Touch current comparison data

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additional waveforms have been included since that meeting

PE Perkins, Convenor IEC TC108/WG5

Measurements in this paper are for the purpose of reviewing some data on equipment to confirm the work of IEC TC 108 (was TC74) wg5: IEC60990, Measurement of Touch Current and Protective Conductor Current.

IEC60990 has proposed using peak value touch currents to properly account for the non-sinusoidal touch currents expected in modern equipment brought about by the continued introduction of direct power semiconductor devices and their application to equipment.

Dalziel, in his 1943 paper[i], clearly pointed out that "… the electric-shock value due to relatively small electric currents are controlled by the crest value of an a-c wave and not by its root-mean-square value …" properly relating the physiological effects to the peak value of current. This was reconfirmed by Hart[ii] in 1985. RMS measurements were normally used because most equipment traditionally had sinusoidal Touch Current waveforms plus non-sin measurements were considerably more difficult to make with older instrumentation. Therefore the traditional values for Touch Currents were taken by dividing the physiological peak value by the sqrt 2 to get the proper RMS value. In view of reversing this trend, the usual RMS Touch Current values should be multiplied by the sqrt 2 to get the proper peak value giving the same physiological effect.

Regarding the spike nature of the TC waveform, the broadband measurement of IEC 60990 properly accounts for the additional HF current that can be tolerated by the body; these impulses recur well under the approximately 1 sec. heart cycle needed to restore the heart's resistance to VF.

It is known that for modern switching power supplied equipment that the input current waveforms are non-sinusoidal for these equipments and it has been expected that the leakage current waveforms would also be non-sinusoidal. Unfortunately, there has been a dearth of direct measured data to show the current status of events. Further, there has been a great hue & cry that the measurements were not obtainable, for a variety of reasons. The measurement issue has disappeared with the introduction of digitizing measurement equipment.

These type test measurements shown here were gathered with commercially available test equipment. A Simpson 228 true RMS reading, with burn hazard, let-go and reaction response networks (as specified by IEC60990), leakage current meter was used as the basic measuring instrument for the TC; a Tektronix THS720P Digital scope was attached to the 1 volt full scale meter amplifier output at the jacks provided on the front of the Simpson to capture the waveforms shown here.

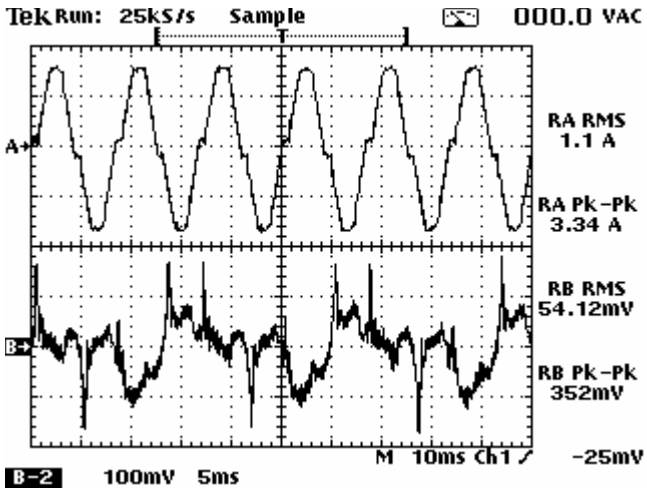
The TC measurements were made as the usual chassis-Neutral/Earth measurement, normal and reverse polarity and with switch OFF and ON including any other operator switches in each position. Input power measurements were also made on each equipment. The largest measured value is shown in each example.

Note that the use of power factor (harmonics) corrected power supplies is driving the touch current waveforms further away from the sinusoidal waveforms that had been experienced from AC driven equipment in the past. This further confirms the use of touch current peak measurements for equipment in order to properly show the electric shock effect of modern equipment.

Peak value TC measurements should always be made when non-sine TC's are present.

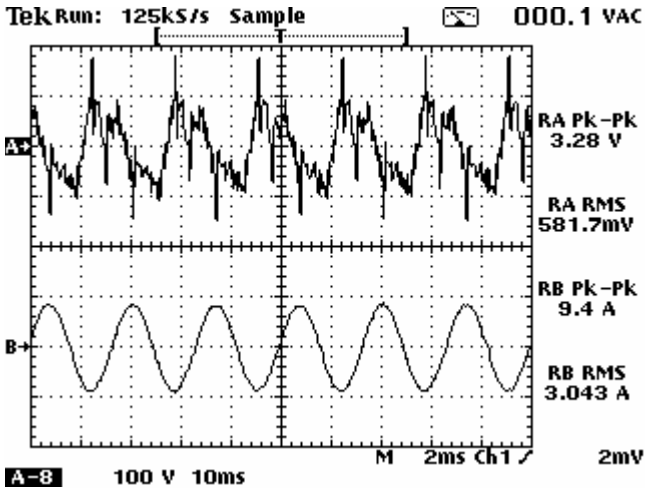
Additionally, the fundamental frequency for some TC waveforms is included.

