
**Panel session**

**Preassessment of Flicker due to Loads Served from the Utility Grid**

# How can flicker level be determined before a customer is connected to the electric grid

**(09GM0079)**


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# Introduction

**Light flicker is visual discomfort caused by voltage fluctuation**

**Main flicker sources:**

Electric Arc Furnace Welding machines Other appliances

Flicker is defined as a power quality value by standards and grid access contracts. Flicker is one of the main complaints of LV customers

Generally, it is easy to measure overall flicker level at a point of grid, but it is not very easy to quantify flicker emission level from one customer, particularly, when a number of customers have been connected to the grid.

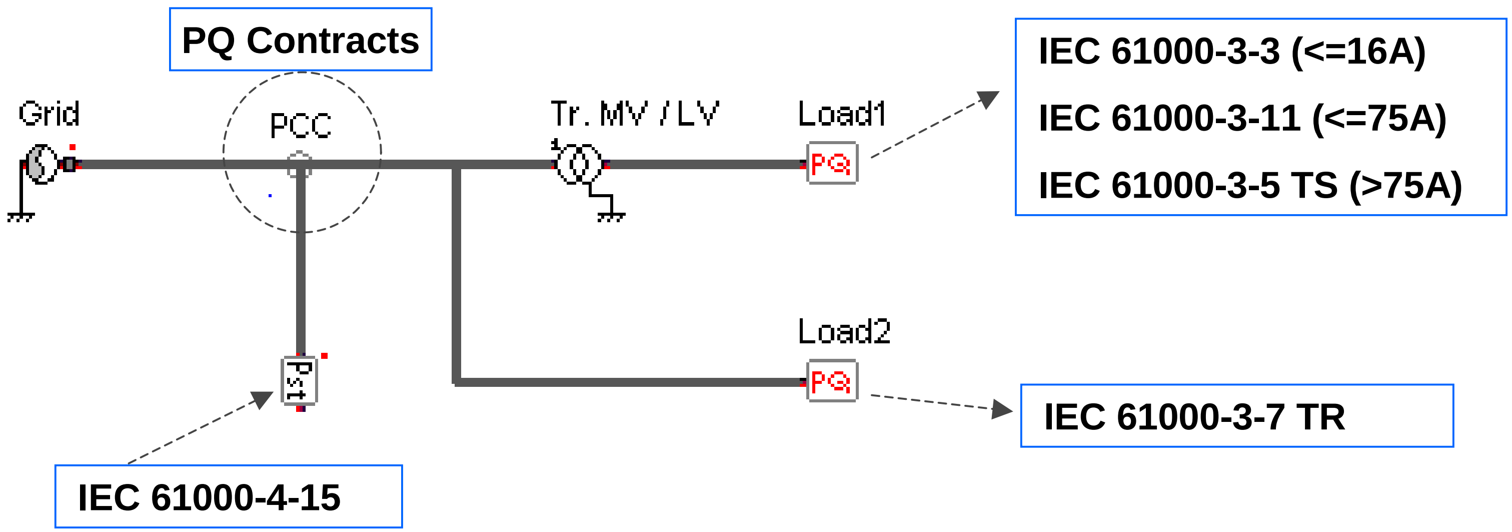
Flicker assessment is one of main tasks of a system operator before the customer connection

**This presentation will introduce flicker preassessment methods of IEC procedure and French grid access contracts**

# Some IEC Standards regarding flicker issues

IEC procedure provides guidance on principles that can be used as the basis for determining the requirements for the connection of fluctuating installations to public power systems. Here are some relevant standards:

- **IEC 61000-2-2: the compatibility levels of flicker in public low voltage power supply systems**
- **IEC 61000-3-3, 61000-3-11, 61000-3-5 give flicker emission levels for LV equipment**
- **IEC technical report 61000-3-7: assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems**
- **IEC 61000-4-15: technical specification of flickermeter**

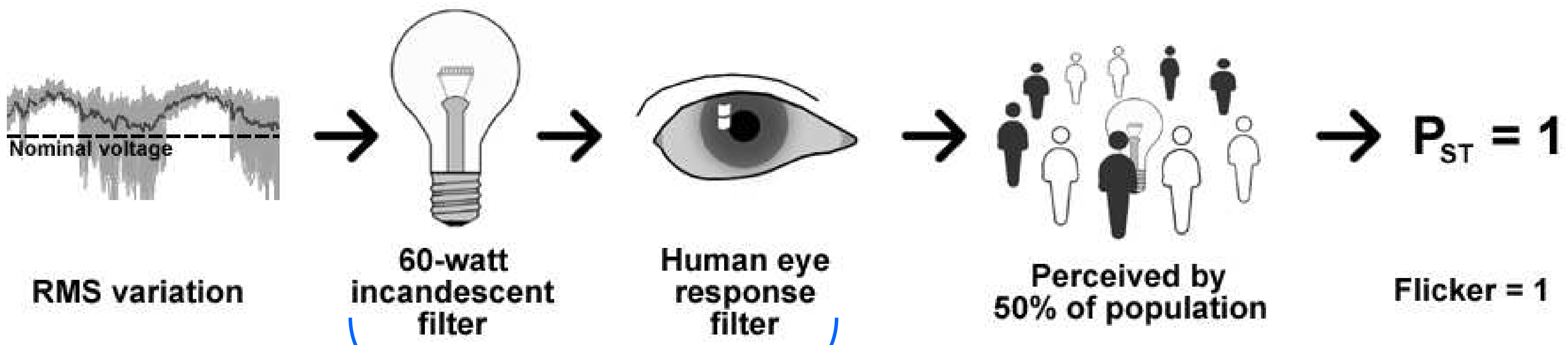



IEC Standards are not mandatory!

