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ANALYSIS AND DESIGN MODIFICATIONS FOR UPGRADE OF STORAGE RING BUMP PULSE SYSTEM DRIVING THE INJECTION BUMP MAGNETS AT THE ALS*

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A fast (4.0 ms half period) resonant discharge pulse system, using SCRs, was designed and constructed to drive the injection bump magnet system at the Advanced Light Source (ALS)[1]. The commissioning process revealed a high frequency resonance (T = 800 NS) superimposed on the driver discharge wave form. In addition, the peak amplitude of the magnet load recovery current exceeded design specifications. A SPICE analysis confirmed the suspected mechanisms for the parasitic ringing and the excessive load current "undershoot." This paper will address the subsequent analysis, measurements, and modifications carried out during the maintenance shutdown in June 1993.

I. INTRODUCTION

This paper will a short review the pulser electrical system design, and continue with a more extensive discussion of the problems discovered during commisioning, the subsequent SPICE analysis of the system, the subsequent modifications made to the electrical system and finally the discuss the new wave forms measured more complete description of the injection process, the magnet layout and specifications and electrical system of the magnet drivers can be found in a previous paper.

II. BASIC SYSTEM LAYOUT

The sinusoidal current wave form required to drive the injection magnets is generated by the resonant discharge of a capacitor bank through a distributed array (64 total) of high voltage Silicon Controlled Rectifiers (SCRs) switches through a very low inductance transmission line (4 groups or 8 parallel cables) to the predominantly inductive magnet load. The basic topology for the pulse system is shown in Figure 1. The four parallel bipolar SCR-capacitor discharge modules that are shown in Figure 2.

III. ORIGINAL MEASUREMENTS

The bottom trace in Figure 3 is the output current from one of the four SCR pulse units.

IV. A SPICE ANALYSIS

A simplified model of the pulse system was developed using an Integrated Circuit Emulator (IsSPICE)[2]. The basic SPICE circuit is shown in figure 5. This simple circuit is a distillation of the major circuit elements of the pulse system: the series/parallel combination of the 16 energy storage modules

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capacitors (C1), the 64 SCR switches (X1), the 8 anti-
reversing diodes and saturating reactor switches (D1), the 32
coaxial cables (LOSSYLN, T1), and the magnet load (L1).

Figure 3: Magnetic field (upper trace, 666 gauss/div.) and
pulser output current (lower trace, 500 amps/div.)

The lumped elements L2 and R5 represent the distributed
inductance and resistance of the SCR switches. C2,3 and
R3,4 represent the combined RC anti-ringing snubber circuits
employed in the system. Circuit elements that have
underlying complex sub circuit models include: LOSSYLN,
T1 a distributed parameter lossy transmission line and voltage
source PULSE, V5 which contains a switch control wave
form that mimics the delay and nonlinear turn-on
characteristics of the SCRs modeled by SWITCH, X1.

Figure 4: Magnet current wave forms (overlaid) in "upstream"
and "downstream" bump magnets (100 amps/div.).

The large well defined circuit elements (R2, C1, D1, T1,
the snubbers and L1) were connected together adjusted until
bulk characteristics of the simulator wave forms were in good
agreement with measured system wave forms. By virtue of
the complexity of the distributed pulse system the
measurement or precise calculation of the parasitic
components (esp. L3 and R5) would be very difficult and
time consuming. As a consequence the parasitic components
(L2, L3, R5, and V5) were added and empirically adjusted to
mimic the measured wave forms in Figures 3 and 4. As
shown in Figure 6 the resultant model generates source and
load wave forms that give reasonably good agreement in
period, amplitude and general wave shape with the measured
wave forms. The resultant circuit model strongly suggests a
likely source of the high frequency parasitic oscillations.

The ringing is initiated by the initial turn-on transient
created by unrestrained inrush of current (high di/dt) into the
large shunt capacitance presented by array of low inductance
(high capacitance) transmission cables. The exponentially
decaying oscillations are the result of a parasitic resonance
between the distributed parallel inductance of the SCR pulse
units and the cable shunt capacitance. Changing the switch
inductance (L3) or the number of cables will dramatically
alter the frequency and amplitude of these oscillations.

A reasonable solution to the resonance problem is shown
in Figure 7. The parasitic ringing on the pulser current (top
trace) is almost completely eliminated and the magnet load
current reverse recovery amplitude is within the 1%
specification. This effect was brought about by halving the
number of coaxial cables from 16 to 32, thus lowering the
cable input capacity and replacing the RC snubbers with
resistors thereby considerable reducing the parasitic and bulk
(undershoot) resonance effects. Further reducing the number
of cables would decrease the ringing effects and the excessive
di/dt but conversely increase the period of the magnet current
pulse beyond its specified requirements. The magnitude of
the di/dt at the beginning of the pulse current wave form was
moderately reduced and its duration, in excess of 1500
amps/us specification, was halved.

Figure 5: The basic SPICE circuit used in analysis of pulse
circuit
V. ACTUAL MODIFICATIONS AND RESULTS

All the component values suggested by the SPICE models were applied to the Bump system. The number of coaxial cables was halved and the R-C snubbers were replaced by straight resistors. The resistor size was selected by power dissipation calculations obtained from the SPICE runs. As a protective measure, the core area of the saturating magnetic switches was doubled to further protect the SCR's from the remaining excessive di/dt. The correlation between the SPICE wave forms and the actual measured wave forms in Figures 8 and 9 is quite good.

VI. CONCLUSION

A condensed and simplified SPICE model was been created to understand the mechanism of excessive di/dt, and parasitic ringing observed in the current wave forms of the recently constructed resonant discharge pulse system at the ALS. The SPICE model identified significant circuit problems and the appropriate corrections were made.

VII. REFERENCES


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