Earth-Fault Compensation Controller EFC60m

THE PROVEN POWER.

TRENCH

Application

In resonant grounded power distribution networks the neutral point of the network is connected to earth by means of a stepless adjustable inductor. If the resonance circuit formed by the adjustable inductive coil and the earth capacitance of the network is tuned to or close to resonance, the fault current is greatly reduced in case of a line-to-earth fault (earth fault). In most cases the arc caused by the fault current is extinguished without the need to switch off the faulty part of the network.

As the Arc Suppression Coil (ASC) and the earth capacitance form a resonance circuit, the neutral-to-ground voltage of the network depends on the value of the inductance of the ASC and reaches a maximum when the ASC is tuned to resonance. The ASC can be tuned automatically by evaluation of the voltage maximum of the resonance curve (by coil adjustment) or by impedance-measurement of the resonance circuit (by current injection).

Due to the growing share of cables today networks become more symmetric, so that the peak resonance voltage, which is caused by the natural network asymmetry, consequently decreases. On the other hand, interferences, e.g. caused by load fluctuations or decentral generation, increase. The neutral to ground voltage, which is the only control criteria for the automatic controller therefore looses its quality. Control problems probably lead to excessive stress on the mechanism of the ASC and / or to annoying error messages.

Since the multi-frequency current injection enables network analysis with frequencies, different from the operating frequency, the EFC60m proves to be a compact new control device, which is extremely resistant to network interferences.

Control Algoritm

Determining the resonance peak by Multi-Frequency Current-Injection

By means of a thyristor the 50 (60) Hz injection current can be pulsed quickly. This generates side bands around the 50 (60) Hz main frequency. The evaluation of the side frequencies makes this method immune to network interferences.

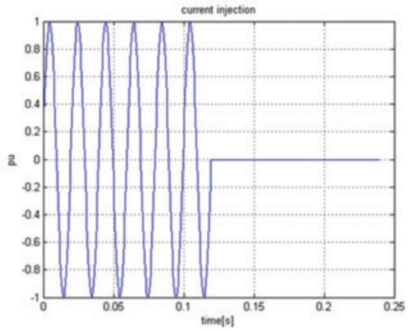

Fig. 1: pulsed 50 Hz injection current

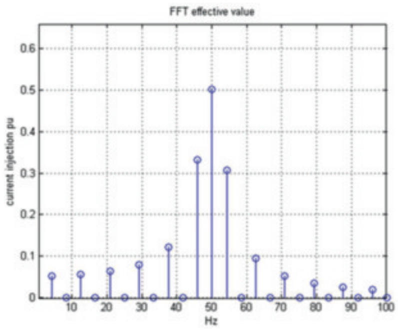

Fig. 2: generated frequency spectrum

In addition, by evaluating at least two frequencies, a calculation of the total capacitance or inductance of the zero sequence system can be performed, taking into account possibly existing fixed coils or decentral coils.

Determining the resonance peak by 50 (60) Hz - Current-Injection

It is possible to calculate the resonance curve by injecting a current at fundamental frequency into the zero sequence system of the network and to measure the vectors of both the neutral-to-ground voltage and the injected current. It is therefore not required to change the coil position. This protects the adjustment mechanism in case of fluctuating neutral to ground voltage against too frequent use.
Where a network is essentially symmetrical and the neutral-to-ground voltage extremely low, it is possible to increase the neutral-to-ground voltage by using the current injection permanently so that changes of the network configuration provide a reliable signal for the controller (inverse operation mode).

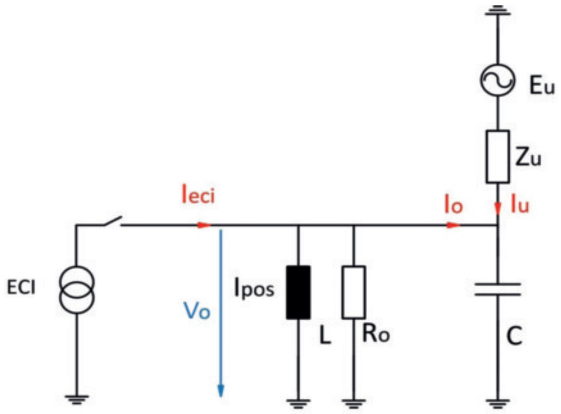

Fig. 3: Current injection into zero sequence system

The fundamental frequency injection can be activated alternatively to the multi-frequency method, if the neutral to ground voltage is sufficiently stable.

