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A RIPPLE REDUCTION TECHNIQUE FOR POLY PHASE POWER SUPPLIES

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Accelerator Division Technical Note
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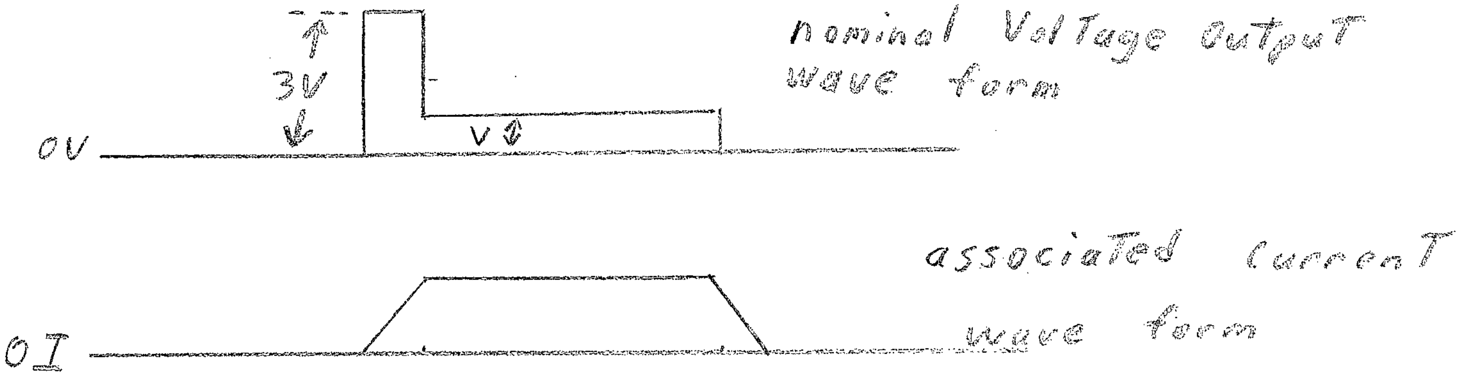
Summary

This note deals primarily with 60 Hz ripple associated with the Acme power supplies (12 ϕ) used to power high field quadrupole magnets in the AGS ring.

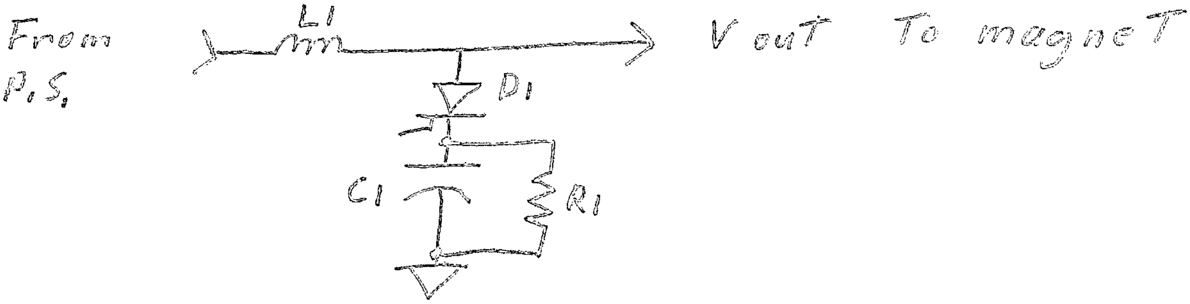
Introduction

The horizontal quadrupole power supply and associated magnet load are used as an example.

The magnet, or load to the power supply, is 30 mhy's in series with 208 milliohms. The power supply is a 12 phase SCR controlled unit with an associated current crossing voltage feedback loop. The unit is operated in a pulsed mode with a duty cycle of approximately 50% and a PRR of 3 seconds.



In conjunction with the power supply is a ripple filter of the LC type.



