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Energy Efficient DeQuing for SLAC klystron Modulators

V.V. Nesterov, R.L. Cassel

Stanford Linear Accelerator Center,
Stanford University, Stanford, CA 94309

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ENERGY EFFICIENT DEQING FOR SLAC KLYSTRON MODULATORS*

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ABSTRACT

Two hundred and forty Klystron Modulator Stations at SLAC were converted to a new deQing circuit configuration. With the help of the new deQing circuit, the energy stored in a charging choke at the moment of deQing is no longer dissipated in a resistor but is being constantly returned to the power line. The design considerations and a circuit layout will be presented.

INTRODUCTION

Klystron Modulator Stations at SLAC provide rf voltage to beam accelerating sections of the linac portion of the SLAC accelerator. There are 243 stations total, and each one of them consists of a dc rectifier resonantly charging a pulse forming network(PFN) which is in turn discharging into a klystron tube using a hydrogen thyratron as a switching element. The amplitude of the PFN voltage is controlled by a deQing unit connected in parallel to a charging choke. The charging choke has a secondary winding to match the relatively low voltage components of the deQing unit to a high voltage charging circuit in the primary winding.

DEQING CIRCUIT DESCRIPTION

Figure 1 shows a simplified schematic of the SLAC Klystron Modulator deQing circuit. It consists of the secondary of the charging choke L1, two SCR's CR1 and CR2, a power dissipating resistor R1, energy storage capacitors C1, its first level capacitor electronic over voltage protection, a relay-based, second-level capacitor over voltage protection, an inverter with associated firing board, a matching transformer T1 connected to an AC line, and a switch S1 which selects either a dissipative or energy recovering mode of deQing circuit operation.

It is well known that deQing of a resonance charging of a capacitive load is possible at any moment after the current at the resonance choke has reached its maximum value. Thus there are about 90 electrical degrees of available deQing range. From practical considerations of a desirable regulation of the PFN voltage and the ability of the Klystron Modulator De-Quing circuit to dissipate energy, a maximum deQing angle of 5 electrical degrees has been chosen.

When a dissipative mode is selected (see Fig. 2), the gate of the second SCR CR2 is connected to its anode by the contacts of the relay RL1, and the energy stored at the charging choke at the moment of deQing, controlled by the firing of the first SCR CR1, will be dissipated in the resistor R1 before the next charging cycle begins. To protect the resistor R1 and the other components of the deQing circuit from an excessive energy flow, the circuit has a fuse connected in series with the resistor R1.

In energy recovery mode (see Fig. 3), relay K1 is energized, and CR2, which is normally non-conducting, serves as a part of capacitor C1 for protection from over voltage. At the moment of deQing, the energy accumulated in the charging choke will start to flow into the capacitor bank C1 from where it is then transferred by the inverter to an AC line. Two diodes D1 and D2 prevent the electrolytic capacitor bank C1 from seeing a reverse voltage or current.

There are two levels of protection from over voltage in this capacitor: one, an electronic EOVP, and one based on a relay switching. An electronic over voltage protector, having a SIDACtor as a threshold element, constantly monitors the voltage across the capacitor C1, and, if this voltage exceeds a specified value, switches the deQing circuit from the recovery into the dissipative mode by switching the second SCR CR2 to conduction. The second level of the over voltage protection has a resistive divider B2 connected across the capacitor C1, and voltage from this divider controls relay K2. When capacitor C1's voltage reaches a predetermined threshold, energized relay K2 will trip relay K1, thus switching the deQing circuit to a dissipative mode of operation. The circuit will also operate in dissipative mode in the case of disappearance of the deQing control voltage.

All components of the new energy recovery DE-Quing circuit except the line transformer T1 and dc chokes L2 and L3 are assembled on the same aluminum plate which is mounted on the

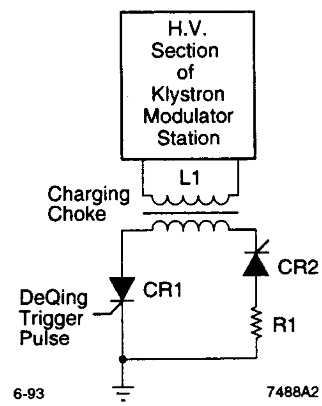

Figure 2

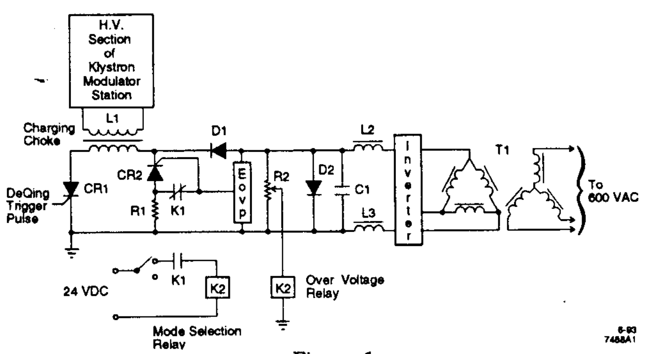

Figure 1

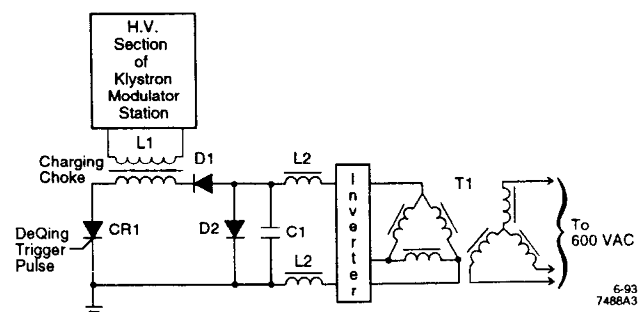

Figure 3

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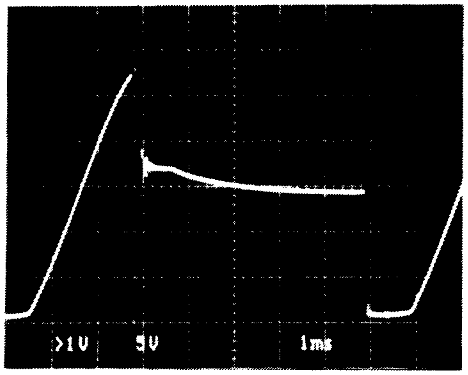

Figrue 4

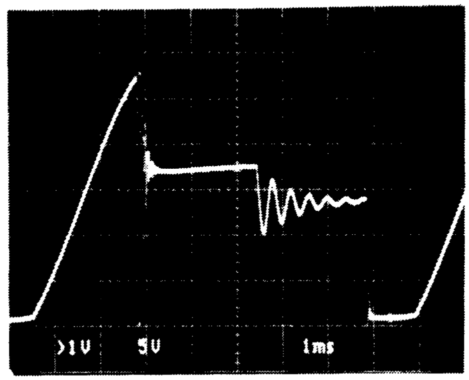

Figure 5

Klystron Modulator cabinet wall. The inverter is built with SEMIKRON modular packaged SCR devices mounted on a convectionally air-cooled heat sink together with an ENERPRO 6-pulsed firing board. The second SCR CR2 was added to the CR1 heat sink. Figures 4 and 5 are the oscillograms of the charging choke secondary winding voltage during the deQing dissipative and recovery modes respectively.

CONCLUSION

The energy saved by the recovery circuit at SLAC with Klystron Modulators running at 120 pps and deQing at 4.6% is on average more than 5 kW per station or more than 1 MW total. Several months of operation have proven the reliability and efficiency of this deQing energy recovery configuration.

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