Vo	neutral to ground voltage
ECI	current injection device
L	inductance of Petersen coil
Ipos	coil position (stated in Ampere)
Ro	equivalent resistance, representing losses
C	capacitance of network versus ground
Io	zero sequence current (mostly capacitive)
Iu	unbalance current
Eu	equivalent voltage for unbalance current
Zu	asymmetry impedance of network

Determining the resonance peak by minor coil movement

During a tuning operation the ASC is adjusted by a small amount. Measuring the coil-position as well as the neutral-to-ground voltage during the adjustment operation, the controller computes the detuning factor v, the asymmetry factor k and the damping factor d, which determine the resonance curve of the neutral-to-ground voltage. Taking into consideration a customer settable under- or overcompensation, the controller calculates the necessary position and directly adjusts the ASC to the calculated value. In order to achieve a high tuning accuracy, the controller moves the coil beyond the resonance point, if allowed to do so (Vo <Vmax). This is particularly necessary for small displacement voltages and voltage fluctuations due to interference effects.

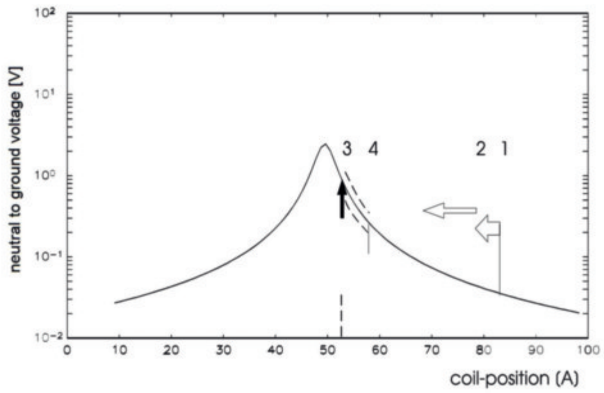

Fig. 4: control with coil adjustment

In the EFC60m this method may be used as a backup, e.g. in the event of current injection failures.

Important network parameter :

v = Ipos—Ires / Ires [%]	detuning factor
Iv = Ipos—Ires [A]	detuning current
Ipos [A]	coil position
Ires [A]	resonance position of network
d = Id / Ires [%]	damping factor
Id [A] = Vo/Ro	damping (residual) current
k = Zu * jωC [%]	asymmetry factor

Design features EFC60m

Hardware

- Microprocessor based controller 19“ -rack mounted (3 RU), width 84 HP with integrated current injection.
- Optimized operation by means of a graphic 7“ LCD touchscreen.
- Extended operation via PC by means of a terminal program E-Soft
- Indication of the digital outputs via customer labelled and parameterized LEDs at the front
- Central acquisition and display of arc suppression coil alarms via LEDs at the front
- USB A and B at the front
- Analogue output modules 0...20 mA for external indication of coil position and neutral to ground voltage.

Hardware Options

- Alternative power supply
- Additional external digital inputs
- Additional external digital outputs
- IEC 61850 Ed2 module (externally mounted)
- Assembly variant on mounting plate
- Assembly variant in electrical cabinet (outdoor design for mounting at the coil—controller and coil already wired and prepared)
- Variant without current injection (tuning with coil adjustment)
- Additional parallel inductance L2 in order to increase the injected current (L2 externally mounted)

Fig. 5: EFC60m

Operation

Easy operation by means of an integrated 7“ Colour-Touchscreen. This display can principally be installed remotely from the controller, if a communication over Ethernet is possible.

