Ankara Rapid Transit Project – Phase 1

Vehicle Propulsion System

GEC ALSTHOM

TRANSPORT

1.0 Introduction

1.1 Background

Phase 1 of the Ankara Rapid Transit System is being constructed by a consortium of Canadian and Turkish companies. It consists of 14 km of double track most of which is underground. The vehicle fleet for phase 1 comprises 36 3-car units. The design of the cars is based on the latest generation of vehicles from Bombardier Inc. of Canada which are also being supplied to Toronto Transit Commission. The propulsion system is the responsibility of GEC Alsthom Traction Ltd.

1.2 Propulsion System

The propulsion system supplied by GEC Alsthom Traction Ltd. for phase 1 of the Ankara Metro System utilises well proven DC chopper equipment and DC traction motors.

The metro vehicles are designed to run as either 3 or 6 car units, each 3 car unit consists of two motor cars and one trailer car, configured as MC-TC-MC. This arrangement is different from the Toronto cars which is MC-MC, i.e. all axles motored.

The traction motors are longitudinally bogie mounted and drive through right angle gearboxes. The motors use the latest class 200 silicon insulation which ensures a high reliability and long service life.

In common with the traction motors the line filter inductor and motor smoothing inductors also use class 200 silicon insulation. In order to meet the increased duty imposed by the addition of the trailer car the traction motors are force ventilated.

All other equipment on the vehicle is naturally cooled. The propulsion equipment is housed in a single pannier case measuring 2.4 × 3.7m (See "Figure 1: Pannier Case".). This makes for rapid equipment installation by the vehicle builder with a minimum of mechanical and electrical connections to be made. The line filter inductor and the two motor smoothing inductors, which are positioned in the centre of the pannier, are mounted directly to the vehicle underfame not to the pannier case itself. This slightly increases the number of electrical connections which have to be made by the car builder, but it substantially reduces the structural weight of the pannier case as it does not have to support the weight of the inductors.

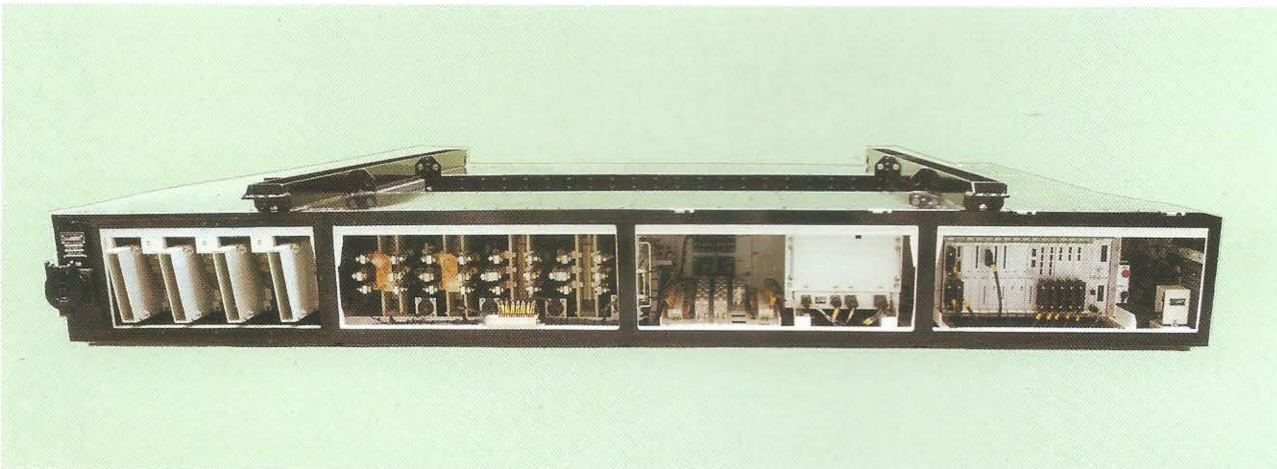

Figure 1: Pannier Case.