)Portable projector C (with pfc power supply):
Input current and leakage current waveforms



max measured leakage current = 0.54 mArms or 1.755 mApk at 253V (60 Hz)
Itc peak/rms ratio: 0.352/0.054/2 = 3.250
input peak/rms ratio: 3.34/1.1/2=1.519

)Telecom equipment (w/pfc) in a cabinet:
Leakage current and input waveforms.



measured leakage current = 0.58mArms at 127.2V;
expect 1.168mArms or 3.293mApeak at 253V.
Itc peak/rms ratio: 3.28/0.5817/2=2.819 (60 Hz)
input I peak/rms ratio: 9.4/3.043/2=1.545

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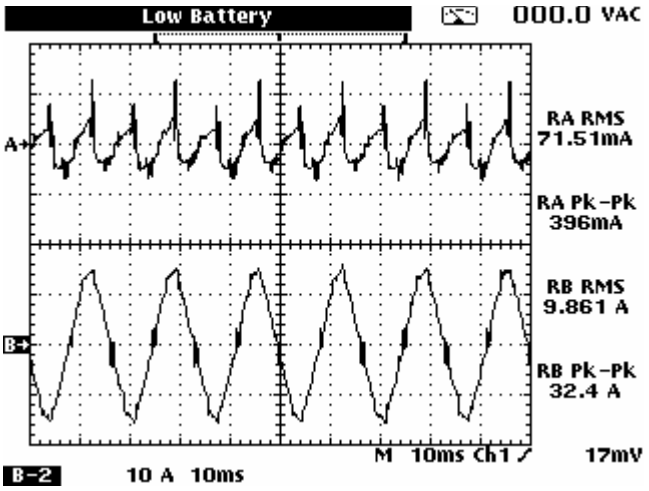
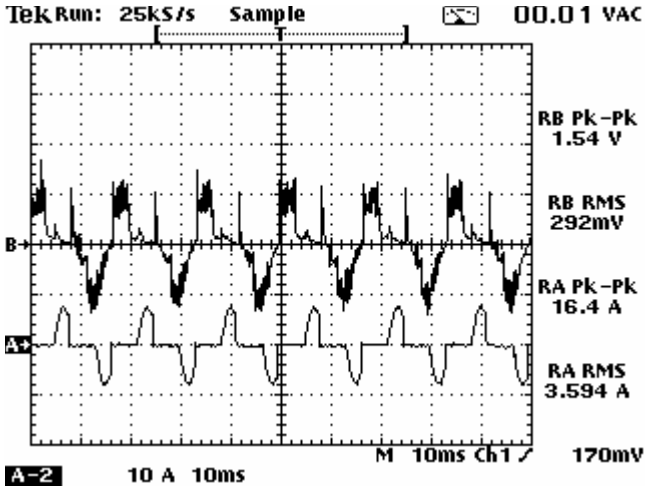
)Industrial server A (with pfc power supply):
Leakage current and input current waveforms.



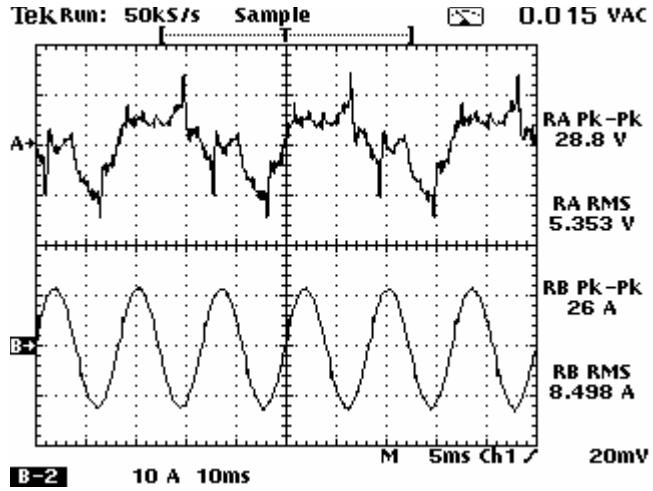
Measured leakage current = 0.0715mArms (center-tapped to earth) at 254V. (60 Hz)
Expect 0.143mArms at 254V line-to-ground.
Itc peak/rms ratio: 396/71.5/2 = 2.769
Input I peak/rms ratio: 32.4/9.861/2 = 1.643

)Variable speed drive exerciser: (running at half speed)
Leakage current and input current waveforms.



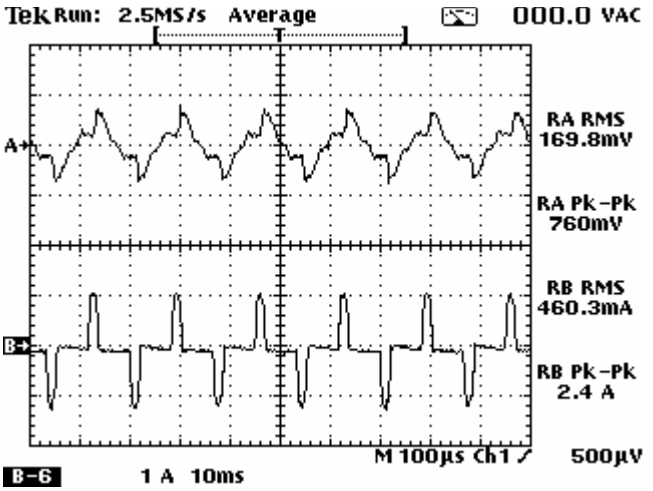
measured leakage current = 0.0876mArms at 120.5V;
expect 0.184mArms or 0.485 mApk at 253V. (60 Hz)
Itc peak/rms ratio: 1.54/0.292/2=2.637
input I peak/rms ratio: 16.4/3.594/2=2.282

)Telecom equipment B in a cabinet (with pfc power supply):
Leakage current and input current waveforms



max measured leakage current =0.5353Arms at 127.2V; expect 1.065mArms or 2.865mApk at 253V.
Itc peak/rms ratio: 28.8/5.353/2 = 2.690 (60 Hz)
input peak/rms ratio: 26/8.498/2 = 1.530