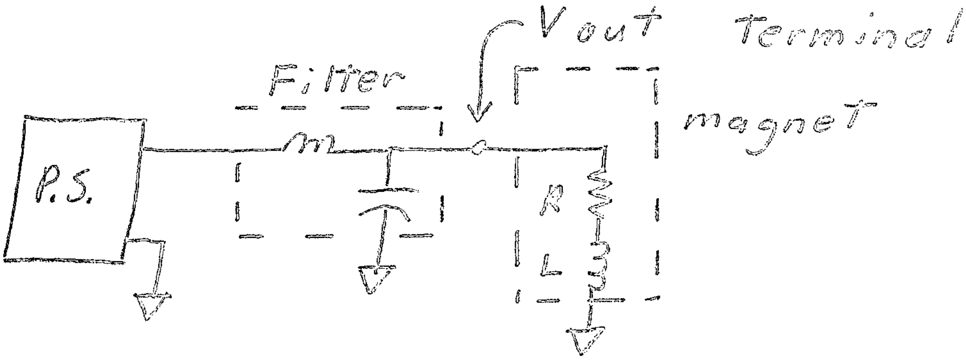
where

L_1 = 2 mhy @ 500 amp d.c.
C_1 = 7.8 kuf electrtolytic cap.
D_1 = SCR
R_1 = 0.3 Ω water cooled res.

It is the v_{out} to magnet which we are concerned with here.

Body

If one considers the basic components of this system, one sees:



At any time the ripple across the magnet is:

$$V_{ripple} = \Delta V_{out}$$

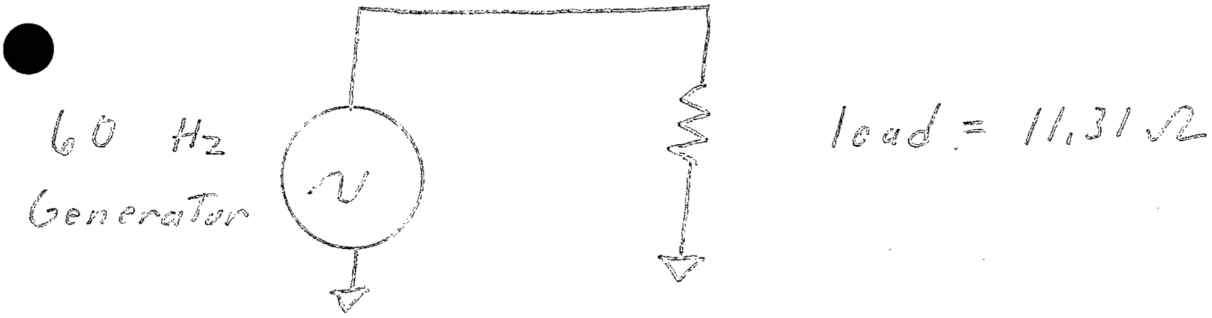
$$I_{ripple} = \frac{\Delta V_{out}}{Z_{magnet}}$$

where $Z_{magnet} = \sqrt{R^2 + X_L^2} = 11.31\ \Omega$

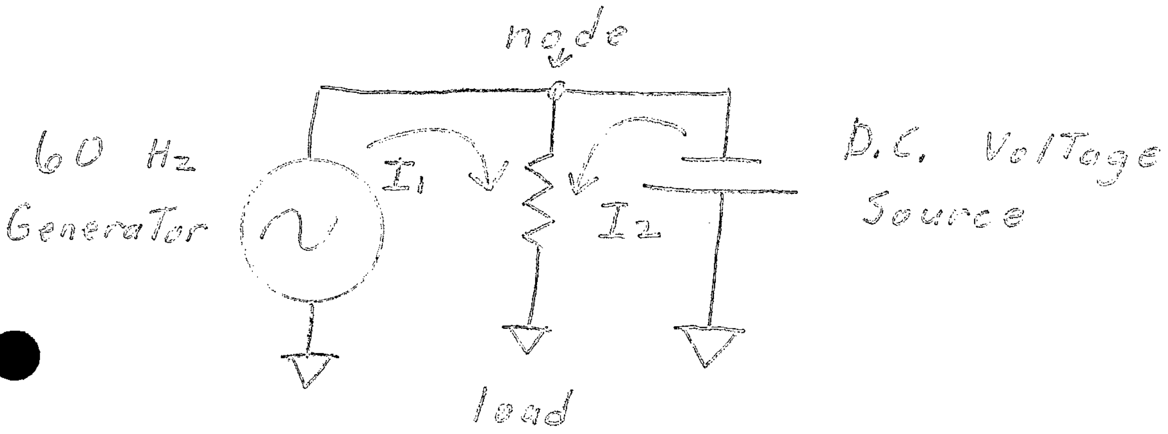
R^2 = Resistance^2 = $0.2^2\ \Omega$

$X_L^2 = 2\ \pi FL = 2\pi\ (60)\ (0.030) = (11.31)^2\Omega$

Simplifing the set up, allowing only for a.c. 60 Hz analysis, yields:



