TRENCH



Neutral Point Treatment with focus on Resonant Earthing

Content

- Neutral Point Treatment
- Resonant Earthing



Earth Fault Protection System EPSY



- Arc Suppression Coils
- Earth Fault Compensation Controller
- Selective Earth Fault Detection

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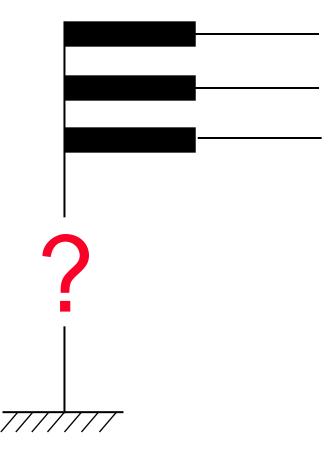


Earth Fault Protection System EPSY



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Neutral Point Treatment



Neutral Point Treatment General

- Neutral Point Treatment affects the operational performance of power grids in the event of asymmetrical faults.
 - Single phase-to-earth faults are the dominating type of failures in distribution systems
 - flashovers on insulators (pollution)
 - flashovers due to overvoltages (lightning, switching operations)
 - ageing of cable insulation
 - physical damage (construction work; falling trees)
- Type of Neutral Point Treatment determines the line-to-earth voltage and the magnitude of the earth fault current The effects are
 - insulation stress (steady-state and transient overvoltages)
 - hazard to human safety (rise of earth potential)
 - stress of earthing devices
 - interference with signalling and communication lines
- Aim of Neutral Point Treatment
 - to limit system overvoltages and overcurrents to safe levels
 - to facilitate failure detection
 - to enable reliable operation with minimum disturbances

Neutral Point Treatment Methods of System Earthing

Choice of Neutral Point Treatment is vital for an economical and reliable supply of electric energy

Main Criteria:

- system voltage level
- network structure, size, operation mode
- expenditure on earthing devices and protection equipment
- failure characteristic
- quality of power supply
- legal aspects (national standards)

Isolated Neutral

star point of transformer not connected to the earthing system or connected via measuring/protection devices with very high impedance

Resonant Earthing

star point of transformer is earthed via an Arc Suppression Coil

Low Impedance Earthing

star point of transformer is earthed solidly or via a current limiting device (resistor or reactor)

Neutral Point Treatment

| isolated S Ci Ci Ci E | compensated XD CL CL CL E | low-ohmic | |
|--|---|------------------------|--|
| I _C | I _{res} | I _{sc} | |
| $f_e = \sqrt{3}$ | $f_e = \sqrt{3}$ | f _e ~ 1-1,4 | |
| arc self extinction | arc self extinction | steady arc | |
| cont. power supply | cont. power supply | immediate interruption | |
| limited to small networks with I _C < 35A | up to a I_C of few hundred A I_{res} < 65A / up to 123 kV | > 123 kV | |

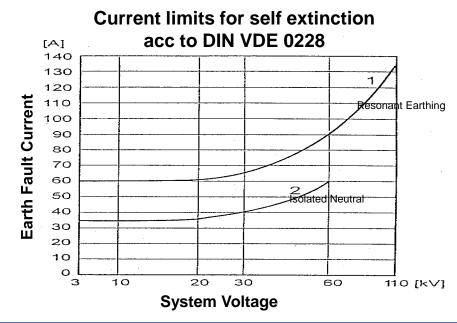
Neutral Point Treatment Extinction of Earth Faults

Most of faults are temporary and are cleared by self extinction of the power arc (depending upon the type of neutral earthing)

Self extinction is possible if the fault current is small enough ⇒ systems with High Impedance Earthing

The extinction of power arcs depends upon

- current magnitude
- recovery voltage rise time
- arcing time, length of the spark gap
- wind velocity



Neutral Point Treatment Equipment Earthing

Metallic parts of electrical equipment must be earthed in order to

- protect the equipment against excessive overvoltages
- limit damage to the material
- limit hazard to the public

Standards specify the max. permissible earth fault voltages

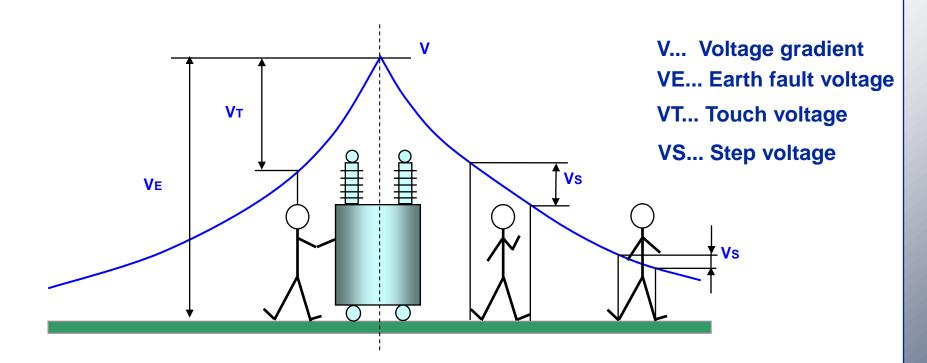
⇒ affect practice of system neutral earthing

$$V_E = I_E . R_E$$

R_E ... Earthing resistance I_F ... Earth fault current

Reduction of excessive voltage level is an economical trade-off between lowering the earthing resistance or decreasing the earth fault current (change to Resonant Earthing, network splitting)

Neutral Point Treatment Hazardous Voltages

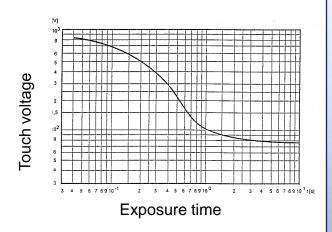


In hazardous incidents only a minor share of the earth fault voltage V_E is applied to a person.

Neutral Point Treatment Touch Voltages

Max. permissible touch voltages are defined in European Harmonic Document HD 637 S1:1999 (CENELEC)

For faults which are cleared within a certain time the max. permissible touch voltages are limited to 80 V (valid for t > 5s).



This requirement is fulfilled by one of the two following assumptions:

- Earthing resistances are considered low enough to prevent dangerous touch voltages (e.g. urban areas or industrial networks with common earthing of MV and LV system)
- If $V_E \le 2 * V_T = 160 V$

If these assumptions are not valid it is possible to fulfil the standards by taking addiditional measures e.g. potential control by means of grounding electrodes.

The max. permissible value for the step voltage is not defined.

Neutral Point Treatment Application Survey

| | Germany [km] | | Austria [km] | | | Total share | |
|--------------------|--------------|---------|--------------|--------|--------|-------------|-----|
| | 10 kV | 20 kV | 30 kV | 10 kV | 20 kV | 30 kV | [%] |
| Isolated | 30 409 | 655 | 1 052 | 2 824 | 249 | 98 | 9 |
| Resonant earthing | 86 779 | 184 097 | 14 110 | 7 851 | 27 884 | 14 348 | 87 |
| Low-ohmic earthing | 11 480 | 3 988 | 11 | 15 | 0 | 0 | 4 |
| Total grid length | 128 668 | 188 740 | 15 173 | 10 690 | 28 133 | 14 446 | 100 |

Neutral point treatment in Germany and Austria *

Resonant earthing is also applied in:

- Scandinavia
- numerous Central European countries
- Eastern Europe

Neutral Point Treatment with focus on Resonant Earthing

Content

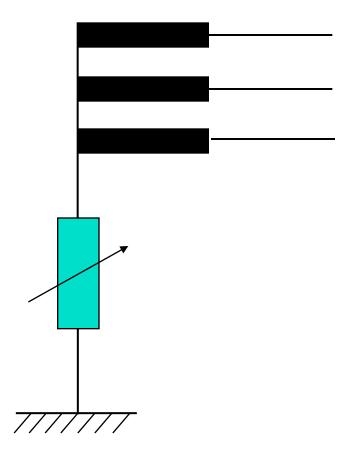
Neutral Point Treatment



- Resonant Earthing
- Earth Fault Protection System EPSY



- Arc Suppression Coils
- Earth Fault Compensation Controller
- Selective Earth Fault Detection



Resonant Earthing General

Inventor

Waldemar Petersen
(System was first applied during 1917
in Ludwigsburg/Germany in a 10 kV network)

Basic idea

To compensate the system's earth capacitance by an equal inductance resulting in a significant decrease of the earth fault current

Equipment

Single-phase, high-impedance reactor (ASC or Petersen coil) connected between system's neutral and earth



Resonant Earthing Features

Auto extinction of arcs

Self clearing of gaseous insulation is considerably enhanced by the delayed rise-time of the recovery voltage (restriking is unlikely)

Continuity of power supply

In case of a permanent earthfault, the system may continue operation without loss of power for the consumers

Human safety

Low fault current minimizes the rise in earth potential

⇒ low step- and touch-voltages

Reduction of damage

At the fault location

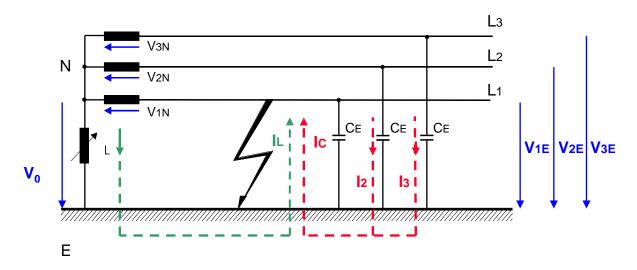
Reduced interference

With adjacent communication or signalling lines

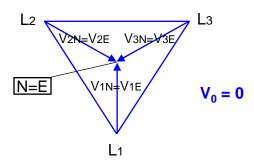
Reduced substation earthing effort

Low cost of earthing equipment

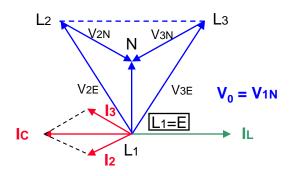
Basics - Theory



Voltages in normal operation



Voltages during earth fault



Resonant Earthing Basics - Features

Under normal operation

The potential of the system's neutral is governed by the asymmetry of the 3 phases to earth.

