AC Traction Locomotives

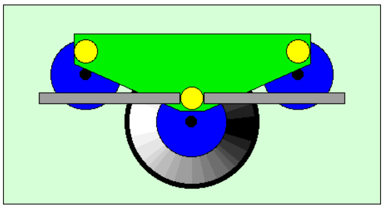
Early 20th Century AC locomotives can be said to arise from 2 design schools, the American as lead by **Westinghouse** and the European as lead by **SLM**. Each group of engineers approached the problem differently based upon the available sources of AC flux. Thus the US designs used a single phase 60Hz source and the Europeans used initially 3 collector 3 phase system at 16.6Hz, then later a single phase 16.6Hz source which they converted to 3 phase to run the motors. This forced the Europeans to develop large motors moving at slow speed while the Americans used geared smaller motors without relying of "field weakening" techniques. Allied to this the conditions of the locale gave rise to vastly differing design criteria...

The European School.

This was based on side rod locomotives, the advantages were that most of the technology used to produce a locomotive of this type was "to hand". The uneven power pulses of a side rod loco would not be too limiting as the speed of the loco would not be very high.

The locomotive above left is an early 3 phase 3 collector example, the central transformer and the “taps” for the field windings of the motor can be seen. The loco above right is also a 3 phase 3 collector locomotive. The large “shield” on the side of the locomotive is actually one of the two motors, this one and the other on the other side -share a common shaft to a central gear wheel, thence to the output shaft to the drive shaft, which can be seen between the two axles. In the case of the locomotive on the right field weakening was achieved by foot operated knife switches. A set of large rubber boots was issued to the driver to “kick in” and “kick out” the contacts. There was no insulation -other than air space. To be fair at this time there would have been no insulating material available that **could** have taken the voltage.

The early european customers for these locos were the BLS and their mountain freight system. Power transmission to the wheels was by a triangular yoke, reffered to as either a "Scotch Yoke" in the UK or as a "Kando Drive" in the rest of the EU. In this an electric motor was at either end of a point and the lower point drove the central drive shaft.



The reason for this arrangement had to do with the transversly mounted AC motors which had to have large field windings -often the motors had a 2 metre diameter and where 1 metre thick. The tapped field winding were enabled at 3 steps of linking with 3 steps of field weakening -giving 9 possible combinations. The shot below left shows the drive rods and Kando drive of a 1904 built 1-E-1 loco of the BLS.

As technology improved the motors got smaller and it the Kando drive reached it ultimate level in the case of the SLM "Krokodils" . Here the motors where stepped above and below the main drive axle -so the Kando drive yoke appears to be angled with respect to the line of the bodywork. The example above right is from a Ae6/6 of the SBB.

An alternate system was the Buchelli drive which used two fixed arms that were geared to lock into parallel motion.

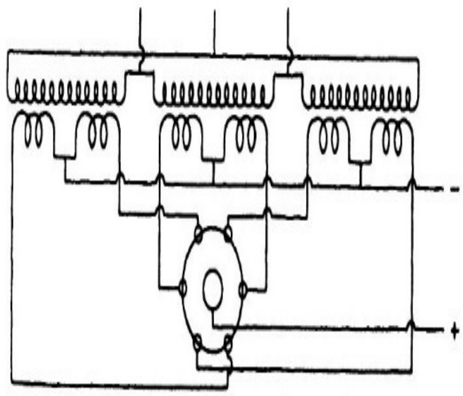
The American School.

Given the higher frequency of the US supply lines of 60Hz, the designers opted to have smaller constant field strength motors, and use differing voltage taps on a transformer to alter the voltage fed to the motor. This is a rational solution as the size of a transformer decreases with the frequency of the flux. The type of motor used, a series wound type, would therefore increase and decrease rotation with respect to the voltage applied. However the sudden increases in voltage would cause a snap snatch to the motor shaft and cause gear wear to be increased. The development of the "quill drive" in Germany proved to be the main answer to this problem.

