Hubbell Industrial Controls

Steel Industry – Unbalance in electrical networks & Welding Case Study

Steel industry training – Unbalance in electrical networks

Basic concepts – Unbalance

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- In a three-phase AC electrical system, unbalance (also known as imbalance) refers to a situation where the RMS voltage or current is not equal between the three phases, or if the phase shift between the phases is not equal to 120°
- Unbalance is usually expressed in percentage value, but its interpretation is based on the definition used; IEC, NEMA and IEEE all have their own definitions for unbalance.
- The most commonly used one is the IEC definition based on negative and positive sequence components:

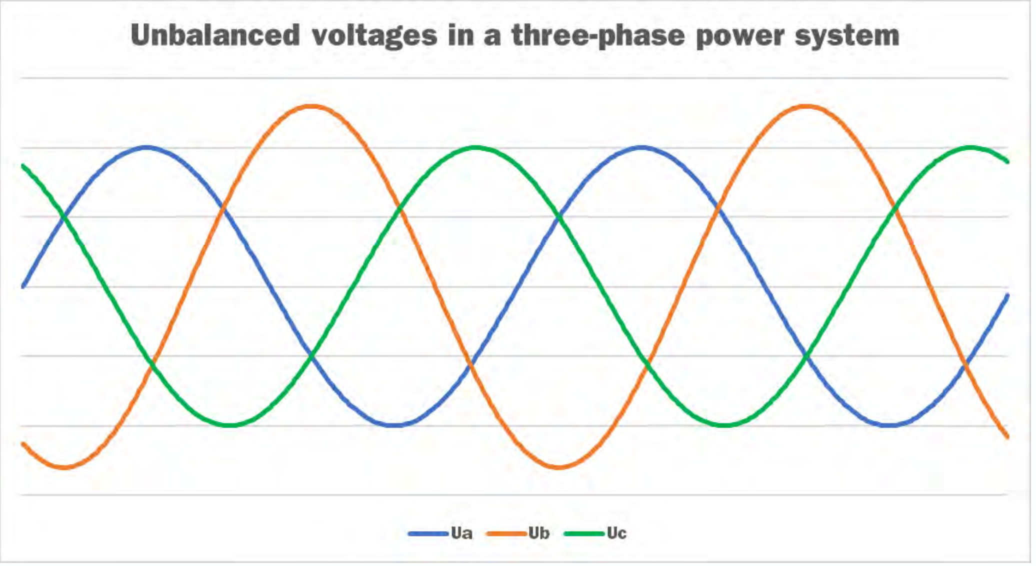
$$\mathrm{VUF}(\%) = \frac{V_2}{V_1} * 100\%$$

$$\mathrm{IUF}(\%) = \frac{I_2}{I_1} * 100\%$$

Basic concepts – Unbalance

- In the US, the more intuitive NEMA definition for voltage unbalance is also relevant:

$$\mathrm{LVUR}(\%) = \frac{\max \textit{voltage deviation from the avg line voltage}}{\textit{avg line voltage}} 100\%$$



Basic concepts – Unbalance

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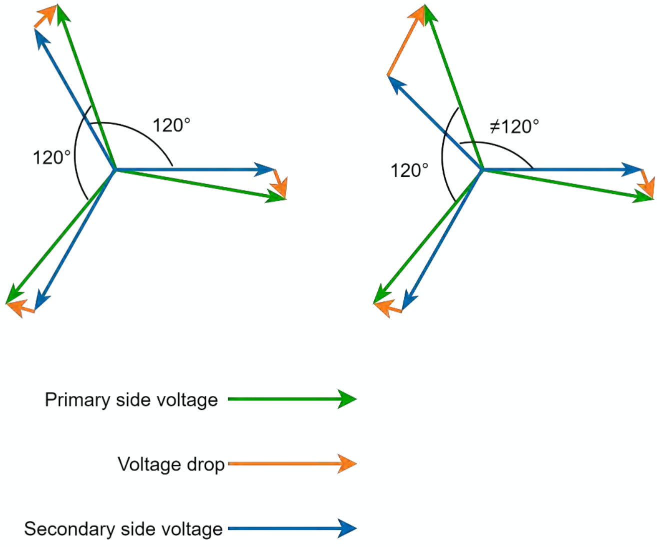
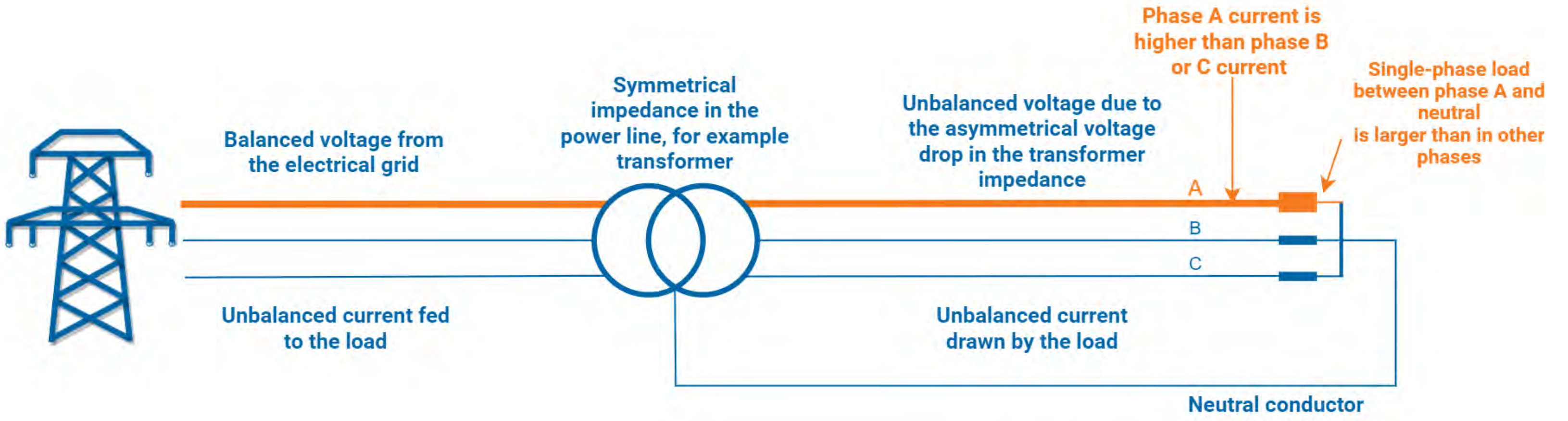
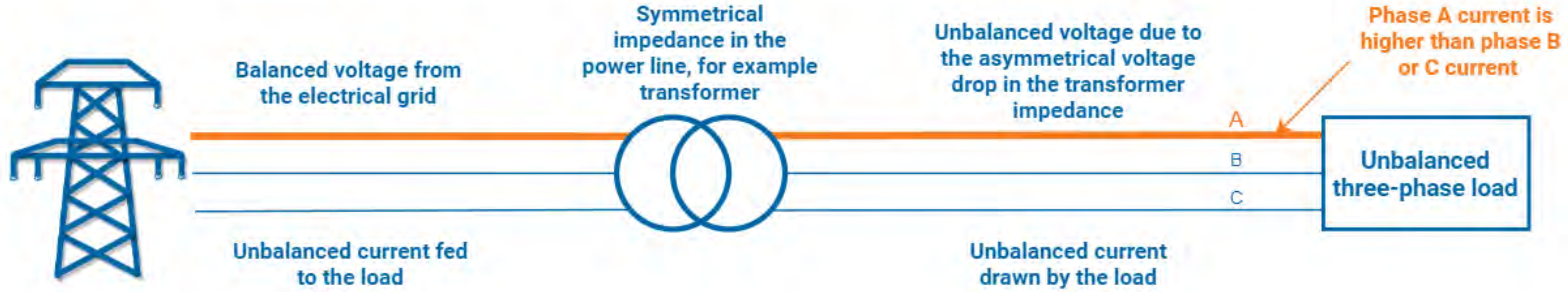
- Unbalance can theoretically be caused by asymmetrical generator or power system design, but usually it is always caused by asymmetrical load currents.
- Asymmetrical three-phase loads and unevenly distributed single-phase loads are examples.