Assuming a symmetrical network the neutral point potential is equal to earth potential, resulting in a neutral-to-earth voltage of zero.

During earth fault condition

- ⇒ A single line-to-earth fault leads to a potential rise of the neutral point and therefore, also, of the non-affected phases.
- ⇒ The delta line-to-line voltages remain constant.
- ⇒ The sound phases drive currents via the earth capacitances to earth which return into the system at the fault location.
- ⇒ Earth fault current

$$I_C = I_2 + I_3 = 2 \omega C_E \cdot V_{1N} \cdot \sqrt{3 \cdot \cos 30} = 3 \omega C_E V_{1N}$$

Basics - Residual Current

In case of a well tuned network only a small residual earth fault current flows at fault location

$$I_{res} = \sqrt{3} \cdot \omega \cdot C_E \cdot (d + jv) \cdot V_{1N}$$

I_{res} is mainly determined by the degree of damping (d) and detuning (v)

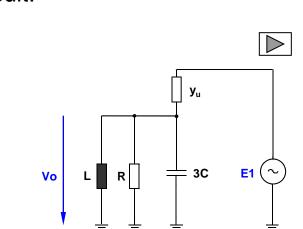
I_{res} originates from losses of :

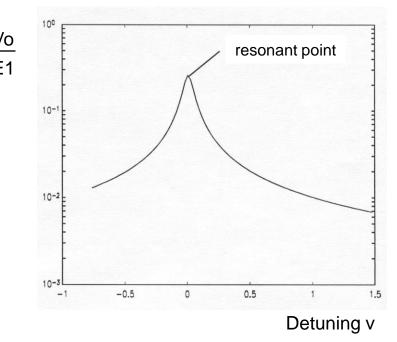
- Line-to-earth conductances
- Earth fault resistance
- Earth return path
- Line resistances
- ASC

The total earth fault current also comprises a certain amount of harmonic currents

Resonance Curve

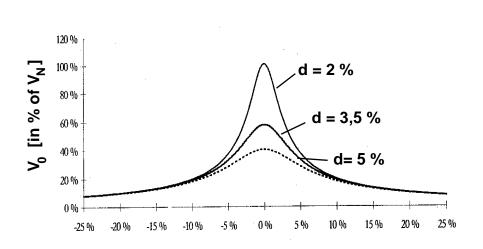
By employing symmetrical components we arrive at the following equivalent circuit:



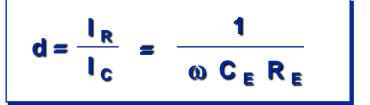


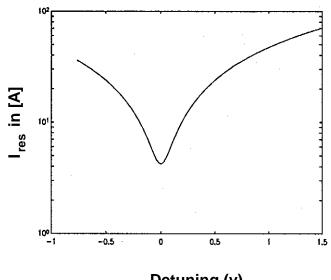
At exact tuning to the resonant point the neutral-to-earth voltage reaches a maximum.

Damping/Detuning



Detuning (v) in %

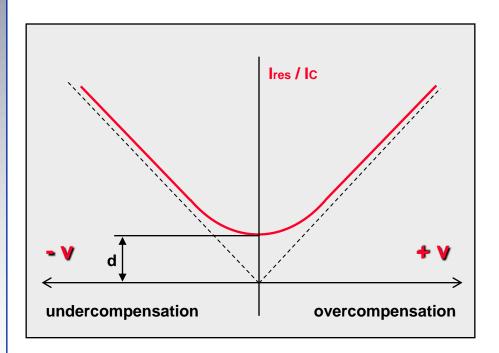




Detuning (v)

$$V = \frac{I_1 - I_C}{I_C} = \frac{1}{\omega^2 L 3C_E} - 1$$

Fault Current



Exact tuning of the ASC to the resonant point (i.e. minimum of the v-curve) means:

- minimisation of the earth-fault current
- improvement of self-extinction of the earth fault arc
- minor damage caused by the arc
- low touch-potential and step voltage

Resonant Earthing Selection of Detuning Degree

Compromise between

- Neutral-to-earth voltage (V₀) under normal operation
 ⇒ max permissable voltage stress of electrical equipment
- residual earth fault current (I_{res}) in case of a single-phase to earth fault \Rightarrow limit for arc-extinction, damage

No general rule due to specific power system configurations

- Resonance Tuning (v = 0) Ideal, as consequental effects of an earth fault can be minimised. Not applicable in networks with high degree of natural asymmetry
- Overcompensation (v > 0) Customary in small, insignificantly meshed networks with untransposed overhead lines and without parallel exposure of metallically seperated systems
- Undercompensation (v < 0) Appropriate in ample and density meshed networks or networks with extended parallel exposure to other systems

Resonant Earthing Earth Fault Events

| Method | Isolated | Compensated by fixed ASC | Compensated by adjustable ASC |
|---|--------------------|--------------------------|-------------------------------|
| Interruptions per year due to earth fault | BB1: 40 BB2: 55 | BB1: 25 (-37 %) | BB2: 22 (-60 %) |
| Successful self-extinction of arcs | | BB1: ~ 50 % | BB2: ~ 80 % |

20 kV Substation in Italy

Busbar 1: $I_C = 170 A$

Busbar 2: $I_C = 130 A$

Resonant Earthing Comparison

100 % Earthfaults



Isolated system

- high fault current
- reduced self-extinction
- power interruptions

Compensated System

- 70 ... 80 % transient faults
 - ⇒ self-extinction by the ASC
 - low fault current
 - delayed recovery of phase-to-earth voltage
- 20 ... 30 % steady faults
 - ⇒ low fault current
 - increased human safety
 - reduced damage
 - reduced interference
 - reduced earthing effort
- cont. power supply possible

Resonant Earthing Benefits



- Human safety: Low fault current minimises the rise in earth potential - low step and touch voltages
- Possible continuity of power supply during a single phase-to-earth fault
- The delta-voltage remains constant for the consumers
- Self-extinguishing of arcs due to the delayed recovery of the phase-to-earth voltage
- Reduction of damage at the fault location
- Reduction of interferences with other ground-bound wires or cables
- Reduced substation earthing effort compared with isolated networks

Neutral Point Treatment with focus on

Resonant Earthing Content

Neutral Point Treatment



Resonant Earthing



- Earth Fault Protection System EPSY
 - Arc Suppression Coils
 - **Earth Fault Compensation Controller**

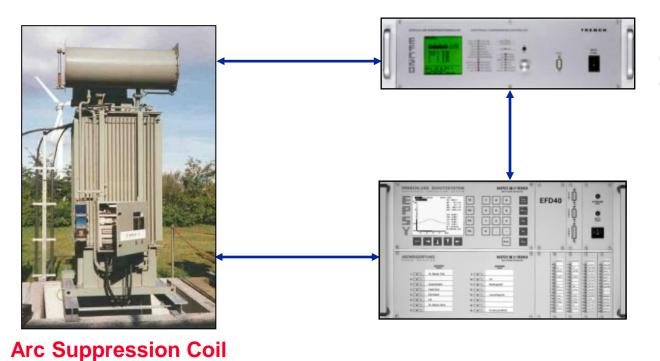


Selective Earth Fault Detection



EPSY - Earth Fault Protection System

System Components



Earth Fault Compensation Controller

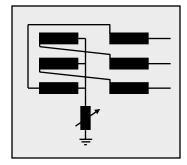
Earth Fault Detection



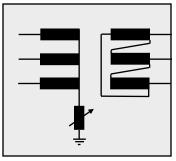
Arc Suppression Coils Connection of Arc Suppression Coils

ASC's are connected between the neutral of a transformer and earth. The selection of the transformers is made with regard to :

- zero- sequence impedance (Z₀ <<)
- thermal capability for the additional load of the neutral current
- Suitable transformer types
 - ⇒ transformer in Star-Zigzag configuration
 - ⇒ transformer in Star-Delta configuration (Ynd or Dyn)
 - ⇒ transformer in Star-Star configuration with compensating winding (rated for 33% of the transformer power rating)
- Insuitable transformer types
 - transformers in Star-Star configuration without compensating winding
 - ⇒ shell type transformers
 - ⇒ five limb transformers



Star-Zigzag



Star-Delta

In the absence of power transformers with suitable capacity or available neutral point a separate earthing transformer (ZN-configuration) must be provided for the connection of the ASC.

Arc Suppression Coils Design Requirements

Adjustability

The system phase-to-earth capacitances vary due to

- line switching operations
- network enlargement
- environmental conditions

To compensate the earth-fault current at any system condition the ASC must be adjustable in an adequately wide range.

Saturation Characteristic

The VI-characteristic of an ASC should be linear within nominal voltage variations.