The design problem with a series wound motor running under AC flux is the the maximum speed of rotation is linked to the frequency of the AC flux. Thus the maximum possible speed of rotation of the series motor was 60 revolutions per second or 3,600 RPM... This limited the maximum speed of any drive axle. The net result was a system that was quick to accelerate to a fixed speed -this made it popular with urban commuter transport companies. But, it did not have the long haul freight and passenger service potential.

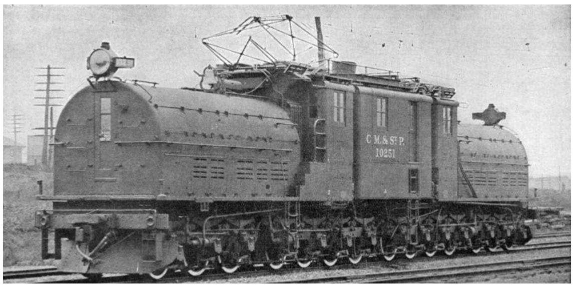
The solution was for the US railways to generate their own AC (25Hz) and to install phase convertor transformers with rectifiers in their locomotives which enabled them to use DC traction motors. This gave them a system that was simple and robust -but **very** large...

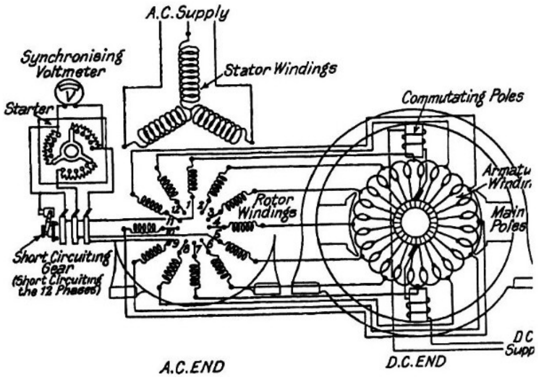
The most common one was the "Ignitron" -a 6 phase mercury arc type operating in a cooled steel jacket. The most famous example of this is the Penn Rail Road GG-1.



The “Ignitron” was located at each end of the locomotive and the phase convertor transformer in the centre. This achieved good tractive load at the expense of having to duct coolant from a central tank. Unfortunately the coolant chosen was **P**oly **C**hlorinated **BiPhenol. This Class 1A carcinogen plus the lack of 25Hz AC flux ensures that no GG-1 will ever run again...**

The other method was to use "rotators" -which were basically synchronous AC motors driving a set of commutators thus rectifying the AC into pulsed DC. The most successful was the La Cour design, (below right). These were large 12 phase systems which rotated with unfortunately high gyroscopic precessional forces... The locomotive below is a Milwaukee "BiPolar". The convertors were again located at the ends of the loco with a central transformer.





The wave form below is from an “Ignitron” recitifier and shows just how well the AC was converted to DC.

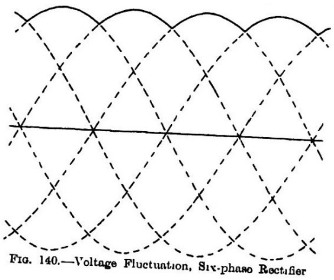


Fig. 140.—Voltage Fluctuation, Six-phase Rectifier

The ripple would have been 5% at 360Hz -which represented a good level for the time. The decendents of the “Ignitron” lasted up until the mid 1950's powering locomotives of the period.

Post WW2 saw the development of first Germanium and the Silicon recifiers. Thompson SA developed the first high power Germanium diodes suitable for use in a locomotive. SBB was the first railway company to experiment with them. They were a failure. This was due to the delicate nature of the point diodes of the time and the heat that they were exposed to. Thorn Houston developed Silicon Diodes which did not have as low a voltage threshold as the Germanium Diodes of the time, but were at least reliable -if kept cool...

The next major breakthrough in AC traction came with the development of the Thyristor. This is basically an AC version of a transistor and enabled usage of AC flux throughout the power side of the locomotive. Brush built a demonstrator for the principle.

This was christened “Avocet” by the then Prime Minister Mrs Margret Thatcher -trainspotters called it “The Badger”....

Here is “Avocet” in her GNER blue and red livery at Barrow Hill.

Above the front bogie can be seen the “Z” pantograph and the the “fuse” located between the two insulators.