Basic concepts – Unbalance

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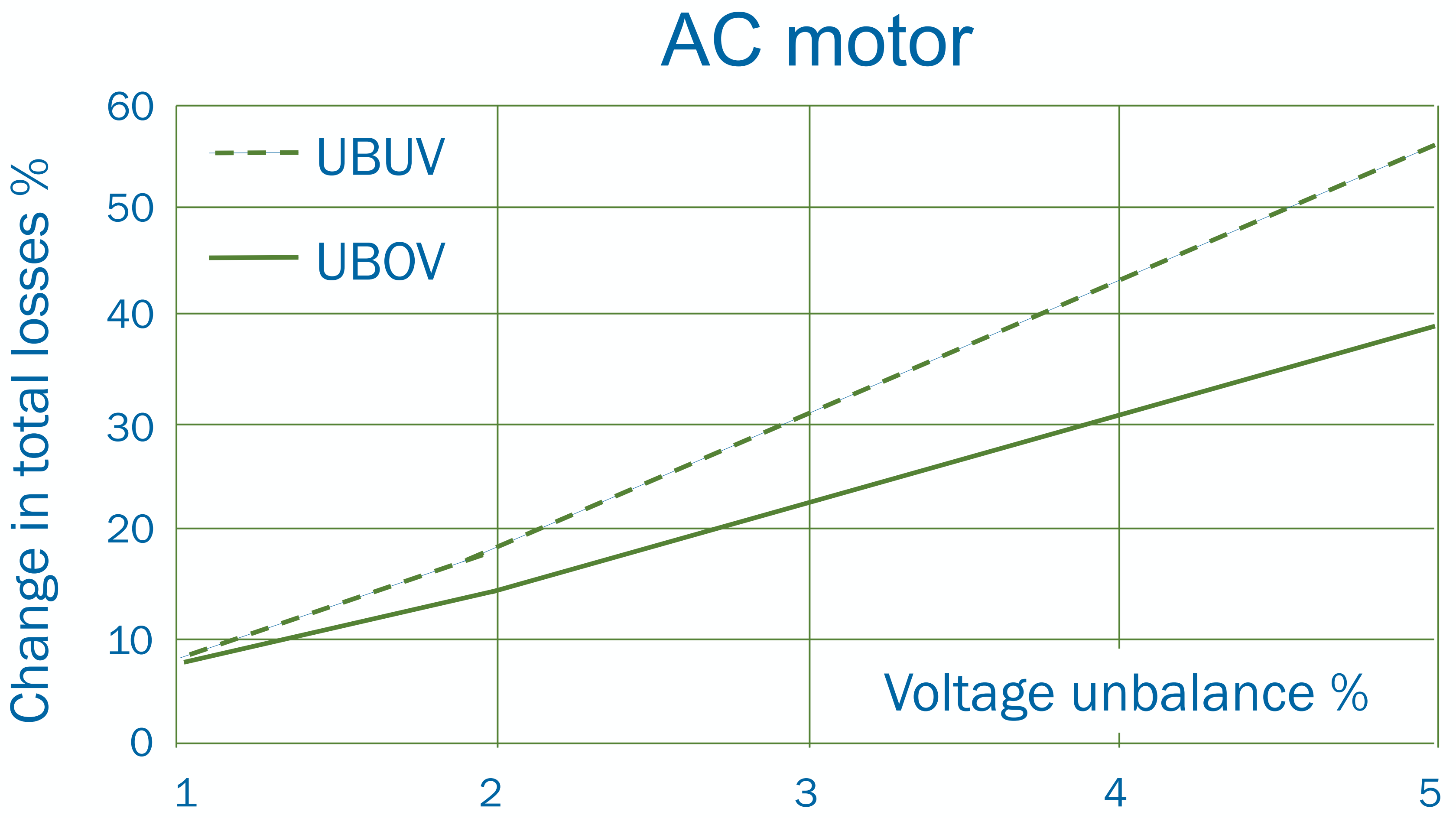
- Unbalanced voltage causes electrical motors to draw unbalanced currents which creates opposing fluctuating torques and temperature rise in windings
- With only 1 % voltage asymmetry in electrical motor's terminals, its lifetime is halved. With 5 %, its lifetime is reduced to 5 % of the design lifetime.
- In VSDs, voltage unbalance causes excessive stress on the filter capacitors and may cause the VSDs to trip. It also causes excess heating of semiconductor components in the power stage
- All power electronic devices will produce more harmonic currents and additionally interharmonics with unbalanced voltage
- Warranties for any electrical equipment may be void if standard limits are exceeded