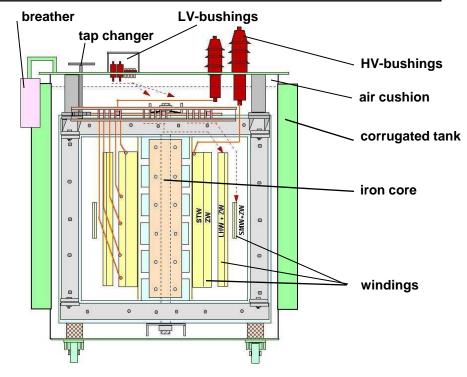
For voltages exceeding the system's phase to earth voltage an ASC should saturate (overvoltage limitation)

IRON CORE REACTOR

Step Adjustable Coil

| Power rating | 100 kVAr - 31500 kVAr |
|------------------|---------------------------|
| Voltage level | 3.6 / √3 kV - 145 / √3 kV |
| Adjustment range | 1: 2.5 (in 5 or 7 steps) |

- Series layer winding (copper wire)
- Multiple subdivided iron core with unmagnetic spacers
- Tapped winding to accomplish the regulation of current
- Off-load tap changer
- Oil-filled corrugated steel tank with air cushion or with oil conservator



Arc Suppression Coils Step Adjustable Coil



Advantages of Stepless Adjustable Coils Continuous current regulation

- - enables exact tuning
 - minimizes the residual current
- Wide current regulating range (1:10 / 1:12.5)
 - to allow for line switching operations
 - to cater for future network enlargements
- Adjustment in during on-load condition
 - the system's neutral is permanently earthed
- Simple and reliable reactor design
 - no switches in the HV-path
 - no system disturbances due to switching operations
- Constant magnetic flux density within the current regulating range
 - suppression of overvoltages
- Ease of current setting
 - reactor adjustment by motor drive
 - automatically tunable



Trench Austria - Available Designs

Trench Austria's Arc Suppression Coils are usually oil-immersed, stepless adjustable and motordriven

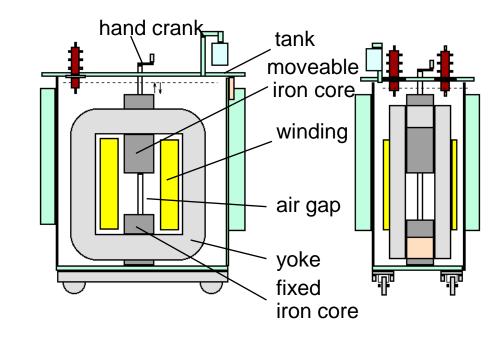
Constructional features:

| Installation | indoor / outdoor |
|--------------------|--|
| Duty | Continuous / short time (2h) |
| Thermal class | A according EN 60289 |
| Cooling method | ONAN (self cooling) |
| Dielectric liquid | mineral oil, PCB free, naphtenic basis |
| Voltage range | 3.6 / √3 kV - 145 / √3 kV |
| Power rating | 160 kVAr - 35 000 kVAr |
| Design types | - sliding core ASC - plunger core ASC (Trench Standard) - plunger core ASC (Conventional design) |
| Current regulating | 1:5 / 1:10 / 1:12.5 |
| range | |

Sliding Core ASC

| Power rating | 160 kVAr - 1250 kVAr |
|------------------|---|
| Voltage level | $3.6 / \sqrt{3} \text{ kV} - 24 / \sqrt{3} \text{ kV}$ |
| Adjustment range | 1:5 (manually adjustable, optional motor drive available) |

- Series layer winding (copper wire), resin impregnated
- one moveable core (at top), one fixed core (at bottom)
- rectangular shaped cores made of laminated steel
- toroidal wound yokes
- oil-filled corrugated steel tank with air cushion



TRENCH

Arc Suppression Coils

Sliding Core ASC



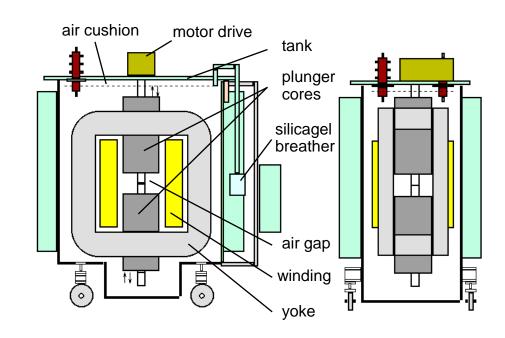




Plunger Core ASC (Trench Austria Standard)

| Power rating | 400 kVAr - 8000 kVAr |
|---------------|--|
| Voltage level | $3.6 / \sqrt{3} \text{ kV} - 36 / \sqrt{3} \text{ kV}$ |
| | 1:10 (1:12.5) (with motor drive) |

- Magnetic circuit (state-of-theart, flux optimized geometry)
 - twin-core design (linearity, no axial forces)
 - two toroidal wound yokes
- Winding
 - several series connected layers
 - copper wires
 - resin impregnated
- Inductance variation by rotation of a centrally arranged spindle by a motor drive unit
- Oil-filled corrugated steel tank with air cushion
- Dehydrating silicagel breather





Plunger Core ASC (Conventional Design)

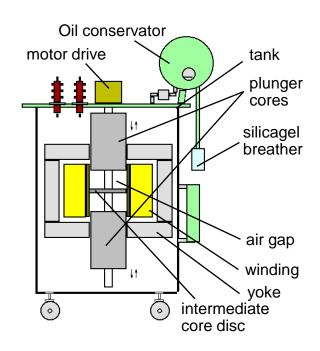
| Power rating | 1600 kVAr - 35000 kVAr |
|------------------|----------------------------------|
| Voltage level | 3.6 / √3 kV - 145 / √3 kV |
| Adjustment range | 1:10 (1:12.5) (with motor drive) |

Magnetic circuit

- twin-core design the magnetic flux is symmetrised with the midplane of the winding no axial forces between core and winding
- intermediate core disc improvement of flux distribution mechanical support of the spindle
- 4-6 C-shaped yokes distributed uniformly around the plunger cores and the winding

Winding

- several series connected layers
- subdivided copper conductor (transposed bundle)
- Inductance variation by rotation of a centrally arranged spindle by a motor drive unit (plunger cores approach or seperate)
- Oil-filled steel tank with detachable oil conservator and flanged radiators (cont. duty)
- Various protection and monitoring equipment



Plunger Core ASC





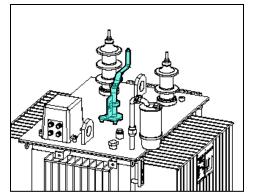
Plunger Core ASC







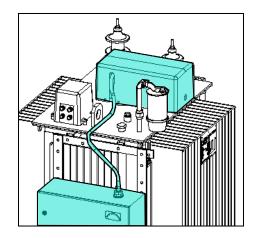
- manually, during off voltage condition
- manually, during on-load condition (precondition: plug in connectors)
- for the low power range (160 kVAr -1250 kVAr)

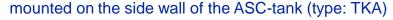


Motor drive unit

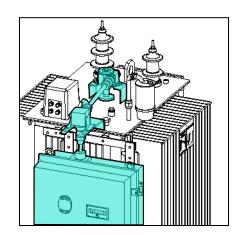
mounted on top of the ASC-tank (type: DMA2)

- direct drive via contrate worm gear
- mechanical position indication
 via flexible shaft in the control cabinet
- for the moderate power range (160 kVAr - 6300 kVAr)

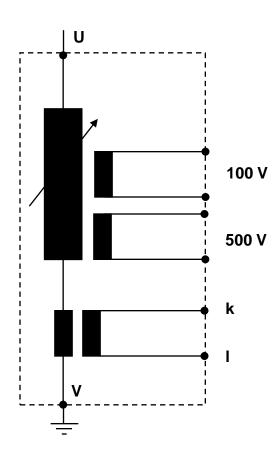




- indirect drive via worm- and angular gear
- mechanical position indication via toothed belt in the motor drive cabinet
- for the entire power range (400 kVAr 35000 kVAr)



Measuring Devices



Voltage Measuring Winding

standard rating: 100 / 110 V, 3 A for connection to indication / monitoring devices such as:

- voltmeter
- earth fault signalization
- earth fault relays
- earth fault compensation controller (EFC)

Power Auxiliary Winding (PAW)

standard rating: 500 V, 5% of ASC power rating, 30s duty, for earth fault detection purposes and for connection to

- low voltage resistor
- current injection device (ECI)

Current Transformer

standard rating: x/5 (1) A, 15 VA, class 1, for earth fault current measurement

Shunt Resistor

Principle

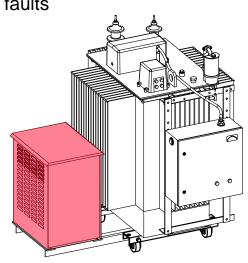
- ⇒ for earth fault detection relays based on the artificial increase
 of the active component of the residual earth fault current
- ⇒ after persistance of the fault for a pre-determined time, an ohmic resistance is connected via the PAW into the neutral circuit
- ⇒ the increased residual current allows improved operation of wattmetric relays during low-ohmic earth faults

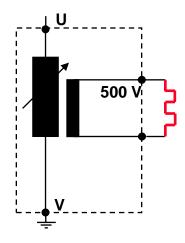
Design

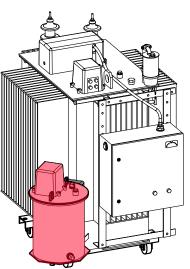
- ⇒ air cooled, low inductance resistor
- ⇒ in stainless steel enclosure
- ⇒ protection class IP23
- ⇒ built-on to the ASC underbase
- ⇒ connected to the 500 V PAW
- ⇒ including contactor
- ⇒ with thermal overload protection

⇒ Options:

- oil-immersed design
- resistor control







Standard Equipment

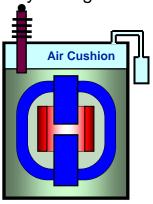
- oil-filled, corrugated steel tank
- with air cushion (no oil-conservator)
- motor drive on top of tank
- underbase with bi-directional rollers or skids
- porcelain shedded bushings acc DIN
- caps over LV-bushings
- voltage measuring winding
- secondary winding (PAW)
- oil gauge without indicating contacts
- thermometer pocket
- dehydrating silicagel breather
- oil filling mineral oil, type Technol 2002
- surface treatment pickled with multiple coating (RAL 7033)

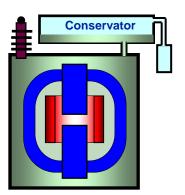
Optional Equipment

- Steel tank with detachable oil conservator
- Buchholz relay
- oil level gauge with indicating contacts
- minimum oil level indicator
- plug-in connections
- protective caps for bushings
- different motor drive models
- current transformer
- surge arrester
- various monitoring devices
- surface treatment
 - Hot/spray galvanized
 - Paint/colour acc to customers specification

Oil Preservation System
In normal operation the potential of the neutral is almost equal to that of the earth potential (very low neutral-to-earth voltage).