)Wall mounted telecom cabinet with external AC power brick:
Leakage current and input current waveforms.



max measured leakage current =0.1698mArms at 123V; expect 0.345 mArms or 0.772 mApk at 253V.
Itc peak/rms ratio: 760/169.8/2 = 2.238
input peak/rms ratio: 2.4/0.4603/2 = 2.607

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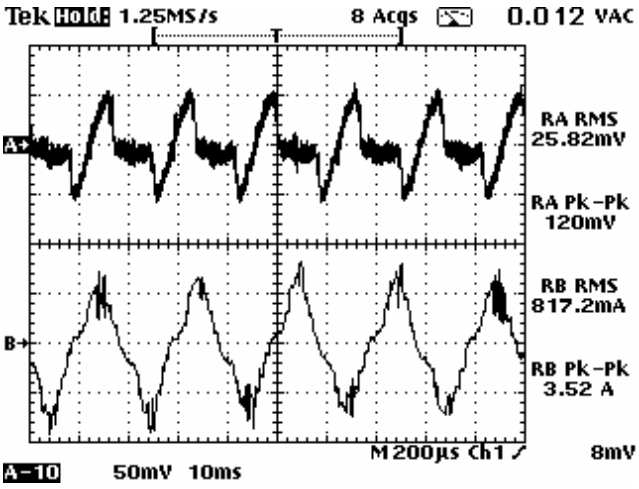
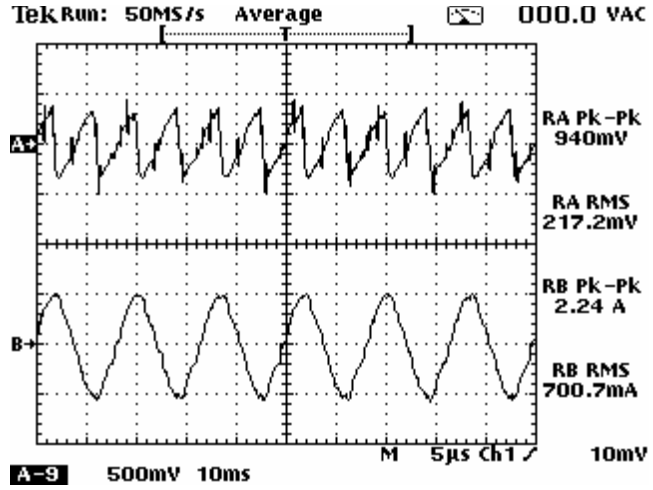
)Portable projector E:
Leakage current and input current waveforms.



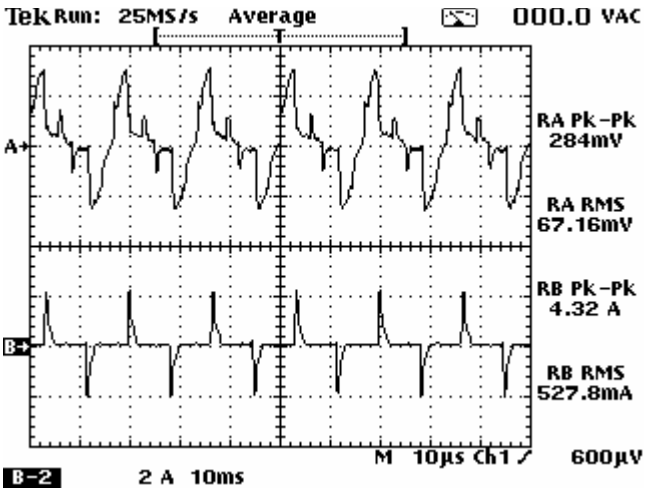
measured leakage current = 0.026mA at 253V.
Itc peak/rms ratio: 120/25.82/2 = 2.32 (60 Hz)
Input I peak/rms ratio: 3.52/0.8172/2 = 2.15

)Portable projector B:
Leakage current and input current waveforms.



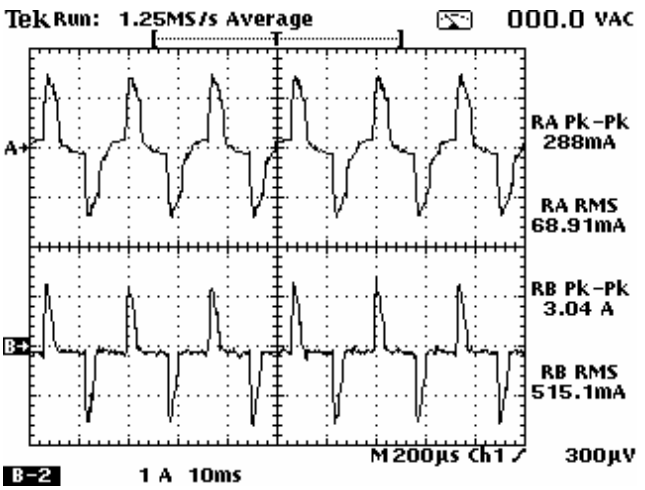
measured leakage current = 0.217mArms or
0.469mApk at 253V. (120 Hz)
Itc peak/rms ratio: 0.940/0.2172/2=2.166;
input I peak/rms ratio: 2.24/0.7007/2=1.598

)Laptop computer C with 3 wire mains plug
Leakage current and input current waveforms.