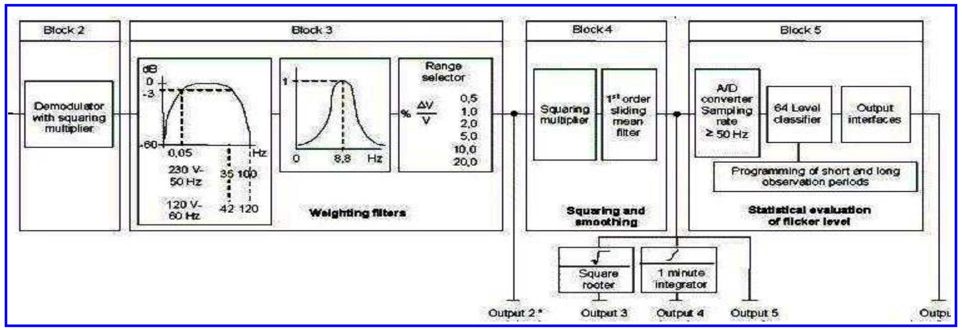
# For information: IEC61000-4-15 Flickermeter

**IEC61000-4-15** defines a measurement chain: Voltage fluctuation -> light flicker -> visual discomfort:

Figure by Alex McEachern, EPRI Power Quality Applications (PQA) and ADA 2009 Conference

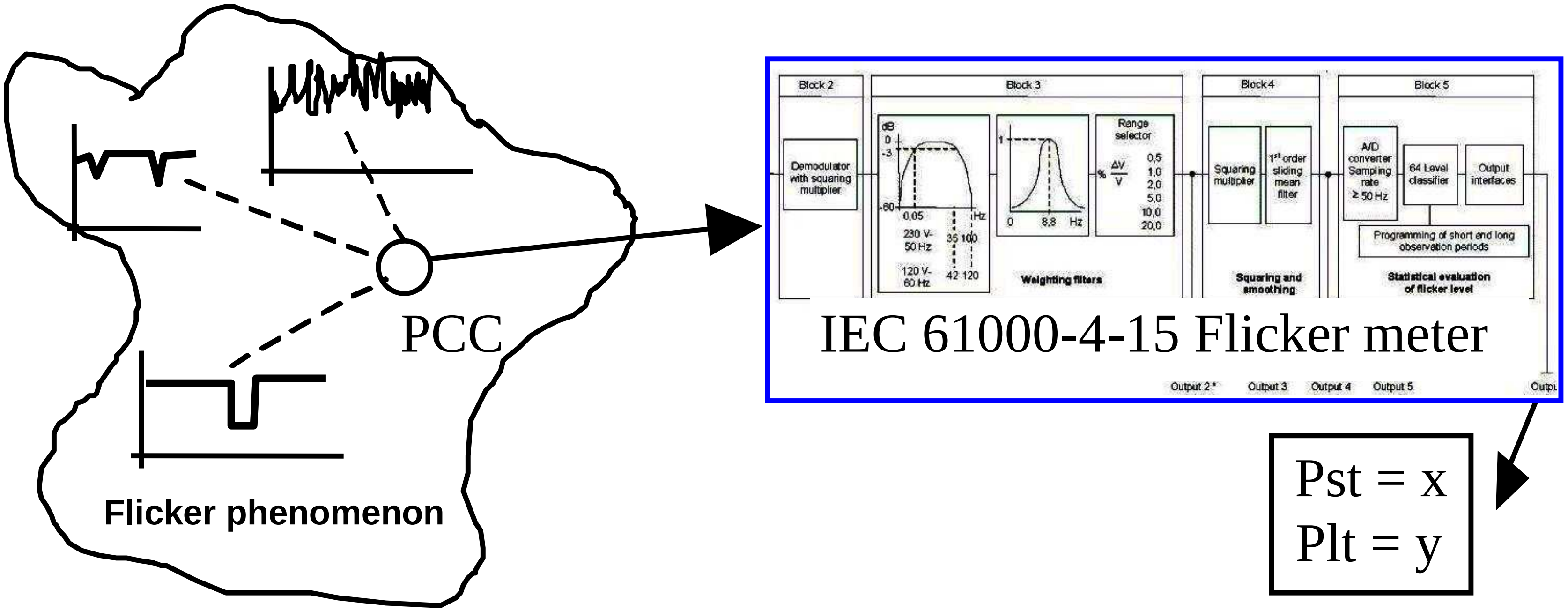



IEC61000-4-15



# Flicker monitoring by IEC61000-4-15 flickermeter

**Voltage variations** **The IEC Flickermeter**




**IEC/TR 61000-3-7:**
Flicker assessment,
general flicker summation law

IEC 61000-4-15 flickermeter converts voltage changes (magnitude and frequency) into unified flicker levels:

<u>short term flicker severity</u> **Pst**
<u>long term flicker severity</u> **Plt.**

# Review of flicker limits by IEC documents and French grid access contract

**Different flicker values in Pst and Plt :**

REVIEW OF DIFFERENT LIMITS OF PST AND PLT BY SOME STANDARDS, TECHNICAL REPORT AND FRENCH GRID ACCESS CONTRACT

| | Pst | Plt |
|---|---|---|
| Compatibility level (IEC61000-2-2) | 1 | 0.8 |
| Planning level (IEC61000-3-7) TR | 0.9 | 0.8 |
| Individual limit (IEC61000-3-7 TR) | 0.35 | 0.25 |
| Basic limit (French DSO contract CARD) | 0.35 | 0.25 |

**Load flicker emission limit (Pst<0.35, Plt<0.25) is the threshold below which detail flicker assessment study is not necessary. This limit is surely conservative if the load is the only one flicker source at PCC.**

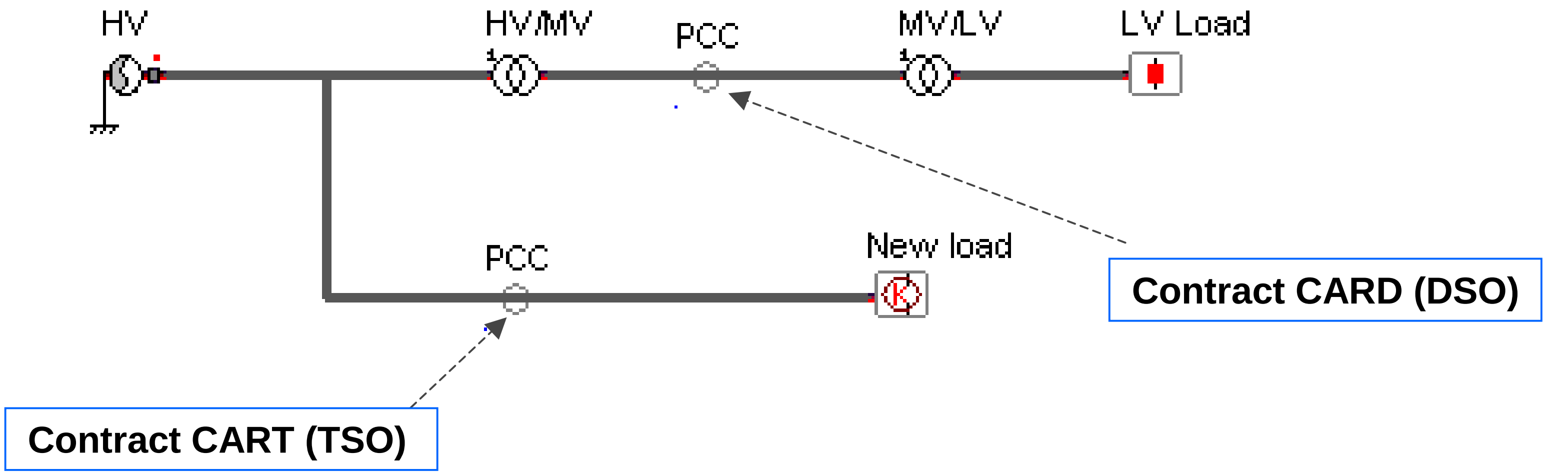
**For the cases Pst>0.35 or Plt>0.25, different stages should be performed before a customer is connected to the electric grid.**

# French grid access contracts: flicker commitments

In France, both of TSO and DSO have their own grid access contracts with flicker commitments, rapid voltage change limits and specifications of load connection procedures.

**CART (TSO grid access contract):**
Customer flicker contribution at PCC should guarantee TSO to comply Plt <1 as voltage characteristics

**CARD (DSO grid access contract):**
Customer basic load flicker emission limits are Pst<0.35 and Plt<0.25.
If these limits are exceeded, detail studies are necessary.