Only during solid earthfaults the potential rises to full phase-to-earth voltage.





ASC-E 0590

- ASC are devices having short loading duration and therefore predominantly low oil temperature over the whole of its life-time.
- Since the ingress of oxygen into the oil is decelerated at low temperatures, the thermal ageing of the insulating oil is reduced.
- Therefore large surface contact between air/oil is not critical.

Two types of open oil preservation systems are utilized:

- Freely breathing system (air cushion) free exchange between ambient air and an air-filled expansion space above the oil surface within the tank
- **Conservator system** free exchange between ambient air and an air-filled expansion space above the oil surface in a seperate expansion vessel

Usually a silicagel breather is fitted into the connection to the atmosphere to prevent the ingress of moisture into the oil.

Special ASC Designs

Sliding Core ASC

- TA special version of a continous adjustable plunger core ASC
- for low power ratings (max 1250 kVAr)
- manual adjustment
- limited current regulation range (1:5)

Fixed Core ASC

- similar design to a step coil (without tappings)
- compensation of invariable network sections (radial lines)

Dry-type Plunger Core ASC

- design of the active part similar to an oil-immersed type
- winding dry-insulated, resin impregnated and air-self cooled
- installation in fire hazardous areas (mines, chemical plants)
- power rating limited to 1250 kVAr and voltage level up to 10 kV

combination of an earthing transformer and an ASC in a common oil-filled tank

Tests on ASC

In general according to EN 60289 (VDE0532)/1994, IEC 289/1988 or other equivalent standards

Routine Tests

- measurement of winding resistance (DC-resistance)
- measurement of current over the whole adjustment range (variable inductance)
- measurement of losses
- measurement of voltage ratio between main winding and auxiliary and secondary windings
- seperate-source power frequency voltage test (for the earth terminal of the main winding in case of non-uniform insulation)
- induced overvoltage test
- operation tests on air gap variation mechanism (motor drive, tap-changer)

Type Tests

- temperature-rise test
- lightning impulse test

Special Tests

- measurement of voltage-current characteristic up to 1.1 times rated voltage
- measurement of acoustic sound level
- further tests on customer's request

Neutral Point Treatment with focus on Resonant Earthing

Content

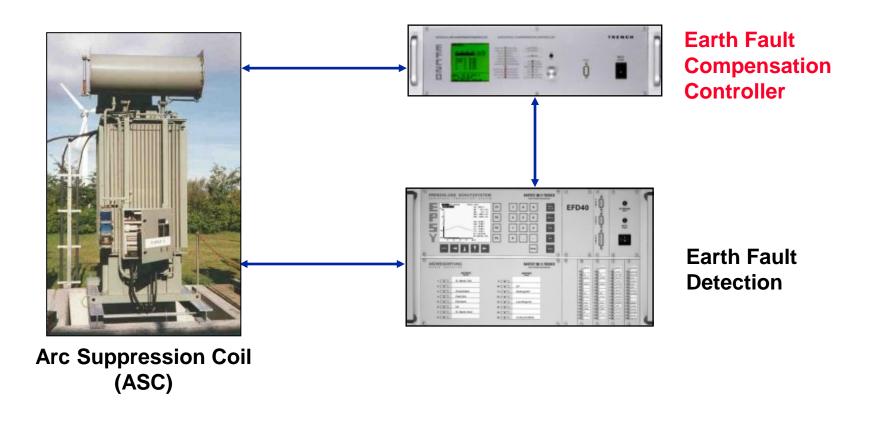
- Neutral Point Treatment
- Resonant Earthing
- Earth Fault Protection System EPSY



- Arc Suppression Coils
- Earth Fault Compensation Controller
- Selective Earth Fault Detection

EPSY - Earth Fault Protection System

System Components



Earth Fault Compensation Controller Different Tuning Methods

Calculation of network-parameters from cable-data

unusual

Grounding of one phase in the substation and tuning of the ASC until the earth fault current becomes a mimimum

unusual

Determination of the resonance curve in a sound network by searching for the maximum-point of the resonance curve

previous systems

Determination of the resonance curve in a sound network by calculation of the network-parameters by a small variation of the tuning

EFC20

Determination of the resonance curve in a sound network by a current injection for improved calculation of the network-parameters (impedance measurement)

EFC20i

EECON Easturas



Earth Fault Compensation Controller

- Automatic control of stepless adjustable ASCs
- ⇒ Operates at low zero sequence voltage V₀ (min 0.3%)
- Faster tuning due to parameter estimation

- Monitoring of network parameters (data recording function)
- Visualisation of digital outputs via LEDs at front panel
- Highly flexible adjustment to the HV-network conditions by easy setting of controller parameter

EECON Easturas



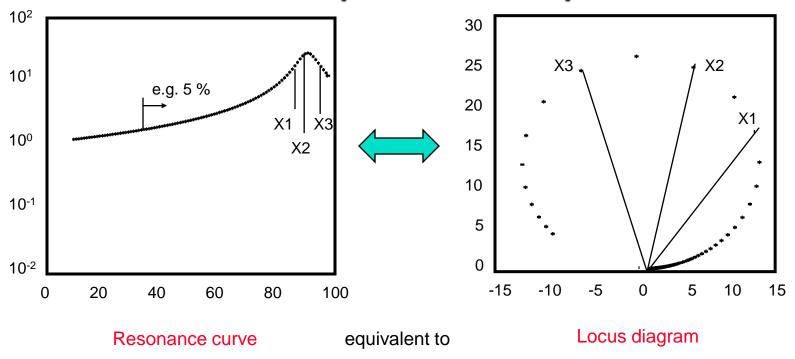
Earth Fault Compensation Controller

- Easy to use with LCDdisplay, scroll wheel and choice of different languages in menu text
- ⇒ Central registration of alarm- and fault notifications of the ASC and visualization by means of LEDs at the front panel
- Software update via serial interface

- ⇒ Additional functions:
 - Control back to ideal compensation (v=0) if an earthfault occurs
 - SCADA (SPAbus, IEC)
 - Several controllers within the same net
 - Adjusting the ASC to a predefined value
 - Automatic resistor control
 - Control of an additional fixcoil
 - automatic switching if U exeeds Umax
- Remote control



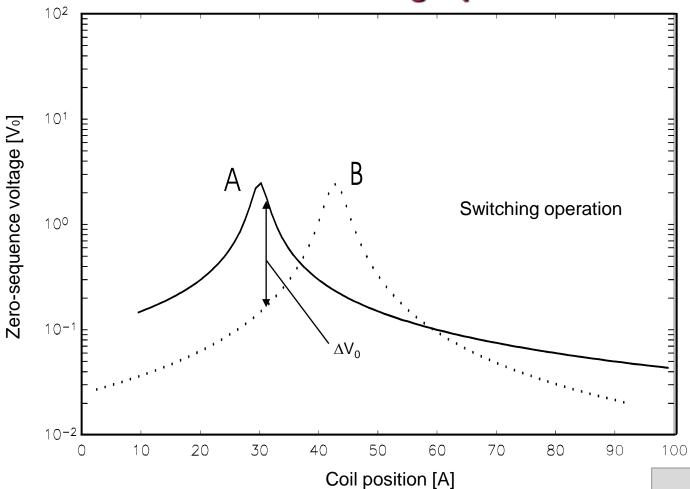
EFC20 Operation Principle



- Calculation of the resonance curve by a small variation of the ASC-tuning
- At very low zero-sequence voltages an additional calculation algorithm is activated

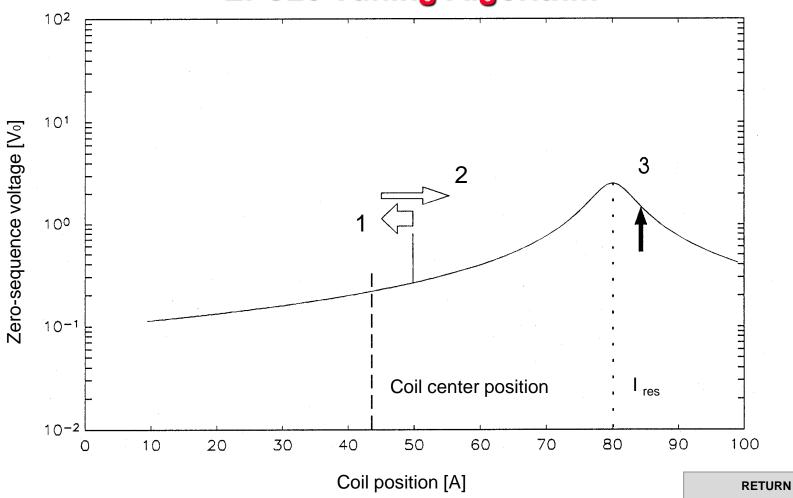
Switching Operation Tuning Algorithm Very Low Vo

