Noble Gas Retention Effect on Klystron High Voltage Stability

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Abstract: *Several fielded klystrons experienced operational interruption due to sporadic arc events. Root cause analysis at CPI Canada revealed that VacIon pumps used to process these klystrons were saturated with nobble gases. Pressure bursts in pumping process indicated spontaneous release of gases back into the system. This process resulted in residual pressure of noble gases in the klystron. The cycle of adsorption and spontaneous release continued in the operating klystron resulting in sporadic high voltage arcing. This paper describes the details of root cause analysis and preventive actions.*

Keywords: Klystron; High Voltage Arc Events; process reliability.

Introduction

During the period of 2012 to 2015 a number of klystrons exhibited HV Arc Alarms upon initial installation. The klystron amplifiers performed well except for occasional HV Arc Alarms occurring once roughly every two days. This phenomenon was confirmed by extended operation at CPI. The problem attracted increased attention due to its critical impact on digital data transmission systems. The majority of the returned units were evaluated, repaired and restored to full performance before being shipped back to customers.

Klystrons were operated continuously in full beam transmit (9kV, 1100mA) both with and without RF. The frequency of the high voltage arc alarming did not reduce substantially, however there were occasionally 2 to 3 day periods during which alarms did not occur.

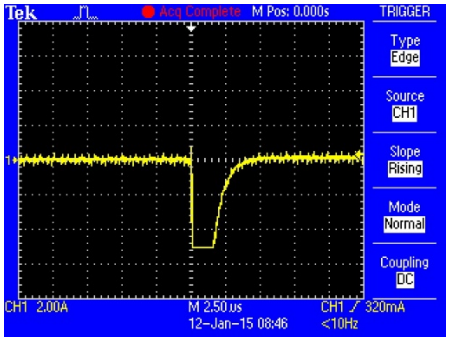

Figure 1. Oscilloscope plot showing the output of a 1:50 current stepdown transformer on the HT line.

One of the HV Arc Alarm conditions displayed beam current transients exceeding 200 Amp (plot Figure1). The arc event was measured on the klystron connection internal to the RF drawer assembly; it was therefore attributable to the klystron itself and not the power supply.

The returned klystrons had various symptoms depending on their individual operating histories. Only a small percentage of total klystron production demonstrated this affect. Internal HV Arcs did not appear to cause permanent damage to the klystron. Arc marks were found on the focus electrode and anode surfaces at areas of peak field strength.

All the affected klystrons maintained good vacuum level over a prolonged timescale and passed a Hi–Pot test at 20kV. Since an internal pressure of $<10^{-8}$ Torr can be expected, the Paschen law mechanism of electrical breakdown is not considered as a possibility and will receive no further attention in this text.

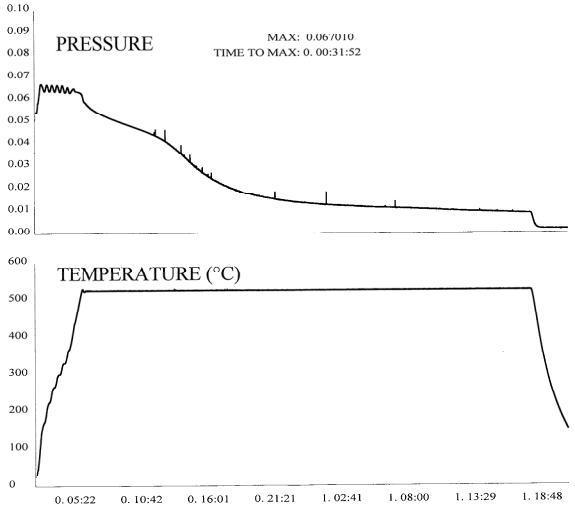

Figure 2. Example of periodical pressure spikes during Klystron out gassing process.

As systematic review of possible factors [1] found that the majority of failed klystrons had similar abnormalities during the pumping process. A review of historical data found the presence of pressure spikes during the pumping process for almost all klystrons exhibiting HV arc alarms in operation. In particular spikes were presented during both the evacuation and cathode activation processes. The majority of klystrons processed did not exhibit any spikes.

Example of exhaust bake-out process with pressure spikes is shown on Figure 2. Pressure level and klystron body temperature are shown via time. The klystron with

presented pump process was reported about 16 arc events during 47 days, and 18 events during next 50 days at customer side.

CMP uses Diode Type VacIon type pumps to reach high vacuum. These pumps provide good pumping speed without contaminating oil vapors and don't require the same degree of maintenance as other types of high vacuum pumps. The pumps are periodically baked and refurbished. The vacuum system is sealed and the VacIon pump current is used as an indication of vacuum level.

The spike effect in VacIon Pumps is well described for Diode Ion Pumps [2]. Symptoms include temporary pressure (current) increases resulting from the re-emission of previously absorbed argon (or other noble gas). This phenomena is referred to as "argon instability" and is explained by the mechanism of argon absorption in this type of pump; being unreactive the noble gases are physically buried in the pump surfaces rather than being chemically bonded like more chemically active gases and can be re- emitted due to sputtering of the covered over areas. Duniway reports the period of the fluctuation is roughly proportional to the base pressure between fluctuations; at 10^{-6} Torr base pressure the period can be minutes, at 10^{-7} Torr it can be hours, at 10^{-8} Torr the period can be days [3]. In our case we monitored similar looking effect at pumps at lower pressure levels between $1x10^{-8}$ and $1x10^{-6}$ Torr. The pressure rose up by one or two orders of magnitude and then fell back. The frequency of occurrence is comparable to that indicated by Duniway's data. Since our software records system parameters only once per 10sec some spikes may be missed and not appear on the plots. In the same way it can affect the spikes amplitude.

Potentially the noble gas partial pressures inside the pump will increase with each additional klystron pumped. A critical concentration of gas has to be reached in the pump surfaces to trigger the onset of the spontaneous desorption process. Each time a new klystron is pumped another dose of noble gas will be added to the system. The first few klystrons will be successfully pumped but eventually the threshold is reached. The selective pumping then results in a high partial pressure of noble gas in the pump. Part of this gas can be released back to attached klystron. Noble gas saturation can occur before pump saturation from other gases. It was found that most affected klystrons were pumped on pumps which were close to scheduled refurbishment.

Altogether the correlation between spikes in the pump process and periodic HV arc effects in klystrons were observed on more than 15 different type klystrons.

The problem was resolved by improving pump maintenance procedures and scheduling. Most problematic klystron were cured by re-pumping on freshly maintained pumps and successfully returned to customers. Since implementation of modified pumping procedure was completed no klystrons have failed for HV Arc Alarms on test and no customer complaints have been reported.

Conclusion

Residual noble gases that provoke unexpected pressure (current) spikes in Ion Pumps are able to provoke the same effect inside high voltage vacuum tubes causing HV arcing during full beam transmit operation of the klystron.

References

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