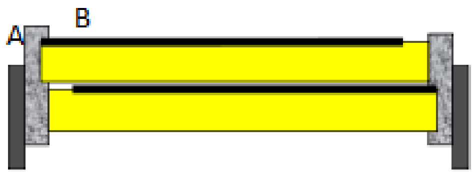
The increasing malfunction of X2 and Y2 capacitors is not only based on manufacturers errors or incoming wetness. The quality of many manufacturers is high but nevertheless malfunctions increase.

It is nothing to wonder about when devices work at 100% in the beginning and after some weeks and months still only has partial functionality or fail completely.

Smart meter manufacturer wonder what the reasons are for that.

Here are the answers:

1) 1-10KV/µs (dU/dt) –values which occur meanwhile more and more often in the supply grid and result in an increased current in the capacitors, parts and circuit board.



2) This raised current causes a burning free between connecting lead (A) and layer, and between winding film and layer (B)

3) This causes „high“ contact resistance, which change the ESR massive.

4) First breakdowns of isolation in the dielectric are shown as round holes in the film. This is the first step of destruction. (see photo right side)

5) The dU/dt peak values cause very high currents and therefore raised temperatures in the capacitor.

6) The extreme temperature differences (heating and cooling) change the potting material (epoxide resin) in its consistence and supports the outgassing of the hardener. The epoxid resin gets porose (microscope analysis).

7) Additionally wetness can get inside.

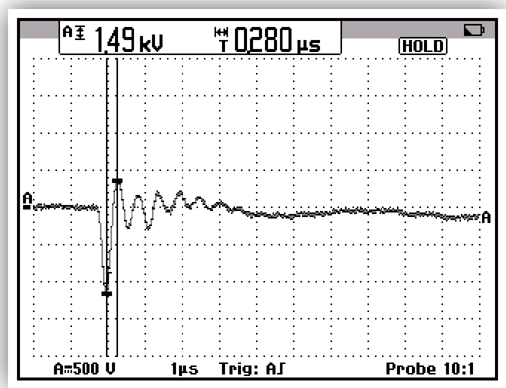
8) Caused by the extremely high current values (up to 11.000 Ampere) and the incoming wetness the metallizing coating vaporizes at high and frequent dU/dt pressure. The destruction is starting.

9) Partially capacitors bloat when the steam gases cannot penetrate through the epoxid resin. If a penetration happens, then there is again the incoming wetness which enforces the process of destruction.

10) The metallizing disintegrates completely.

Facts:

A regular X2 – capacitor of 2,2µF has a maximum dU/dt resistance of 150 - 200V/µs (according to manufacturer information). 200V/µs is already an indicator for a very good capacitor.



The voltage load (depending on location and on grid characteristics) can be measured between 1 - 10KV/µs.
3-5KV/µs is no curiosity anymore

Watch this (meanwhile often measured 5,32KV/µs dU/dt- pulse

This dU/dt is mainly caused by protectors, defect switches, induction devices, welding equipment, X-ray devices in laboratories, short circuits, frequency converter, inverter, solar inverter, thyristor controls, switching power supplies, leading-edge phase control and many more. These dU7dt spikes result in a raised current in the capacitor!

The load of a capacitor can be calculated by the following mathematic formula:

$$Q = C \times U$$

$$\frac{dQ}{dt} = \frac{d(C \times U)}{dt}$$

$$\frac{dQ}{dt} = C \times \frac{dU}{dt}$$

The capacity (Load) of a capacitor is constant against time, so we can transform the formula. $\frac{dQ}{dt}$ = I

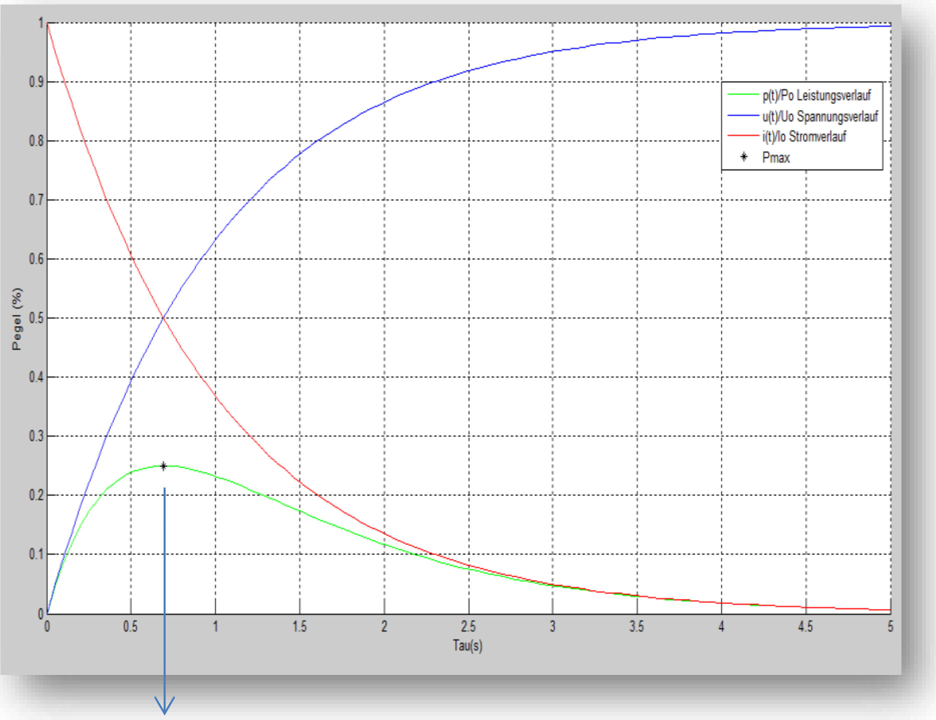
Result: $I = C \times \frac{dU}{dt}$

voltage spike has enough energy to destroy parts of i.g. a capacitor.