Earth Fault Compensation Controller EFC20 Switching Operation

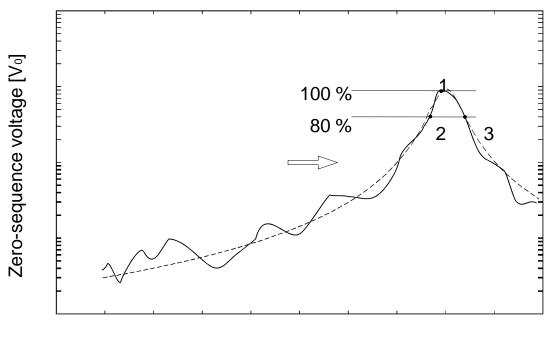


RETURN





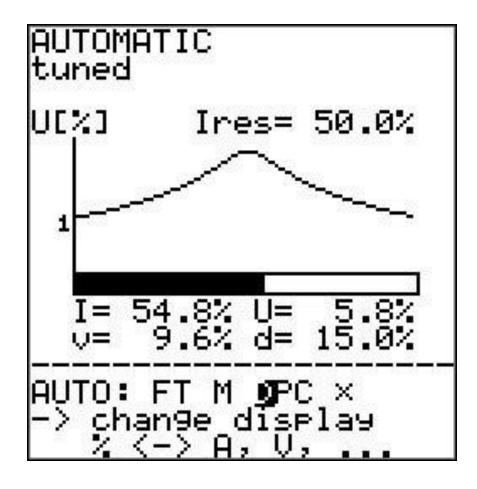
EFC20 - Very Low Zero-Sequence Voltage



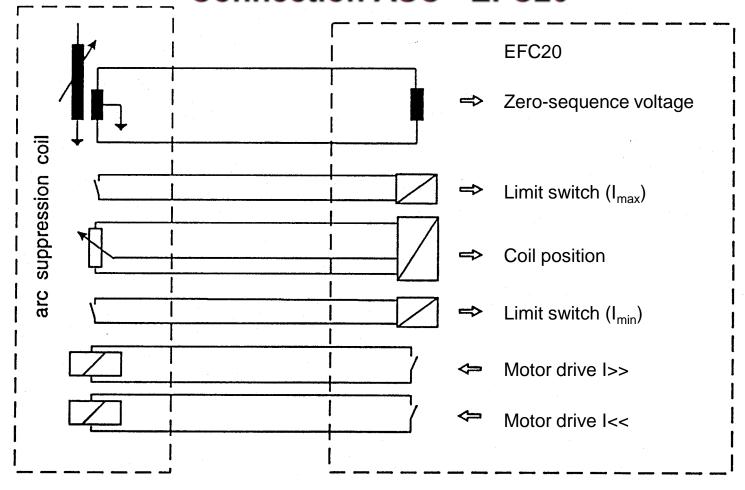
Coil position [A]

RETURN

Earth Fault Compensation Controller EFC20 - Display

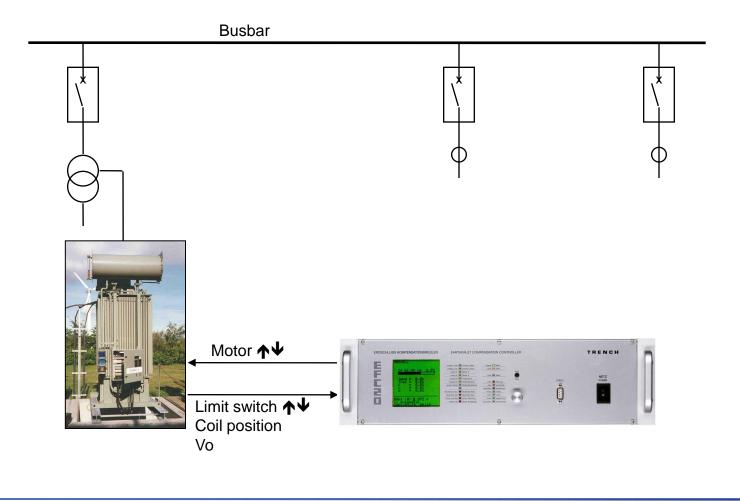


Earth Fault Compensation Controller Connection ASC - EFC20



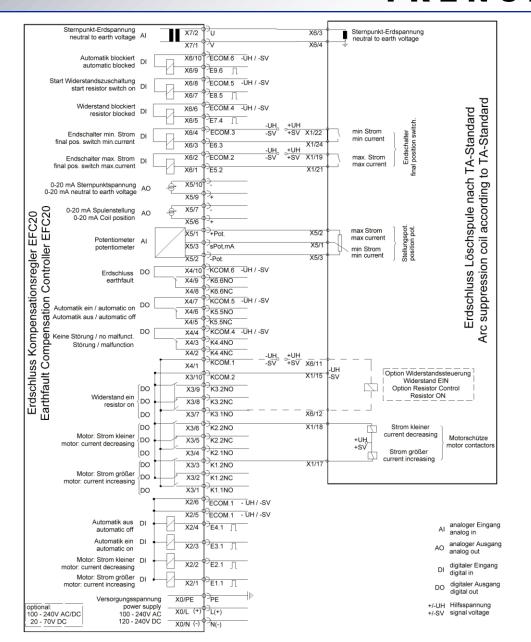
Connection Diagram

Earth Fault Compensation Controller Connection ASC - EFC20



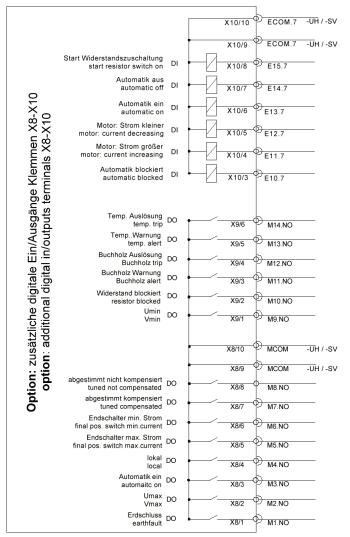
TRENCH

Earth Fault
Compensation
Controller
EFC20 - Connection
Diagram - Standard



TRENCH

Earth Fault
Compensation
Controller
EFC20 - Connection
Diagram - Option



Al analog in

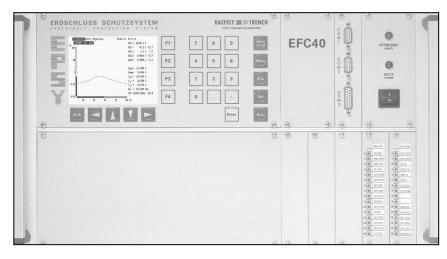
AO analog out

DI digital in

DO digital out

+/-SV signal voltage

Earth Fault Compensation Controller EFC40 Additional Features/Benefits

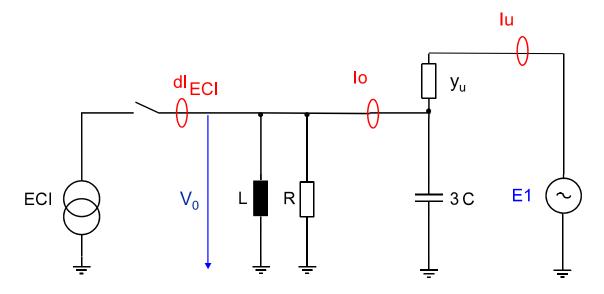


Earth Fault Compensation Controller

Extended methods for the determination of network parameters:

- ⇒ No detuning for the calculation needed
- ⇒ Reliable operation also at lowest zero-sequence voltages V₀
- ⇒ Very fast calculation
- ⇒ Easy to upgrade with earthfault detection

Earth Fault Compensation Controller EFC40 Operation Principle



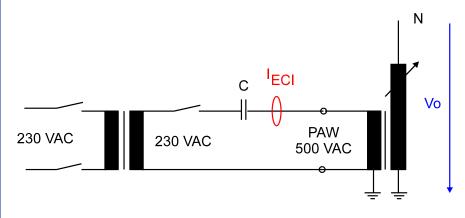
Modification of the zero-sequence voltage by a current injection (ECI):

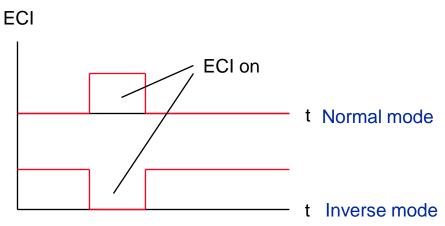
Impedance measurement of the resonance circuit
Separation into real- and imaginary-components

$$Z_0 = \frac{dV_0}{dI_{ECI}}$$

Calculation of the resonance curve

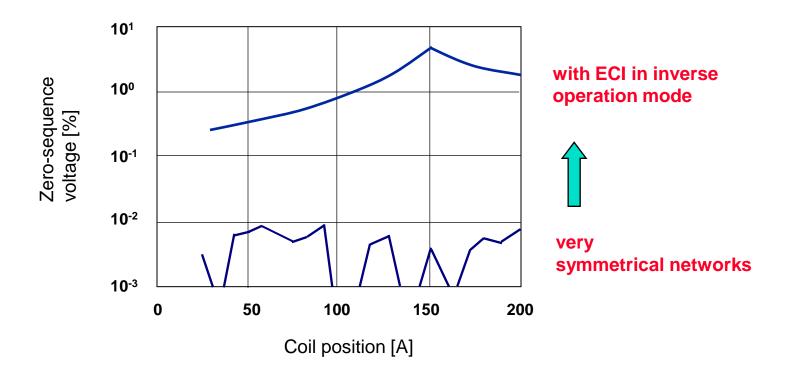
Earth Fault Compensation Controller ECI - Current Injection





