Tricks of the Trade

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During the course of the preparation of the last ToTT concerning transmitter safety, the author was asked by the Editor, Bronek Wedzicha M0DAF, specifically about the use of fuses in HV circuits and generally to describe the techniques used in the construction of transmitters employing high voltage (HV or EHT). There will be many in VMARS who are used to working with DC up to maybe 2500 V. It is fair to say that, up to that voltage, the construction practices are almost the same as for low voltage, LV and medium voltage, MV circuits. However, at voltages in excess of 2500 V, it starts to become tricky. This article will illustrate the techniques applicable up to 16 kV DC. The preferred maximum voltage for high power HF transmitters rated up to 300 kW is 11 kV and it is interesting to note that, for high power MF and LF transmission where the same types of transmitter valves are used, they can generally be pushed to anode voltages as high as 16 kV.

Previous EHT experiences?

Many in VMARS will be familiar with monochrome TV receivers from the 1950s and 60s that employed a small CRT, typically 9–17 inch. The value of the EHT on the tube was 9–15 kV. Later sets, in the 1970s and 80s, had larger tubes often 21–23 inch, requiring higher voltages, *e.g.* 23 kV. The first colour TV tubes ran at 25 kV which remained the norm until the CRT displays were replaced by flat screens.

In the often cold and somewhat damp (pre-centrally heated) 'front rooms' where these early sets resided, there could be a degree of trepidation when a receiver was first turned on after a period of time and, more often than not, the build-up of EHT could be' heard' as *fizzing noises* emanating from the circuitry. Luckily, all would normally be well if the EHT system could survive long enough for the 150 W or so of heat from the rest of the circuitry to dry out the EHT components sufficiently for the leakage to cease.

The receiver manufacturers took precautions to minimise leakage of EHT in the first post-war 9–12 kV sets by employing an insulated holder made of Perspex™ for the wired-in EY51 EHT rectifier valve. In the later 23 kV sets, the DY86 and DY87 were used in polyethylene-enclosed B9A holders, often combined as an integral part of the line output transformer. The polyethylene moulding was well-insulated, smooth, well-rounded and away from other circuitry. These four attributes of the moulding are important and will be referred to again. The author recalls well a TV service engineer, Mr Jimmy Spragg G3APY (now SK) of Sutton-in-Ashfield, Nottinghamshire saying to him that it was imperative that, after replacement of an EY51, no '*pointy' bits of solder* were left on the tags or coronal discharge into free-space could occur.

Above 2500 V

A 5 kW output AM transmitter with a single output tube typically runs at an HT of 7.5 kV and such an output stage was used in the Marconi Wireless Telegraph, MWT H1100 driver unit for the MWT BD272 250 kW sender. The BD272 itself uses a main HT of 11 kV. Thinking now of the actual voltages on the push-pull BD272 RF stages; there is 11 kV on the centre-tap connection on plain carrier, peaking to 22 kV at 100% amplitude modulation. The peak voltages on the anodes themselves can approach 44 kV. Considerable care needs to be taken in the design engineering to ensure that, in operation, flashover, both at RF and DC, does not occur. DC flashovers are particularly damaging to the plant. The photographs in **Figures 1–4** should illustrate how this accomplished.