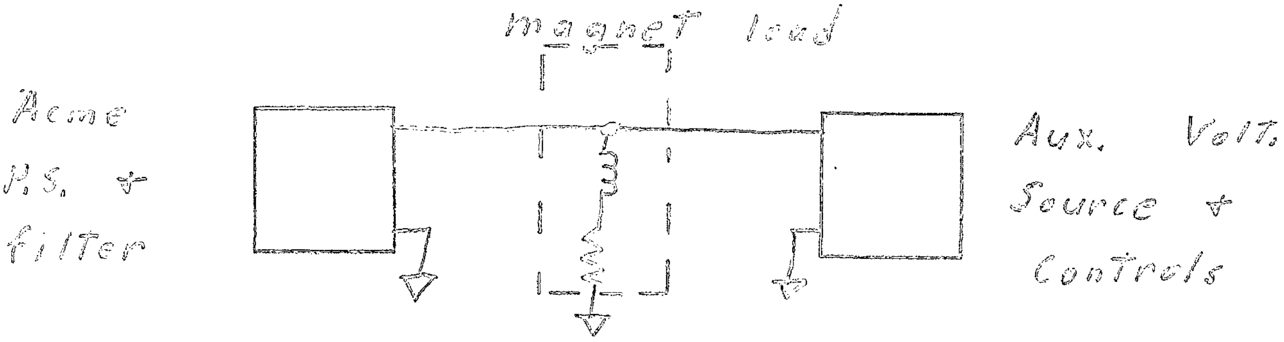
If one were to also apply a d.c. voltage source across the load, the diagram yields:



where the voltage at the load (node) is a combination of the 60 Hz generator output and the d.c. voltage source. The current in the load is simply $I_1 + I_2$.

If the voltage source is of impedance R_1 and the generator is of impedance R_2, where R_1 is $<< R_2$, V load will appear to be that of the d.c. source (provided that the voltage source can supply sufficient current to the load during the time the generator is supplying minimium current.)

This idea taken to our Acme set up (Acme power supply and magnet load) yields:



Preliminary measurements made (without aux. power supply) yields a 60 Hz component of 1.0 volt peak to peak. This gives a first order current variation of

$$\frac{\Delta V}{X_c}$$

where $X_c = X_c$ of filter

$$X_c = \frac{1}{2\ \pi\ (60)\ 7.8 \times 10^{-3}} = 0.340\ \Omega$$

$$\frac{\Delta V}{X_c} \text{ @ 60 Hz} = 2.94 \text{ amps}$$

If a voltage source capable of supplying 2.94 amps at V_{out} (where $V_{out} = V$ d.c. + ΔV) is connected in parallel with the main power supply, V_{out} to load = V_{out} d.c. + ΔV_{out} where $\Delta V_{out} = \frac{\Delta I}{Z}$

$$\Delta I = \frac{\Delta V_1}{R_2} + \frac{\Delta V_2}{R_3}$$

Where ΔV_1 = ripple output from Acme power supply + filter combo.
ΔV_2 = ripple output from aux. power supply.
R_2 = impednace of Acme power supply filter combo.
R_3 = impedance of aux. power supply.
Z = Z of magnet load.