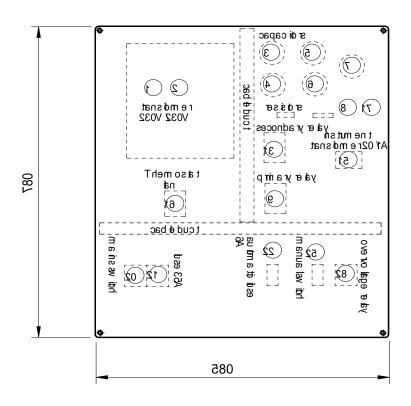
- Current injection via the PAW (or voltage measurement winding or auxilliary transformer)
- No change of the coil position for calculation
- Very fast calculation (2...3 s)
- Also enables trigger-signal and therefore reliable operation in very symmetrical networks
- Inverse operation mode possible
- Simple design (only LV-components)
- Minor power losses

Earth Fault Compensation Controller ECI - Symmetrical Networks

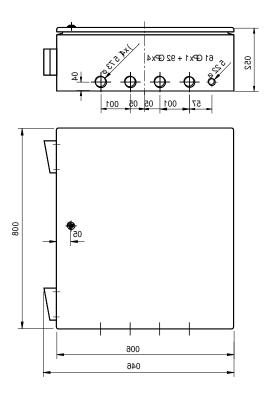




Earth Fault Compensation Controller ECI - Dimensions

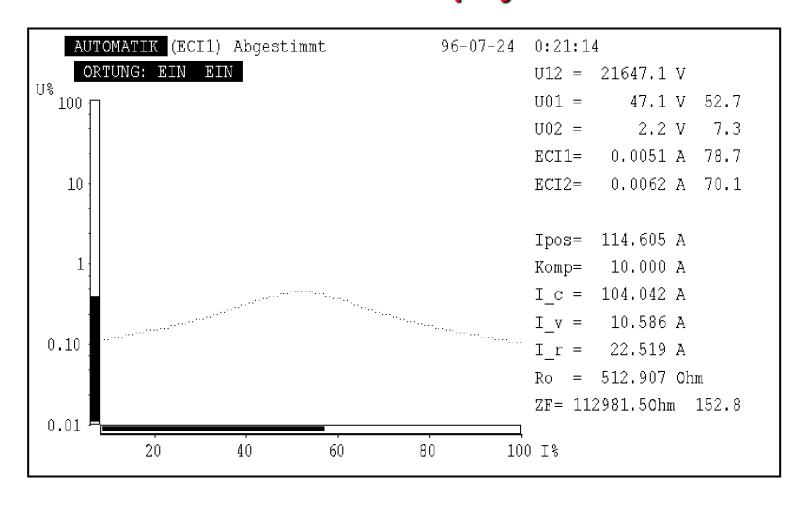


Mounting plates (indoors)



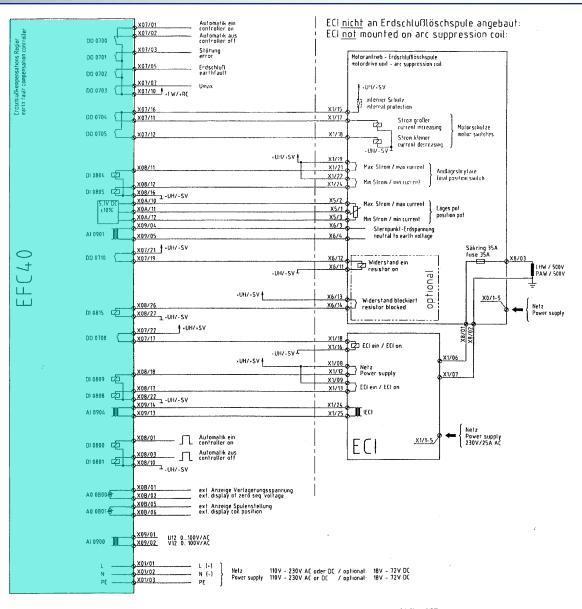
With cubicle (indoors - outdoors)

Earth Fault Compensation Controller EFC40 Display



TRENCH

Earth Fault
Compensation
Controller
EFC40 - Connection
Diagram



UH/SV Hillsspannung / Signal Voltage (24-230V AC/DC) FW/RC . Fernvirkspannung / Remote control

Earth Fault Compensation Controller EFC20i Additional Features/Benefits

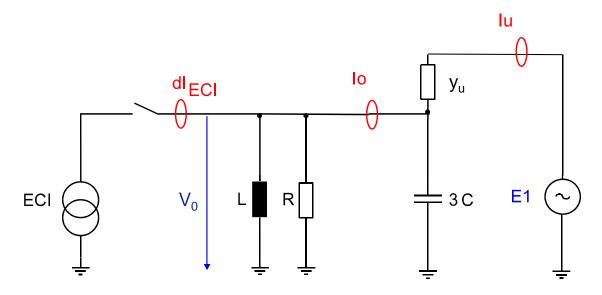


Earth Fault Compensation Controller

Extended methods for the determination of network parameters:

- No detuning for the calculation needed
- ⇒ Reliable operation also at lowest zero-sequence voltages V₀
- ⇒ Very fast calculation
- If current injection line is interrupted an additional calculation algorithm will be activated
- New developed Current Injection Device 19⁻′-rack mounted (3HU)

Earth Fault Compensation Controller EFC20i Operation Principle



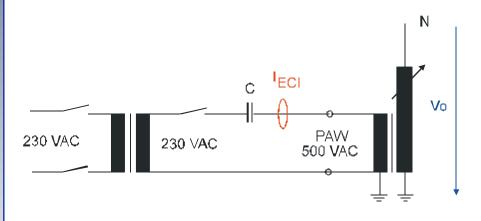
Modification of the zero-sequence voltage by a current injection (ECI):

Impedance measurement of the resonance circuit
Separation into real- and imaginary-components

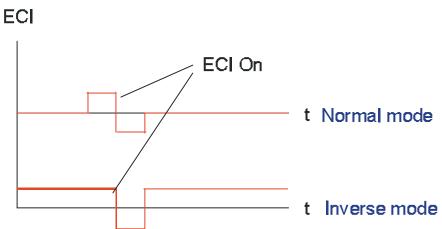
$$Z_0 = \frac{dV_0}{dI_{ECI}}$$

Calculation of the resonance curve

Earth Fault Compensation Controller ECI - Current Injection



- Current injection via the PAW (or voltage measurement winding or auxilliary transformer)
- No change of the coil position for calculation
- Very fast calculation (2...3 s)

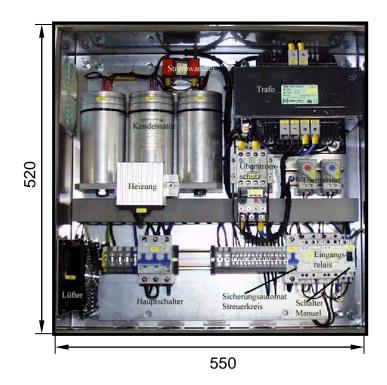


- Also enables trigger-signal and therefore reliable operation in very symmetrical networks
- Inverse operation mode possible
- 19´´-rack mounted, turning pole circuit
- Direction of current injection automatically controlled

TRENCH

Earth Fault Compensation Controller ECI - Dimensions





19´´-rack mounted / turning pole circuit

Conventional design (indoor, outdoor, mounting plate)

Neutral Point Treatment with focus on Resonant Earthing

Content

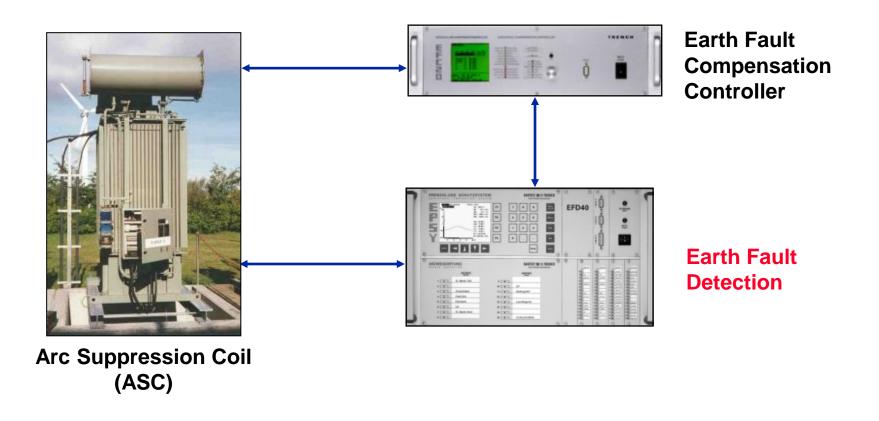
- Neutral Point Treatment
- Resonant Earthing
- Earth Fault Protection System EPSY



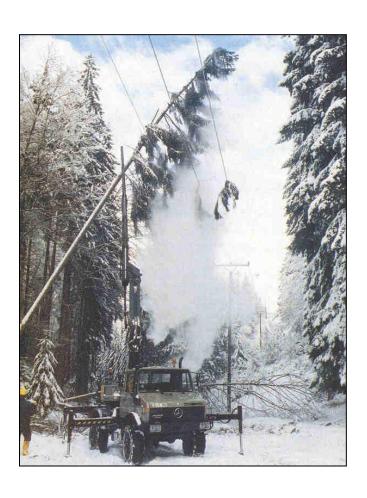
- Arc Suppression Coils
- Earth Fault Compensation Controller
- Selective Earth Fault Detection

