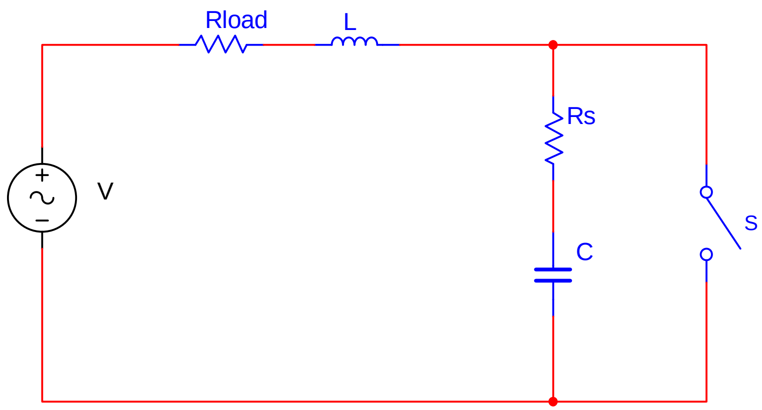
SNUBBER ANALYSIS

The Dual Channel Aquarium Level Control controls the 120 Vac power supplied to the customer's aquarium water pump by switching on and off a 2N6348AG triac. An RC snubber across the MT1 and MT2 leads of the triac limit the maximum transient voltage and maximum dV/dt across the triac leads. Larger loads and reduced power factor will increase these conditions. The ratings for these parameters for a 2N6348 triac are 1200 volts and 5 V/ μsec. The capacitor is rated for 500 V.

This analysis models the output circuit to determine the transient seen across the triac and snubber. The approach will be to model the pump as a series resistance and inductance, Rload, and L, the snubber as series resitance and capacitance, Rs and C. A switch is placed across the snubber Rs and C, opening at time t=0.



Start with defining the 120 Vrms power:

$$Vp := 170 \quad \text{Volts} \qquad \omega := 377 \quad \text{radians}$$

Next, assume a maximum RMS load current and minimum power factor, keeping in mind that the worst case conditions would occur if the triac attempted to turn off the power during the pump's starting transient. Power factor will be expressed as the phase angle, θ, by which the current lags the voltage.

$$Iload := 4 \quad \text{Amperes, RMS} \qquad \theta := \frac{4\pi}{12} \quad \text{radians}$$

The above parameters lead to the following expressions for the load impedance, resistance, and reactance, and inductance.

$Z := \frac{Vp}{\sqrt{2}\cdot Iload}$ Ohms $\qquad Rload := Z\cdot\cos(\theta) \qquad Rload = 15.026$ Ohms

$X := Z\cdot\sin(\theta)$ Ohms $\qquad L := \frac{X}{\omega} \qquad L = 0.069$ Henries

An expression for the 60 Hz 120 Vrms source voltage is provided below. The phase angle θ for the load is placed in the expression for voltage so that the current will be at zero when the switch opens, similar to the operation of the triac:

$$v(t) := Vp\,\sin(\omega\cdot t + \theta) \quad \text{Volts}$$

Values for a snubber circuit are chosen

$$C := .25\cdot 10^{-6} \quad \text{Farads} \qquad Rs := 33 \quad \text{Ohms}$$

The total resistance during the transient is the combination of the load resistance and the snubber resistance.

$$R := Rload + Rs \quad \text{Ohms}$$

Laplace transforms of the source voltage and the transient current are provided below:

$$V(s) := v(t)\ \text{laplace}, t \ \rightarrow 170\cdot\frac{\frac{1}{2}\cdot s\cdot 3^{\frac{1}{2}} + \frac{377}{2}}{s^2 + 142129}$$

$$I(s) := \frac{V(s)\cdot\frac{s}{L}}{\left(s^2 + \frac{R}{L}s + \frac{1}{L\cdot C}\right)}$$

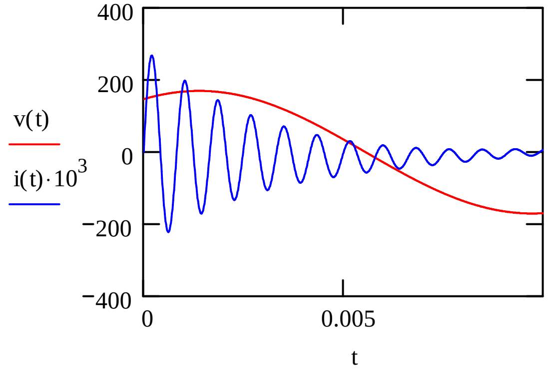
The frequency of the transient current is given by the following:

$$\sqrt{\frac{1}{L\cdot C} - \left(\frac{R}{2L}\right)^2} = 7.604\times 10^3$$

The inverse Laplace transform of I(s) provides the time domain expression for the transient current.

$$i(t) := I(s)\ \text{invlaplace}, s \ \rightarrow 8.094\cdot 10^{-3}\cdot\cos(377.\cdot t) - 1.387\cdot 10^{-2}\cdot\sin(377.\cdot t) - 8.094\cdot 10^{-3}\cdot\exp(-347.8\cdot t)\cdot\cos(7604.\cdot t) + .2808\cdot\exp(-347.8\cdot t)\cdot\sin(7604.\cdot t)$$

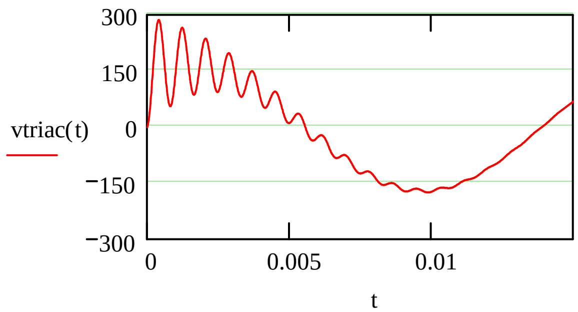
Source voltage and circuit current are shown below.



