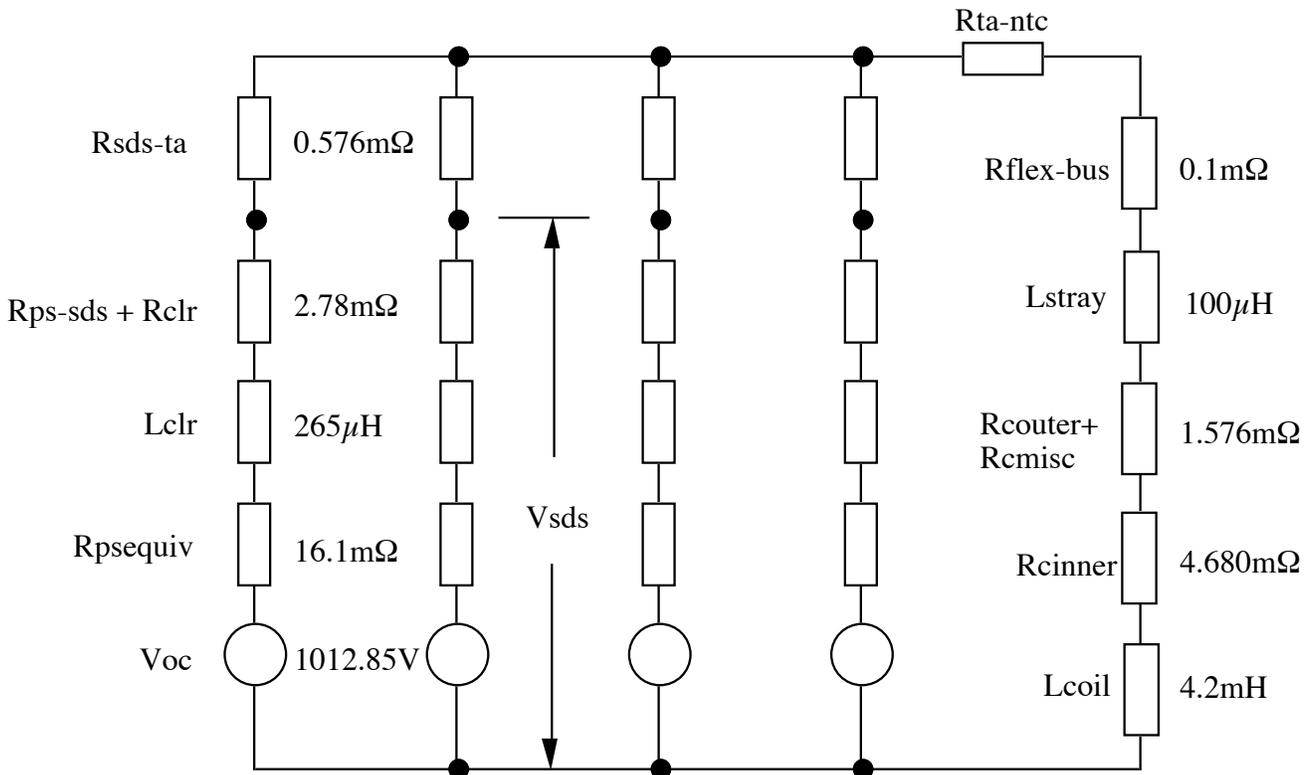*TO: DISTRIBUTION*
FROM: C NEUMEYER
SUBJECT: TF AS-BUILT CIRCUIT PARAMETERS

Reference:

[1] NSTX-CALC-13-2, "TF Coil Parameters"
[2] NSTX-CALC-13-15, "Water Cooled Flex Cable Thermal/Hydraulic Calculation"
[3] NSTX-CALC-13-18, "TF As-Built Circuit Parameters"

This memo (which is also filed in the ref. [3] calculation with supporting documents) provides a reference for the as-built TF circuit parameters.

Equivalent circuit is shown below.

Label	Value
Rta-ntc	
Rsds-ta	0.576mΩ
Rps-sds + Rclr	2.78mΩ
Lclr	265μH
Rpsequiv	16.1mΩ
Voc	1012.85V
Vsds	
Rflex-bus	0.1mΩ
Lstray	100μH
Rcouter+ Rcmisc	1.576mΩ
Rcinner	4.680mΩ
Lcoil	4.2mH

Notes:

1) Rtotal = 16.97mΩ (2 parallels), 12.25mΩ (4 parallels)
2) Ltotal = 4.433mH (2 parallels), 4.366 (4 parallels)

Resistance values are derived in the following spreadsheet.