EPSY - Earth Fault Protection System

System Components



Selective Earth Fault Detection General Requirements

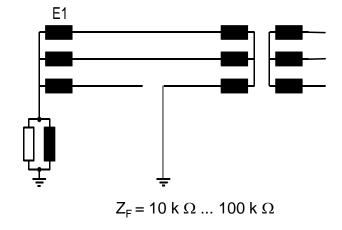


- ⇒ Legal requirements
- Selective and reliable detection of the faulty feeder
- Detection of low and high ohmic earthfaults
- ⇒ Detection of restriking earth faults
- ⇒ Determination of the faulty section on the line

Selective Earth Fault Detection Practical Faults

| | | i |
|------------------------|--------------------|-----|
| Fault type | Typical resistance | EFD |
| Metallic earth fault | 0 100 Ω | |
| Low ohmic earth fault | 0.1 k Ω 1 k Ω | |
| Line on ground or snow | few k Ω | |
| Restriking earth fault | Ω 100 k Ω | |
| Line in tree | 1 100 k Ω | |
| Reverse earth fault | 10 k Ω 100 k Ω | |

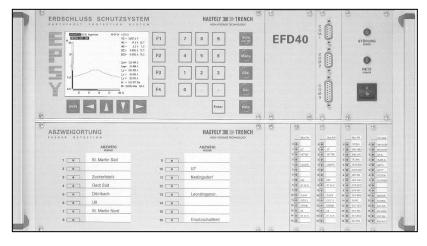




Traditional Relays

Selective Earth Fault Detection EFD10/40

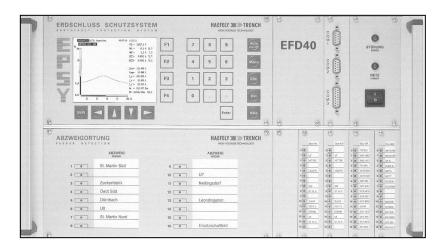
Features



Earth Fault Detection

- Earth fault detection up to a few 10 kOhm (network dependent)
- Based on the admittance method
- Comparing measurement-principle
- Monitoring of network parameters (data recording function)
- Analysis function (oscilloscope, FFT)
- Highly flexible adjustment to the HV-network conditions by easy setting of parameters

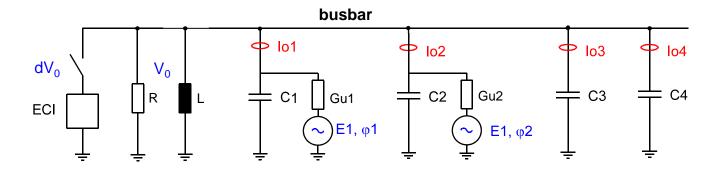
Selective Earth Fault Detection EFD10/40 Features

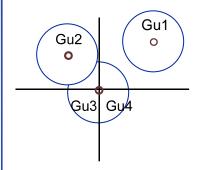


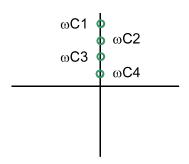
Earth Fault Detection

- Remote control
- Meets electromagnetic compatibility (EMC) requirements
- Options
 - Earth fault distance measurement (polygon method)
 - serial interface (connection to a PC, modem or SCADA-system) incl. Windows terminal program
 - SCADA implementation

Selective Earth Fault Detection Admittance Method Sound Network





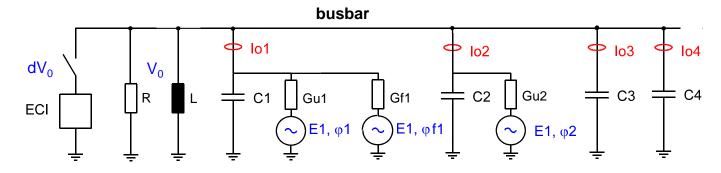


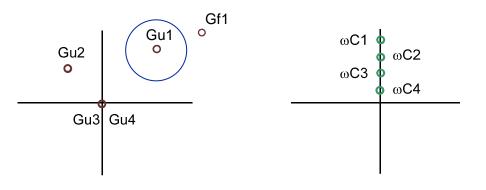
- Reference values of the natural asymmetry and the line to earth capacitance are measured with the help of the current injection device (ECI)
- Monitoring of these values continuously without current injection

Natural asymmetry

Line to earth capacitance

Selective Earth Fault Detection Admittance Method Faulty Network



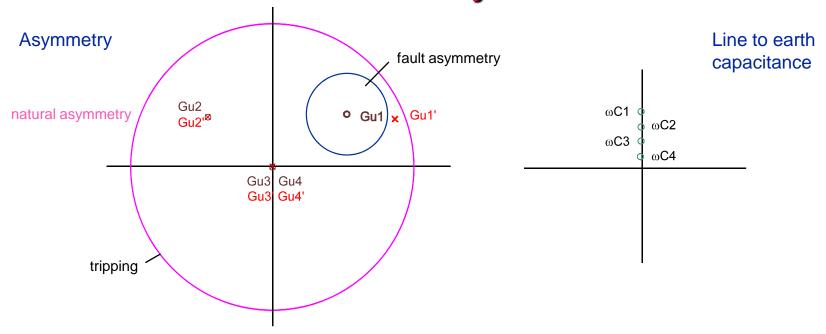


- Feeder with greatest variation of asymmetry will be recognized as the faulty one
- High selectivity
- Sensitivity limits are adjustable
- Switching operations are discriminated

Asymmetry

Line to earth capacitance

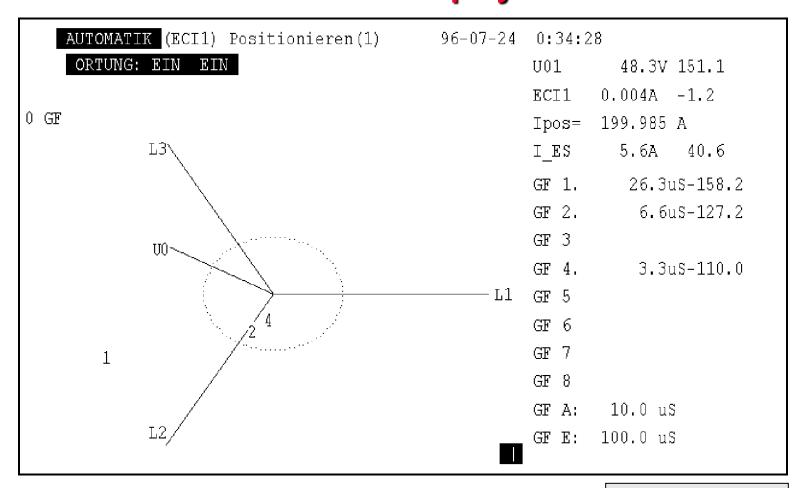
Selective Earth Fault Detection Admittance Method Sensitivity



- Adjustable limits for the asymmetries
- Alarm and tripping thresholds

- Very high sensitivity
- Detection up to a few 10 kOhm

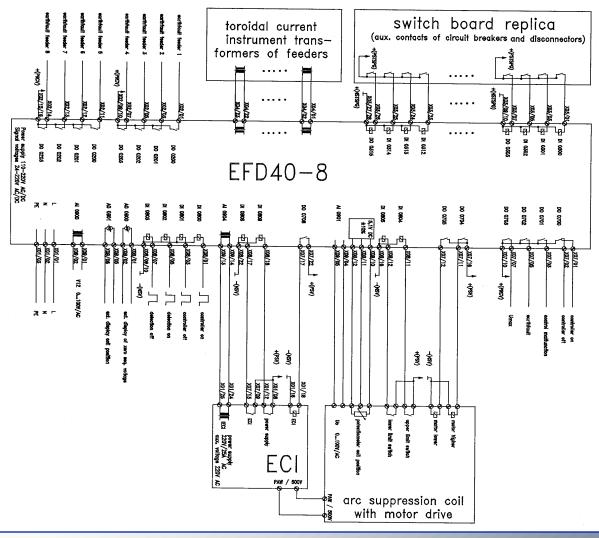
Selective Earth Fault Detection EDF40 Display

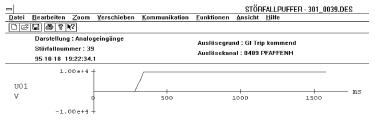


Connection Diagram

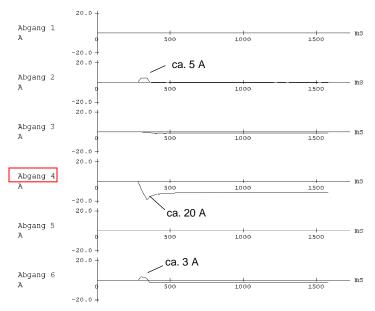
Selective Earth Fault Detection







Zero-sequence voltage V₀



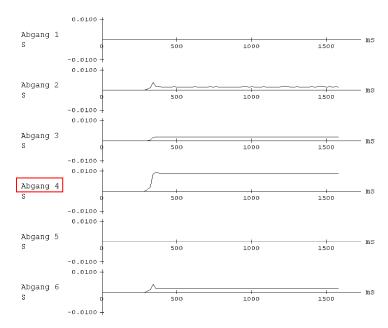
Wattmetric part of I₀

Kreiswerke Gelnhausen, Germany

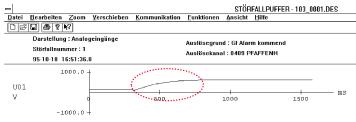
 $V_N = 20 \text{ kV}$

 $I_C = 230 \text{ A / v} = +5\%$

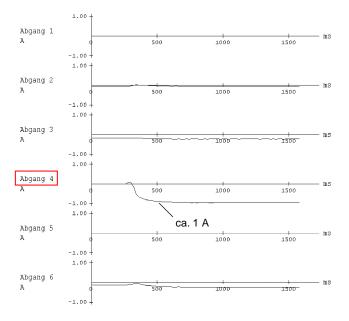
 $Z_F = 0 \Omega / Feeder 4$



Fault admittance variation

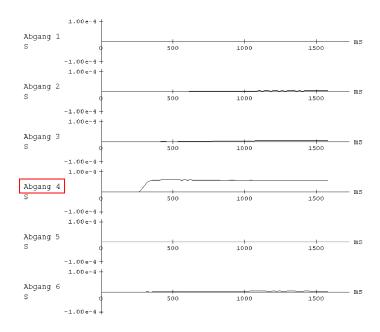


Zero-sequence voltage V₀

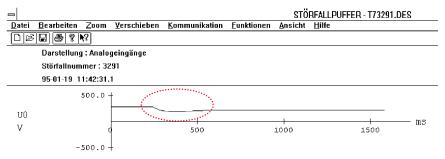


Wattmetric part of I₀

Kreiswerke Gelnhausen, Germany $V_N = 20 \text{ kV}$ $I_C = 230 \text{ A} / \text{v} = 0\%$ $Z_F = 20 \text{ k}\Omega$ / Feeder 4

