for driving tests

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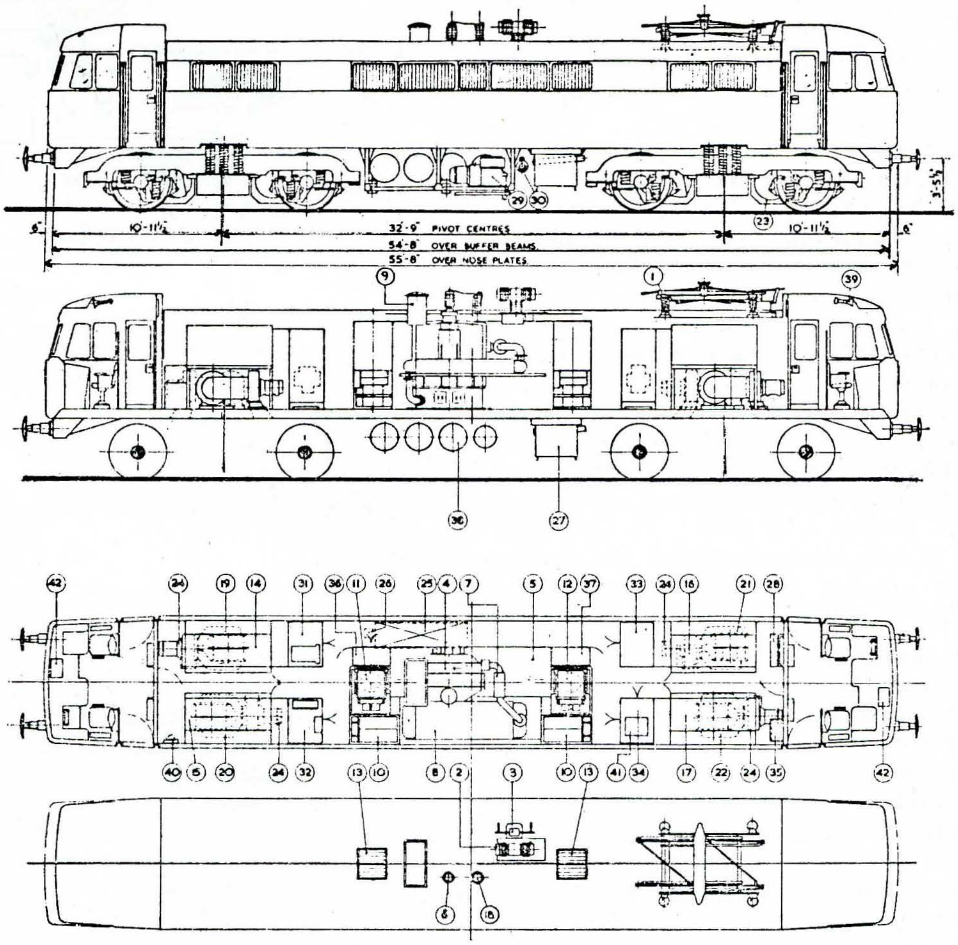


Fig. 1. *General arrangement and layout diagram of BR Class 87 prototype with thyristor control built by GEC. This follows closely the layout of the standard series-production Class 87*

1. Pantograph
2. Vacuum circuit-breaker
3. Earthing switch
4. Main transformer
5. Surge suppression frame and auxiliary equipment
6. Input bushing
7. Transformer oil pump
8. Transformer radiator
9. Conservator
10. Shutters radiator by-pass
11 & 12. Brake resistors Nos. 1 and 2
13. Shutters brake resistor
14-17. Resistor diode rectifiers
18. Divertor
19-22. Smoothing chokes
23. Traction motor
24. Traction motor blower
25. Battery box
26. Battery isolating switch
27. Battery charger
28. Auxiliary rectifier
29. Air compressor
30. Auxiliary compressor
31-34. Control equipment frames
35. Boiling ring
36-37. Air equipment frames
38. Air reservoirs
39. Horns
40. Urinal
41. Train heat and surge suppression
42. Cab ventilating and heating unit

In addition, each motor field is supplied through a bridge having two thyristor arms with single devices and two diode arms with single devices, giving a total of eight thyristors and eight diodes for all field circuits. These are of the same type as are used in the armature circuits. The arrangement of the rectifier cases is such that all of the devices associated with any one motor field and armature circuits are grouped together and each case therefore contains 18 thyristors and 18 diodes. In order to minimise spurious pick-up, certain items in the gate circuits, especially the firing transformers, have been located as close as possible to the thyristors. A major objective has been to eliminate interference in all electronic circuits.