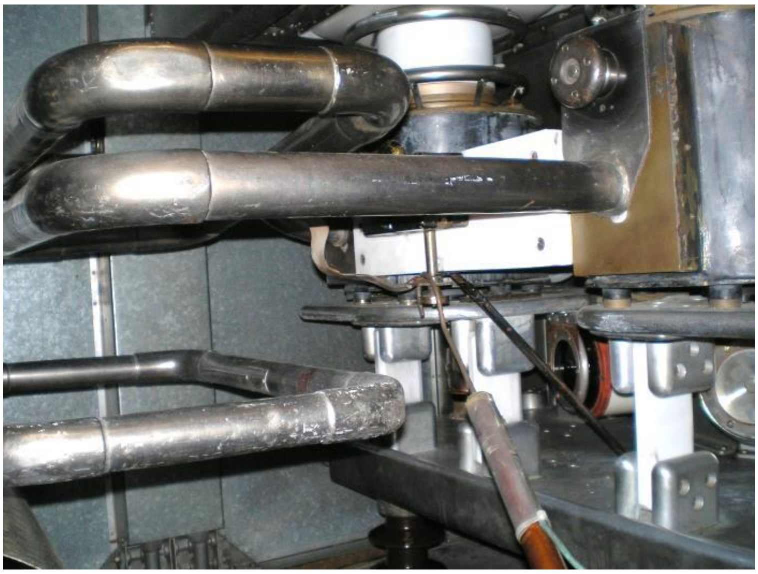

Figure 1. BD272 250 kW RF output stage

Figure 1 shows the side view of the RF output stage of the 250 kW sender. The boilers containing the pair of BY1144L triodes are mounted on thick aluminium chassis plates which have rounded edges and the supports themselves are rounded and mounted on PTFE blocks on to a general chassis which itself is mounted on a set of 9 inch ceramic HV insulators. Note that all fixings in this area on these chassis are into milled holes in the metal with no sign of the fixing hardware being proud. This appears to be one level 'up' from general countersinking. The pair of coils, anode and coupling (in this case on 9 MHz) are also made from nickel-plated copper having smooth, rounded edges. The anode coil is bolted to the boiler, within which the valve is housed and connected by a clamp, and the fixing is a 4 inch boss with four holes into which a special spanner with corresponding lugs is used to tighten. Upon removal of the tool all that remains is a smooth surface.

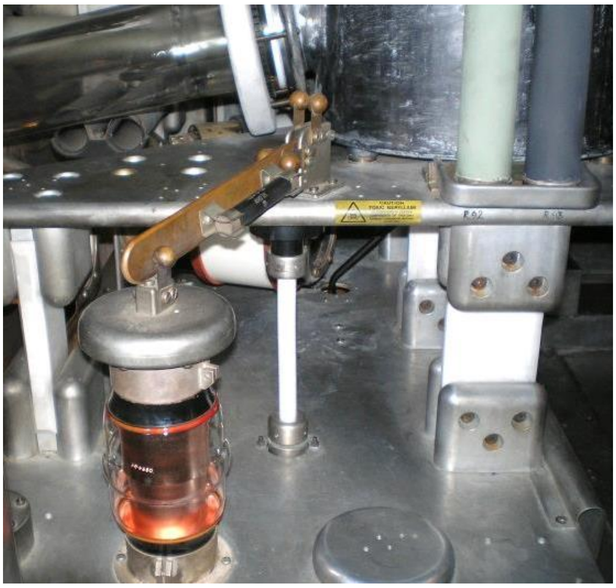

Figure 2. Side view of BD272 250 kW output stage with 3.9 MHz padding capacitor

Figure 2 shows the side view of the final RF amplifier, again with the supporting structure well illustrated. The mounting of a 45 kV-rated 250 pF fixed vacuum capacitor shows the rounded edge lower pillar and a corona shield on the top of the capacitor. These shields were abundant on components in this area and were made of spun aluminium and serve to prevent coronal discharge from what could be sharp edges on regular mounting hardware. There is a pair of copper ball contacts tensioned by beryllium copper fixings to take the rounded copper knife switch blade.

To the right is a pair of anti-parasitic glass, metal-film 68 Ω, 90W resistors with their mounting clips shielded by a smoothed, rounded metal cover. From the grounded de-ionised water distribution pipework, a flexible insulated hose to the base of a rigid PTFE pipe (centre of picture) brings in the cooling water. Note the domed clamps that make the water seal by internal pressure on O rings. These are smooth and a C-spanner is used to tighten them down. The spanner can be inserted into any of four holes.

In the extreme lower right hand corner can be seen a curved aluminium strip which runs along the entire chassis edge to give a point of low coronal activity to prevent flash-over from the anode coils to that deck.

Figure 3 shows a pair of low-value fixed vacuum capacitors that are pneumatically operated as required. The switch blade is effectively a small inductor in series with the capacitor. Note the use of coronal-shielded ball contacts for the lower connection and a contact pad with an associated pad (out of sight) for the point-of-contact upper RF connection. The blade is secured by M6 studs and round dome-head nickel-plated brass nuts rather than regular hexagon nuts, again to minimise corona. The support structure is once again substantial, rounded-edge aluminium plate, gently bent to 90° affixed to insulators that themselves have rounded mounting terminations top and bottom.

Figure 3. Anti-parasitic capacitor fixings in the MCSL B6124 300 kW final RF amplifier