Basic concepts – Unbalance



UBUV = Unbalance and under voltage

UBOV = Unbalance and over voltage

Steel industry training – Welding case study

More efficient and productive welding process

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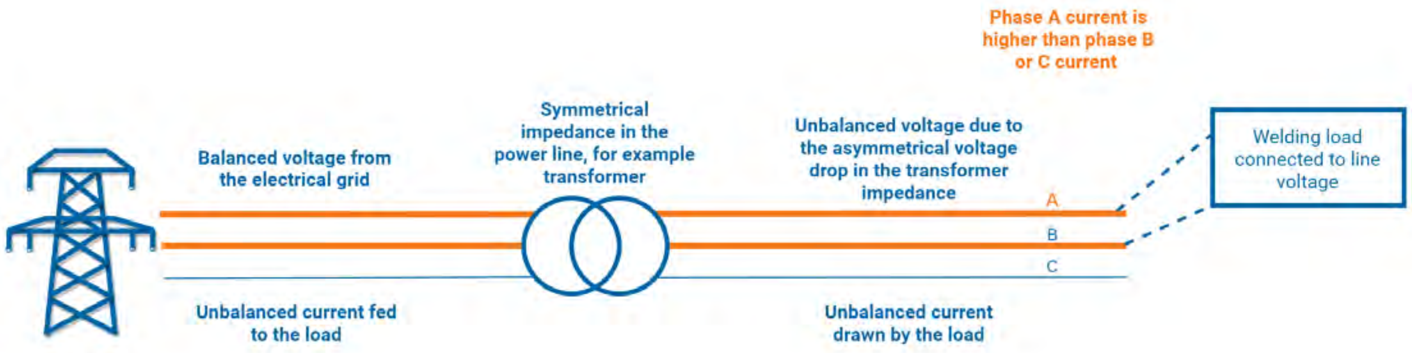
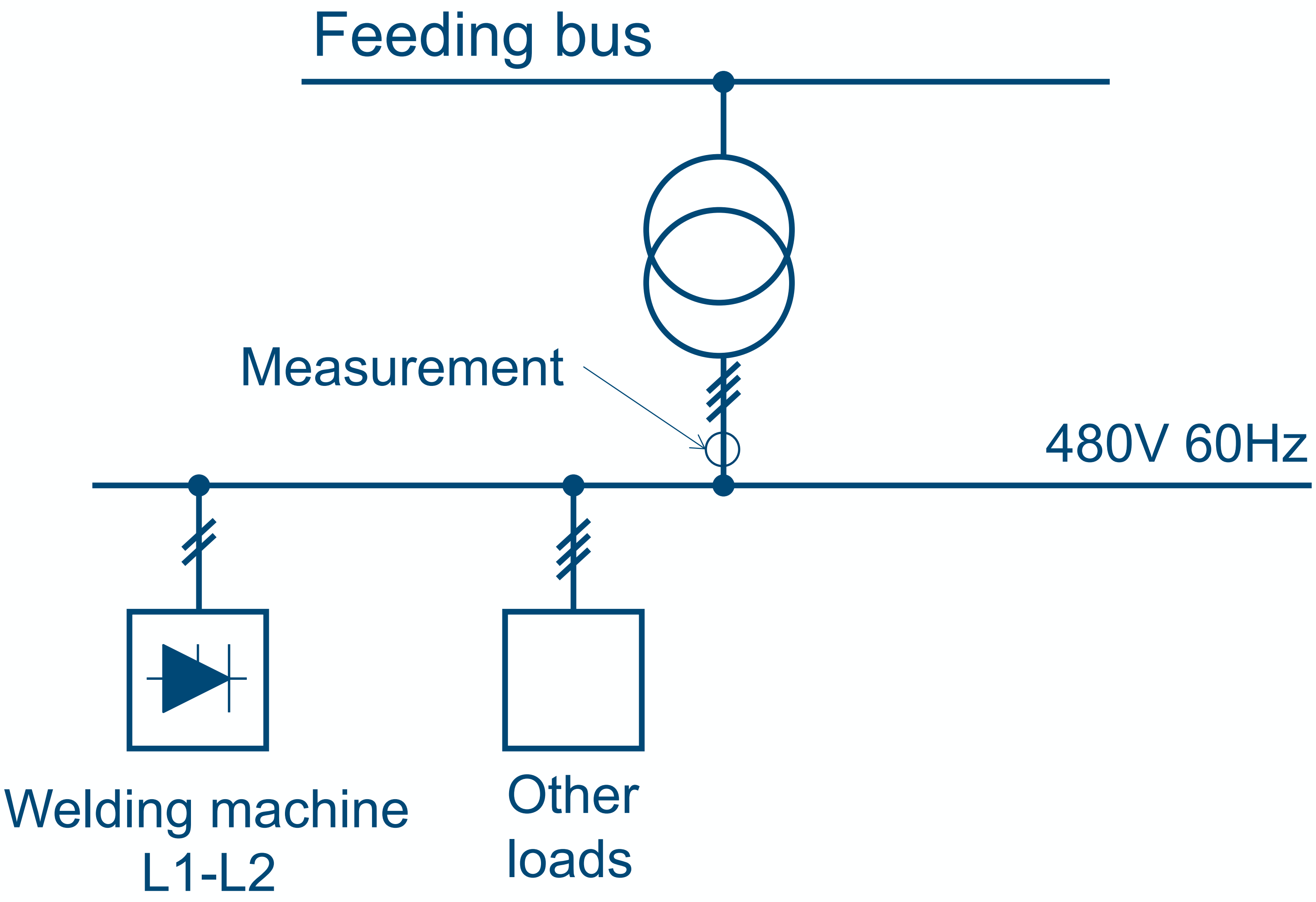
Arc welding devices with dynamic reactive power compensation

- Arc welding devices are often connected to line-to-line voltages and thus naturally cause unbalanced currents in the electrical system, which in turn causes unbalanced voltage
- Welding devices consume significant amounts of rapidly fluctuating reactive power and harmonic currents, which cause voltage fluctuation in the bus also known as **Flicker**
- Flicker in practice means rapid variation of a light source intensity



Welding device compensation



Welding device compensation

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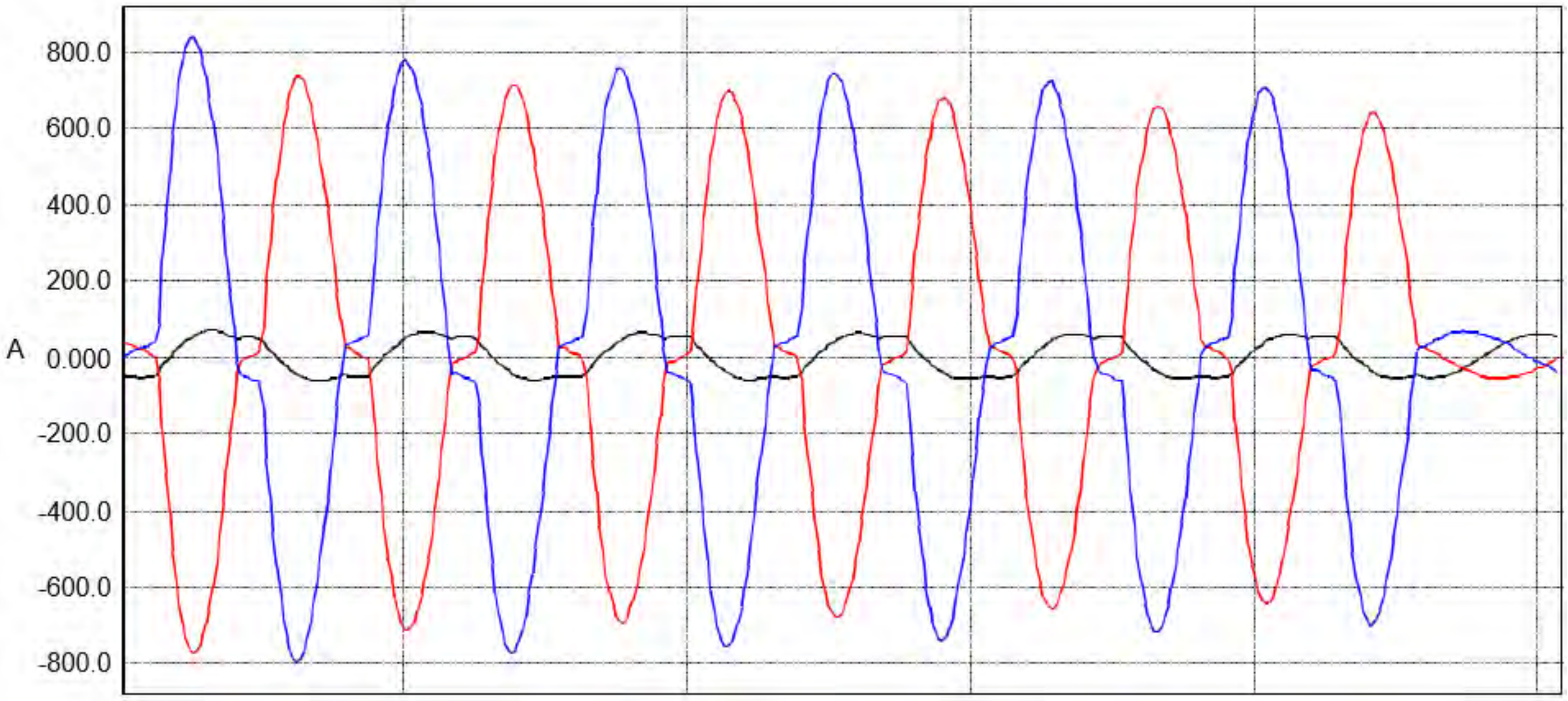
Measured supply currents to the welding machine



