DRSSTC Optimization

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With the introduction of the new class of Tesla coils known as DRSSTCs (Double Resonant Solid State Tesla Coils), many new techniques can be used to optimize their performance. In this paper, I will give an example of how one may attempt to design a DRSSTC for optimal performance. I will also show how good performance can be achieved without exceeding the specifications of the IGBTs.

Note: The specific examples given and the techniques themselves have NOT be verified! They are derived from standard Tesla coil design techniques but their validity in the case of DRSSTCs as NOT been tested! This paper only present the preliminary idea, errors may have been made!!

As in the case of conventional Tesla coils, one may wish to start with the charging circuits. Standard split phase 240VAC is commonly available in the United States. This can easily be rectified and filtered to give a buss voltage of 340VDC which is commonly controlled with a variac avoiding soft start issues. Thus, we will assume a maximum buss voltage of 340VDC.

For a simple inexpensive IGBT we may choose the IRG4PC50FD:

Vces	600V
Ic	70A
Icm	280A
Pd	200W
Cost	$10.28 (DigiKey)

http://www.irf.com/product-info/datasheets/data/irg4pc50fd.pdf

So the question simply becomes, how much spark can we drive with this modest system?

The IGBT is the limiting factor for two reasons. First is that fact that “cheap” IGBTs do not switch very fast. Thus, we need to keep the system's resonant frequency fairly low in IGBT systems. Perhaps in the 50kHz (as opposed to a more typical 200kHz) range. The second factor, is the current. Since the IGBTs become a pass element in the very high current primary LC loop, the currents they have to handle can be enormous. Since the system is “pulsed” we can take advantage of the Icm ratings at 280 amps peak. IGBTs can be far overdriven to say 4X the Icm rating too, but we will limit this discussion to the rated 280 amps.

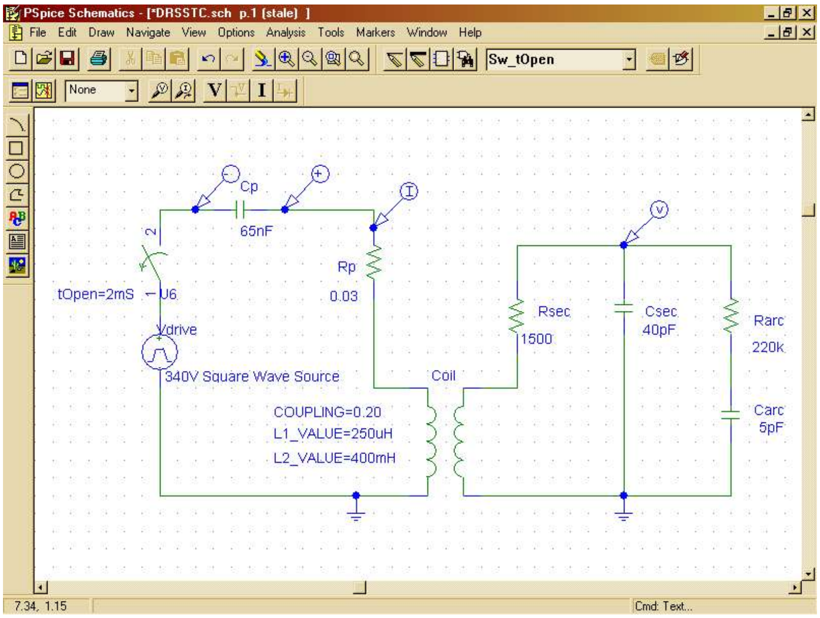
One other common Tesla coil limit can be added here. MMC primary capacitors are commonly available, but we will limit the maximum voltage to 20kV peak. This avoids corona problems and the strings becoming “too large”. It is important to note here that if the primary circuit is only going to run 280 amps peak, the current handling of the conventional MMC may be vastly “too high”. Perhaps money could be saved by using lower peak current rated capacitors...

In our case, we need low resonant frequencies and low peak primary currents. Thus, very large primary inductances are required. This also serves to help reduce primary losses.

