University of Idaho
College of Engineering

ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 29

Today: Flicker

- IEEE-100 definitions:
  - "A perceptible change in electric light source intensity due to a fluctuation of input voltage."
  - "A variation of input voltage sufficient in duration to allow visual observation of a change in electric light source intensity."
- In summary
  - "Flicker" refers to both: 1) a perceptible change in electric light intensity, and 2) the voltage variation responsible for that change in electric light intensity

Some useful flicker references (get these)

- IEEE-519-1992
- IEEE-141-1993
- IEEE-1453-2011/IEC 61000-4-15:2010
- IEEE-1453-2015: *(IEEE Recommended Practice for the Analysis of Fluctuating Installations on Power Systems)*
- *Flicker Interaction Studies and Flickermeter Improvement,* Rong Cai, PHd. Thesis -2009 http://alexandria.tue.nl/extra2/200911297.pdf

Flicker – new challenges

- Goal – predict human perception of changes in luminance AND light spectrum resulting from measured voltage variations
- Voltage variations may include:
  - RMS Dips
  - Interharmonics
  - Amplitude modulation (see PSQ fig. 7.15)
  - Notches
- Challenges:
  - Different lighting technologies respond differently
  - Seemingly identical lighting technologies may respond differently
  - Lighting changes may occur without voltage variations

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The evolution of flicker

Voltage Disturbance	+	Path	+	Vulnerable Equipment	=	PQ Problem
Voltage dip		Transformers/ wiring		Incandescent Lamp		Flicker (voltmeter)
Voltage dips (variable)		Transformers/ wiring		Incandescent Lamp		Flicker (Flickermeter)
Voltage dips Notches Harmonics (Ballast/Driver)		Transformers/ wiring + Ballast/Driver		Ballast/Driver Flourescent and LED lamps		Flicker?

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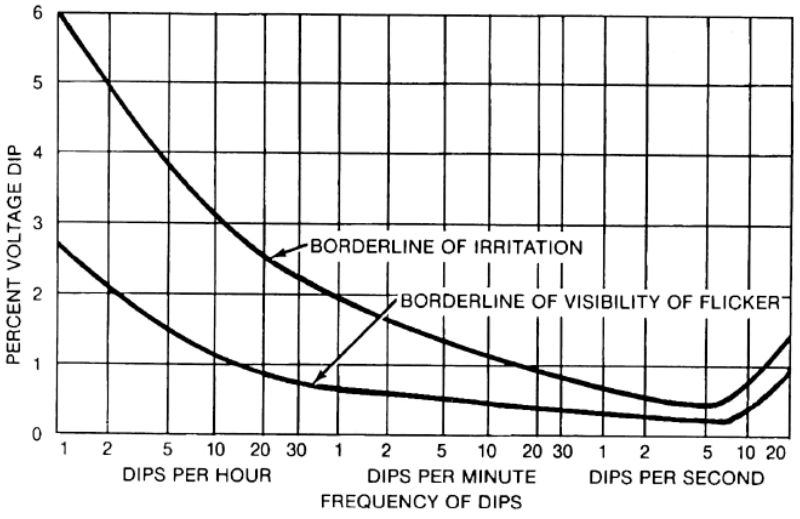
Flicker

- Ch 7 (PSQ) discusses "traditional" flicker
  - Thresholds of objection and perception based on the frequency and the magnitude of the voltage variations (see figure 7.14)
  - Traditional curves are convenient for simple checks of one or two devices
  - Combined effect of multiple magnitudes and frequencies is not reflected in traditional curves

GE flicker curve from IEEE 1453-2015



Continuous, cyclic, or intermittent

- Continuous or cyclic
  - Results in voltage modulation or higher frequency voltage fluctuations
- Intermittent
  - Occasional voltage variations caused by faults, or motor-starts
  - Low to very low frequencies