2.0 Technical Specification

Supply Voltage	: 750v d.c.
Maximum Tractive Effort	: 74kN
Maximum Brake Effort	: 68kN
No. of Motors per MC	: 4
Max Speed	: 80km/h service
	: 88km/h design
Control Equipment	
Case Type	: Pannier
Size	: 3.7m × 2.4m × 0.7m
Weight	: 1.3 tonne (ex inductors)
	: 2.2 tonne (Inc. inductors)
Armature Chopper	: 600A accel.
	: 325A rms
Field Chopper	: 90A max.
	: 38A rms
Rheostatic Bake Chopper	: 1350A max. (2 sec. rated)
(All data is per motor car)	
Line Filter	
Type	: Single Stage LC
Inductor	: Iron Cored
Capacitor	: Electrolytic
Traction Motor	
Rating	: 105kW (Cont.)
	: 115kW (1 Hr.)
Size	: 445mm dia × 802mm
Weight	: 505kg

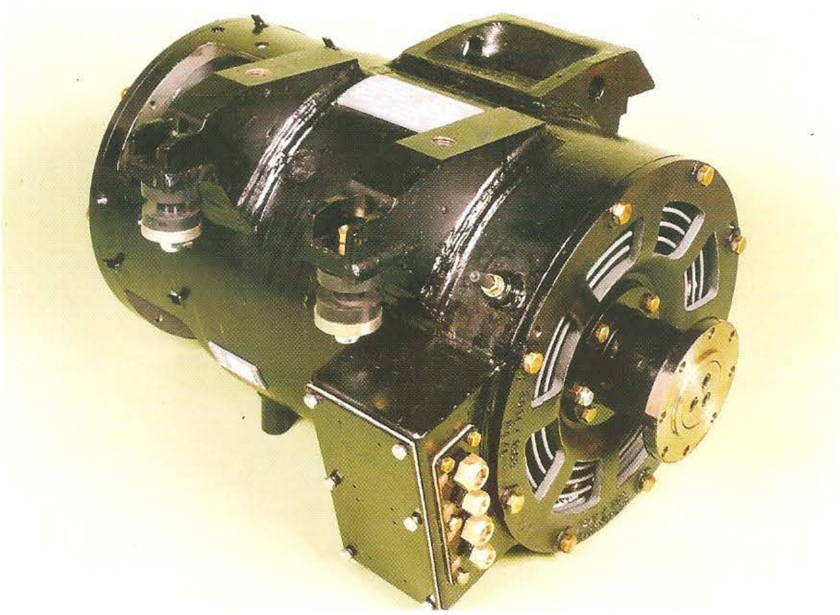

Figure 2: Traction Motor.

3.0 Traction Motors

Each motor car has four traction motors, two per bogie. The motors are of the separately excited type, this allows higher tractive and brake efforts to be achieved at high speed. The motor armature and fields are arranged in series on each bogie, each bogie has an independent armature and field GTO chopper.

4.0 Propulsion Control

4.1 Pannier Case Layout

All the propulsion control equipment is housed in a single pannier case. The pannier case is divided up into different compartments some containing HT equipment and some containing LT equipment. Each compartment is separated from the adjacent one by a steel bulkhead. These bulkheads provide additional stiffness to the case and also act as EMI screens between HT and LT compartments. The arrangement of the equipment in the case is designed to optimise the following:

- Access to Equipment.
- Segregation of HT and LT equipment.
- Routing of Cabling.
- Ease of Manufacture.
- Ease of Installation to Vehicle.

The overall maintenance access to the equipment in terms of both equipment inspection and component replacement is excellent.