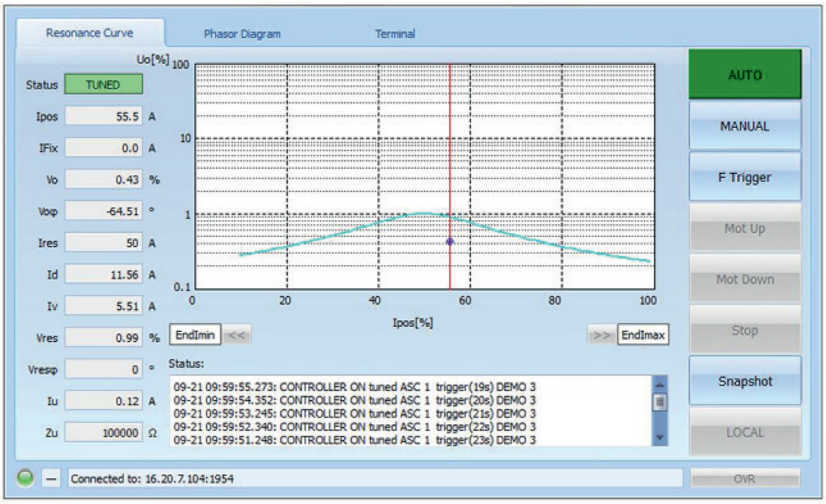

Fig. 6: Resonance curve display at controller and E-Soft

Terminal program **E-Soft** for Microsoft Windows for parameter setting and on-site operation via PC as well as for remote control over Ethernet .

Easy adaption to individual network conditions by flexible parameterisation and changeable pre – set factory values.

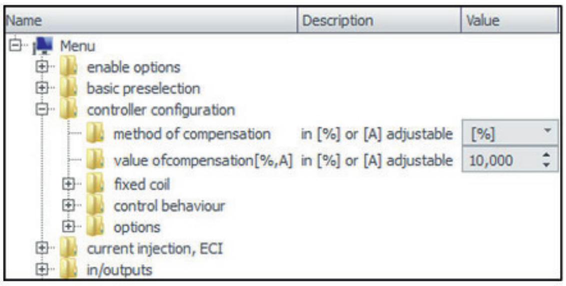

Fig. 7: Parameter tree in E-Soft

Fig. 8: E-Soft C-Interpreter for internal PLC-commands

Software

- easy parameter setting, since pre-set factory values can be adjusted by the user as required.
- high flexibility through software controlled inputs and outputs, free assignment of digital outputs to different state functions as well as free assignment of digital inputs to different control functions.
- powerful PLC—in case special functions are required a powerful PLC is available, which can be programmed with the help of a C-interpreter.
- indication of operating status via a short text message
- counting of various events (e.g. transient earth fault) and controller conditions for statistical evaluations. Data-Download via USB or Ethernet interface (RJ45) onto PC or directly to a USB—stick.
- remote parameter changes by means of a PC connected via USB or Ethernet.
- several parameter levels for adaptive user settings
- Software-Update by USB or Ethernet interface (RJ45) from PC or directly from a USB—stick.

Software Options

- **several controllers within the same network**
  reliable control without mutual influence, no remote connection necessary
- **external circuit breaker**
  adjusting the ASC to a predefined value when the ASC is switched off
- **resistor control**
  automatic resistor control at earthfault
- **fix coil control**
  automatic switching on/off of the fixed coil
- **control at earthfaul**t
  control back to ideal compensation (v=0) if an earth fault occurs
- **SCADA**
  SPABus
  IEC 60870-5-101/103/104
  IEC 61850 Ed2 (with optional external hardware module)
- **automatic switch Vo>Vmax**
  automatic switching of a damping resistor during search operation if V exceeds Vmax
- **vectorial trigger**
  Consideration of amount and phase angle of Vo as trigger criterion.