Max measured leakage current = 0.067mA at 120V
Expect 0.142mArms or 0.299mApk at 253V. (60 Hz)
Itc peak/rms ratio: 284/67316/2 = 2.114
Input I peak/rms ratio: 4320/527.8/2 = 4.092

)Laptop computer A with 3 wire mains plug
Leakage current and input current waveforms.



measured leakage current = 0.0681mA at 120.1V;
expect 0.145mArms or 0.303mApk at 253V.
Itc peak/rms ratio = 288/68.9/2 = 2.090
Input I peak/rms ratio = 3.04/0.5151/2 = 2.951

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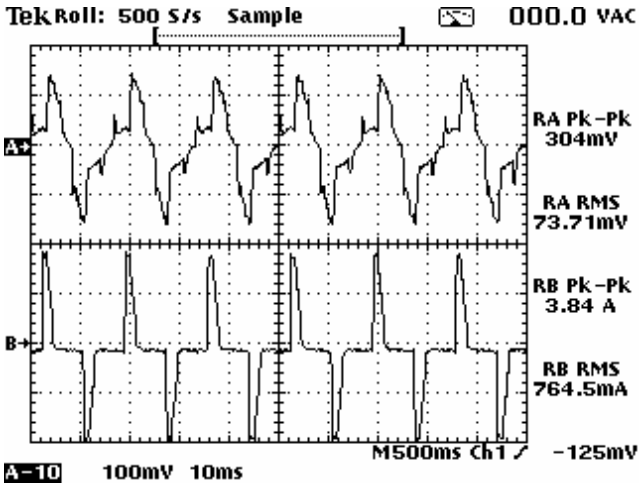
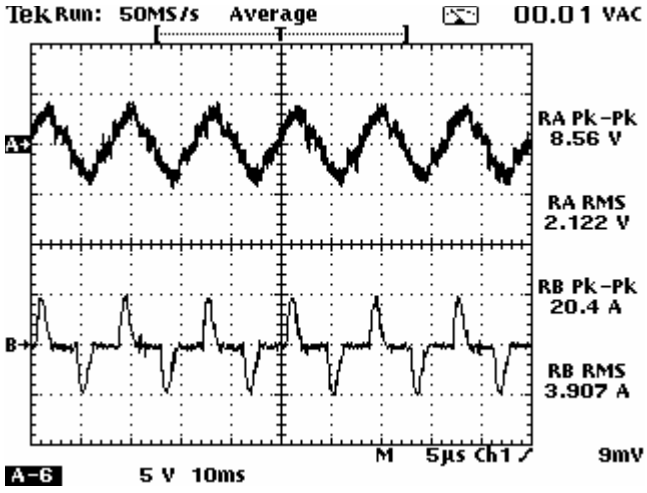
)Laptop computer B with 3 wire mains plug:
Leakage current and input current waveforms.



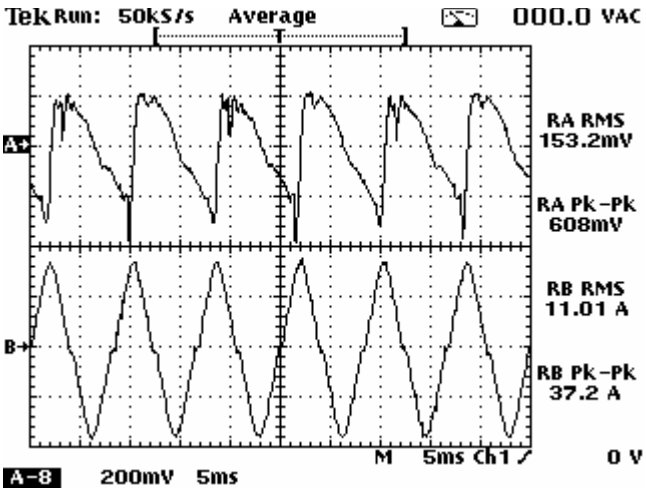
Max measured leakage current = 0.073mA at 121.9V
Expect 0.153mArms or 0.314mApk at 253V. (60 Hz)
Itc peak/rms ratio: 304/73.71/2 = 2.062
Input I peak/rms ratio: 3.84/0.7645/2 = 2.511

)Portable projector A:
Leakage current and input current waveforms.



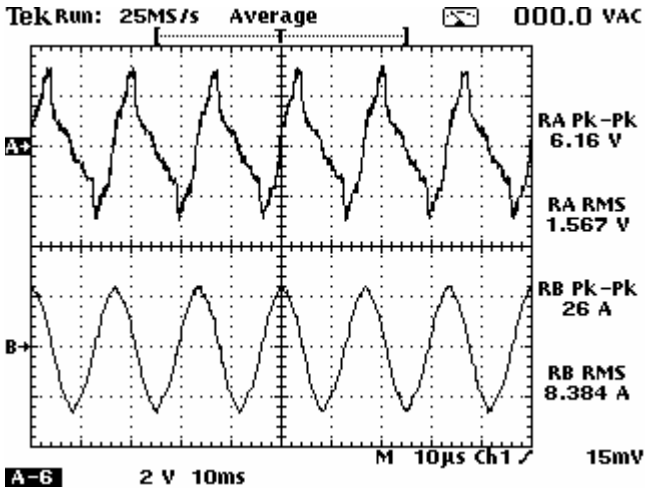
measured leakage current = 0.21mArms at 116V; expect 0.458mArms or 0.924mApk at 253V. (60 Hz)
Itc peak/rms ratio: 8.56/2.122/2=2.017;
input I peak/rms ratio: 20.4/3.907/2=2.611

)Industrial server B (with pfc power supply):
Leakage current and input current waveforms.