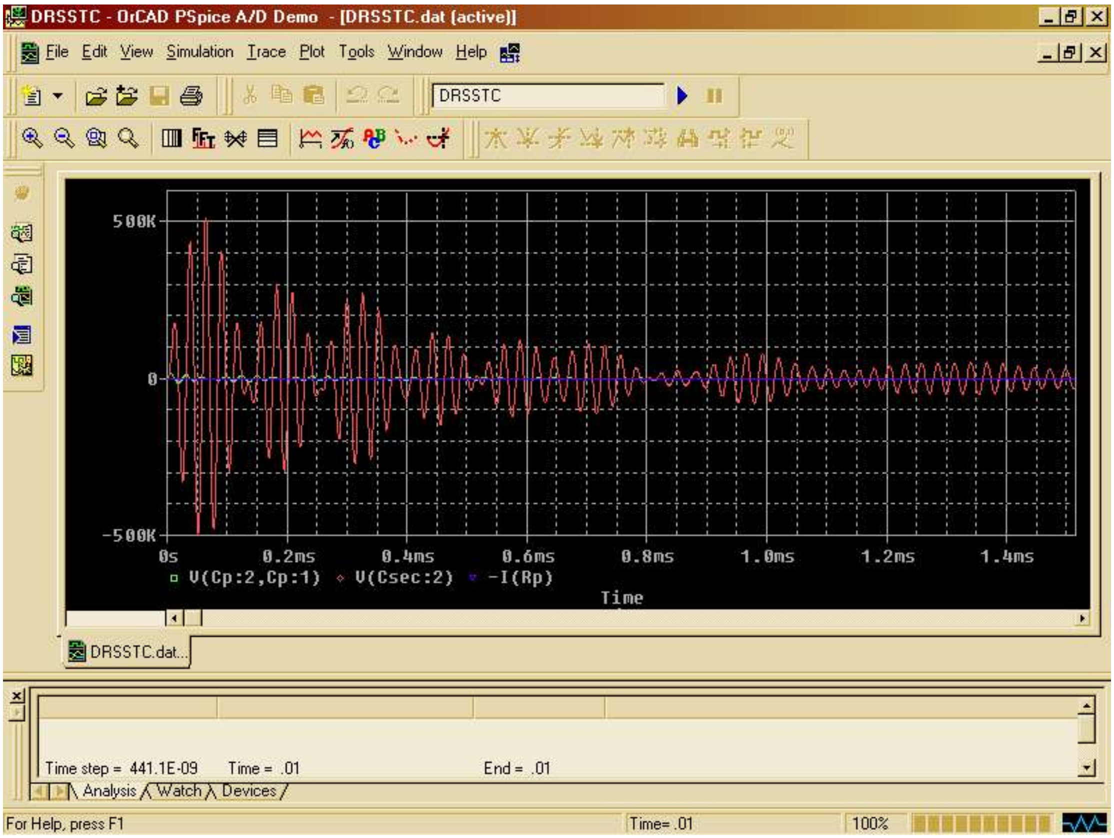
We make a large secondary inductor of thinner wire with many turns and a large topload for a low resonant frequency. Larger diameter coils will have less loss in this case. We will assume we have a 400mH secondary inductor and 40pF of total secondary capacitance. The Fo frequency is ~39.8kHz. We will probably see about 1500 Ohms in secondary losses. We will assume a standard streamer loading model of 220k + 5pF.

The primary is a very large conventional loop with as much inductance as we can practically make while still “fitting” the coil. The primary coil must have low loss, so 1/4 inch copper tubing is still suggested. We will assume this is a 250mH primary coil that is adjustable as needed. If we “wildly” assume the system has a primary loss of about 50 watts and the primary RMS current is about 40 amps, we can roughly guess at the primary circuit loss resistance at 0.03 ohms. That seems reasonable from OLTC and SGTC numbers. The primary capacitor is a fairly conventional MMC designed to hit the resonant frequency needed at 65nF. We can assume the primary to secondary coupling is 0.20.