4.2 Heatsink Modules

The two field choppers, one rheostatic chopper and two armature choppers are all built on the same sized heatsink extrusion and use common components in their construction. The two field choppers are mounted on a single heatsink module, all other choppers have individual heatsink modules. All the heatsink modules are earthed and naturally cooled, and all use alumina as their primary insulation. Because the heatsinks are mechanically very similar their fixings to the pannier case are keyed to prevent a module being put in the wrong position in the case. The heatsink modules, in common with the majority of the propulsion equipment, are designed as line replaceable units. This allows the module to be changed with the minimum of vehicle down time (typically 30 minutes to change a armature, field or rheostatic chopper module). The heatsink modules are attached to the bottom of the pannier case. To prevent the possibility of the modules becoming loose, for whatever reason, and falling on to the track secondary mechanical retaining devices are fitted.

The heatsinks are modular, they each have their own GTO gate drive panels and pulse conditioning panels mounted on the heatsink module (See ''Figure 3: Armature Heatsink Module''.). Pulse conditioning panels control the minimum on-time and off-time of the GTO, and also monitor the GTO health.

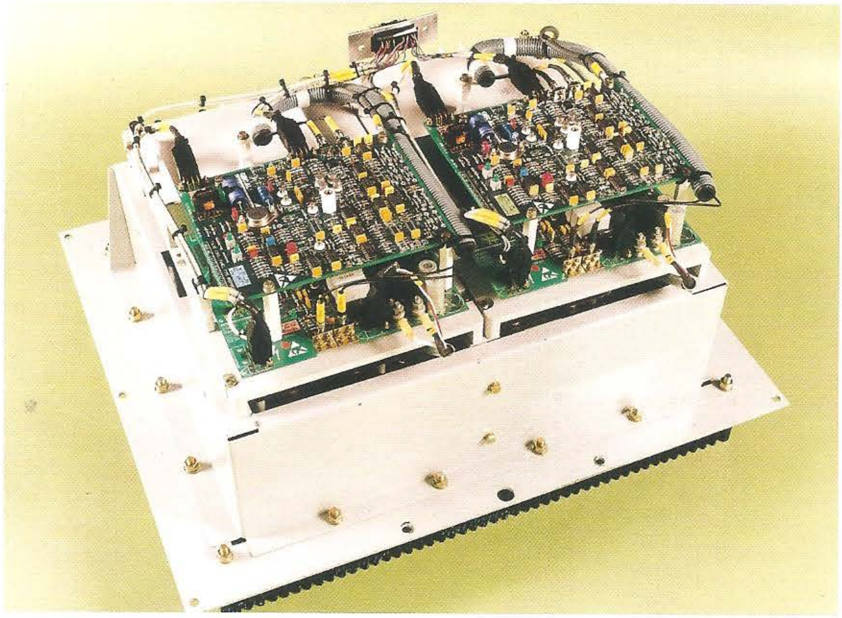

Figure 3: Armature Heatsink Module.

4.3 Switchgear

The control equipment uses two types of HT switchgear, a high speed contactor and an off load isolating switch. Both these components are pneumatically operated and have been designed for low height applications; both can be installed in an equipment case of only 425mm in height. The contactor design incorporates a mechanical overload protection mechanism, which acts as backup protection to the electronic monitoring of currents and voltages in the propulsion system.

4.4 Electronic Control

The core of the electronic control is a service proven microprocessor unit. The unit controls all propulsion logic and demand control functions, it also has extensive fault logging and diagnostic facilities. Access to the fault log and diagnostic functions is via a lap top PC. The PC converts the data from the vehicles microprocessor unit and presents it graphically to the user as well as storing it to its internal hard drive for remote diagnosis or collation. The PC can also be used in real time while the vehicle is in motion to monitor salient parameters from the propulsion control system (See "Figure 4: PC Screen During Real Time Monitoring of Propulsion System.").