Traditional flicker calculations

- Modulation

$$Percent\ voltage\ modulation = \frac{Vmax - Vmin}{Vo} x100\%$$

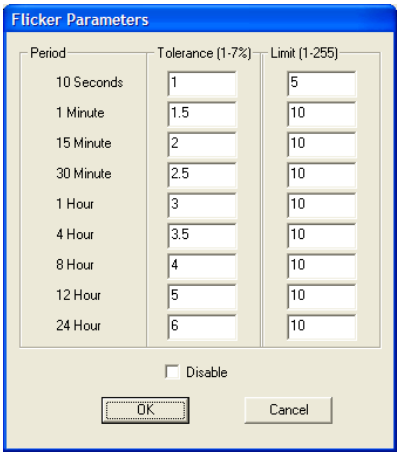
- Flicker

$$Percent\ voltage\ flicker = \frac{Vpre - Vmin}{Vpre} x100\%$$

Vo = average voltage

Investigating traditional flicker

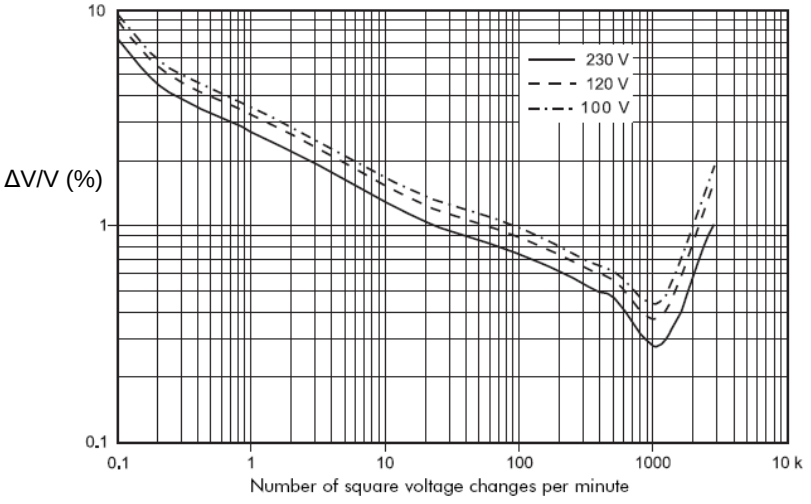
- Measure "pre" and minimum RMS voltage, and record or estimate frequency
- Some PQ recorders approximate threshold curves



The "traditional" way is being replaced

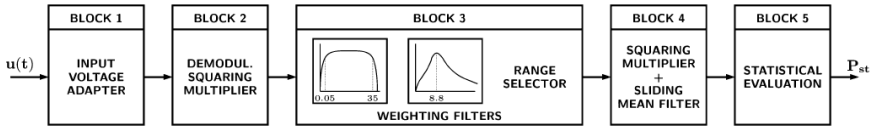
- Complex voltage variations and flickermeters
- IEEE Std. 1453
  - Employs a special "flickermeter" described in IEC 61000-4-15:2010
  - Threshold of irritation is still quite similar to thresholds in IEEE-519-1992 or IEEE-141-1993
  - Simplifies pass-fail testing provided the measuring or analysis tools are available

IEEE 1453/ IEC 61000-4-15 curves



IEEE 1453 Flicker evaluation

- Standard specifies a flickermeter
  - Processes voltage measurements to simulate their effect on incandescent bulbs, and the response of the human eye to those effects
  - Includes response to multiple flicker events of different magnitudes and frequencies
  - See pg. 517 for a block diagram



From: ***Linearity of the IEC Flickermeter Regarding Amplitude Variations of Rectangular Fluctuations***
J. J. Gutierrez, *Member, IEEE, J. Ruiz, Member, IEEE, and S. Ruiz de Gauna*

The IEEE 1453 flicker values

- Flickermeter produces two important values:
  - Pst: The short term flicker – calculated over a 10-minute interval. Value is normalized so that Pst > 1 indicates irritating flicker.

$$P_{st} = \sqrt{0.0314P_{0.1} + 0.0525P_{1s} + 0.0657P_{3s} + 0.28P_{10s} + 0.08P_{50s}}$$

  - Plt: The long-term flicker, used for devices with duty cycles longer than 10 minutes.

$$P_{LT} = \sqrt[3]{\frac{\sum_{i=1}^{N} Pst_i{}^3}{N}}$$

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Statistical compliance evaluations

- Compliance is based on statistical analysis of samples over a short period of time
  - IEC compliance: 95% probability that Pst and Plt will be in the acceptable range
  - IEEE compliance: IEEE recommends extending this probability to 99% for planning purposes in flicker compliance evaluations

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Planning and compatibility levels for Pst and Plt flicker from IEEE-1453

	Planning Level (99%)		Compatibility Level (95%)
	MV	HV-EHV	LV, MV
Pst	0.9	0.8	1.0
Plt	0.7	0.6	0.8

The impact of new loads o Pst and Plt should be evaluated and steps should be taken to keep Pst and Plt below the planning levels at the PCC.

Flicker sources

- Noticeable flicker due to voltage fluctuations depends on three conditions:
  - A variable load
  - System impedance
  - Frequency of the voltage fluctuations
- Typical sources
  - Motors, welding or arc furnaces, compressors, some laser printers, etc. (see figure 7.16 for motor starting)

Flicker mitigation

- Address the three conditions
  - Variable loads
    - Motor soft-starters or ASDs
    - Line reactors on arc furnaces
    - Design specifications in new equipment
    - Break up the load
  - Change the lighting
    - Light output from a CFL flickers about 25% as much as that from an incandescent lamp for similar small voltage fluctuations

Flicker mitigation

- System impedance/capacity
  - Reconductor
  - Larger transformers
  - Static VAR compensators
    - Inject reactive power during motor starts
    - May also correct power factor and filter harmonics
  - Thyristor switched capacitors

Flicker mitigation

- Variation frequency
  - Modify control system –
    - Increase bandwidth on pressure, temperature, level, etc.
  - Modify mechanical system-
    - Match equipment to the load
    - Build "inertia" into the system
      - Thermal mass
      - Increased storage of compressed air

Next time…

- Finish long-duration voltage variations
- Start power quality and reliability benchmarking