So now we follow the time honored technique of throwing it all together and see how it works!!



The model shows that the secondary resonates at 37.562kHz so I needed at adjust the primary inductor to 268.34uH to tune it. So I adjusted that and let it run.



```
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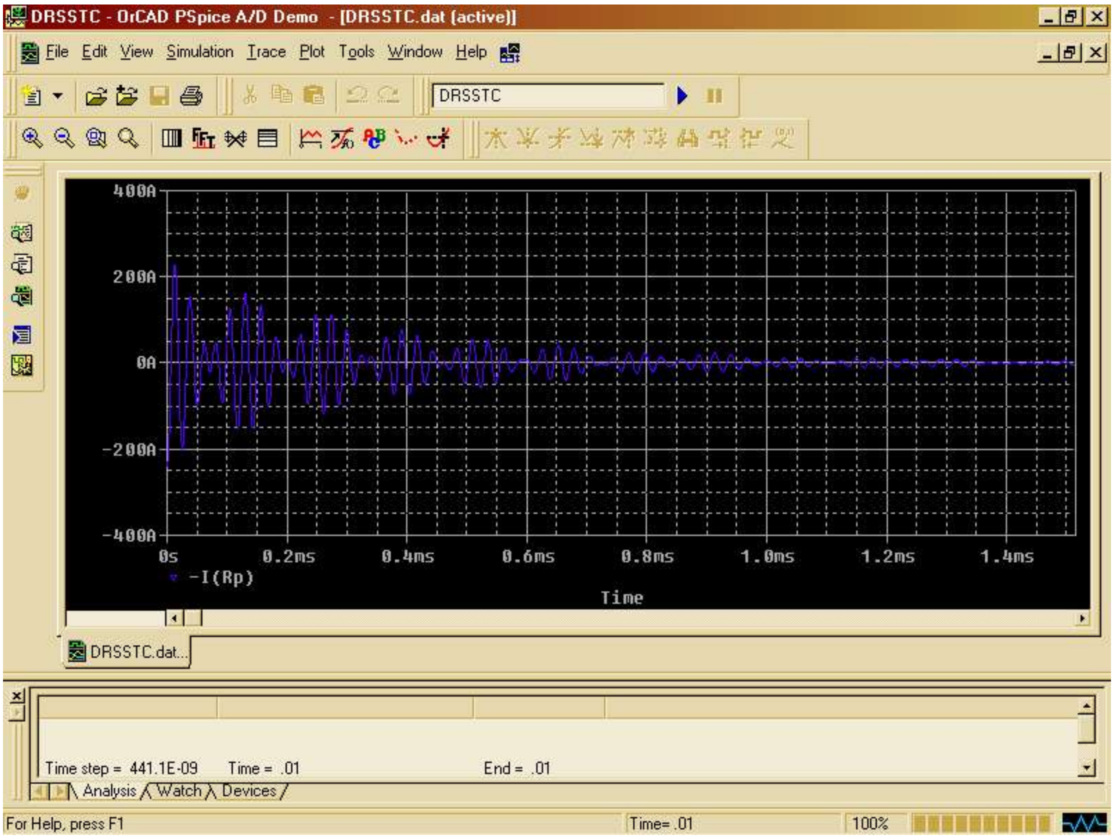
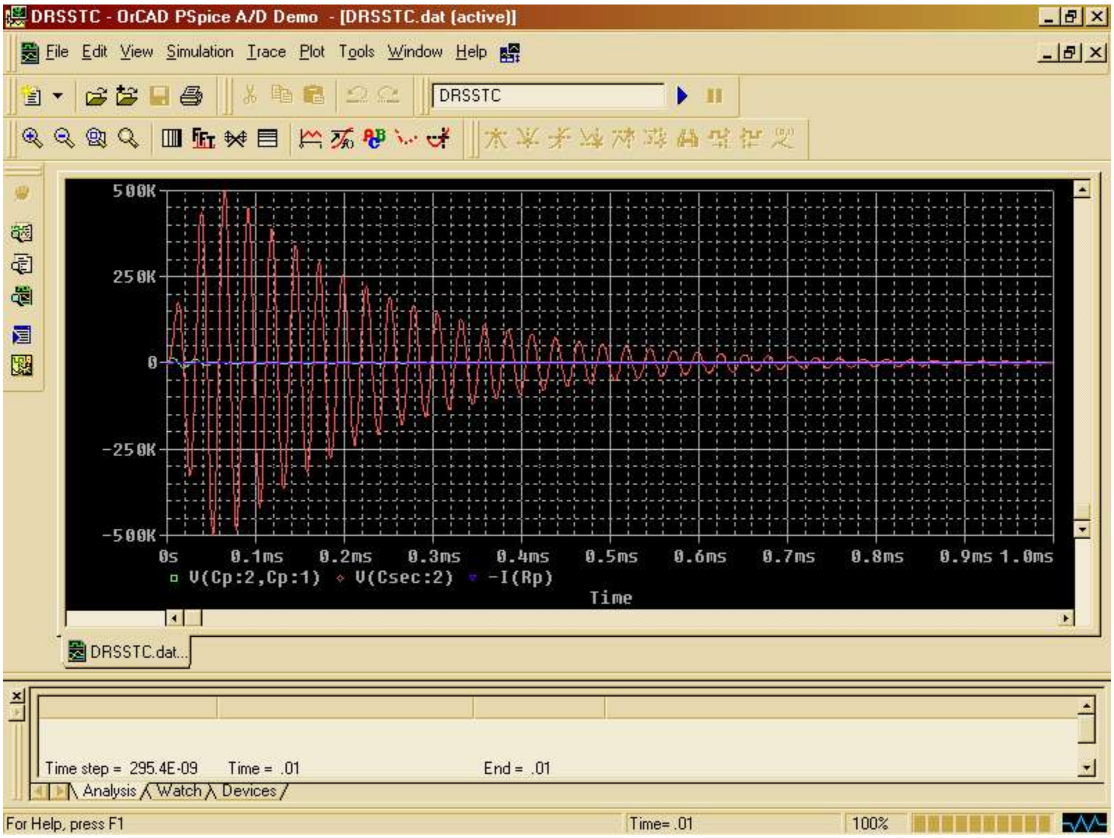
```



```
Time step = 441.1E-09    Time = .01    End = .01
```