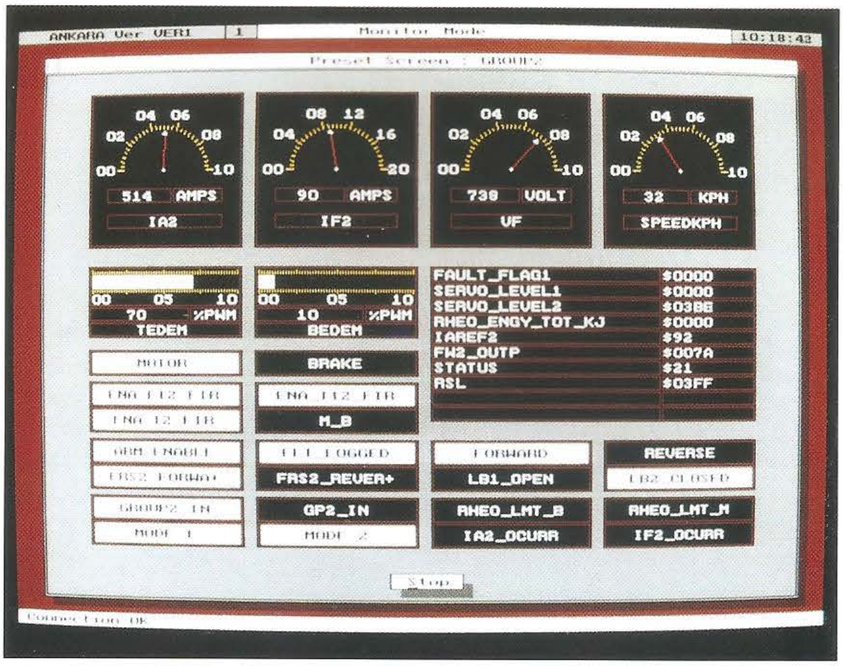

Figure 4: PC Monitor Screen.

4.5 Power Scheme

The power equipment is arranged in a conventional series parallel combination (See "Figure 5: Simplified Power Scheme"). Each bogie group of armature and field windings are independently controlled, and cut-out switches are fitted in the power circuit to allow a faulty bogie group to be isolated. This isolation is carried out automatically by the electronic control system. An indication light is illuminated in the driving cab, once the isolation has been successfully carried out following a fault.

The rheostatic braking chopper also acts as a soft crowbar to control incoming line voltage transients. This feature has allowed direct connection of the line filter to the supply line without a soft charge circuit for the capacitor, which simplifies the equipment and thus increases its reliability.

The rheostatic brake chopper has no free wheel diode around the brake resistor and no di/dt limiting inductor for the GTO. This has been made possible by very tight control of the rheostatic brake circuit stray inductance during the design of the equipment. The removal of these components again increases the overall reliability of the system and reduces its weight.

The brake resistor is fitted with a tapping at 90% of its value, this is connected to a hard crowbar circuit. The hard crowbar is triggered either by excessively high voltage on the supply line or loss of the LT supply to the propulsion system. Once the hard crowbar is fired the line contactors are automatically opened by the hard wired protection circuit. Triggering the hard crowbar when the LT supply is lost, removes the need for permanent discharge resistors to be fitted across the line filter capacitor. This again increases