Technical Data EFC60m

Hardware component	Amount
Standard operating 7" LCD, 800 x 480 pixels (WVGA), Touchscreen,16 LEDs	1
Front 16 LEDs USB-A USB-B for SCADA, PC or modem	 1 1 1
Back USB-A on the backside RS485, 3 pole connector RJ12 →(via converter connector) → RS232 for SCADA modem RJ45 for SCADA or PC	 2 2 1 1
Analog voltage Input 10 mV ... 230 V AC 50 Hz, rated burden < 0,5 VA	5
Analog current Input 0 A … 5 A / AC 50 Hz	4
Analog current Output for e.g. Vo, coil position 0 ... 20 mA/DC, maximum burden at 20 mA/DC: 800 Ohm	3
Coil position Linear potentiometer, 0 ... 200 Ohm or 0 ... 2 kOhm or 0 ... 20 mA/DC - input signal	1
Digital Inputs 4x potential free input 24 ...... 230V AC/DC (aBE) 15x potential free inputs insulated in groups of terminals 110 … 230V AC/DC (BE) (Optional 15x potential free inputs 24-110V DC are mandatory if power supply 80-130V DC is used)	19
Digital Outputs potential free changeover contact (normal open, normal closed) 230 V AC/DC max 5 A continuous, max making capacity 1000 VA, max breaking capacity 30 VA (1x EFC, 2x E-REL)	3
Digital Outputs potential free contact insulated in groups of terminals (normal open) 230 V AC/DC max 5 A continuous, max making capacity 1000 VA, max breaking capacity 30 VA (5x EFC, 10x E-REL)	15
Power supply Standard: 120 - 300V DC 110-230V AC Optional: 80 – 130 DC !!!!(Observe polarity – internal fuse blows in case of wrong connection) Power consumption max. 20W	1
Maximum permissible overvoltage at the voltage inputs 230V AC continuous (2 x Un for 1s)	
Maximum permissible over current at the current inputs (1,2 x In continuous, 100 x In for 1s)	