Welding device compensation

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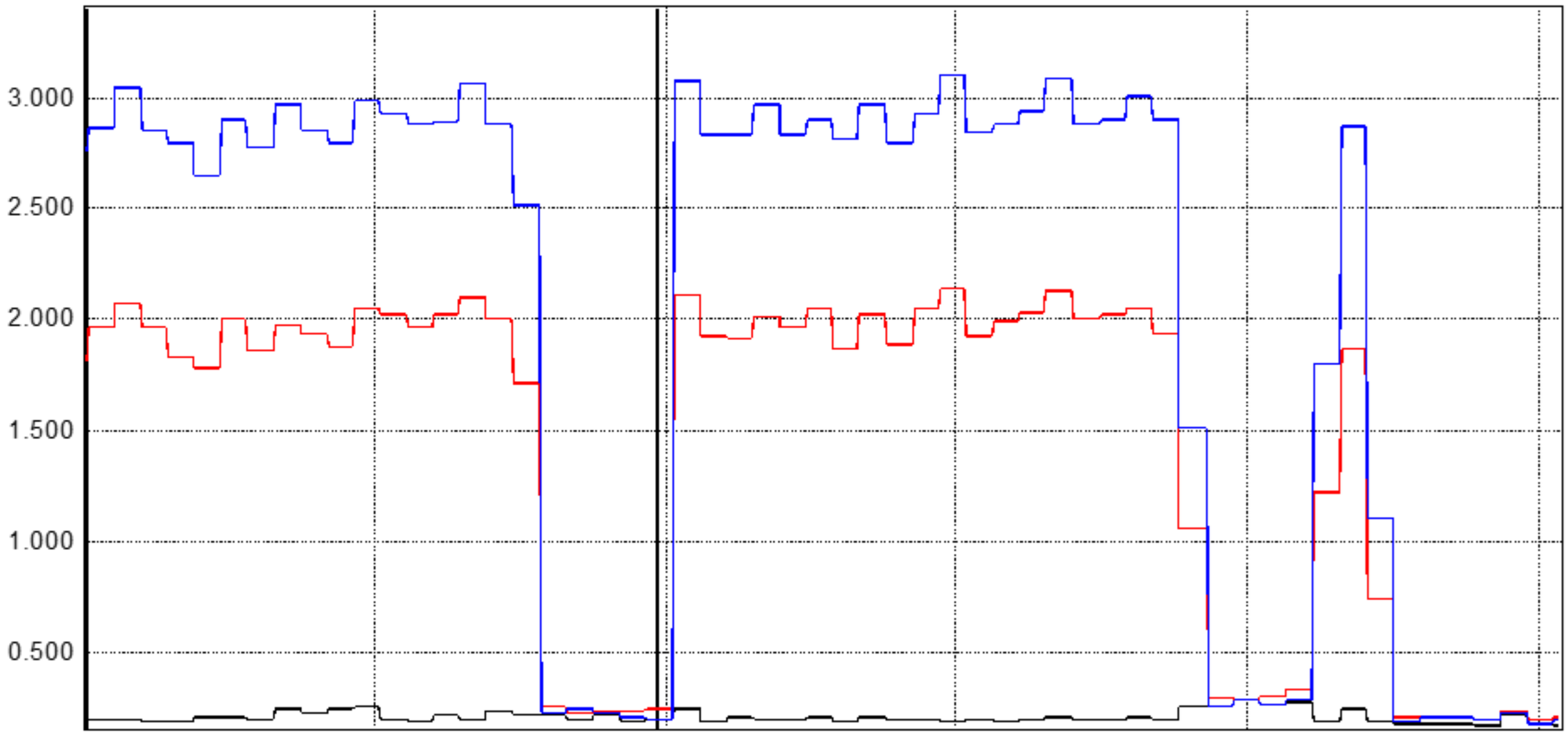
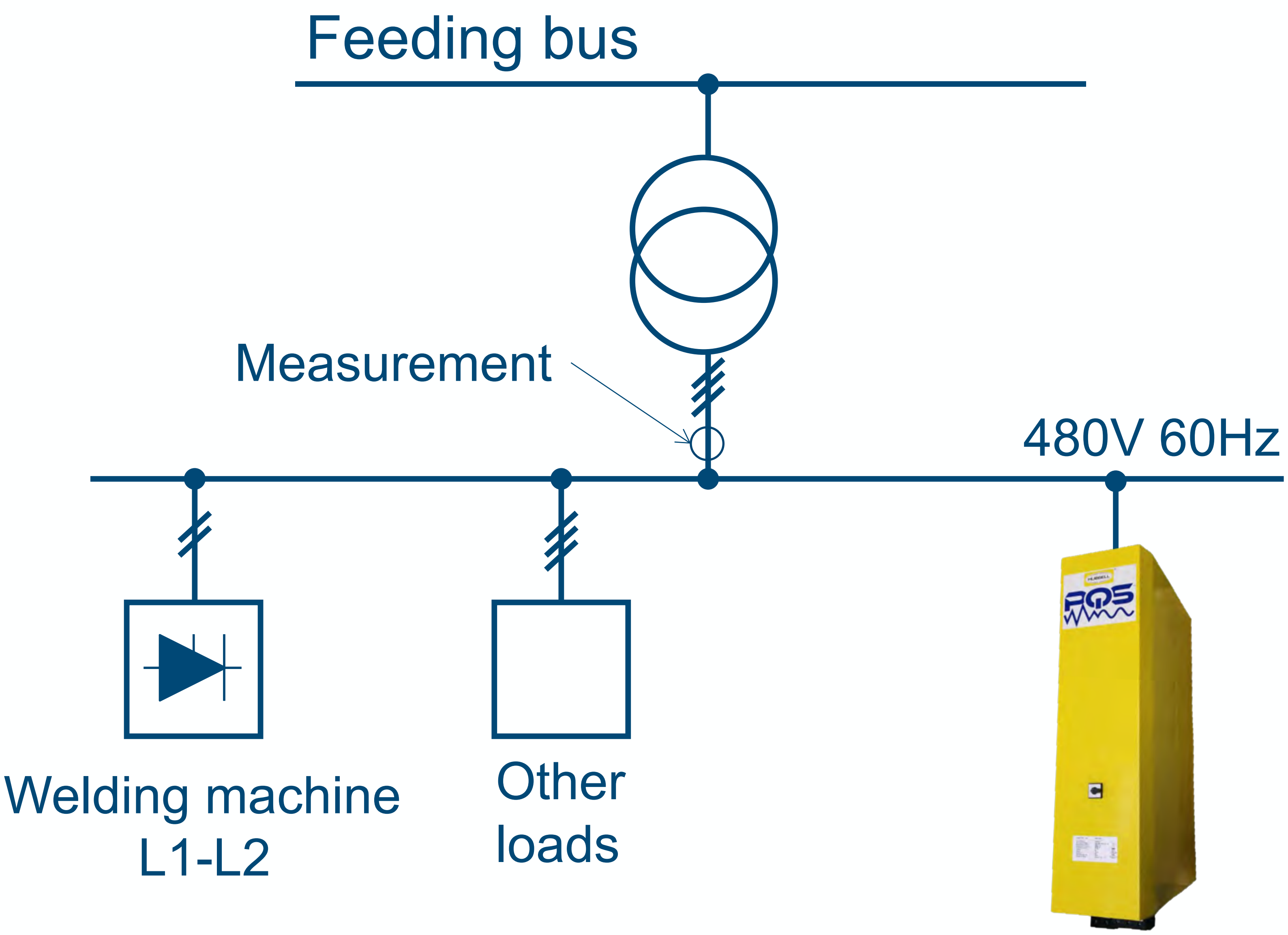
Measured flicker before compensation