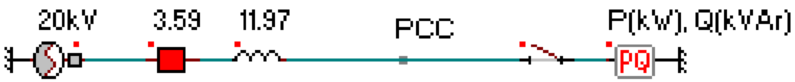


# IEC method: simplified assessment by Pst = 1 curve

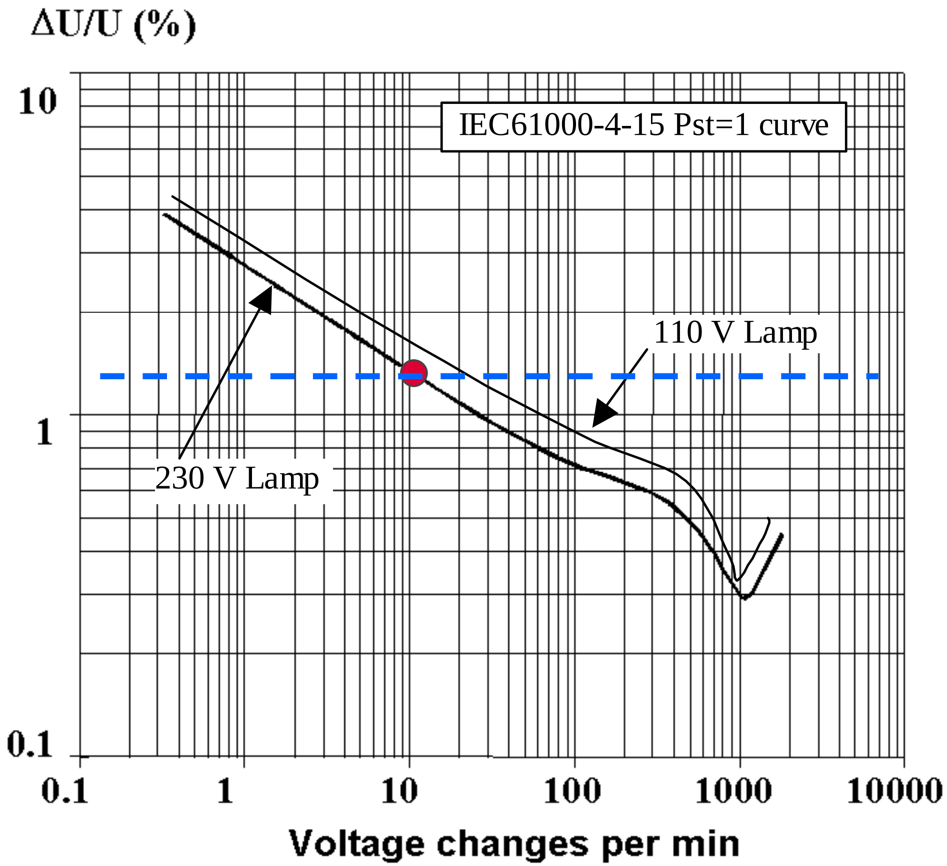
## Actual application of IEC flicker curve Pst = 1 in pre-connection assessment

**Here is an actual example.**
A manufacturer wishes to install a 50Hz electric welding machine. The cycle repetition time of the welder T (**ON + OFF**) can be regulated **from 2s to 20s** with instantaneous powers **P=400kW**, **Q=300kVAr** when welder is ON.
As input technical parameters, total upstream grid impedance at POE (MV of 20 kV, 50Hz) is given: Zg = 3.59 + j11.97 Ω.

First, maxi relative voltage change at PCC caused by the welder is calculated by powers P, Q and grid impedance Zg:




$$\frac{\Delta U}{U} = \frac{R \cdot P + X \cdot Q}{U^2} = \frac{3.59 \cdot 400000 + 11.97 \cdot 300000}{20000^2} = 1.26\%$$