Mechanical Data EFC60m

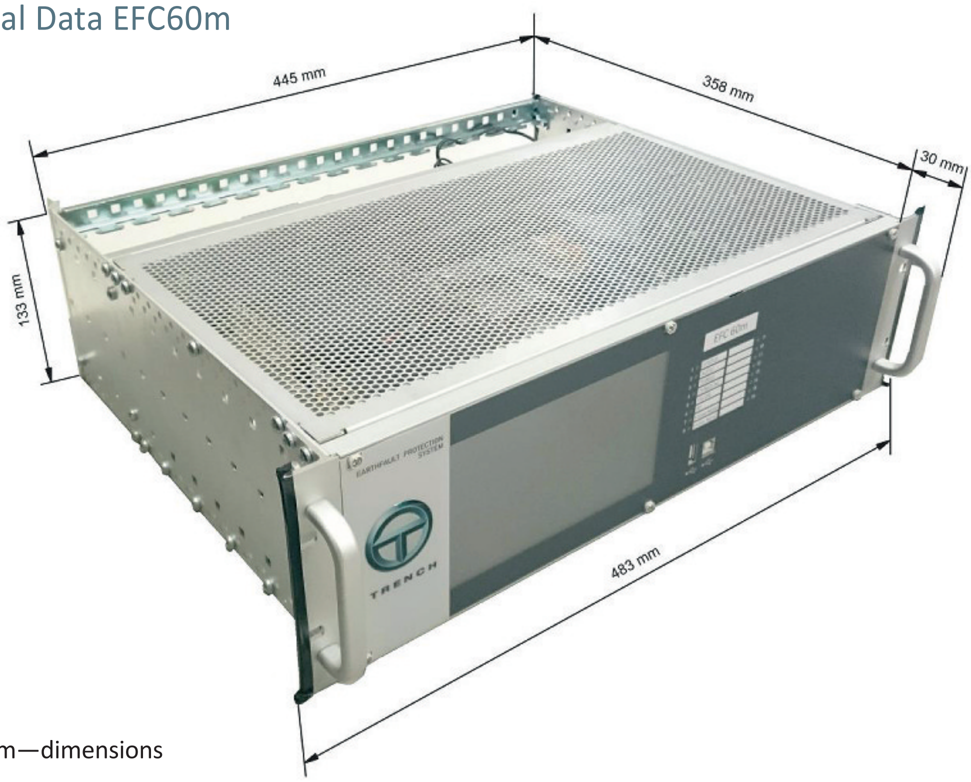

Fig. 9: EFC60m—dimensions

Mechanical Data	
Dimensions	EFC60m Rack Width 483.0 mm Height 133 mm Depth 388 mm (incl. handles) cut-out for front mounting : Width 450 mm, Height 134 mm necessary gap below and above : min. 1 HU (44 mm)
Weight	18 kg
Temperatures	Operation 0°C... +40°C Storage -25°C... +55°C Transport -25°C... +70°C
Max. installation altitude	≦2000m. a.m.s.l.
Humidity (24 h average)	from 5% to 95% acc. IEC 60255-1
Protection class	IP20

Multi-Frequency Current-Injection

The Current Injection Device ECI is used to produce differential measurement values by means of a current injection into the zero-sequence system. The injection components are integrated inside the EF-C60m 19" rack and connected to the control unit. Where a network is essentially symmetrical the neutral-to-ground voltage is extremely low and no specific resonance curve is available. In such case the neutral to ground voltage can be increased by permanent current injection, so that network changes will reliably lead to a trigger of the tuning procedure. (Inverse mode with 50 Hz permanent current injection).

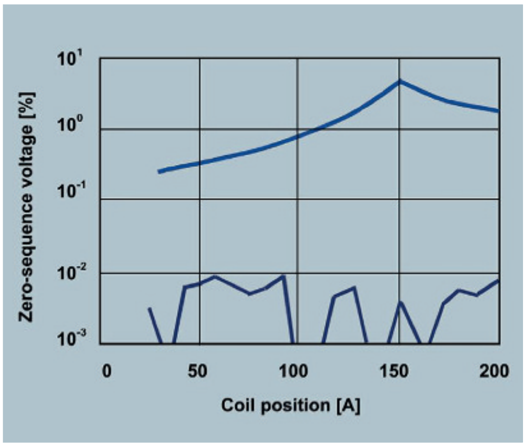

Fig. 10: Inverse mode of current injection

The current is injected into the zero sequence system via a suitably rated power auxiliary winding of the arc suppression coil. The current injection device essentially consists of a current limiting inductance, thyristor and a control unit.

A residual current device (RCD) must not be used in the 230 V AC power supply, because there is no galvanic separation between current injection device and the grounded power auxiliary winding.