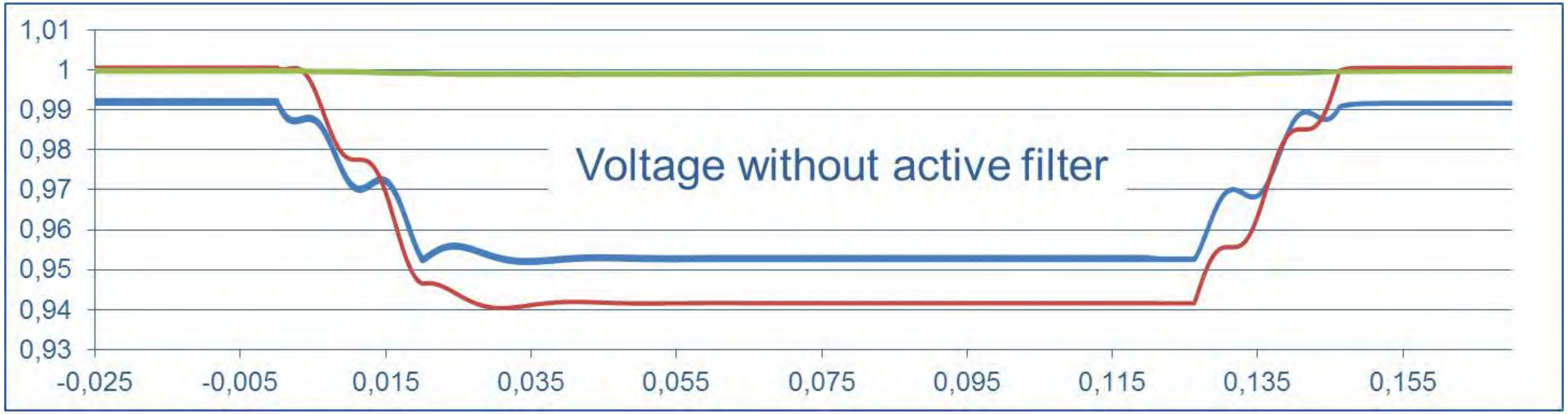


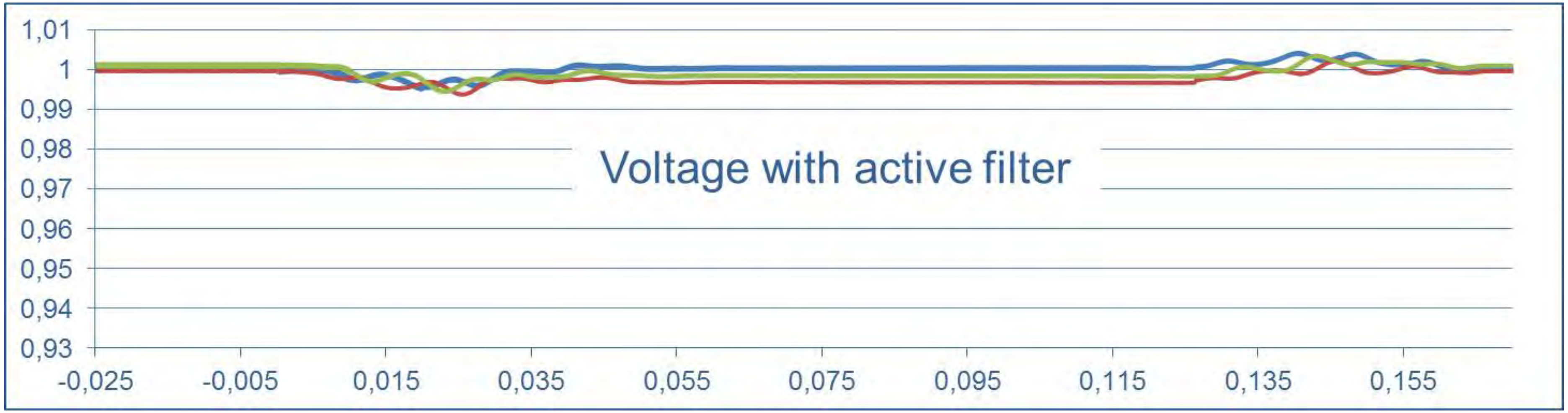
Welding device compensation



Welding device compensation

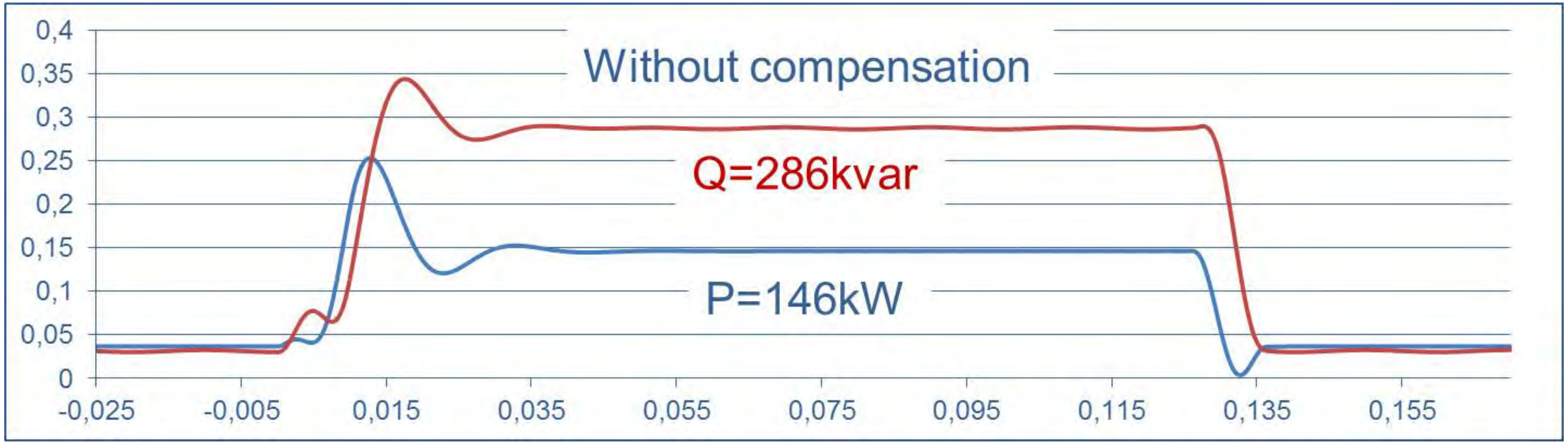
Voltage stabilisation with active filter