So not too bad!! The large inductor knocked the primary current down well. Thee primary voltage peaks at 14.77kV and the primary current at 240amps. If we set the quench time to 68uS we get a realistic situation.



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Time step = 295.4E-09    Time = .01    End = .01
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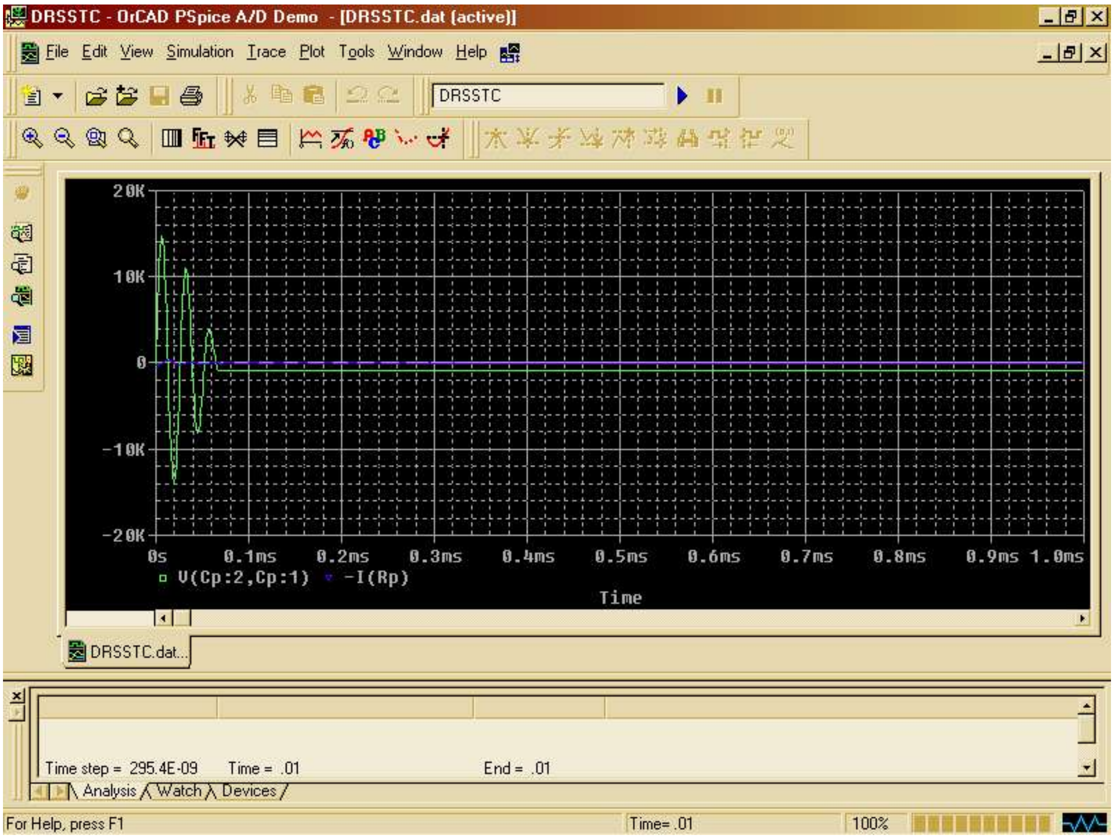