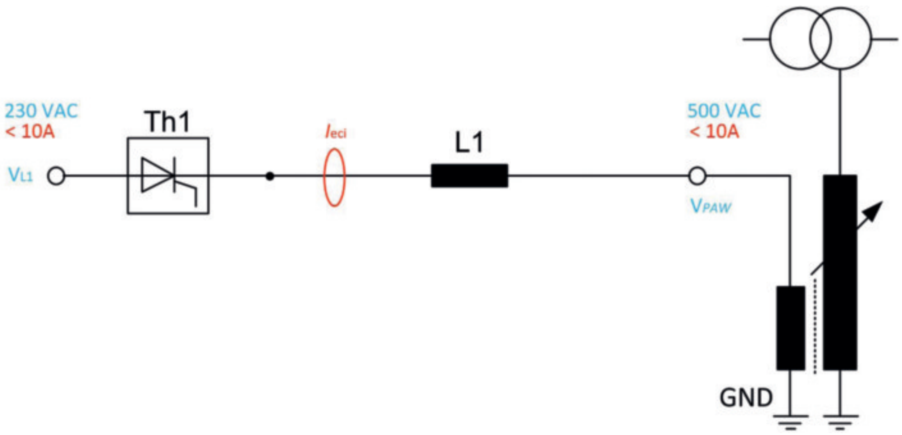

Fig. 11: Multi-frequency current-injection

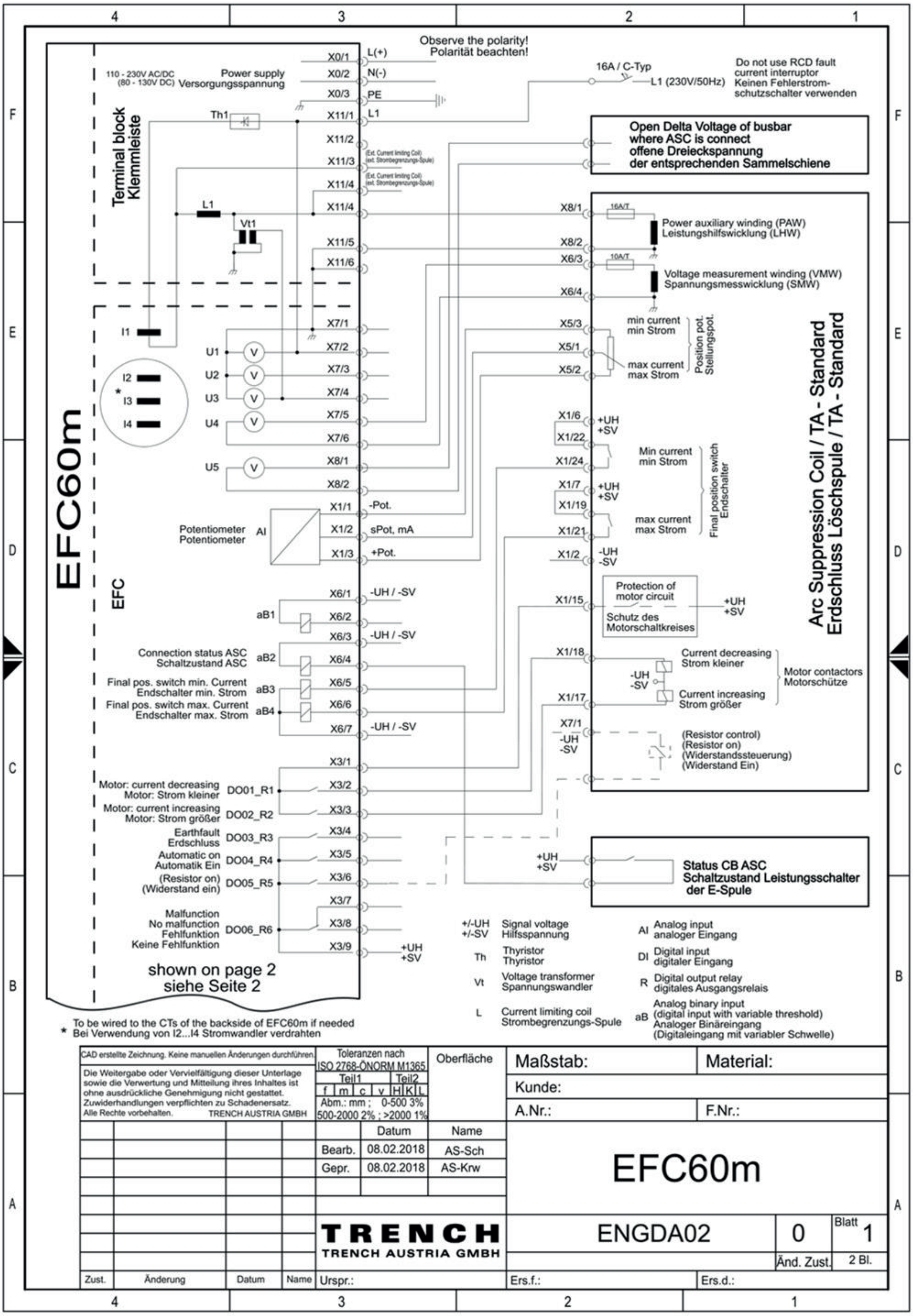