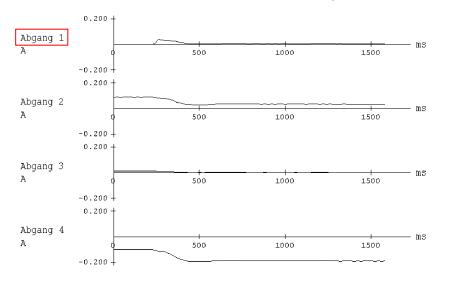


Fault admittance variation

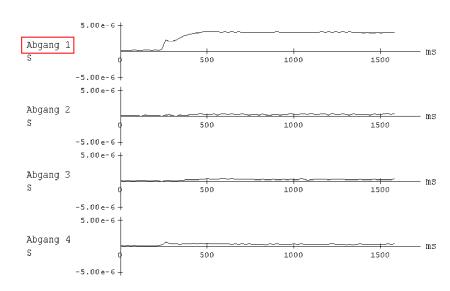


OKA, Austria $V_N = 30 \text{ kV}$ $I_C = 70 \text{ A} / \text{v} = +10\%$ $Z_F = \text{Line in tree} / \text{Feeder 1}$

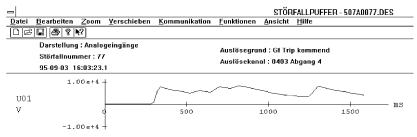
Zero-sequence voltage V₀



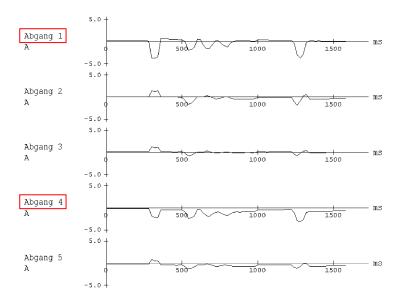
Wattmetric part of I₀



Fault admittance variation

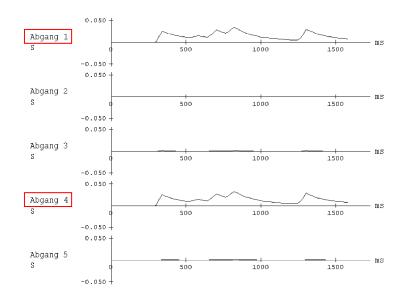


Zero-sequence voltage V₀



Wattmetric part of I₀

MEAG Halle, Germany $V_N = 20 \text{ kV}$ $I_C = 95 \text{ A/v} = 0\%$ $Z_F = Restriking earthfault$ Loop with feeder 1 and feeder 4



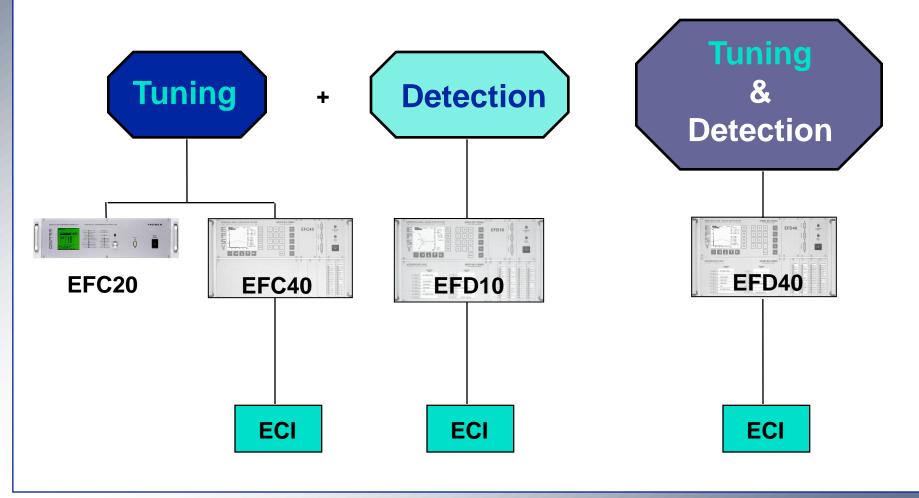
Fault admittance variation

Selective Earth Fault Detection EFD10/40 Performance



- Field tests in different european countries confirm the selective detection of earth faults up to 100 kOhm
- Convincing performance compared to conventional earth fault-relays
- Proven service in existing installations across Europe
- According to VDE this method is acknowledged as state of the art

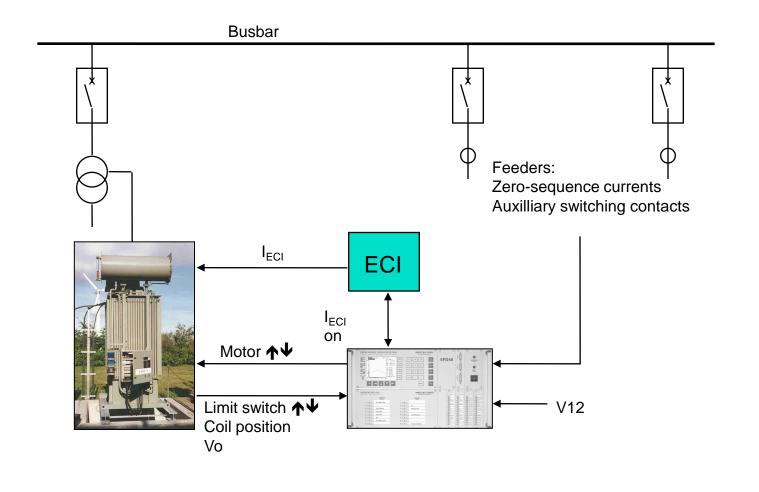
EPSY - System Engineering Electronic Components



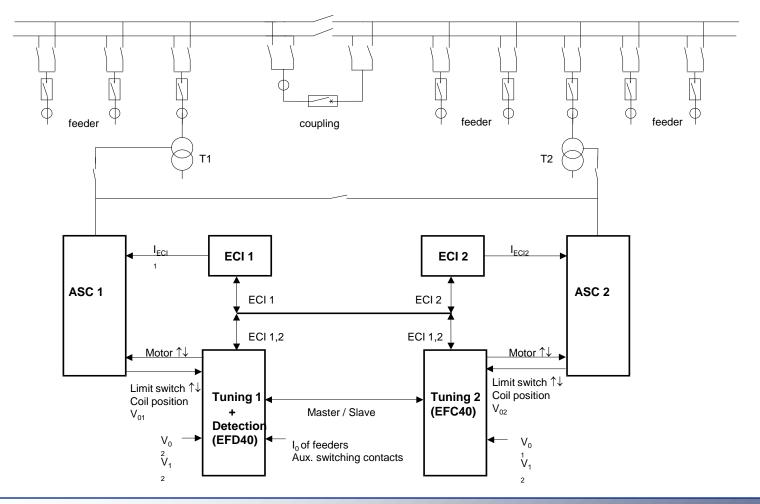
EPSY - System Engineering Technical Data

| | Tuning | | Detection | Tuning & Detection | |
|--|---|-------|-----------|-------------------------------|--|
| | EFC20 | EFC40 | EFD10 | EFD40 | |
| Upgrade with tuning | | | opt. | | |
| Upgrade with detection | - | opt. | | | |
| Expansion to 24 feeders | | | opt. | opt. | |
| Tuning by coil detuning | х | X | | X | |
| Tuning by impedance measurement with ECI | | Х | | Х | |
| Detection with low and high ohmic earth faults | | | Х | Х | |
| 2 busbar operation mode | opt. | Х | Х | Х | |
| Serial interface | | opt. | opt. | opt. | |
| SCADA implementation (SPABus, IEC870, VDEW6) | opt. | opt. | opt. | opt. | |
| Analog inputs | 2 | 9 | 16 | 17 | |
| Analog outputs | 2 | 2 | 0 | 2 | |
| Digital inputs | 9+6 | 16 | 32 | 32 | |
| Digital outputs | 6 + 14 | 16 | 32 | 32 | |
| Height (19" module) | 3 Hu | 6 Hu | 6 Hu | 6 Hu | |
| Power supply | 120 110 to 230 V DC/AC Option: 24, 48, 60 V DC | | | | |

EPSY - System Engineering1 Busbar Configuration



EPSY - System Engineering 2 Busbar Configuration



EPSY Summary



- Enables network operation according to existing laws
- Unrivaled performance in earth fault compensation control and earth fault detection
- Modular design and easy extension possibility
- Already prepared for future developments
- Complete system for tuning and detection
- Easy adaptation to various network configurations
- Easy to use and handle
- Attractive price