The four fully-suspended traction motors are basically GEC Traction type G412 d.c. four-pole machines as fitted to Class 87 except that the main field windings have been designed to accept some five times the voltage and one-fifth of the current of the series motors to suit separate excitation.

The power circuit comprises four separately-fed traction-motor armatures and four separately-fed individually-controlled field windings. The latter are all fed from an auxiliary winding in the main transformer and each via a half-thyristor bridge and reversing contacts. The armature circuit of each motor is supplied from two series-connected half-thyristor bridges each of which is connected to a separate secondary winding in the main transformer. Two motor armature-bridge circuits share a common secondary winding. Each armature circuit comprises a contactor, overload smoothing-reactor and a dynamic-brake resistor and contactor. Also included is a current-measuring device for producing the necessary signal for control purposes.

The principle of operation is that the voltage applied to each armature is dependent on the firing angle of the thyristors in the armature bridges. The resulting current is measured and a derivative controls the value of current admitted to the field such that the ratio of armature current to field ampere-turns is appropriate to the particular and varying conditions required.

Up to half voltage, one bridge per motor is used, the firing of the thyristors in that bridge being gradually advanced until free-firing is attained. The fully-retarded thyristors in the second bridge are then gradually advanced to add an increasing voltage from the second secondary-winding to that of the first until both bridges are fully advanced and full motor-voltage is attained. Further increase in speed is obtained by retarding the firing of the thyristors controlling the field so that the proportion of armature to field current is increased giving weak field running.

Immediate suppression of wheel-slip conditions

In the occurrence of transient wheel-slip the inherent "shunt" characteristic of the separately-excited motor will quickly restore adhesive working. Where slip is persistent, if only a proportion of the motors are slipping then the speed difference is detected and the field strength of the slipping motors is clamped to the value of the strongest field and the armature current reduces naturally until wheelslip is arrested.

With a four-axle spin, the acceleration of all four wheels is detected causing the fields to be clamped and the reduction in armature currents is accentuated by phase delay of the thyristor until wheelslip ceases.

For braking, each armature circuit is closed on its braking resistor and the field current increased by thyristor control until a retarding effort equivalent to that which would be obtained from the air brakes is attained, subject however, to overriding current limit control as fitted to Class 87 locomotives. When the controller is moved to "off" the thyristors are used to relieve the motor contactors of normal rupturing duty (but leaving them as the main back-up). They are also used to provide extremely rapid protection in the event of motor flashover. Protection of the thyristors against breakover and against failure as a diode is by fuses. The individual control of each separately-excited field enables optimum adhesion and rapid recovery from wheel-slip.

Driving—manual and advanced

The driving position is as for standard BR a.c. locomotives and when using "manual" control, the driving technique is exactly as for the standard locomotives. An additional scale of handle position markings for setting the tractive effort is fitted however, for use with "advanced" driving and for this mode the speed required is also set (by a separate control). The relevant circuits are taken through a selector changeover-switch which is locked by the master-controller key, to prevent movement except in power "off" conditions and has two positions, "manual" and "advanced".

In the "manual" position, the equipment responds to standard driving procedure, movement of the master-controller handle between the "hold" position and the "notch-up" position causing the voltage to the traction motors to be increased by amounts generally similar to those provided by advancing step-by-step on the mechanical tap-changer. Similarly, movement to "notch-down" causes a reduction in voltage for each movement equivalent to a notch on the tap-changer. The run-up and run-down positions increase or reduce respectively, the applied voltage at a rate consistent with that provided by the tap-changer.

The "advanced" position brings into action the pre-selected "speed" and "T.E." features. These provide a performance envelope which is attained automatically with smooth notchless progression. The master controller is operated using the additional scale previously mentioned and the positioned-notches used for manual operation are made inoperative by the operation of a second cam which also operates a changeover switch. Movement of the handle to position 1 closes the motor circuits and provides a tractive effort suitable for handling a light locomotive. Movement from position 1 to maximum gives infinite variation of tractive effort between that of position 1 and the selected maximum thus enabling a driver to make gentle starts. A tractive effort boost-button allows an increase in tractive effort to be available for a short period to demonstrate higher adhesion levels. The tractive effort selected will remain constant until the set speed has been attained or until maximum voltage has been reached whereupon acceleration to the set speed is according to the inherent characteristics.