Fig. 12: EFC60m wiring diagram—standard / page 1

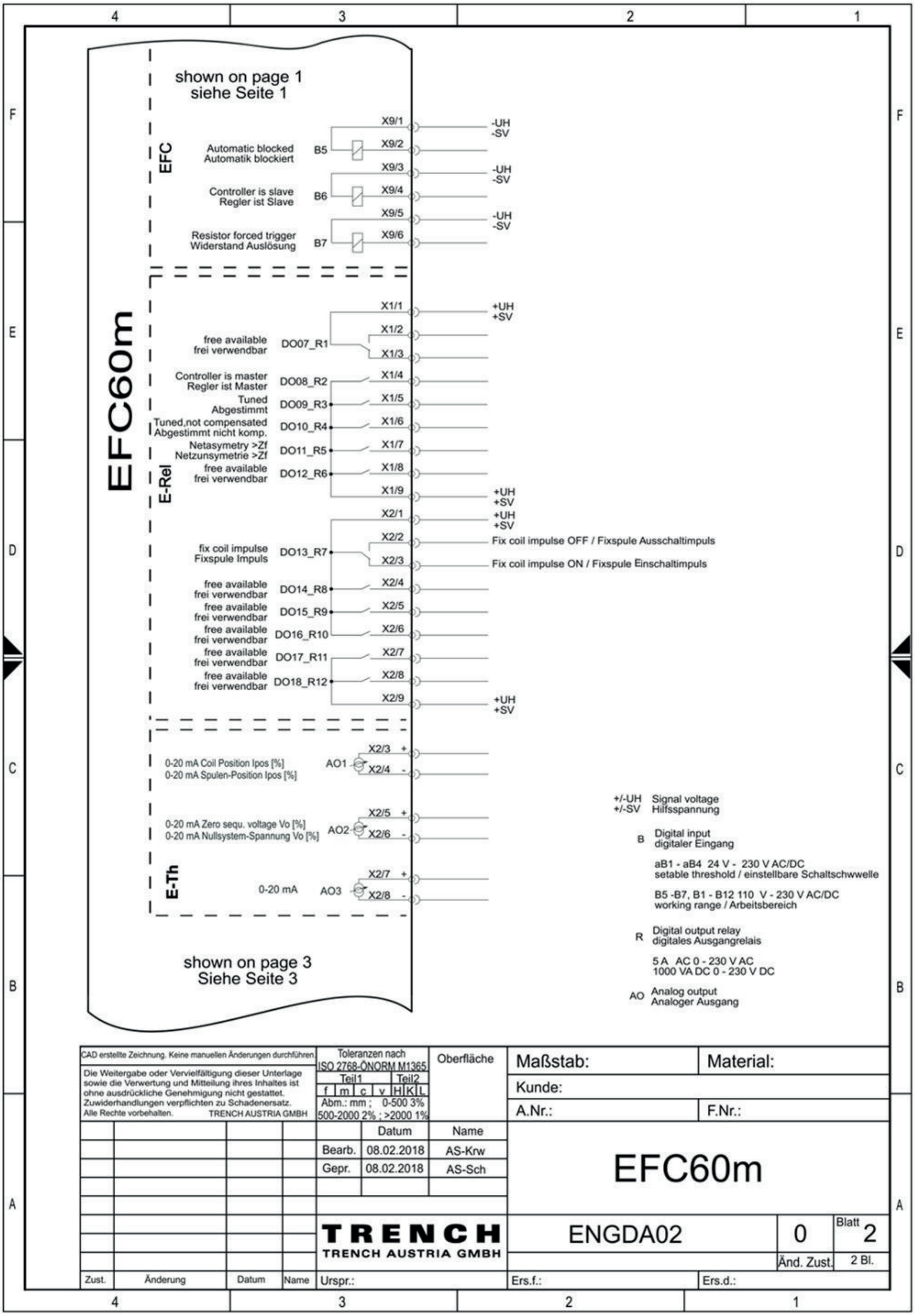

Fig. 13: EFC60m wiring diagram—standard / page 2