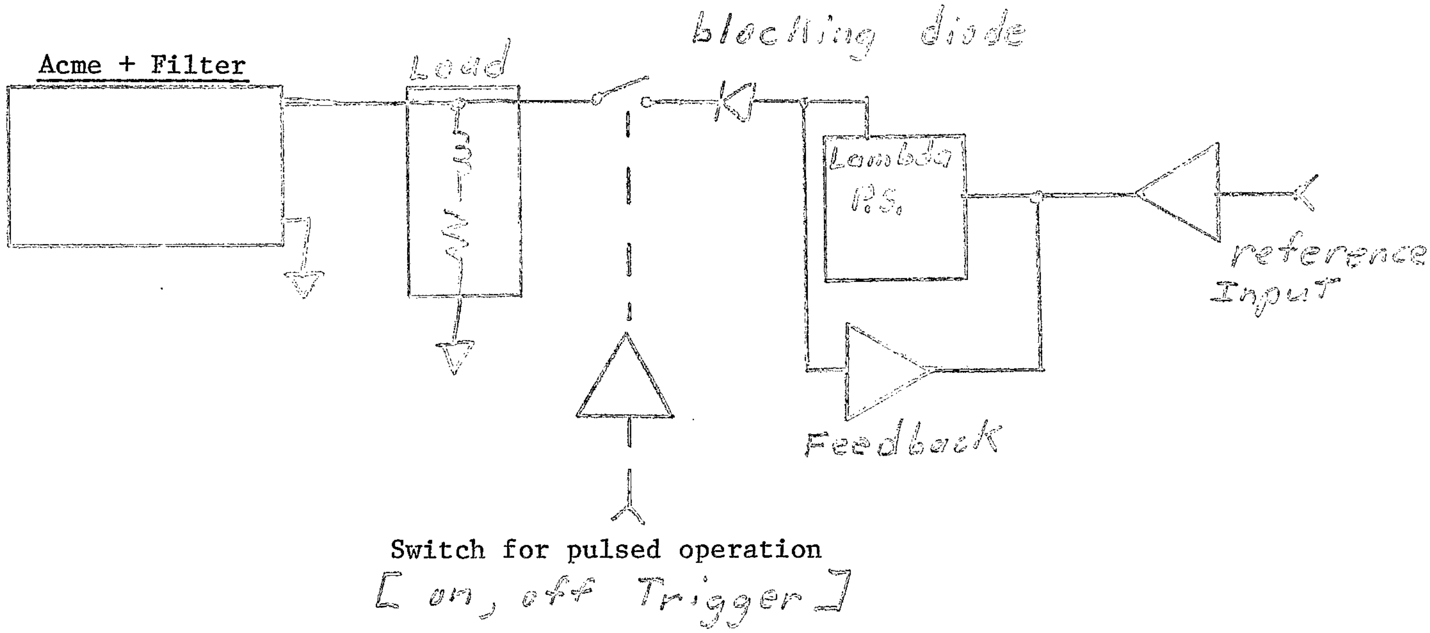
Four our experiment, a Lambda 9 amp 36 VDC power supply, Model #LK343AFM was used. Associated controls were also implimented which control the Lambda power supply. Its reference was taken from the Acme's reference and, therefore, tracks the Acme power supply's output. The Lambda requires a reference of 1 volt in for 1 volt out, therefore, an amplifier was installed for the Acme power supply's reference is 1 volt in for 50 volts out.

Nominal output for the Acme power supply is 115 amps at 24 VDC. This falls into the voltage limits of the Lambda power supply (0-36 VDC).

The Acme power supply impedance is primarily its filter. AT 60 Hz this impedance $Z = 0.754\ \Omega$.

The Lambda impedance is taken as $\frac{\Delta V}{\Delta I}$ where $\Delta V = \Delta V$ of load, ΔI = 10% → 90% rated current. $\frac{\Delta V}{\Delta I}$ = 10 mil Ω's as per Lambda.

This yields a miximum ripple attenuation factor of 0.754/0.010 = 75.4



Conclusions

The system was exercised for a magnet current of 75 amps through 125 amps with no degradation of ripple suppression. Our results showed a peak to peak ripple of 45 mV at 60 Hz. This gives a ripple reduction factor of 1.0 ÷ 0.045 = 22.2. The anticipated reduction factor was 75.4. Investigation showed that this discrepancy is due to the interconnection impedances associated with the aux. power supply. If these impedances were made lower, the results would improve.

mvh