**From the curve, for Pst<1, voltage changes < 10/min or T > 12s (if the welder is the only one flicker source)**

# IEC procedure Stage 1: Simplified flicker level evaluation

**IEC procedure Stage 1: by apparent power variation ΔS and number of voltage changes r**

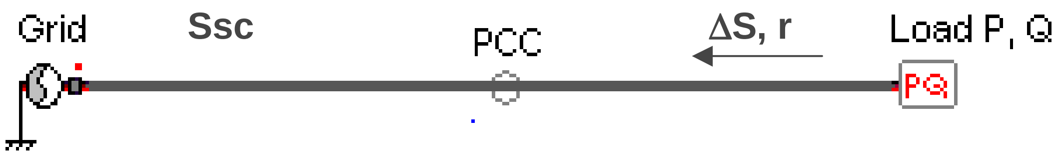



TABLE II

LIMITS FOR THE RELATIVE CHANGES IN POWER AS A FUNCTION OF THE NUMBER OF CHANGES PER MINUTE

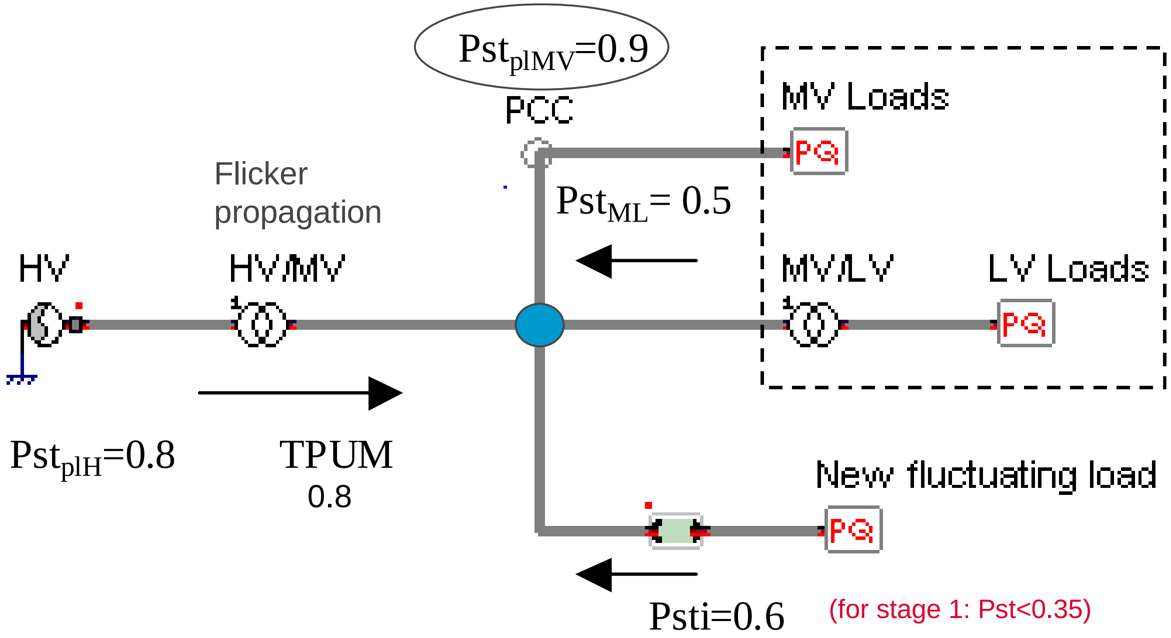
| r/min | K= ΔS/Ssc | Corresponding Pst computed by IEC 61000-4-15 flicker meter emulator |
|---|---|---|
| r > 200 | 0.1 % | 0.35 (for r=1000) |
| 10 < r < 200 | 0.2 % | 0.32 (for r=200) |
| r < 10 | 0.4 % | 0.31 (for r=10) |

**Recommendations by IEC61000-3-7**

**Application of this method is very easy if ΔS and r are known**

# IEC procedure Stage 2: Emission limits relative to absorption capacity of actual system

**System operator can accept the connection of a load whose individual flicker emission limit exceeds the values defined by stage 1, if the actual grid has some more absorption capacity.**




**Based on planning level $Pst_{plMV}$ at this PCC, the highest emission limit Psti_high of the new installation should be defined by IEC summation law:**

$$\mathrm{Psti\_high} = \sqrt[3]{\mathrm{Pst}_{\mathrm{plMV}}{}^{3} - (\mathrm{Pst}_{\mathrm{plHV}} \cdot \mathrm{TPUM})^{3} - \mathrm{Pst}^{3}} \quad = 0.69$$

# IEC procedure Stage 3: the possibility of acceptance of higher emission levels on a conditional basis

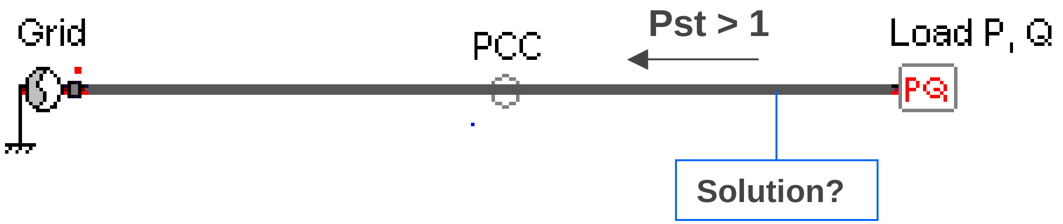
**IEC Stage 3 concerns the possibility of acceptance of higher emission levels on a conditional basis, i.e. all exception cases where the connection conditions can't be met by studies performed in stage 2.**

**Details studies are carried out to analyze the whole system capacity in flicker absorption in order to decide whether the system operator can accept the higher emission levels on a conditional basis.**

**A possible agreement should be discussed between system operator and customer.**

In France, a certain industrial site with electric arc furnace has get grid connection during a negotiated period (Pst > 1) in order that the customer can take necessary mitigation solution.

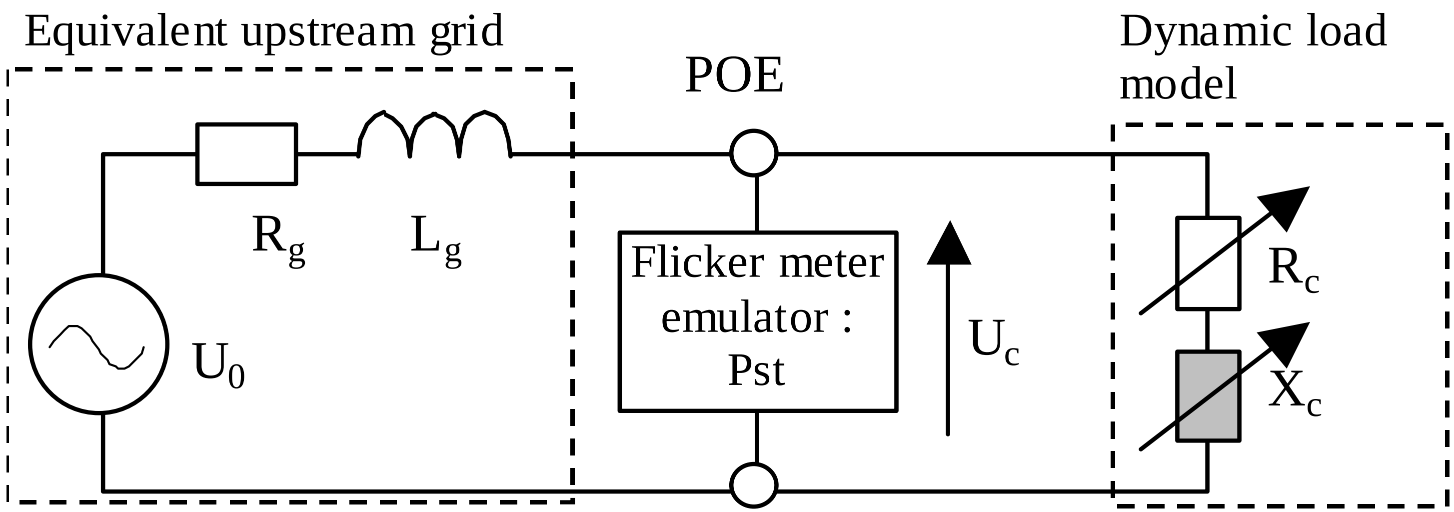
**If neither acceptance nor agreement could be made in this stage, the connection is impossible and the customer has to take necessary mitigation solutions.**



