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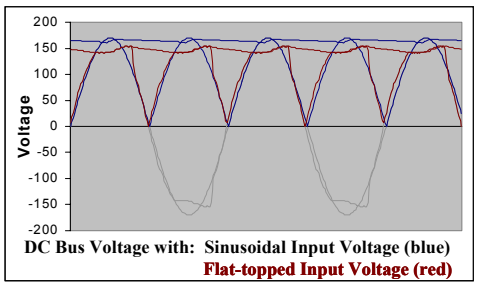
9. What ill effects do harmonics created by the computer power supplies have on themselves?

As voltage becomes more and more distorted, it will begin to have a negative effect on the connected equipment. A flat-topped voltage waveform can affect a switch-mode power supply (SMPS) in at least 2 major ways:

- A reduced peak voltage will translate to a lower DC bus voltage in the SMPS. Input current to the SMPS will increase because the computer or other electronic load still requires the same amount of power. Increased I^2R losses in the SMPS accelerate the aging of its components.
- Power disturbance ride-through capability is reduced since the reduced peak voltage means the large filter capacitor on the DC bus of the SMPS will be able to store much less energy.

When an SMPS is supplied by a voltage waveform with a flattened peak (red trace in Figure 9.1) rather than a nearly pure sinusoidal voltage (blue trace), the DC bus voltage is reduced proportionately (red trace). With a lower DC bus voltage, the SMPS will need to draw more current in order to deliver the same amount of power required by the load (I = P/V). This increase in current will result in increased component heating from higher I^2R losses and a reduced life expectancy of the components due to their higher operating temperature. For example, a 10% decrease in peak voltage (from 169V to 153V) will increase the SMPS line current by about 11% which will in turn increase the I^2R portion of the SMPS losses by about 23%. The correlation of SMPS failures with increased voltage distortion is usually subtle because equipment aging takes time to accumulate.



- Voltage flat-topping reduces DC bus voltage
- Lower DC voltage, increases current and I^2R losses (heat)
- Pre-mature component failure results from higher operating temperatures

10% drop in peak voltage produces

11% increase in current and

23% increase in I^2R losses

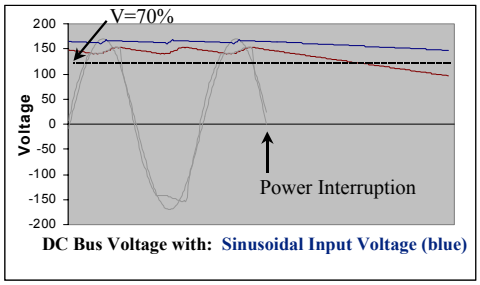
$$P = V\,I$$

If $V = 0.9$ pu, $I = \frac{P}{V} = \frac{1.0}{0.9} = 1.11$ pu

$$P_{Loss} = I^2R = (1.11)^2\,(1) = 1.23 \text{ pu}$$

Figure 9-1: How voltage flat-topping affects DC bus voltage and equipment over-heating

The first purpose of the large filter capacitor on the DC bus of an SMPS is to reduce the voltage ripple. The second purpose is to support its electronic load during a power disturbance that produces a momentary power interruption or major power dip. Since a typical SMPS is capable of operating for short periods at voltage levels as low as 70%, we can calculate the reduction in ride-through time if the initial voltage stored in the capacitor is below its rated peak voltage. For instance, if the peak voltage supplied to the SMPS is flat-topped by 30%, the ride-through capability is essentially zero and the I^2R losses are twice those present at rated peak voltage.



- Voltage flat-topping reduces DC bus voltage
- Lower charging voltage on smoothing capacitor, reduces stored energy
- With less stored energy ride-through capability is reduced

10% drop in peak voltage reduces ride-through capability by 37%

Energy recovered from capacitor during ride-through: $W_R = 1/2\ C\ (V_1^2 - V_2^2)$

With drop-out voltage = 70% ($V_2 = 0.7$ pu)

$V_1 = 1$ pu,	$V_1 = 0.9$ pu
$W_R = (1^2 - 0.7^2)$	$W_R = (0.9^2 - 0.7^2)$
$= 0.51$ pu	$= 0.32$ pu

$$\frac{(0.51 - 0.32)}{0.51} \times 100\% = 37\%$$

Figure 9-2: How voltage flat-topping affects equipment ride-through capability

With the correct initial peak voltage, the stored energy in the capacitor will often provide several cycles of ride-through capability before its voltage is reduced to 70% of nominal. This is dramatically reduced however, when the SMPS supply voltage is flat-topped because the energy stored in the capacitor is proportional to the square of the voltage. Figure 9-2 shows how a 10% reduction in the peak voltage supplied to computer equipment will reduce the power dip ride-through time by about 37%. Without the correct peak voltage, the smoothing capacitor in the SMPS will not be fully charged. Initially lower stored energy means that the capacitor will support the load for a much shorter period during a power interruption. When voltage flat-topping becomes severe enough, brief power interruptions such as those characterized by the lights flickering, will begin to affect equipment that would otherwise be unaffected.

In order to ensure reliable operation of power electronic equipment as well as other equipment on the power system, it is important to simultaneously maintain the correct level of both RMS voltage and peak voltage. This can best be achieved by using harmonic mitigation equipment that minimizes voltage distortion throughout the system by removing the harmonic currents from interacting with the upstream supply and distribution equipment.

