How A Class 90 Works

Or The Secrets of The Black Magic Box.

The class 90 locomotives first entered service 22 years ago. They represented a step change in design over the earlier classes of electric locomotive. The biggest change was the tap changer had been eliminated, and replaced by power electronics. Not only did this reduce the maintenance requirement of the locomotive it also meant that the power could be applied much more smoothly, and very accurately controlled. The locomotives were equipped from new with TDM [Time Division Multiplex] control. This was to enable push pull operation with Mk3 coaches, to enable higher utilization of the loco and by eliminating the need for the loco to run round at the end of the journey.

In many respects the class 90's are a conventional AC electric locomotive equipped with 4 DC traction motors. Each motor is controlled by its own power pack, which can be individually isolated in case of failure. AC traction motors were still a little way off when the locomotives were designed. However the need to rectify the AC supply to DC for the motors forms the basis of the class 90 control system. The supply voltage of a nominal 25000 volts AC is not used for traction purposes. The higher voltage is for ease of power transmission, and to ease the problems of voltage drop over long distances, and high current loads at peak demand times.

Each power pack has dual stage thyristor controlled bridge rectifier. Each with its own secondary winding on the main transformer. This is the heart of the machine. The thyristor is a three terminal device which will act as a conventional diode, and block current flow from the cathode to the anode. But unlike a diode current will not flow in the forward direction unless a positive current pulse is applied to the gate terminal. The transformer turns the supply voltage into the voltage required by the power pack. The rectifier is the device which turns the AC supply into a DC supply for the motors.

When the loco is starting from rest only the first bridge is conducting. The thyristors in the first bridge are in a state known as fully retarded. As the thyristors are advanced the rectified current in the bridge starts to flow to the traction motor. When the thyristors are fully advanced. The second bridge starts to conduct, with the thyristors fully retarded. These are then advanced until the bridge is also fully conducting, and full power to the motor is being supplied. A refinement on earlier traction motors is the motor field windings are not in series with the motor armature, but separately excited from an independent source. This is known as SEPEX control. As the motor turns an opposing force known as back EMF [electro motive force] is induced in the motor field winding. This can be controlled by the locomotives field converter.

When the driver calls for power, the power controller generates a reference signal which is compared with a reference signal generated by the closed loop control systems which monitor the actual motor armature and field currents. Any difference between the demand reference, and actual reference signals is detected, and the control system will adjust the firing angle of the thyristors as required. The control system will also monitor the output from all four power packs, as a big difference may indicate a wheelslip condition. The control system can then take action to correct this condition. This is what gives the class 90 their high acceleration rate, when required.

The locomotives also have a weight transfer system to help them put maximum tractive effort to be applied without wheelslip. As in a car when accelerating the weight moves to the back. The weight transfer system reduces the amount of current allowed to the leading motor in each bogie. This allows more current to the motor taking the greater amount available weight. This method allows for very fine control of power, and largely eliminates the tendency for electric locomotives to slip when accelerating hard in poor rail conditions. In fact in 2008 when the ACLG's 86101 was working for Hull Trains the Friday evening train had a hard job keeping the timings, as they had been compiled for a class 90. The 86 just could not put power down to the rail quickly enough. Other machines within the loco include two air compressors, cooling fans, oil circulating pumps for the transformer oil, lighting, and battery charging.

The locomotive is equipped with automatic air brakes for working trains, a straight air brake which acts on the locomotive only, this is normally used when shunting, and a Rheostatic brake which acts with the automatic air brake. All the Rheostatic brake does is to use the energy in the rotating motors as a generator. The output is then fed through a resistor bank. This is force air cooled. This why sometimes it is possible to see loads of hot air coming out the top of the loco when arriving at stations. The advantages of using the Rheostatic brake is it reduces brake block, and wheel wear. Needless to say if the electric brake fails the automatic air brake will function in the normal way.

One of the initial selling points of the locomotive was increased use, and reduced maintenance downtime. Higher use is helped by using them in push pull mode on passenger trains. The TDM signals are received from the DVT on Mk3 sets by means of the three wire cables which run down both sides of the train. A common cause for failure is when the digital signals are corrupted by interference from on board equipment. The buffet car is a normal suspect, but lighting inverters, and public address equipment can also be a cause. Those with satellite TV will know the problems you get when the atmospheric conditions are poor. Control inputs from the driver in the DVT are transmitted to the loco which will then interpret them into power settings in the normal way. The brakes are controlled by a unit in both the DVT, and the locomotive. The leading brake control unit will send three digital signals to the trailing brake control unit to release the brakes, and a combination of whether the signal is on or off gives the required brake steps. If the signal is corrupted or lost an emergency brake application will be made. In the normal cause of events a push pull train set will apply the brakes from both ends, but release them from the front. This is a requirement for train travelling at over 100mph. Mk4 coaches, and 91's work in the same way. But their cables are slightly different, and do not seem to suffer the same interference problems. This is also why 90's can work with Mk4 coaches.

This article is intended as a basic introduction to how the locomotive works, and I have tried to not go into too much technical detail. I hope people will find it interesting. I must admit I do not know if the magic boxes which house the control electronics are really black. They are green on HST's, and I think they are light grey on the brush 89.