NSTX

53-960606-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: ROBICON POWER SUPPLY PULSE CAPABILITY

This memo presents an analysis which confirms that the ESAT building Robicon power supplies can be pulsed for 5.0 seconds as required for NSTX.

The original specification (PPPL RFP No. 86-001A) requirement was:

T1-T4 300V/5kA/1.5 sec once every 180 sec
DF 200V/10kA/1.5 sec once every 180 sec
IF 500V/20kA/1.5 sec once every 180 sec

In addition, a steady state rating equal to 0.25 per unit of the pulsed rating was required.

The proposed NSTX duty is for a 5.0 second pulse length once every 300 seconds.

A comparison of the specification rating vs. the proposed duty is given in the following table:

	T1-4	DF	IF
Pulse Current	5000.0	10000.0	20000.0
Pulse ESW	1.5	1.5	1.5
Repetition Period	180.0	180.0	180.0
RMS Current	456.4	912.9	1825.7
Steady State Rating	1250.0	2500.0	5000.0
NSTX Pulse Current	5000.0	10000.0	20000.0
NSTX ESW	5.0	5.0	5.0
NSTX Repetition Period	300.0	300.0	300.0
NSTX RMS Current	645.5	1291.0	2582.0

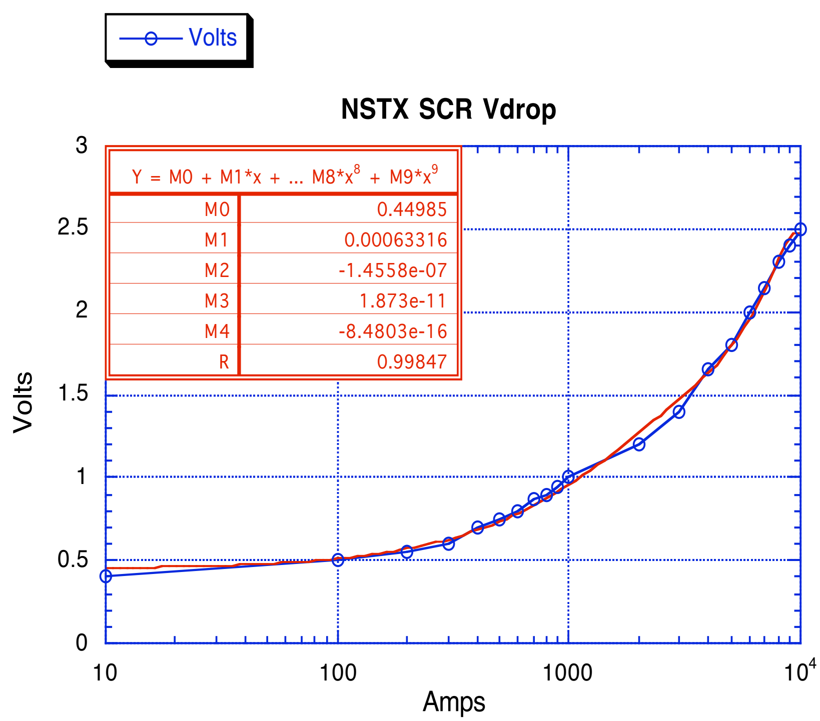
Concerning the original specification, it is noted that the requirement for a steady state rating of 0.25 per unit of the pulsed rating was the design driver for the rms current. Although the NSTX rms current requirement exceeds that associated with the original pulse rating, it is substantially less than the required steady state rating.

For power supply components which are air cooled (the bus bars, cables, and transformers, etc.), their thermal time constants are >> than the NSTX repetition period. Therefore, their heating is driven by the long term rms current. Since the NSTX requirement is less than the steady state rating, it is concluded that they can comfortably carry the NSTX pulse.

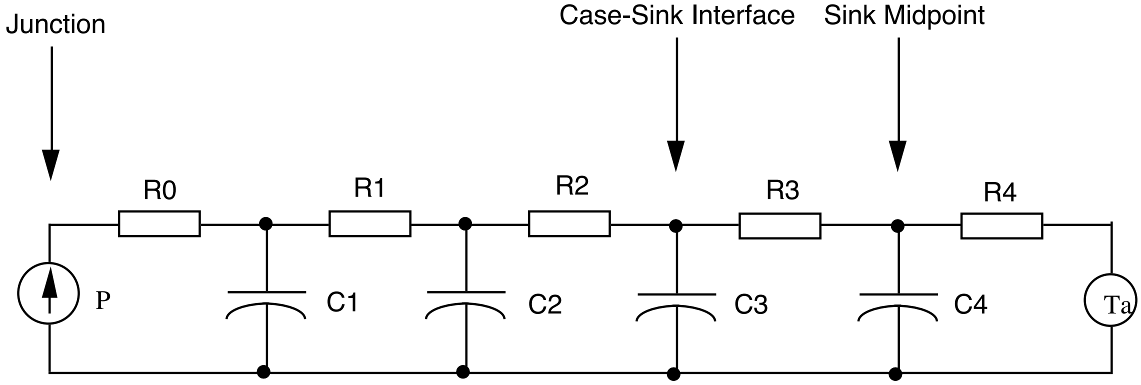
For power supply components which are water cooled (the thyristors and current sharing resistors), their thermal time constants are on the same order as the NSTX pulse length, and << than the NSTX repetition period. Therefore, their heating is driven by the pulse current, not the rms current.