Measured leakage current = 0.1532 mArms at 253.8V
Itc peak/rms ratio: 608/153.2/2 = 1.984 (120 Hz)
Input I peak/rms ratio: 37.2/11.01/2 = 1.689

)Rackmounted computer system A (with pfc power supply):
Leakage current and input current waveforms.



max measured leakage current = 1.567mArms, 3.08mApk at 254V. (60 Hz)
Itc peak/rms ratio: 6.16/1.567/2=1.966
input I peak/rms ratio: 26/8.384/2=1.554

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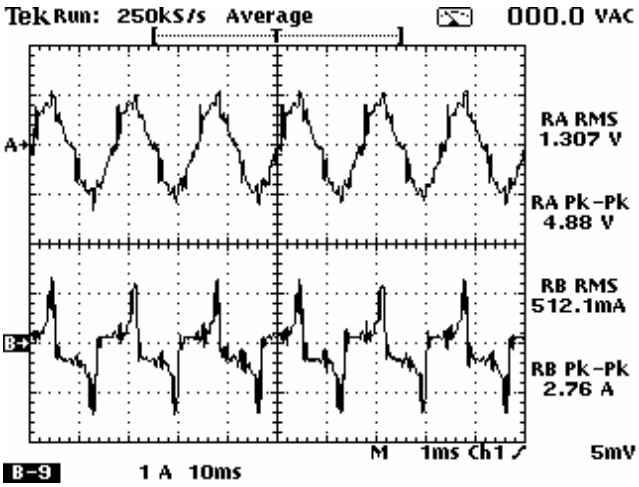
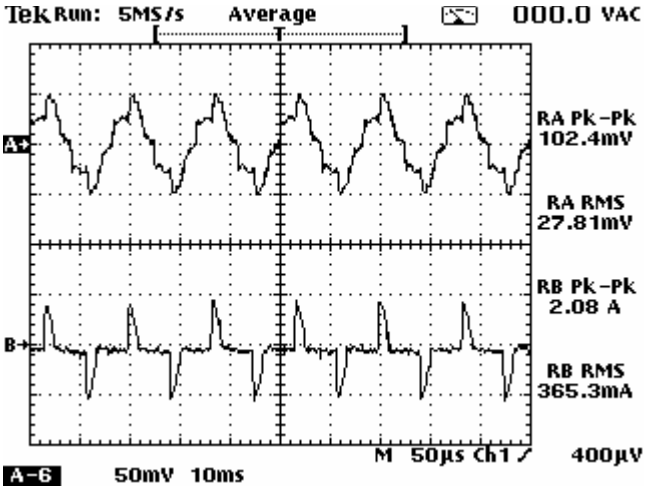
)Laboratory instrument – med:
leakage current and input current waveforms.



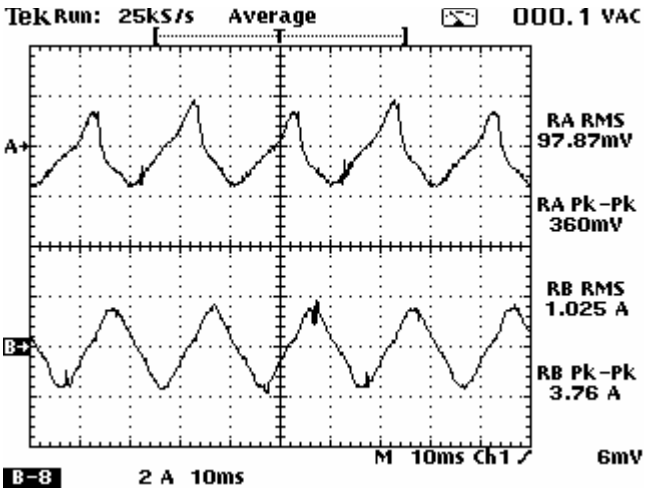
max measured leakage current = 1.307mArms,
4.88mApk-pk at 253V. (60 Hz)
Itc peak/rms ratio: 4.88/1.307/2 = 1.867
Input I peak/rms ratio: 2.76/0.5121/2 = 2.695

)Laptop computer D – 2 wire mains plug
Leakage current and input current waveforms



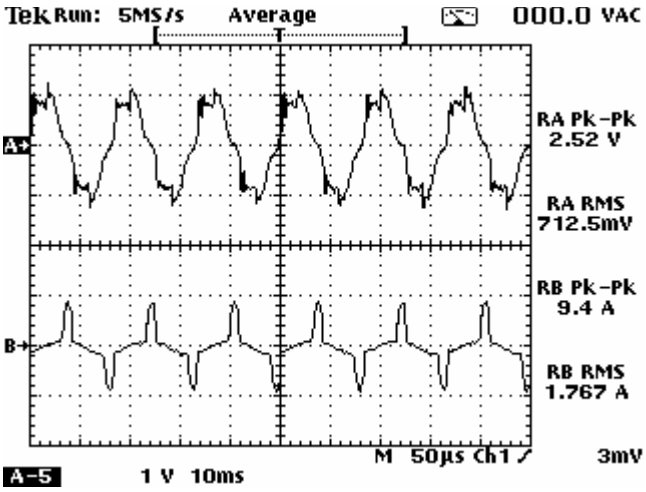
measured leakage current = 0.0.0278mArms at
120.8V; expect 0.058mArms or 0.107mApeak at 253V.
Itc peak/rms ratio: 102.4/27.81/2 = 1.841 (60 Hz)
input I peak/rms ratio: 2.080/365.3/2 = 2.848

)Portable projector D (w/ pfc):
Leakage current and input current waveforms



max measured leakage current = 0.098mArms,
0.180mApk at 253V. (111 Hz)
Itc peak/rms ratio: 360/97.87/2 = 1.839
input I peak/rms ratio: 3.76/1.025/2 = 1.834

)Small telecom system:
Leakage current and input current waveforms.