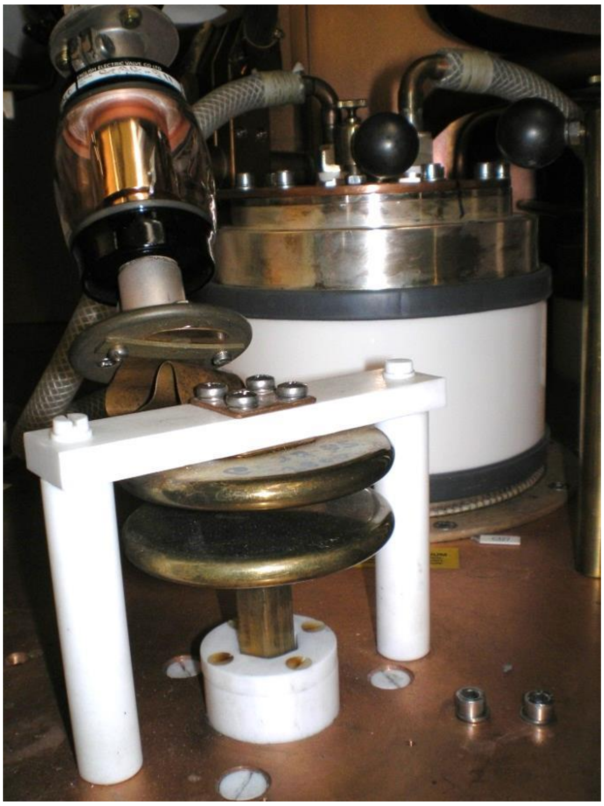

Figure 4. RIZ 250 kW sender showing motorised neutralising capacitor *etc*

The use of PTFE material as an HV insulating medium is illustrated in **Figure 4**. The motorised neutralising capacitor is formed by two smooth rounded disks where one is fixed and attached by round head stainless steel bolts to the PTFE support with a copper tail up to the end of a series pair of 25 pF, 50 kV vacuum capacitors. These have a circular smooth-edged terminating plate. The moving neutralising disk is within a further PTFE assembly which affords both high voltage isolation through the chassis and a low friction medium for the mechanical motion. The Croatian RIZ Transmitter Company use countersunk stainless steel screws and Allen screws with domed nuts or straight into threaded bosses in high voltage areas. They also employ large cabinets with plenty of spacing for HV and RF assemblies. For HV distribution, RIZ often do as MWT and MCSL (successor to MWT) did by using the inner of RG8/URM67 50 Ω coaxial cable as a wire, sometimes leaving the outer copper and plastic insulation hence making a screened DC lead with an exposed tag/insulated end of some 6 inches and terminating the outer to chassis.

For amateur use, it is possible to copy the way MSCL designed a feed-through connection for a fixed neutralising capacitor, *i.e.* to cut a 37 mm hole in the chassis and across it bolt an insulating sheet. Through the sheet over the centre of the hole run a length of, say, 4 BA studding bolted each side and connect to either end.

Fusing at 11 kV

Mention was made earlier of HV fusing and the author has to confess that, during a 40-year broadcast transmitter career, he was not aware of such devices until the final few years when RIZ installed three 250 kW senders at Woofferton.

The 11 kV incoming mains supplies to all ten senders, from the site's own two substations, are controlled by oil circuit breakers (OCBs) for MWT BD272 or RIZ senders, or vacuum circuit breakers (VCBs) for the MCSL B6124 senders. These have the requisite executive control with regard to overload protection and on/off (closed/open) control. Under normal conditions, the OCBs stay closed all the time and the VCBs open and close as required when the MCSL B6124 senders come off and on the air.

In the RIZ 250 kW senders, a separate cubicle was provided within which are three 11 kV AC vacuum switches, to switch the sender on and off, and three 11 kV AC fuses. The incoming 11 kV AC mains passes first through the vacuum switches and then out through the trio of fuses to the primary of the main HV transformer. These particular fuses are manufactured by the German Company SIBA. The main HV transformer has three separate secondaries, each with 48 separate 800 VAC windings and four 400 VAC windings, for the digitally controlled modulator assembly **[1]**.

Figure 5. A SIBA plug-in fuse with an 813 tube for comparison

Figure 5 shows the plug-in SIBA fuse alongside an 813 valve for comparison. The outer coating on the ceramic body is highly polished and the end caps are silver-plated and have rounded edges.

Figure 6. SIBA fuse type designation label

The rating label of this particular fuse (**Figure 6**) shows the following: SIBA, Made in Germany, D-44534 LÜNEN. It is described as *HH Teilberichssicherung, HV Back-up fuse*. The maximum running current is 100 A and the voltage rating is 6–12 kV. The maximum rated fault-breaking rupture current is 63 kA. It is suitable for indoor and outdoor use.

Reference is made to 'striker-medium' followed by '80 N' so whether the interruption is assisted within the body by some sort of mechanism with a release force of 80 Newtons is open to further research and conjecture.

The SIBA website is devoid of further information regarding the actual mode of operation but a comprehensive PDF data sheet is available for the range of fuses **[2]**.