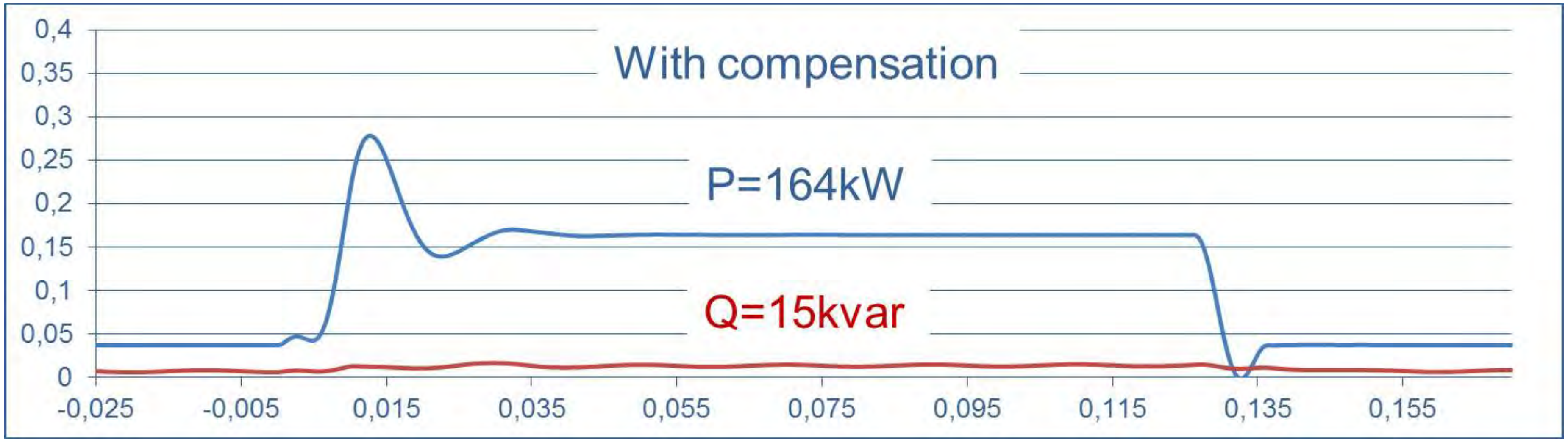




Welding device compensation

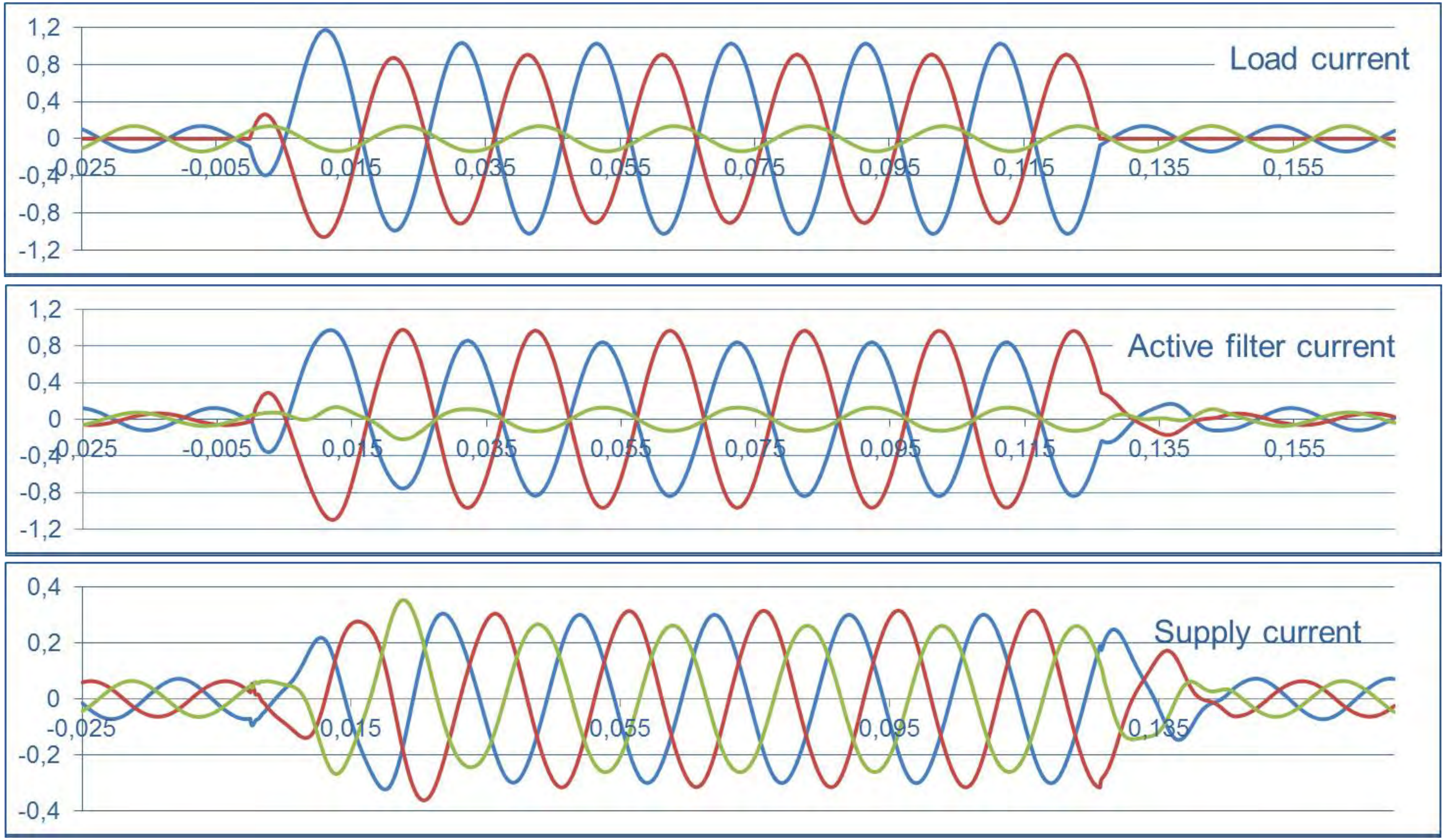
Active and reactive power with and without compensation