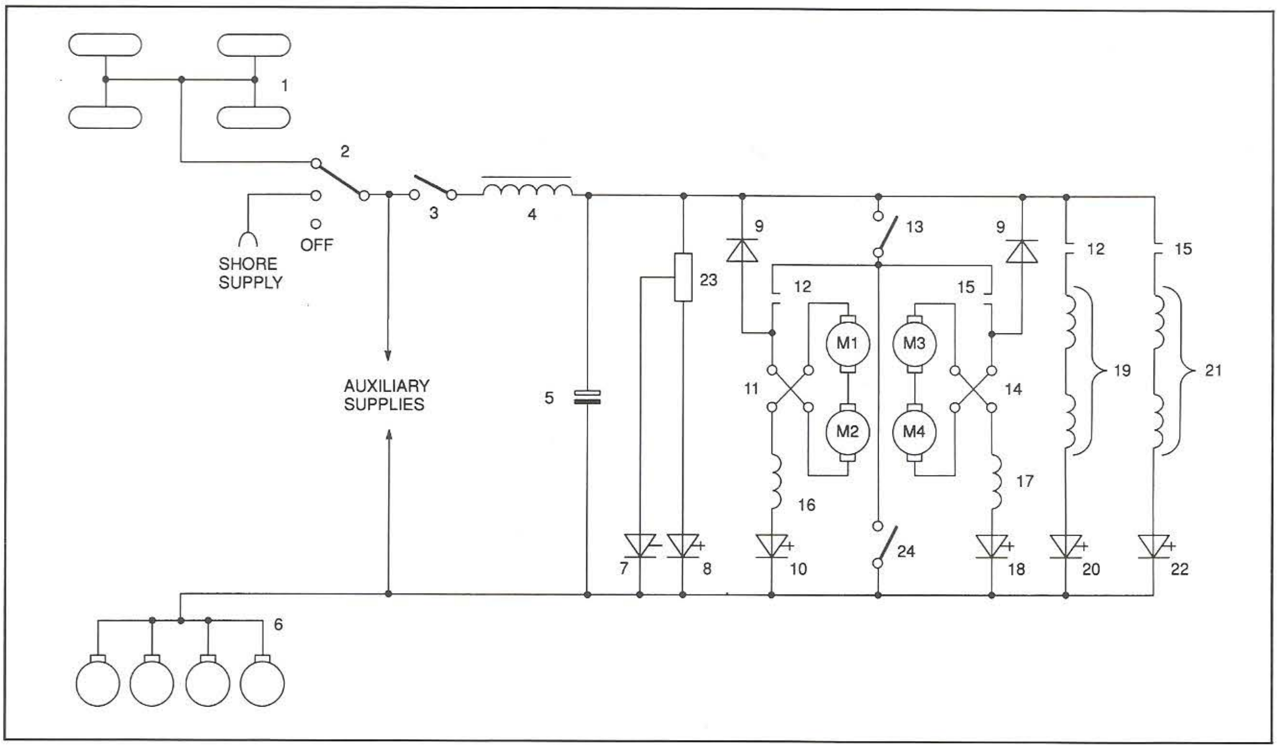

Figure 5: Simplified Power Scheme.

Key to Power Scheme

Item	Description	Item	Description	Item	Description
1	Current Collector Shoes	9	Free Wheel Diode	17	Group 2 Motor Inductor
2	Input Selection Switch	10	Group 1 Armature Chopper	18	Group 2 Armature Chopper
3	Line Breaker	11	Group 1 Forward Reverse Switch	19	Group 1 Motor Fields
4	Line Filter Inductor	12	Group 1 Isolation Switch	20	Group 1 Field Chopper
5	Line Filter Capacitor	13	Motor Contactor	21	Group 2 Motor Fields
6	Current Return Brushes	14	Group 2 Forward Reverse Switch	22	Group 2 Field Chopper
7	Hard Crowbar Thyristor	15	Group 2 Isolation Switch	23	Brake Resistor
8	Rheo Brake Chopper	16	Group 1 Motor Inductor	24	Brake Contactor

reliability and reduces weight. As an added safety feature the line capacitor has a neon indicator connected across it. This indicator can be viewed from the outside of the equipment case before any maintenance work is attempted.

The armature and field circuits are fitted with energy recovery snubber circuits. These circuits recover the transient energy produced when a GTO is turned off, and feeds it back to the motor through the armature or field windings during the next on pulse. The equipment is fitted with two shore supply receptacles, this allows the shore supply to be connected on the same side of the vehicle irrespective of the vehicle orientation in the consist. The Shore supply is connected to the vehicle by a manually operated knife switch. To prevent this switch breaking current a mechanically interlocked push-button is fitted alongside the switch. This push-button has to be pressed before the switch can be moved, auxiliary contacts on the push-button ensures all vehicle auxiliary and propulsion loads are switched off before the knife switch is moved.

5.0 Inauguration

Phase one of the system will be operational by the end of 1997. This will be after extensive commissioning tests both at the car builders works in Canada and on site in Turkey.

The electrical propulsion equipment completed testing at GEC/A.T. combined test facility during 1994.

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