The Robicon rectifiers use a mix of 1600V, 1200A thyristors from various manufacturers (National Semiconductor, Westinghouse (now Powerex), etc.) which are all assumed equivalent in rating and characteristics to the Westinghouse device, now Powerex type T9GO.

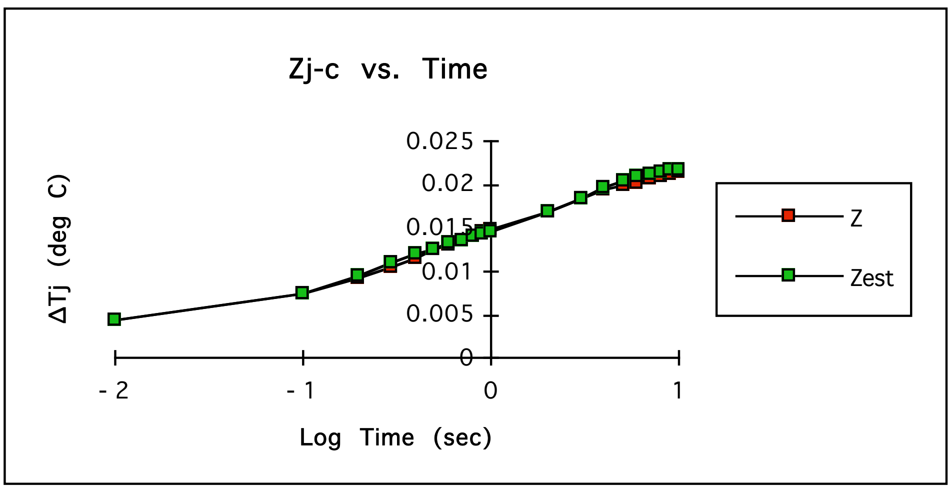
A curve fit to the published voltage drop vs. current function is given in the following figure.

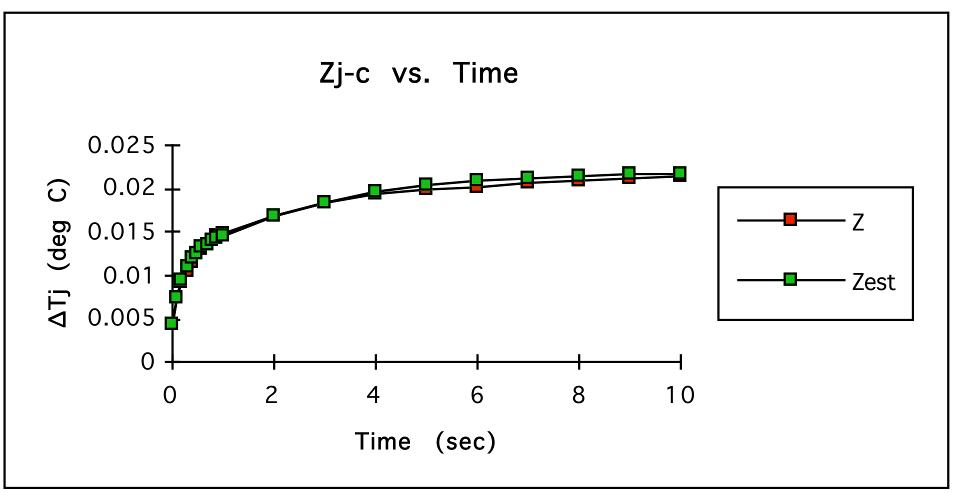


An electrical analog model of the thermal behavior of the device was constructed as follows:



To determine R0, R1, R2, and C1 values, a curve fit procedure was used against the published transient thermal impedance curve for the device. Semi-log and linear curves showing a comparison between the response of the model and the published data is given in the following two figures.





The SCRs are clamped to a water cooled heat sink on one side and a solid copper block on the other. To facilitate a simple simulation of the effect of these heat sinks, is was assumed that both sides of the SCRs are clamped to the solid copper blocks; the effect of the water cooling was neglected. The copper blocks were modeled using the R3,C3, and R4, C4 model elements, with parameter values based on the properties of copper and the dimensions of the blocks.

For the final model, an additional thermal resistance was added to R2 to account for the case-to-heat sink interface impedance.