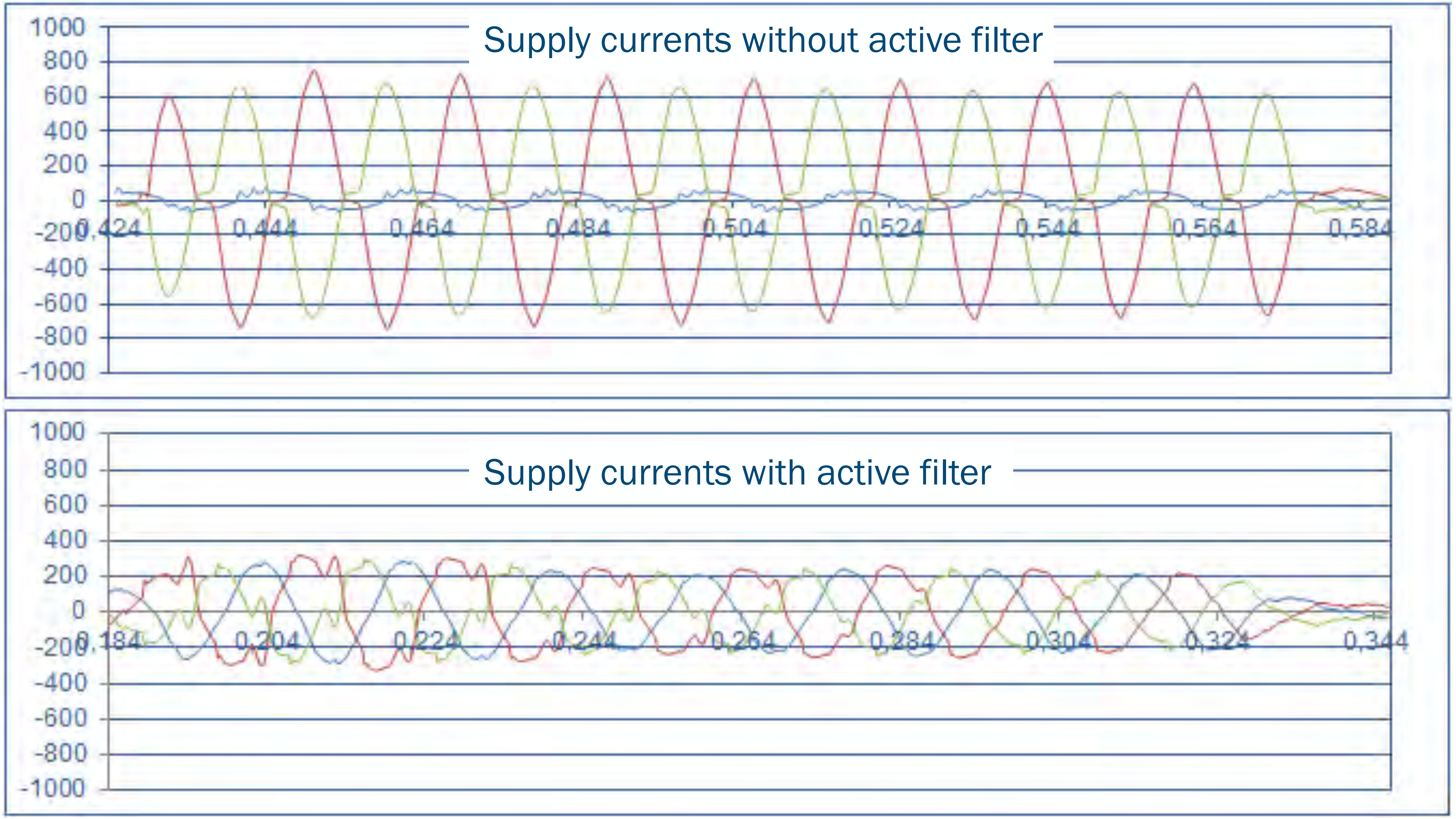
Welding device compensation

Symmetrisation of the phase currents of the welding load



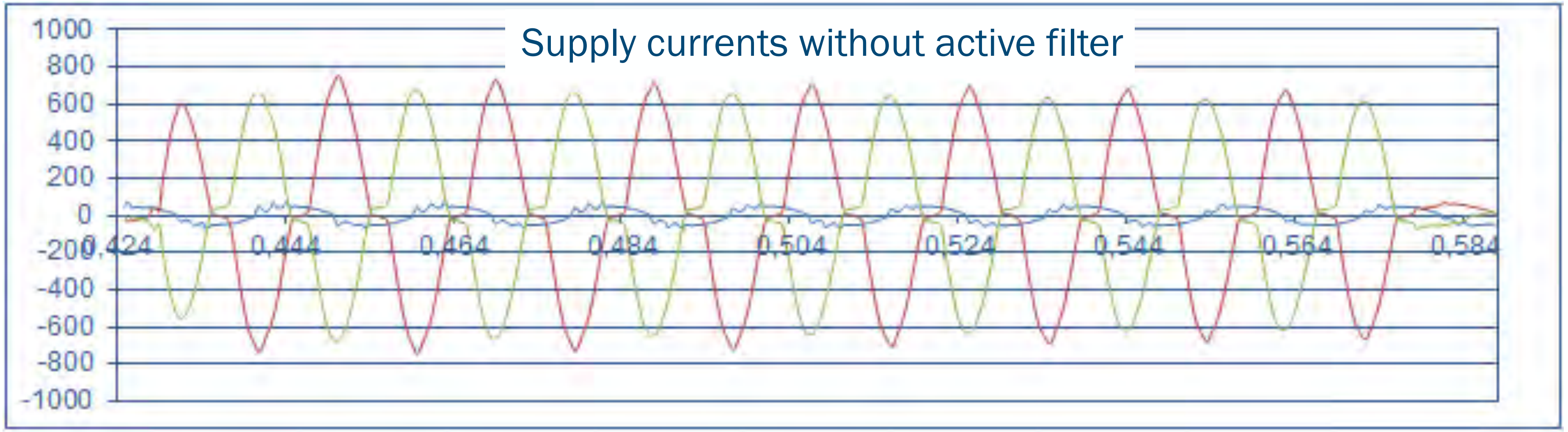
Welding device compensation

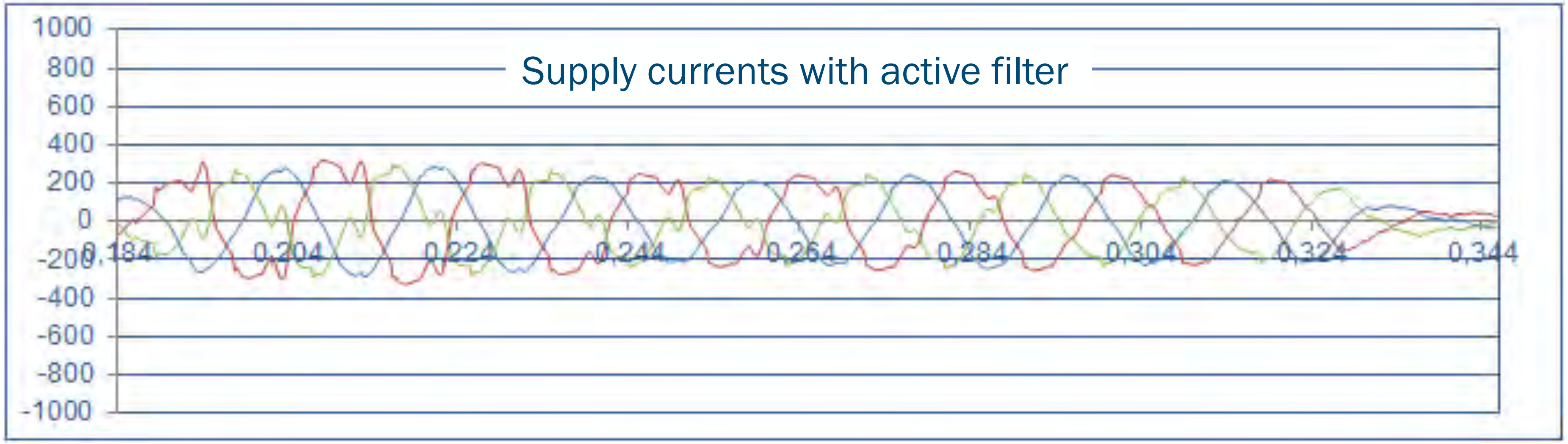
Supply currents from the network – the maximum current is three times less!



Welding device compensation

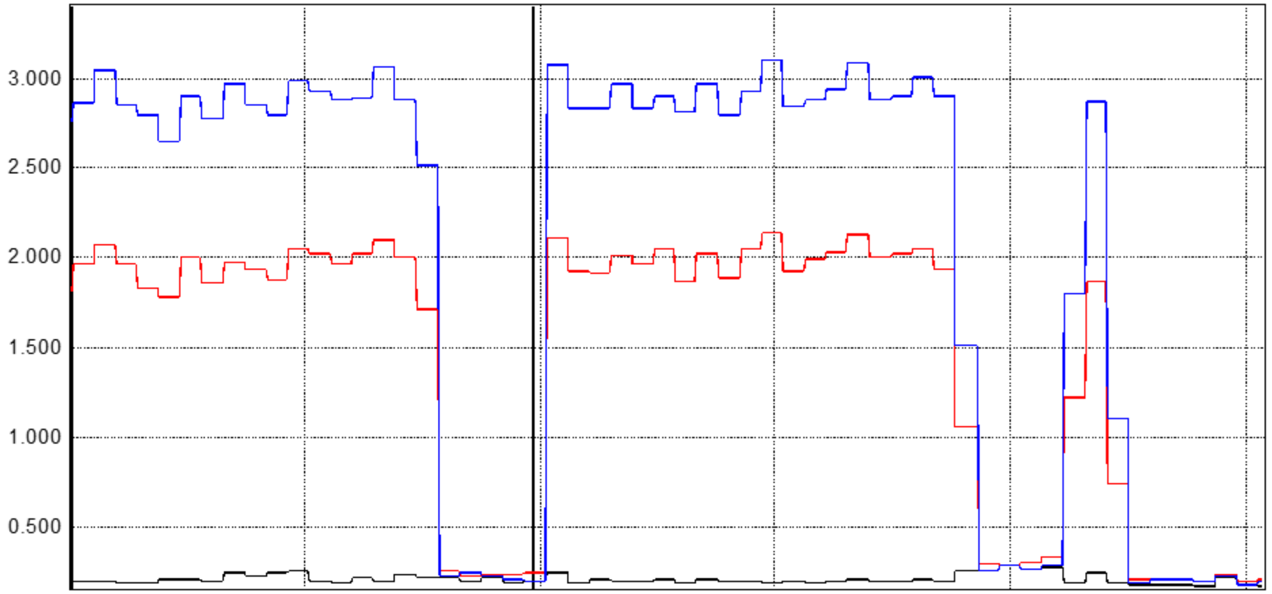
Same figures with the same scale – the maximum current is three times less!

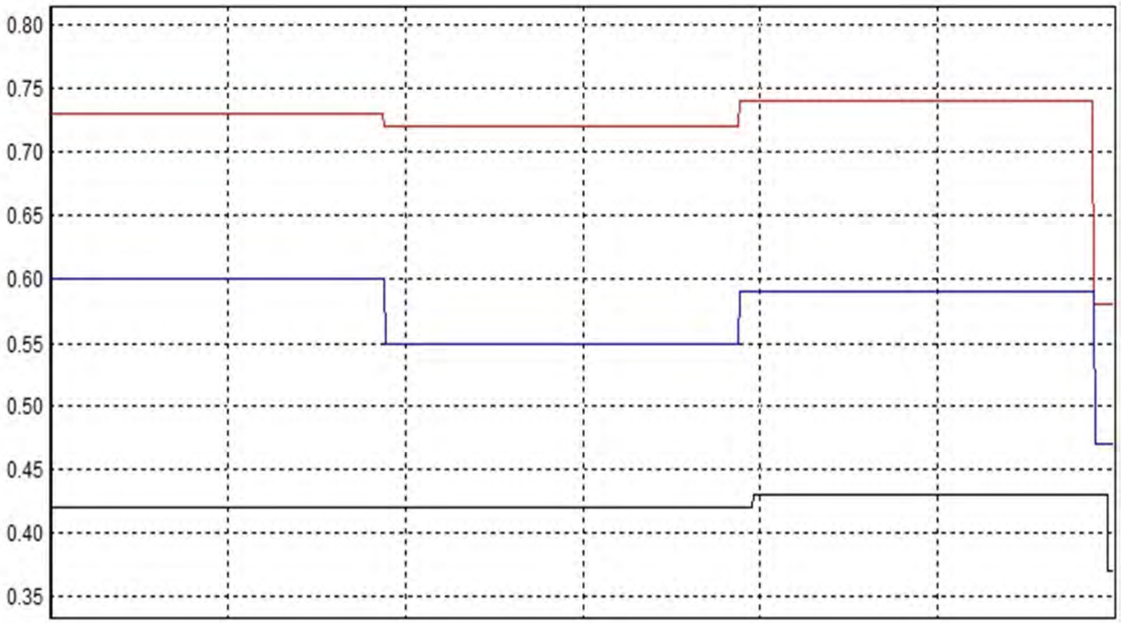




Welding device compensation

Measured flicker before and after compensation





Welding device compensation

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	Fundamental current		
	Filter OFF		
	L1	L2	L3
	A	A	A
	700	700	50
Approx. relative ohmic losses I^2R	100%	100%	0,5%
	Filter ON		
	L1	L2	L3
	A	A	A
	220	220	220
Approx. relative ohmic losses I^2R	9.9%	9.9%	9.9%

Payback

- Active power from 146 kW -> 164 kW ~ 12.3 % increase!
- This means that the client bring 12.3 % more energy in the process in the same time!
- Total ohmic losses are decreased by 80 %
- This means less temperature rise in the feeding transformer and other network components
- By correcting the harmonic distortion and unbalance in voltage, standard limits are met and other technical issues caused by them are avoided

Key takeaways

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- A welding device draws unbalanced currents in a three-phase system because they are connected to line-to-line voltage
- These currents have significant reactive and harmonic content, which can draw the voltage down
- With the APEX active harmonic filter, we can correct these problems, reduce losses and increase the productivity of the whole welding process

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