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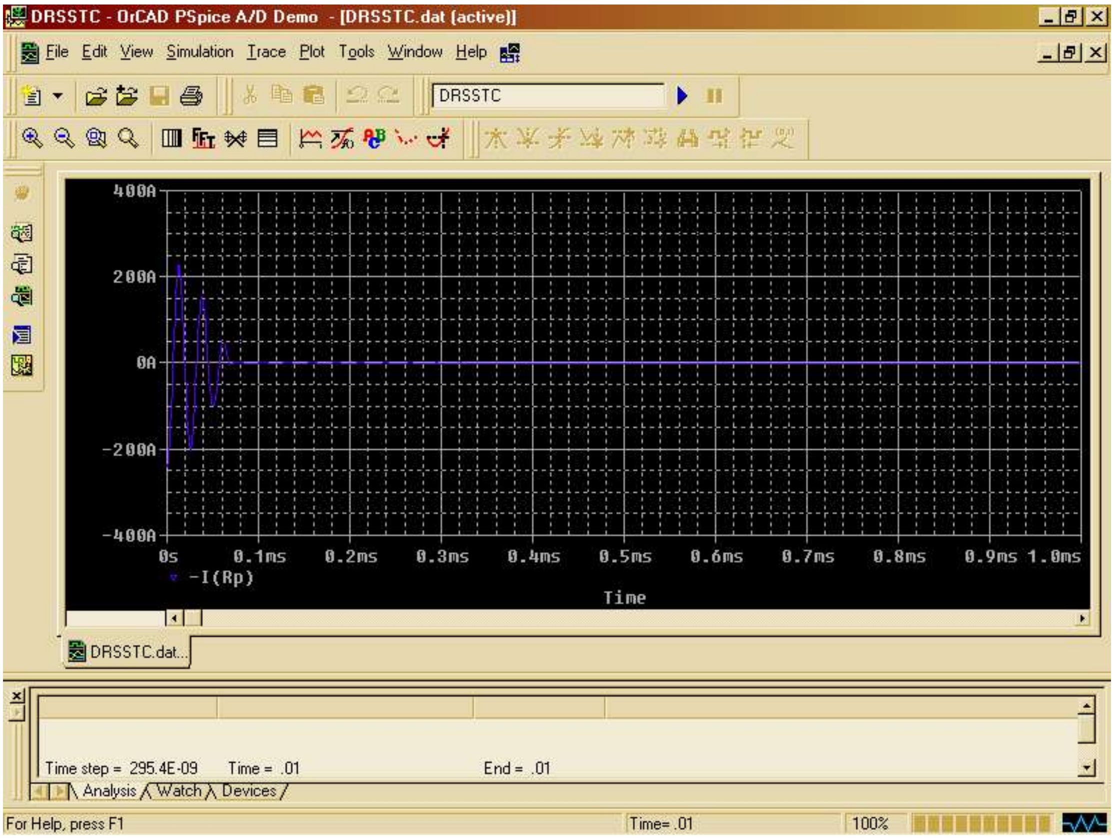
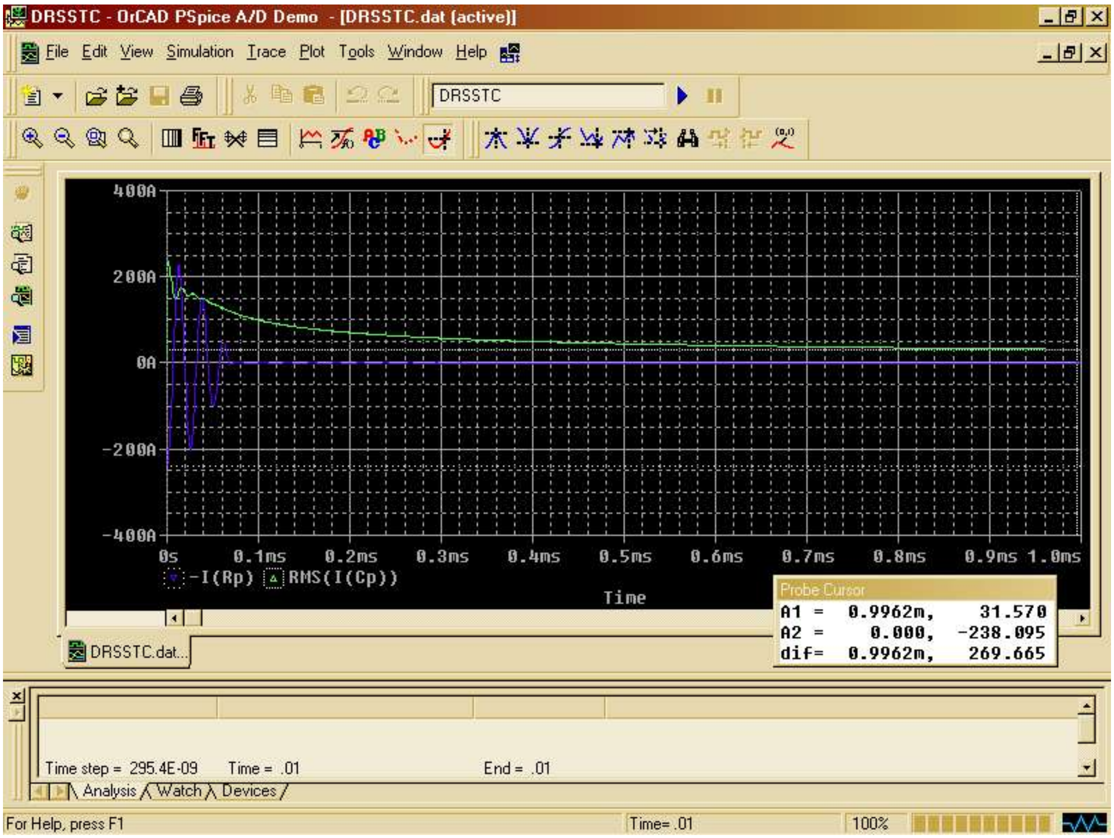
Time step = 295.4E-09     Time = .01                    End = .01
```