Measured leakage current=0.7125mArms, 2.52mApk-pk at 128V; expect 1.408mArms or 4.98mApk-pk at 253V. (60 Hz)
Itc peak/rms ratio: 2.52/0.7125/2 = 1.768
Input I peak/rms ratio: 9.4/1.767/2 = 2.660

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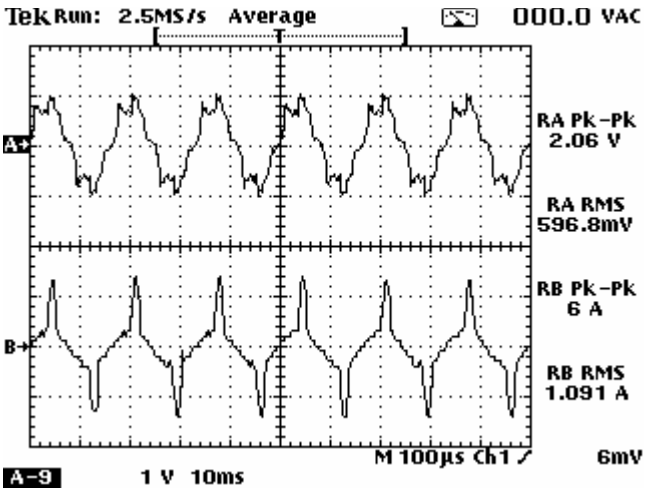
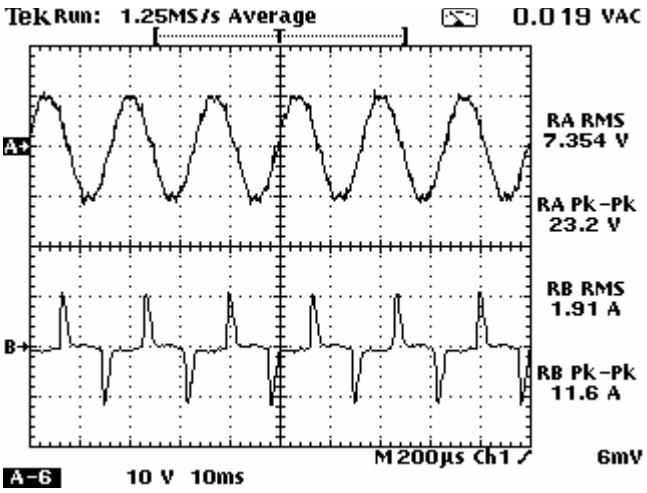
)Small telecom pedestal system:
Leakage current and input current waveforms.



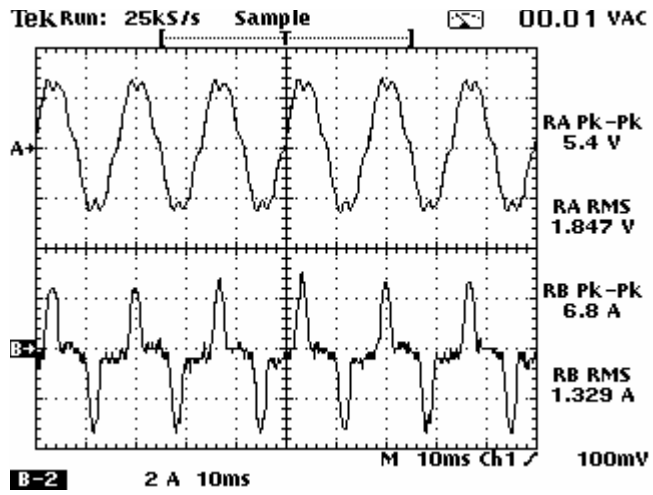
max measured leakage current = 0.597mArms,
1.03mApk at 253V. (60 Hz)
Itc peak/rms ratio: 2.06/0.5968/2 = 1.726
input I peak/rms ratio: 6/1.091/2 = 2.750

)SOHO computer system:
Leakage current and input current waveforms.



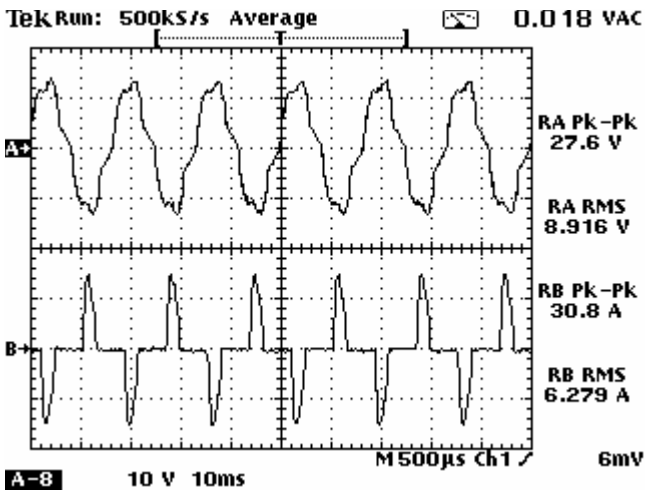
max measured leakage current = 0.75mArms at
120.4V; expect 1.545mArms or 2.436mApeak at 253V.
Itc peak/rms ratio: 23.2/7.354/2 = 1.577 (60 Hz)
input I peak/rms ratio: 11.6/1.91/2 = 3.037

)Monolithic computer system:
Leakage current and input current waveforms.



