Inrush Worked Example

The magnetizing curve of a transformer is as follows:

Current	0	0.5	1.0	3.0	5.0	10.0	14.0	19.0
Flux Density	0	056	0.8	1.34	1.52	1.64	1.68	1.70

Assume that the normal maximum flux density is 0.8 Tesla. Prior to energization the flux density is 0.1 Tesla. Suppose that a sinusoidal voltage source is used to energize the transformer.

(a) Determine the worst case peak transient inrush current.
(b) Sketch the first half-cycle of current and the source voltage as a function of time for this condition.

INDUCTOR EXAMPLE

$$e(t) = N\frac{d\phi(t)}{dt} \qquad \phi = BA \Rightarrow = NA\frac{dB(t)}{dt}$$

$$B(t) = \frac{1}{NA}\int_0^t e(t)\,dt + B(0)$$

FOR STEADY-STATE (PHASOR)

$$\int \Longleftrightarrow \frac{1}{j\omega}\times \qquad ; \qquad \frac{d}{dt} \Longleftrightarrow j\omega\times$$

$$\hat{B} = \frac{1}{NA}\frac{1}{j\omega}\hat{E} \Rightarrow \hat{E} = j\omega NA\hat{B}$$

$$E_{max} = \omega NA B_{max} \qquad (0.8T)$$

$$= NA\omega(0.8)$$

$$e(t) = E_{max}\cos(\omega t + \theta) \qquad \theta = 0 \text{ POINT ON WAVE}$$

$$= NA\omega(0.8)\cos(\omega t + \theta)$$

$$B(t) = \frac{1}{NA}\int_0^t NA\omega(0.8)\cos(\omega t+\theta)\,dt + B(0)$$

$$= \frac{1}{NA}NA\omega(0.8)\frac{1}{\omega}\left[\sin(\omega t+\theta) - \sin\theta\right] + 0.1$$

$$B(t) = 0.8\left[\sin(\omega t+\theta) - \sin\theta\right] + 0.1$$

WORST CASE B MAGNITUDE?

$$\theta = \frac{3\pi}{2} \Rightarrow \theta = -90°$$

AT $\omega t = \pi$, $t_{PEAK} = \frac{\pi}{\omega}$

$$B_{PEAK} = 0.8[1+1] + 0.1 = 1.7\,T$$

$$i_{PEAK} = \underline{19\,A}$$

Matlab Code for Solution

```
%  Routine for Plotting Current Inrush
 delT=pi/(180*377)
for i=1:181;
    time(i)=(i-1)*delT;
    v(i)=1.0*cos(377*(i-1)*delT-(pi/2));
    b(i)=0.8*(sin(377*(i-1)*delT-(pi/2))-sin(-pi/2))+.1;

    % Use linear interpolation to calculate current;
    if (b(i) >= 0) & (b(i) < .56);
        cur(i)=((.5-0)/(.56-0))*(b(i)-0)+0;

    elseif (b(i) >= .56) & (b(i) < 0.8);
        cur(i)=((1.0-0.5)/(0.8-0.56))*(b(i)-.56)+0.5;

    elseif (b(i) >= .8) & (b(i) < 1.34);
        cur(i)=((3.0-1.0)/(1.34-0.8))*(b(i)-0.8)+1.0;

    elseif (b(i) >= 1.34) & (b(i) < 1.52);
        cur(i)=((5.0-3.0)/(1.52-1.34))*(b(i)-1.34)+3.0;

    elseif (b(i) >= 1.52) & (b(i) < 1.64);
            cur(i)=((10.0-5.0)/(1.64-1.52))*(b(i)-1.52)+5.0;

    elseif (b(i) >= 1.64) & (b(i) < 1.68);
            cur(i)=((14.0-10.0)/(1.68-1.64))*(b(i)-1.64)+10.0;

    elseif (b(i) >= 1.68) ;
        cur(i)=((19.0-14.0)/(1.70-1.68))*(b(i)-1.68)+14.0;

    end;
 end;

plot(time,cur,time,v)
xlabel('Time (Sec)')
ylabel('Voltage and Current')
```

Matlab Plots