```
Time step = 295.4E-09     Time = .01                    End = .01
```

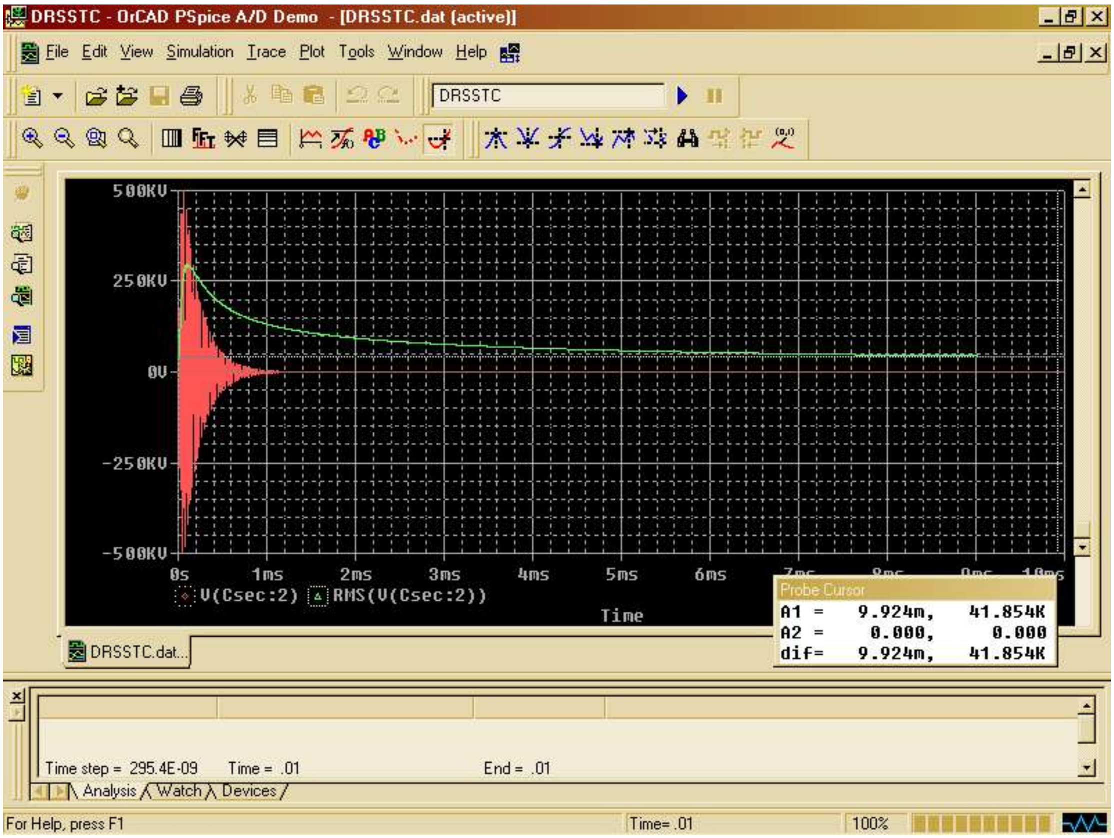
The primary RMS current for PRF of 100Hz is 31.57 amps:



```
Probe Cursor
A1 =   0.9962m,     31.570
A2 =    0.000,    -238.095
dif=   0.9962m,    269.665
```

```
Time step = 295.4E-09    Time = .01          End = .01
Time= .01
```

The RMS voltage to the load is 41.8kV. **In a 220k ohm streamer, the power to the streamer is 7.942kW!! That suggests a streamer length of 160 inches!!**



```
Probe Cursor
A1 =    9.924m,     41.854K
A2 =    0.000,       0.000
dif=    9.924m,     41.854K
```

```
Time step = 295.4E-09    Time = .01          End = .01
Time= .01
```

The real "key" to all this is to take into account the primary voltage, current, and frequency. If we have a primary frequency of 40kHz and want a peak current of 280 amps at 20kV. We really know the primary design.

R = V / I = 20000 / 280 = 71.43 ohms

Rl = 2 x pi x Fo x Lp = 2 x pi x 40000 x Lp = 71.43   Lp = 284.2 uH

Fo = 1 / (2 x pi x SQRT (Lp x Cp)   Cp = 55.7 nF

System losses change all this some, so real measurements and models help.

QED...