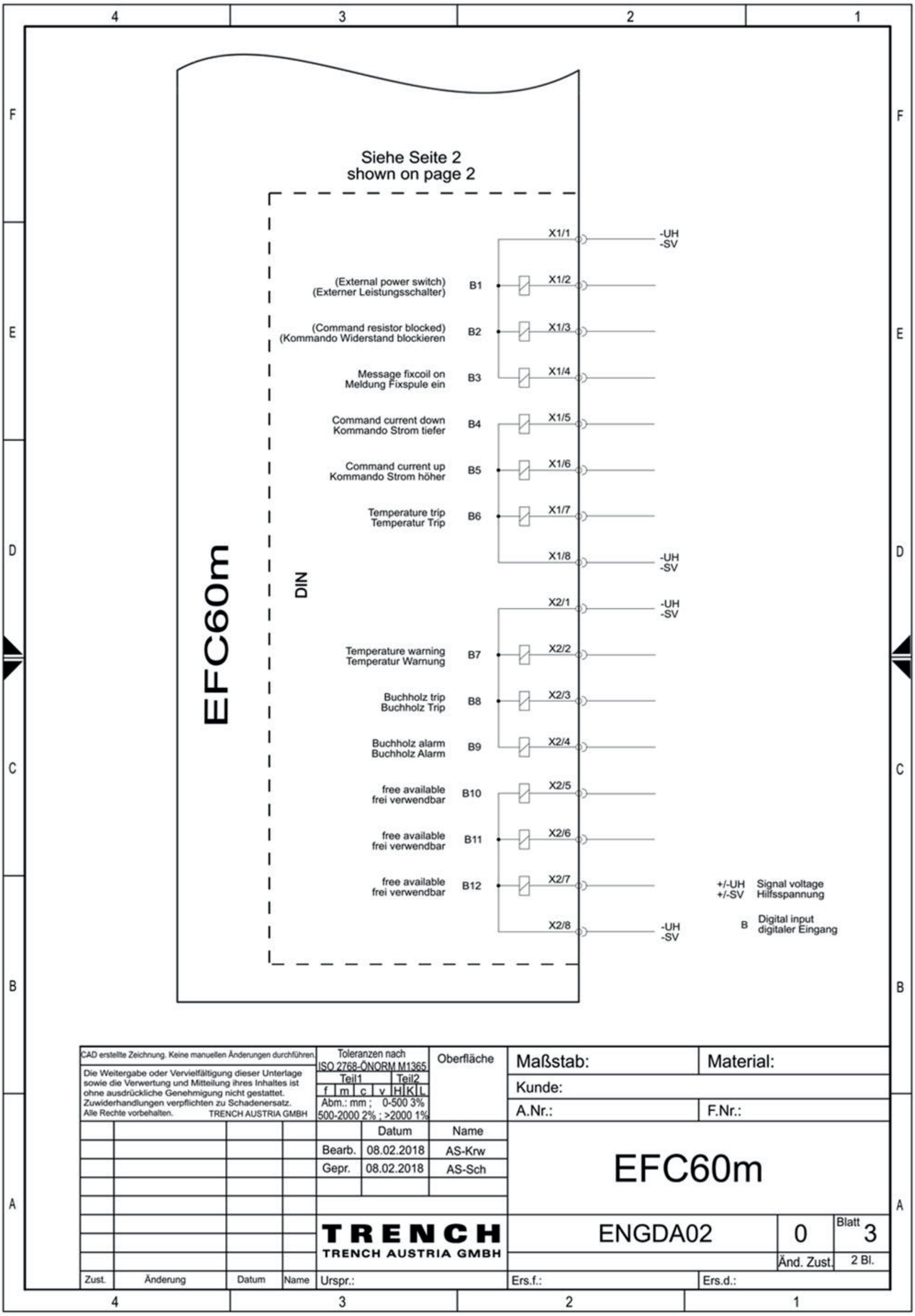

Fig. 14: EFC60m wiring diagram—standard / page 3

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