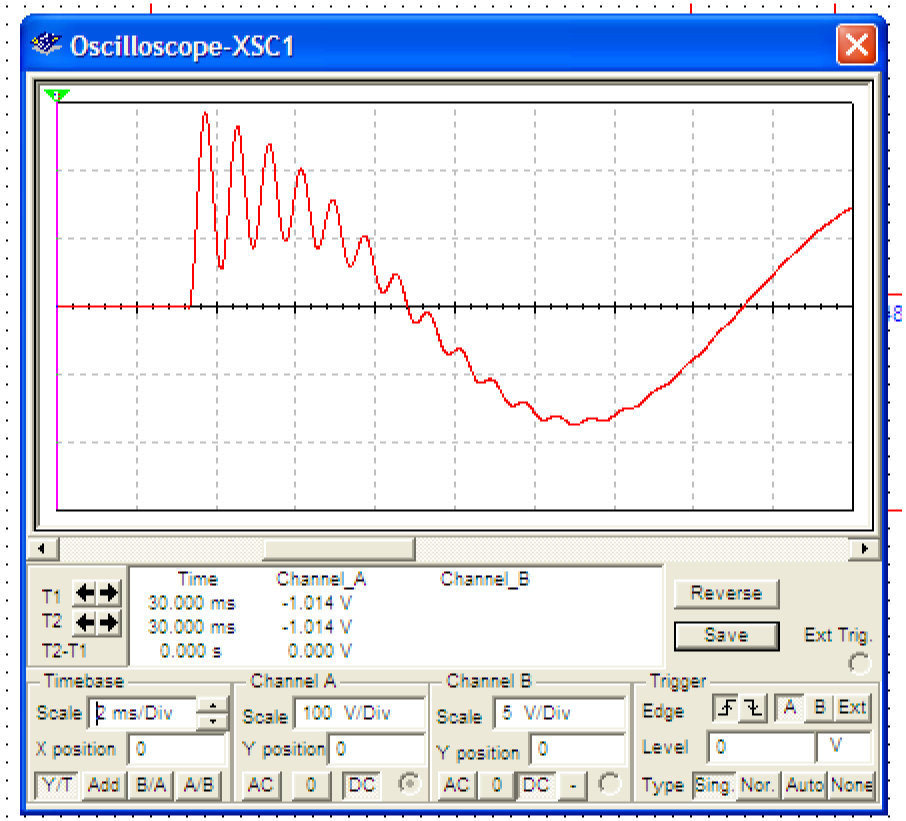
From the circuit current, the voltage transient across the triac can be derived.

$$\text{Vtriac}(s) := I(s)\cdot\left(Rs + \frac{1}{C\cdot s}\right) \qquad \text{Volts}$$

$$\text{vtriac}(t) := \text{Vtriac}(s)\ \text{invlaplace}, s \ \rightarrow 147.\cdot\cos(377.\cdot t) + 85.4\cdot\sin(377.\cdot t) - 147.\cdot\exp(-347.\cdot t)\cdot\cos(7604.\cdot t) - 1.725\cdot\exp(-347.8\cdot t)\cdot\sin(7604.\cdot t)$$

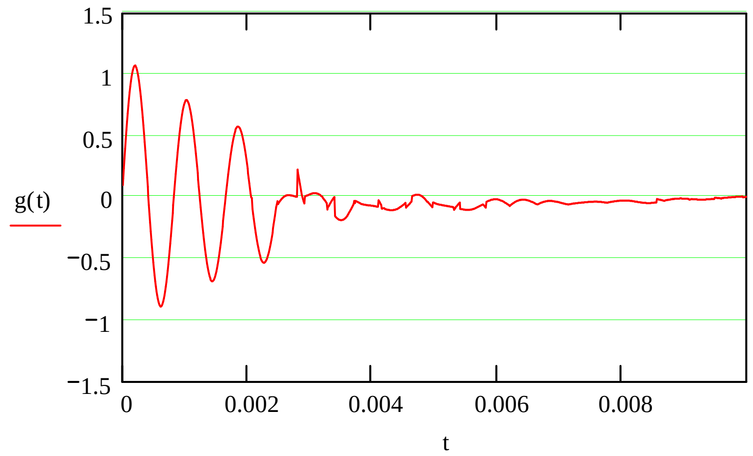


A verification of the above performed in Multisim provides the following plot of the transient voltage which agrees with the above analysis



An expressiong for the rate of change of the traic voltage is derived, in term of V/μsec

$$g(t) := 10^{-6}\left(\frac{d}{dt}vtriac(t)\right) \qquad \frac{V}{\mu sec}$$



CONCLUSON:

From the above, its is seen that for an assumed load of four amps operating at a 60 degree angle, or 50% power factor, the maximum voltage seen by the triac and snubber capacitor is approximately 290 Volts and the maximum dV/dt across the triac is limited to about 1 Volt per μsecond. These values are well below the ratings for the triac and snubber capacitor.