Circuit control

A two-wire stop-and-start is effected by separate control of the motor contactors and the thyristor firing-circuits. Overload relays and earth-fault trip the vacuum-circuit breaker under fault conditions. Under line-interruption, the equipment will switch off in all modes of operation and for consistency in driving it is necessary for the master controller to be returned to the "off" position and then on return of line volts, put into the required operative position, although this is not strictly necessary when the equipment is in the "advanced" mode. Electric braking will be controlled from the air brake valve as on Class 87 but the absence of a mechanical tap-changer response is quicker and the thyristors provide notchless braking-effort progression.

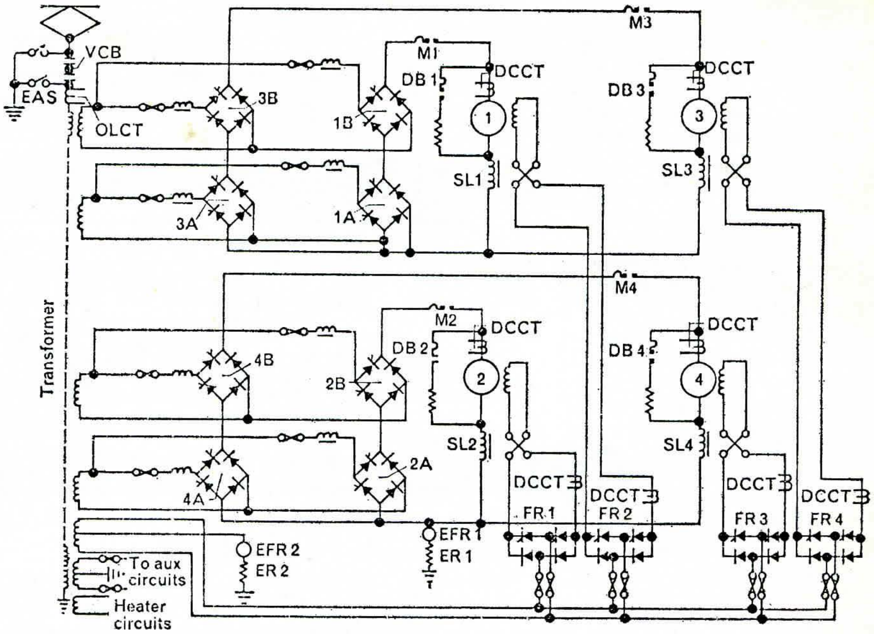
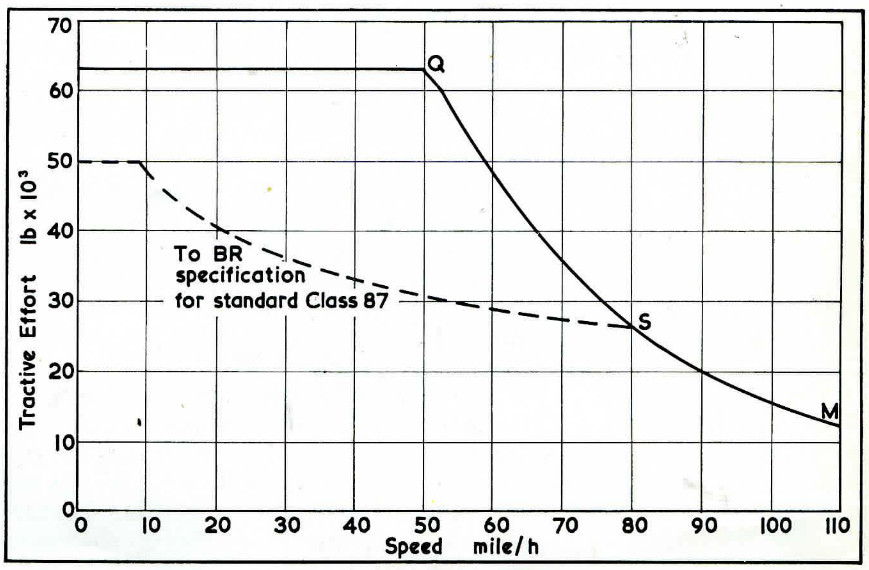


Fig. 2. *Schematic circuit diagram of Class 87 No. 87101 locomotive*

VCB	*Vacuum circuit-breaker*
EAS	*Earthing switch*
EFR	*Earth-fault relay*
ER	*Earth resister*
DCCT	*d.c. Transformer*
DB	*Dynamic brake contactor*
M	*Motor choke*
SL	*Motor choke*
FR	*Field rectifier*

Fig. 3. *Tractive effort/speed characteristics of Class 87 No. 87101 showing the latter's performance which is well [illegible] that of the standard Class 87 until the point 'S' is reached*



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