# Flicker assessment study by simulation with IEC flickermeter emulator

As last resource for assessing flicker emission level from the irregular load variation cases, the method based on dynamic modeling is used by power quality engineer. The modeling can be carried out in a time domain analysis or electro-mechanic transient simulation software, it includes:

Grid modeling, Flicker source (dynamic load) modeling and IEC flickermeter emulation.

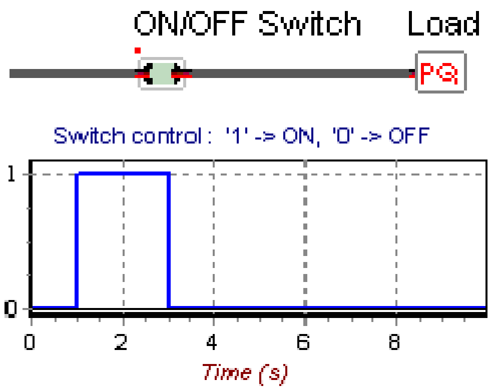


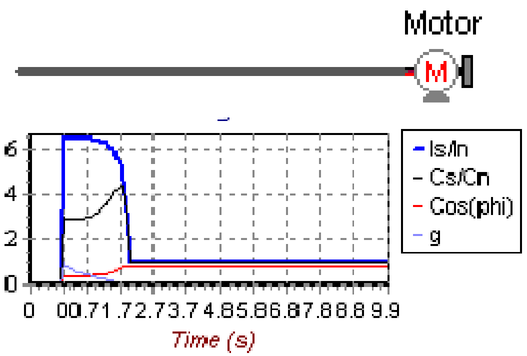

**IEC 61000-4-15 flickermeter**

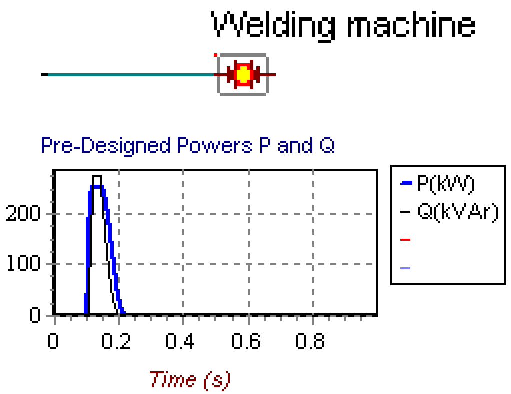
- **Waveform**
- **RMS values**

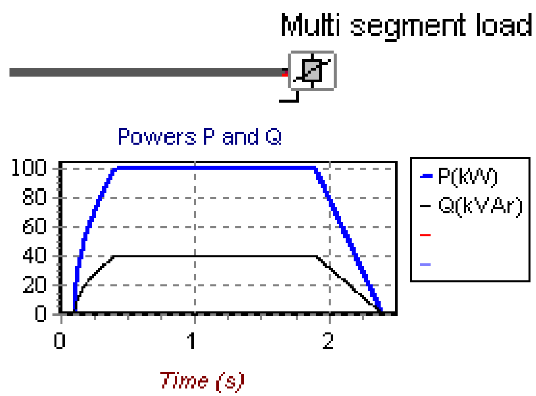
- **ON/OFF load**
- **Motor starting**
- **Welder**
- **EAF, et al**

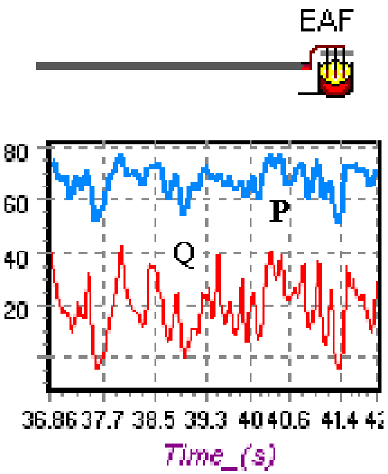
# Flicker assessment study by simulation with IEC flickermeter emulator: some flicker source models