Element	Name	Data	Value		Reference
Inner Legs	Rcinner		4.680	mΩ	Calculated
Outer Legs	Rcouter		1.090	mΩ	Calculated
Joints, Flags, Flexs etc.	Rcmisc		0.486	mΩ	Calculated
Subtotal	Rcoil		6.256	mΩ	Calculated
Flex Cable, Bus Bar, etc.	Rflex-bus		0.100	mΩ	Calculated
Subtotal			6.356	mΩ	
Transition Area to Test Cell	Rta-ntc		0.610	mΩ	Measured
SDS to Transition Area	Rsds-ta	=2*(0.304+0.292+ 0.285+0.28+0.298 +0.287+0.279+0.2 79)/8	0.576	mΩ	Average of Measurements
Nominal Subtotal			7.542	mΩ	
Test Shot Data: R=V/I		=400/53050	7.540	mΩ	Derived from Shot Data
Delta			-0.002	mΩ	
Delta			-0.024	%	
Vps open circuit	Voc		1012.850	Volt	Basic Rating
Test Shot Data: R=(Voc-V)/I		=(Voc-777)/50	4.717	mΩ	
Requivalent per branch			18.868	mΩ	
Power Supply Branch Inc'l Clr	Rps-sds+Rclr	=(2.47+2.44+3.3+2 .91)/4	2.780	mΩ	Average of Measurements
Ips*f/60			13541.667		
Power Supply Requivalent	Rpsequiv		16.056	mΩ	Calculated
Nominal Subtotal			18.836	mΩ	
Actual Subtotal			18.868	mΩ	Derived from Shot Data
Delta			0.032	mΩ	
Delta			0.171	%	
2P ∑R			16.974	mΩ	
4P ∑R			12.257	mΩ	
2P ∑Resistance-Rinnerlegs-CLRs-RPSS			3.766	mΩ	
4P ∑Resistance-Rinnerlegs-CLRs-RPSS			3.313	mΩ	

The following points are noted:

1) Coil resistance calculations are from ref. [1] and are consistent with the measurements made during commissioning by J. Chrzanowski (total 6.31mΩ at coil terminals vs. 6.26mΩ calculated).

2) Resistance values are at 20°C. Coil inner leg resistance varies considerably during a pulse.

3) Water cooled flex cable resistances were calculated in ref. [2] at 90$\mu\Omega$. Here an additional 10$\mu\Omega$ is added for the air cooled copper bus run.

4) The combined total resistance estimate, up to the SDS cabinets, where the voltage measurements are made, agrees very well with $R = V/I$ where V is the measured flat top voltage during a 4.5kG test shot.

5) Using curve fit data developed by N. Fromm during the TFTR 6T operations the power supply voltage, for 4 sections active on a feeder with a 0.5Ω feeder reactor, is:

$$V = 1012.85 - 0.018818 * I' + 2.4386e{-}7 * I'^\wedge 2$$

$$\text{Where } I' = I * freq/60$$

At 65Hz, 50kA/4 parallels the equivalent resistance is of order 16mΩ.

6) Using the above power supply equivalent resistance along with other measurements of the resistances on the power supply side of the SDS, the combined total resistance estimate, down to the SDS cabinets, where the voltage measurements are made, agrees very well with $R=(Voc-V)/I$, where Voc is the power supply open circuit voltage, V is the measured voltage just prior to flat top when the power supply is fully on ($\alpha=0°$) and I=50kA, during a test shot.

7) Total effective resistances are indicated in the table for the case of 2 and 4 parallel TF operation.

8) The data entered in the PSRTC for external circuit resistance (ECR) excludes that resistance associated with the coil inner legs, the power supply equivalent resistance, and the CLRs. Therefore the last set of values indicated in the table are the appropriate PSRTC entries for the 2 and 4 parallel cases.

9) Stray inductance is attributable to the cable run.

10) With the above data the PSRTC simulation results are in excellent agreement with the field measurements.