Example 1: 2,2µF; dU=5KV/µs; I = 11.000Ampere
Example 2: 2,2µF; dU=10KV/µs; I= 22.000 Ampere
Example 3: 2,2µF; dU=5KV/ms; I= 11 Ampere
Example 4: 2,2µF; dU=10KV/ms; I= 22 Ampere
Example 5: 2,2µF;dU=200V/µs; I= 440 Ampere

Potential energy shown with the example of a 2,2µF capacitor.

$$\Rightarrow E_{max} = U_0 \times I_0 \times 0{,}5^2$$



The result is:

5KV/µs=13.75MW
10K/Vµs = 55MW
5KV/ms = 13KW
10KV/ms = 55KW
200V/µs = 22KW
200V/ms = 22W

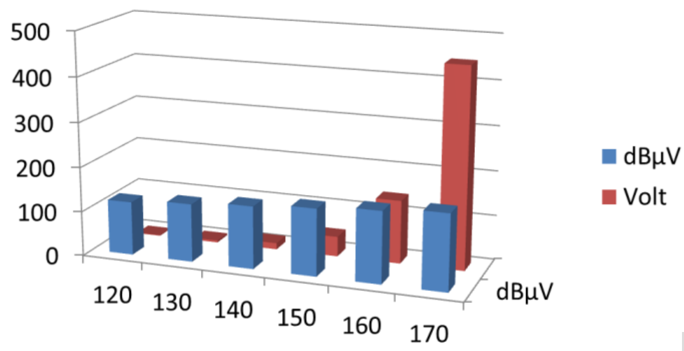
Temporally maximum activity value

All mentioned dU/dt – reasons are generated in the lower frequency range (2-200KHz)

Typical frequencies:

Frequency converter	5 – 20kHz
USV-devices	15 – 25kHz
Switching power supply	20 – 300kHz
Lamp EVG's	20 – 200kHz
Induction and welding installation	150 - 200KHz

Additionally they create (meanwhile measurable) disturbing voltage in a normal domestic home supply grid (250VAC) of up to 160dBµV. from 1KHz – 500KHz



dBµV	Amplitude $\hat{U}$
120	1,41
130	4,47
140	14,14
150	44,72
160	141,42
170	447,21

$$dB = 20 * \log_{10}\left(\frac{U_1}{U_2}\right)$$

Disturbance voltages of approx. 160dBµV cause an additional voltage spike in the supply grid of up to 141V and supports the above mentioned destruction process

Conclusion:

Contrary to the public assumption that a dU/dt peak value in the µs-range had no destructive energy, experience shows that it indeed has one. The basics of the norms EN 61000-4-4, and 61000-4-5 (which should prove the disturbance resistance and immunity of a device), is not sufficient anymore because the testing parameters are from the 1980´s, when only trafo mains adapter had influence on the supply grid quality.

Parts like capacitors had to get smaller and smaller in the past. The film thickness and the metallizing have been reduced from 7µ to 3µ.

Ferrites have not been used according to frequency related qualification in EMC devices, but mostly according to dimensions and prices.

Therefore it is clear that even with low asymmetric disturbance currents of only few mA, the core material gets into saturation and loses the filter characteristic. In most cases the filter becomes even an additional network load.

Solution Statement!

1) **Existing norms, like for example, EN 55011 to 55022 have to be expanded from an actual frequency range of 150KHz to 30 MHz to a frequency range of 1KHz to 30 MHz . The maximum interference limits in the range from 1KHz to 150KHz has to be reduced from 80dBµV to 60BµV.**
2) **The actual surge and burst norms have to be adapted to the actual network load.**
3) **The used parts have to be classified and immunized.**
4) **The used parts for EMC- activity, mostly ferrites, have to be qualified to absorb high-energy transients and dU/dt. This is very important for elimination of disturbance voltage in the kHz range. Capacitors have to be resistant against high asymmetric currents and dU/dt loads up to 10 KVµs. Hereby it is important that ESR stays constant and the capacitor does not affect an interfering reflection on its own.**

These technical solutions (3-4) are not based on a wanted ideology or theory, but are realized in Bajog electronic filters, which are partially already for 22 years in non-stop use without decrease of performance.

Filter for military, measurement and test cabins, high voltage laboratories, medium voltage devices (35.000 V), like wind, water, bio, and combined heat and power plants, as well as dU/dt filter in elevators are subordinated a daily check by their operation purpose. This is because TE-measurements and EMV-measurements would not lead to a proper result if the cabin and especially the filter would not bring the needed performance.

Especially in terms of elevators older motors would immediately be affected by isolation breakdowns and short circuits, when the used dU/dt-filter would have a loss of performance and the dU/dt values of 10KVµS, which are created in the FU-exit, would not been reduced to max. 500Vµs. These filters are in permanent use in many Schindler elevators since 1990 – 1993.