Measured leakage current = 0.055mArms at 126.1V;
expect 0.110mArms or 0.161mApeak at 253V.
Itc peak/rms ratio: 5.4/1.847/2=1.7101 (60 Hz)
input I peak/rms ratio: 6.8/1.329/2=2.558

)Projection display system A:
Leakage current and input current waveforms.



max measured leakage current=0.89mArms at 120.9V;
expect 1.862mArms or 2.883mApeak at 253V.
Itc peak/rms ratio: 27.6/8.916/2=1.548 (60 Hz)
input I peak/rms ratio: 30.8/6.279/2=2.453

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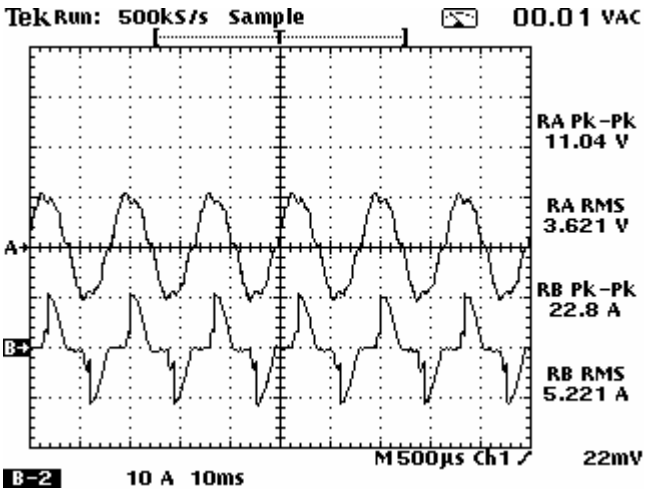
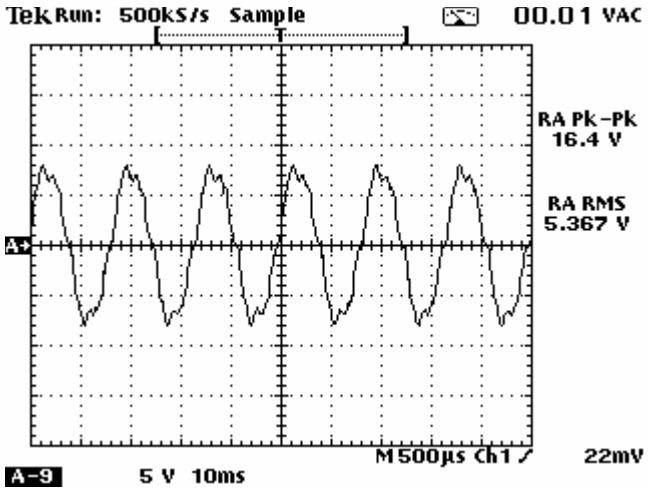
)Desktop copier:

Input current waveform (B)



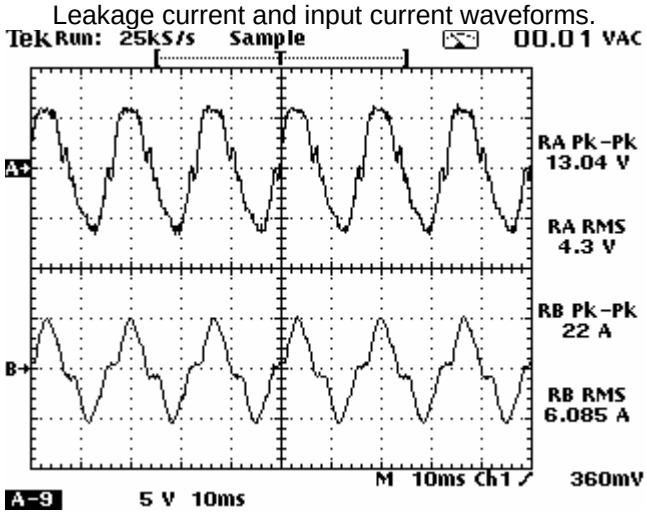
Leakage current waveform (A)



max measured leakage current=0.537mArms at 121V;
expect 1.123mArms or 1.715mApeak at 253V.
Itc peak/rms ratio: 16.4/5.367/2=1.528 (60 Hz)
input I peak/rms ratio: 22.8/5.221/2=2.183

)Rackmounted computer system B (with pfc power supply):

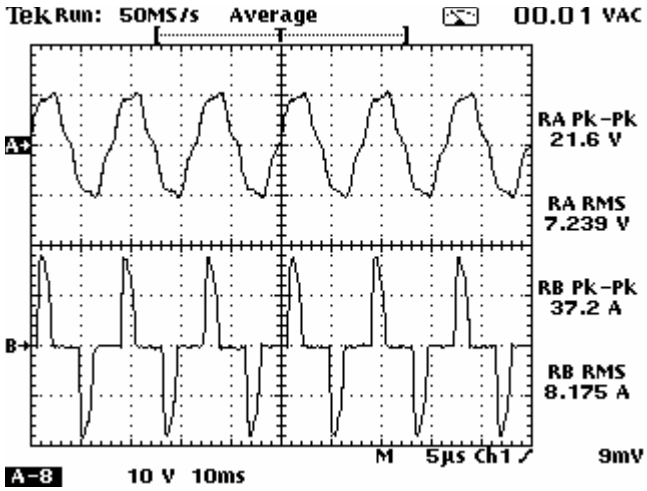
Leakage current and input current waveforms.



Measured leakage current=4.3mArms at 240V; expect 4.55mArms or 6.90mApeak at 254V. (60 Hz)
Itc peak/rms ratio: 13.04/4.3/2=1.516
input I peak/rms ratio: 22/6.08/2=1.808

)Projection display system B:

Leakage current and input current waveforms.