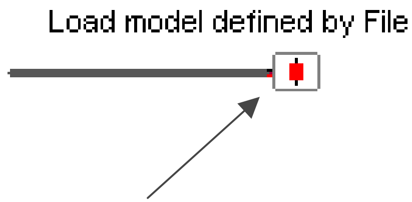


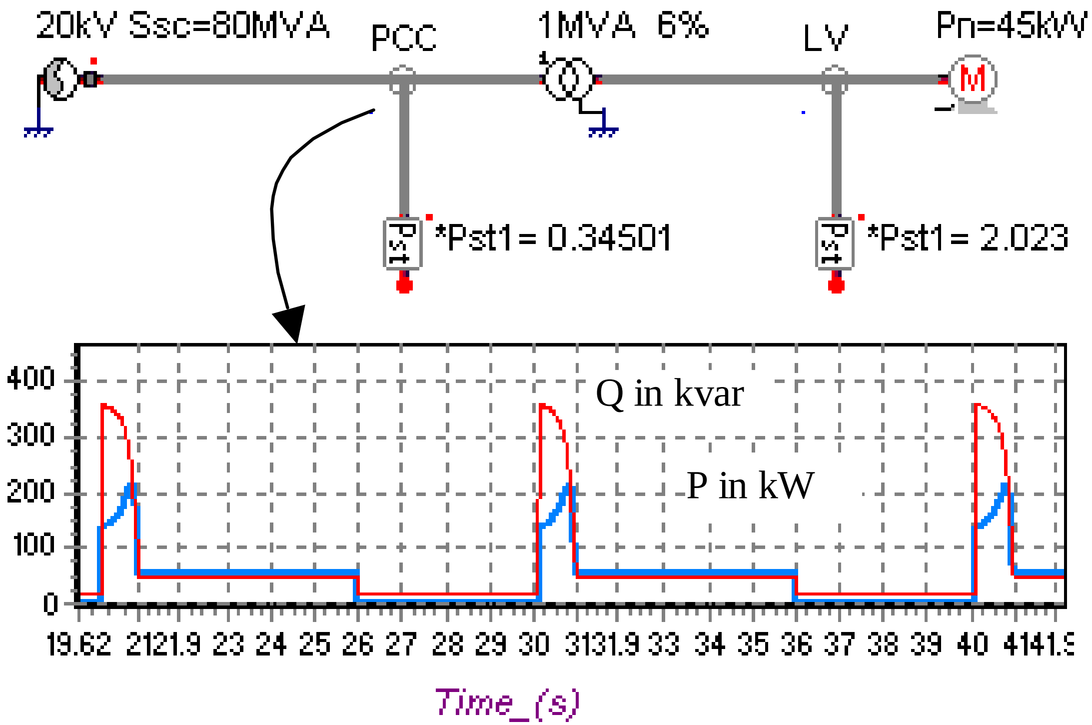




**Power evolution data offered by manufacturers**

**By site recording in a similar installation**

# Case study 1: Flicker assessment study by simulation with IEC flickermeter emulator

Here is an example: An MV customer wants to install a 45kW LV electric motor in a production process, the motor will be powered by a 1 Mva transformer behind the PCC. The motor will be used with direct line starter every 10s; the starting duration is 1s with peak starting current of 6.2xIn and the motor runs during 5 s at each working cycle. Here is the electromechanical transient simulation result at PCC:



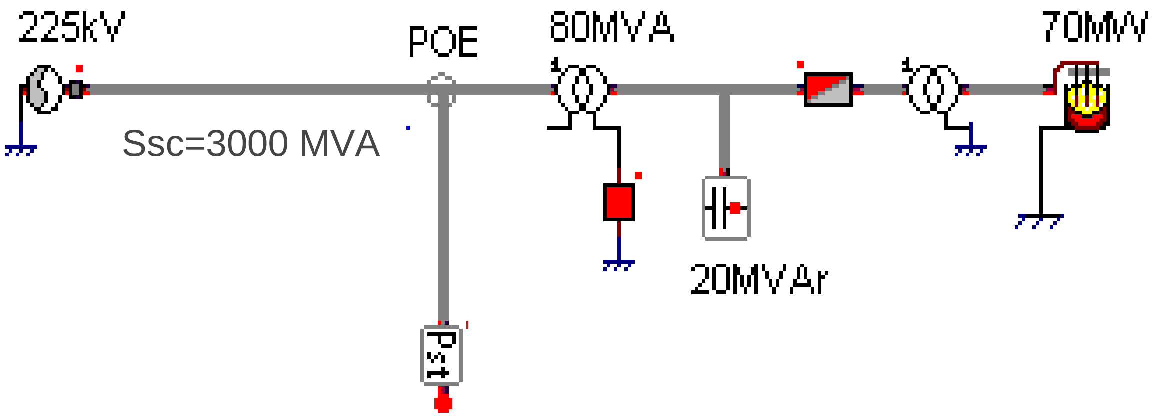

**Remark:**
In an electromechanical transient simulation, the flickermeter emulator must accept RMS voltage at input values (modified version of IEC61000-4-15).

Necessary modification is necessary [14].