Modularised HV rectifier assemblies

By way of completeness and to show an HV rectifier system without discrete fusing protection, reference is made to the MCSL B6124 senders installed at Woofferton in 1980. Here the incoming AC mains, after the substation executive VCB control and overload monitoring, is passed *via* an off-load motorised isolator switching unit into the primary of the main HV transformer. In this case, the three secondaries of *c*. 10 kV RMS are connected to the inputs of the three Jennings vacuum switches shown as vertical white ceramic units in **Figure 7**. When the sender is required to be powered, these switches close and the AC is passed to the three diode bridges and on to the smoothing components, chokes and capacitors.

Figure 7. MCSL B6124 main HV rectifier

At the base of the photograph can be seen two of the three series arms of 350 Ω, 400 W resistors and 0.005 µF, 10 kV Wego™ block capacitors which are used to suppress switching transients as the rectifier is initially powered. To the left and right of the unit are the three plus three banks of series-connected arms of the three-phase bridge rectifier modules. Each rectifier module consists of seven separate series-connected heatsink-mounted diodes with a suppression capacitor of 0.002 µF and combined resistors of 40 kΩ in parallel with each diode. **Figure 8** illustrates these assemblies. The substantial plastic insulators holding the insulated mountings away from the rectifier frame can testify to the fact that HV is present.

Figure 8. Individual diode and suppression modules

The four D's

When restoring, maintaining and using apparatus that employs high voltage it is worth considering the four 'D's:

- Damp
- Dust
- Detritus
- Deterioration

Reference had already been made to damp with regard to the early TV sets and, for our use of amateur transmitters, it is still pertinent. Much of our equipment is stored, often for considerable periods of time, in sheds and out-buildings many of which are unheated. Great care needs to be taken when re-commissioning such equipment after periods of storage and non-use. If possible, the equipment needs to be taken to a heated room, say at 10°C, and left for a few days to acclimatise to the raised temperature without the possibility of formation of condensation on the units. After acclimatising, the temperature can be raised gently and, hopefully, the dampness will be driven off.

It is prudent to inspect the units and check out for dust and detritus**.** Dust and damp are not good partners as possible current conducting paths can be created leading to flashover upon powering. Examples of detritus are best expressed as remnants of spiders, *etc*. as well as neoprene rubber cable sleeves that seem to decay to a messy oily conducting medium. After the units have been cleaned up and the dust and detritus removed, it is well worth initiating a regular, preferably documented, cleaning routine to ensure that all HV points are kept clean and shiny. On high power broadcast equipment this is a very important requirement despite the reluctance of some staff to conduct 'sender cleaning'.

The final 'D' is deterioration. Many of us will have rescued equipment that has been stored for many years and has seen years of service in a bygone age. When conducting restoration, it is important to recognise that deterioration will have taken place. Particular regard needs to be taken of cabling and transformers. The RCA ET-4336 transmitter from the early 1940s is a prime example of the need to be vigilant on cabling. Much of the cabling is fabric covered and ingress of damp can be a problem. The author recalls that, during the MF conversion of the 45-year old BBC/RCA units at Gloucester in 1988, a nasty flashover resulted between a trio of laced HV cables that connected the 2000V-0-2000V windings of the main HV transformer to the full-wave rectifier assembly. The load imposed on the supply side of the mains transformer by the secondary fault was sufficient to dip the lights in the building.

In other equipment, old VIR (Vulcanised India Rubber) cable can be a real liability as the insulation deteriorates, the lead-sheathed type being even more troublesome. Mention was made in a previous (non ToTT) article **[3]** concerning paxolin (SRBP) valveholders which are often employed for full-wave valve rectifiers and are exposed to the full potential of the XXX-0-XXX mains transformer winding. Paxolin is notorious for absorbing moisture and internal tracking with subsequent breakdown can occur. One other tracking problem on valveholders is on International Octal types when high power, audio valves such as KT88 and 6550 with anode potentials as high as 600 to 750 V are used. The insulation, mainly on paxolin but even phenolic valveholders, can fail between pin 3 (anode) and pin 2 (heaters) due to the high DC and AC potentials in push-pull service. The obvious answer is to use a valve with a top-cap anode or, if that is not possible, consider the use of a ceramic holder, bearing in mind that the inter-pin valve-base insulation is still under stress.

Conclusion

It is hoped that the description of the high voltage techniques here will assist members in managing HV within their prized possessions

References

1. D Porter G4OYX. Tricks of the Trade, *Signal* 2008, **6** (January), 17-19.
2. http://www.siba-fuses.com/upload/images/service/SSK_mitKlapper_21-05-13-EN-web.pdf
3. D Porter G4OYX. A humdinger of a smell, *Signal* 2013, **29** (November), 19-22.

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