Measured leakage current = 0.72mArms at 119.7V;
expect 1.521mArms or 2.269mApeak at 253V.
Itc peak/rms ratio: 21.6/7.239/2=1.492 (60 Hz)
input I peak/rms ratio: 37.2/8.175/2=2.275

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Summarizing results.

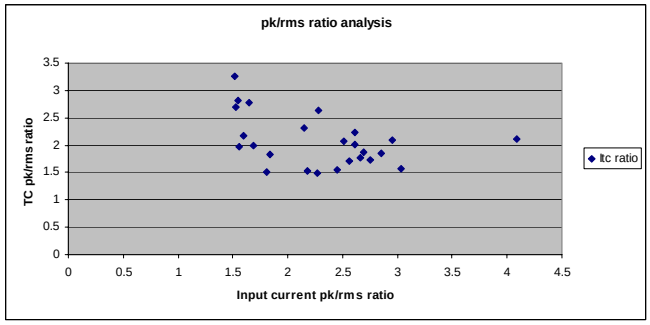


Figure 1: pk/rms ratio analysis

This data leads to my ongoing comment that pfc power supplies (Input ratio near sqrt 2) are pushing the TC pk to rms ratio higher – a more complex TC waveform. Review the waveforms at the beginning of the paper again.

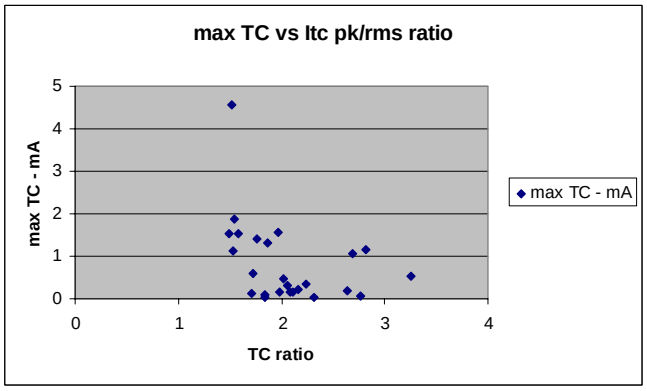


Figure 2: Max TC vs the TC pk/rms ratio

These figures compare the value of the current to the pk/rms ratio.

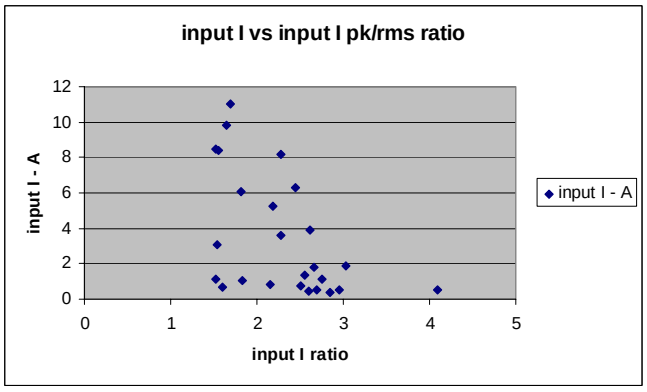


Figure 3: Input Current vs Input pk/rms ratio

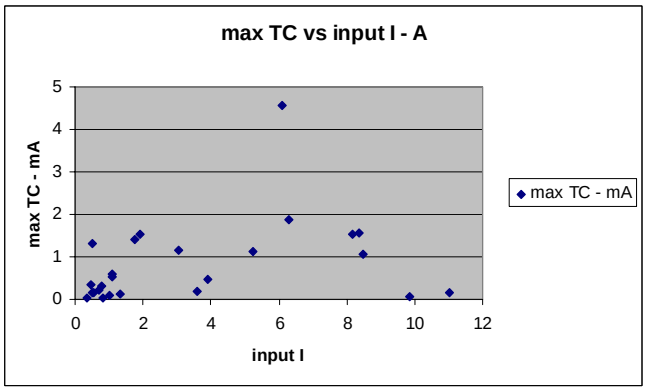
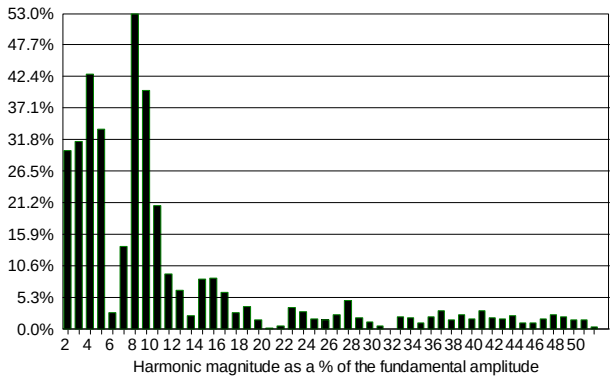


Figure 4: Max TC vs Input Current

In most of these cases the measured rms TC is below the 3.5mArms limit usually used. However several of these would not pass the 5mApk limit if the pk/rms ration was 3.250 (the first example). In this case the rms limit is 5/3.25 = 1.54mArms.

The fundamental frequency of the TC is line frequency in most cases with superimposed hi-frequency components, evidently from the mains switching circuits for both the power conversion and the power factor correction. One example is:



Voltage:
Current: Ref A
Harmonics: 51
Type: Current Magnitude

Figure 5: Industrial Server A TC harmonics

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[i] Effect of Wave Form on Let-Go Currents, Charles F Dalziel, AIEE Transactions in Electrical Engineering, Volume 62, December 1943.

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