The values used in the model are summarized in the following table:

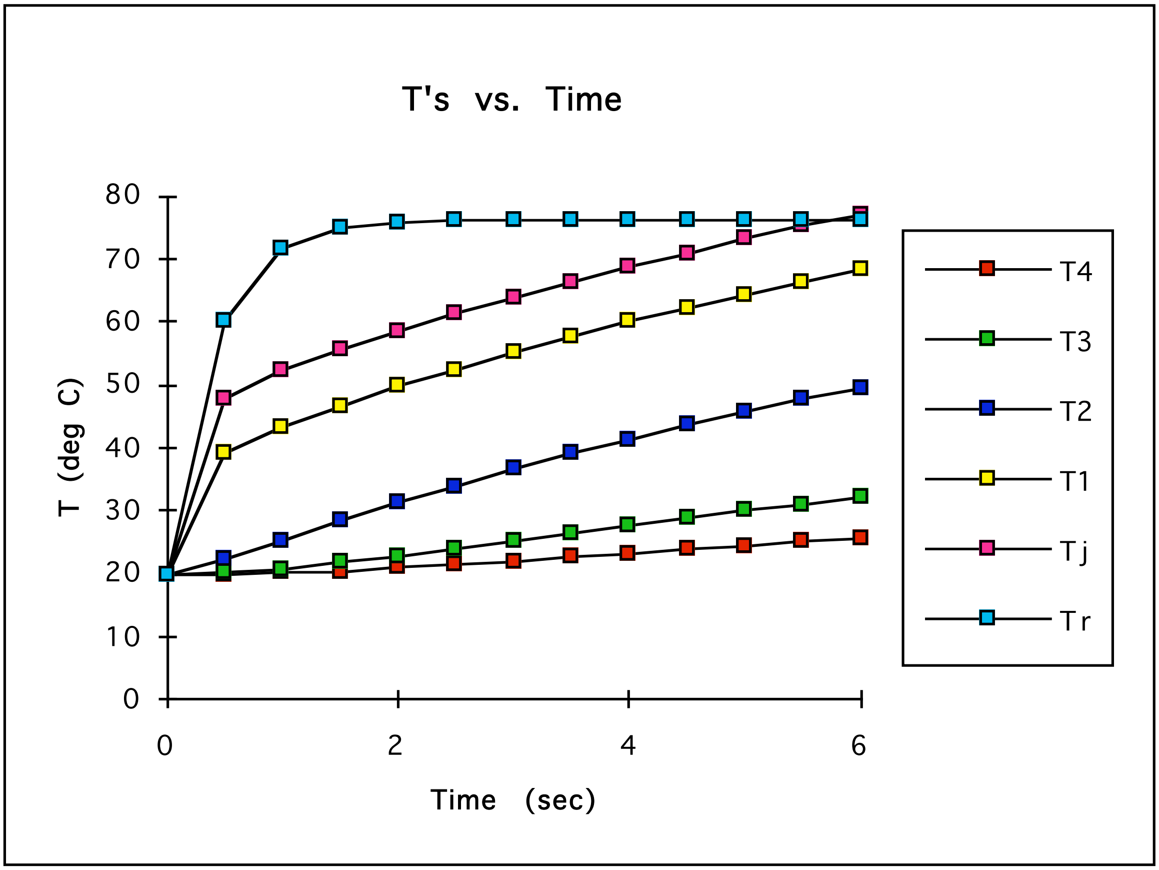
Element	Thyristor on Infinite Heat Sink	Thyristor on Heat Sink
R0	0.004	0.004
R1	0.009	0.009
C1	24	24
R2	0.009	0.0165
C2		275
R3		0.0079
C3		114
R4		0.0079
C4		114

Units of R are deg C/watt, and units of C are Joule/deg C.

For the calculations of junction temperature due to DC input current, the thyristor average power dissipation was assumed to result from the conduction of a square pulse of current with a 1/3 duty cycle.

For the monel current sharing resistors, a single RC analog circuit was used to estimate the temperature rise, with the thermal resistance based on the mass flow and film resistance at a water flow rate of 3.0 GPM. The estimated thermal resistance and capacitance are 0.0211 deg C/watt and 18.9 Joules/deg C (0.4 second thermal time constant).

All of the subject units utilize two parallel 6-pulse rectifiers with interphase transformer. The number of parallel thyristors per bridge leg is one for the 5kA supply (T1-T4), two for the 10kA supply (DF), and three for the 20kA supply (IF). Assuming an imbalance of 10% between parallel 6-pulse bridges, and 10% between parallel thryistors, the peak current per thyristor in all cases amounts to roughly 4kA. The simulated temperatures of the thyristor junction, the intermediate nodes in the thermal model, and the monel resistor, due to a current of 4kA per device, are shown in the following figure.



Since both the thyristor junction temperature and resistor temperature remains well below 100C, it is concluded that the 5.0 second pulse is feasible.

The extent to which control/protection adjustments/modifications may be required has not been thoroughly investigated. The fault detectors use a junction temperature simulator circuit, and may include various pulse time limiting circuits, which may need to be re calibrated/modified.

It is recommended that the manufacturer be consulted with regard to the proposed duty, that modifications be made to the controls/protection as required, and that dummy load tests be performed with 5.0 second pulses. Indeed as part of this work the manufacturer was asked to assess the proposed duty, but was not willing to do so without a fee. Therefore we may have to pay for his opinion/recommendations.

The spreadsheets used for the calculations are attached.

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