The simulation shows the Pst at PCC is 0.345. So it is compliant with stage 1 assessment

# Case study 2: Flicker assessment study by simulation with IEC flickermeter emulator

Another example of flicker assessment at POE concerns an electric arc furnace (EAF, 70MW, 50Hz) connected at HV grid.

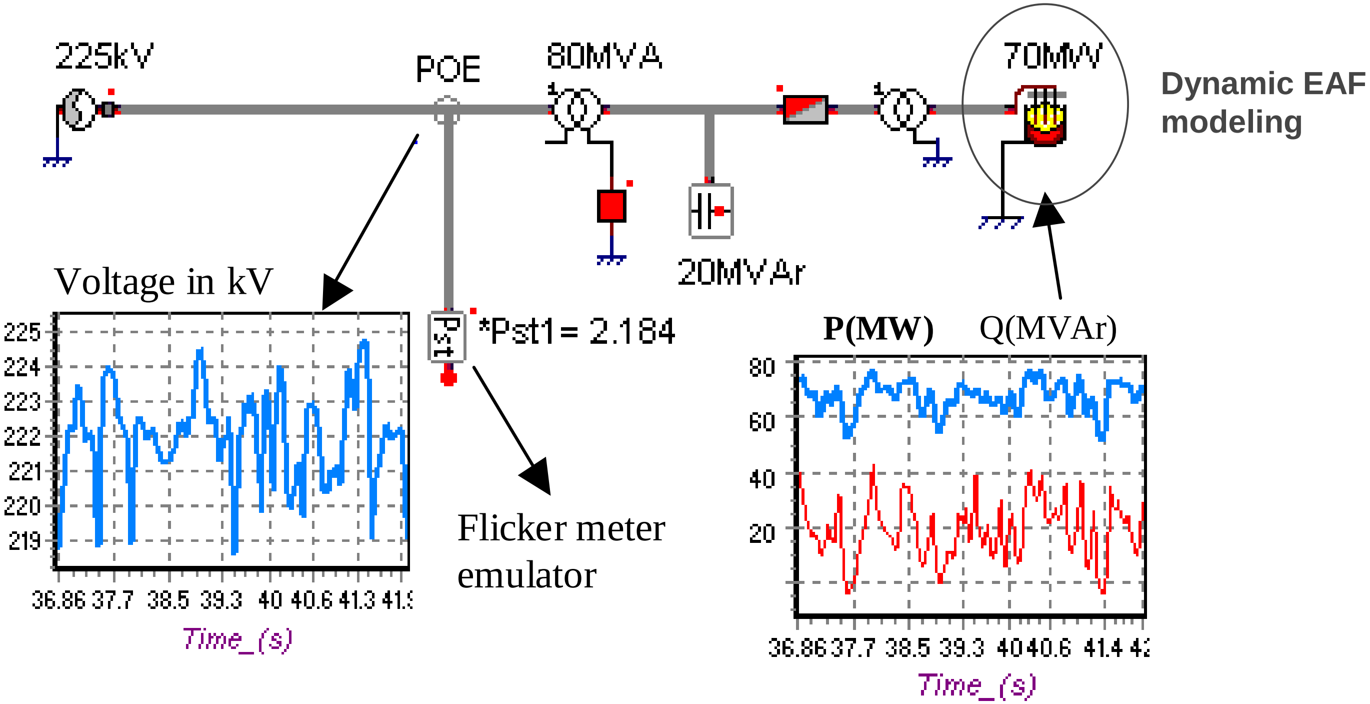



Stage 1: simplified computation
For an arc furnace, we can take total rated power as fluctuating one, so the power ratio ΔS/Ssc at POE reaches 2.33%. Stage 1 criteria of IEC61000-3-7 does not be applied due to the high ratio of the fluctuating power to short-circuit power for r>200/min (see Table II).

In this case, stage could be complied only if ΔS/Ssc at POE < 0.1%.

# Case study 2 (followed): Flicker assessment study by simulation with IEC flickermeter emulator

This case has been studied by the simulation of grid, flickermeter and dynamic load in a PQ software based on electromechanical transient computation:




The simulation shows only the EAF can cause Pst=2.184 and the compatibility level is exceeded.
**A stage 2 study at this POE is not necessary** and the customer shall discuss with system operator if a stage 3 study is possible. If a direct connection of this load is impossible from stage 3 study, the customer shall take additional corrective measures to reduce the flicker emission level.

# Conclusion

- IEC flicker assessment procedures have been used and adapted by system operators into their grid access contracts. It is possible to apply some simplified IEC methods to accomplish pre-connection studies with compliance of relevant IEC standards and local power quality commitments.

- For sophisticate case studies, the recommended method is to perform grid simulation with IEC flicker meter emulators and flicker load models. The grid can be modeled by an equivalent fictitious model or directly by accessing system operator's database. A flicker meter emulator is recommended in power quality software. Flicker meter method can make acceptable flicker assessment of any fluctuating installations to connect to the grid.

- French grid system operators have integrated IEC flicker assessment rules in theirs grid access contracts and studying tools (Simple flicker calculator, on-line tool for system operators, simulation software for power quality engineers).