EARTH FAULT DETECTING METHODS ON COMPENSATED NETWORKS

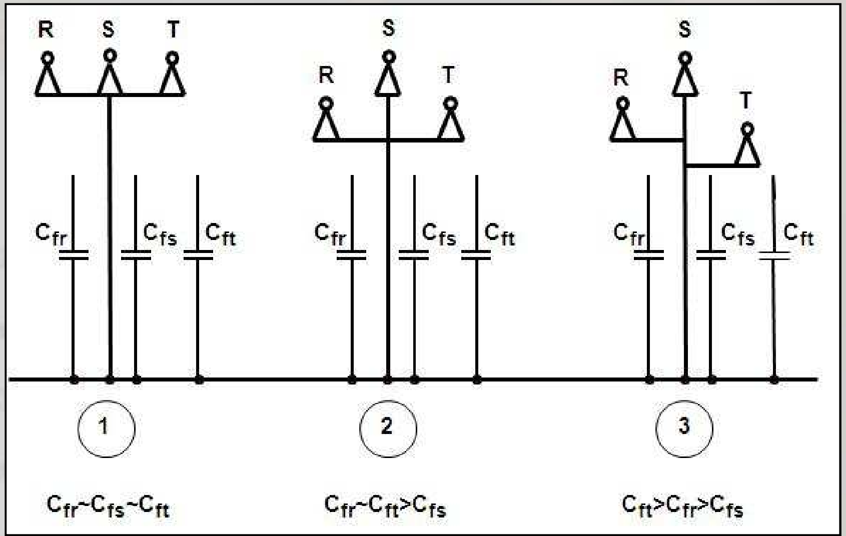
SUMMARY

- Events during normal network condition
  - Asymmetry on compensated networks
  - Usage of Petersen coil controller
- Events during single earth-fault condition
  - Prevention of evolving permanent earth faults
  - Main types of permanent earth faults
- Different methods for detecting earth faults
  - Residual definite time overcurrent protection
  - Directional residual delayed overcurrent protection
  - Transient earth fault protection
  - New method: admittance earth fault protection

ASYMMETRY ON COMPENSATED NETWORKS

SOURCES OF ASYMMETRY ON COMPENSATED NETWORKS

- Asymmetrical arrangement of phase conductors



- Iron core structure of power transformers
- Isolator's leakage resistance
- Asymmetrical elements connected to the network

CONSEQUENCES OF ASYMMETRY

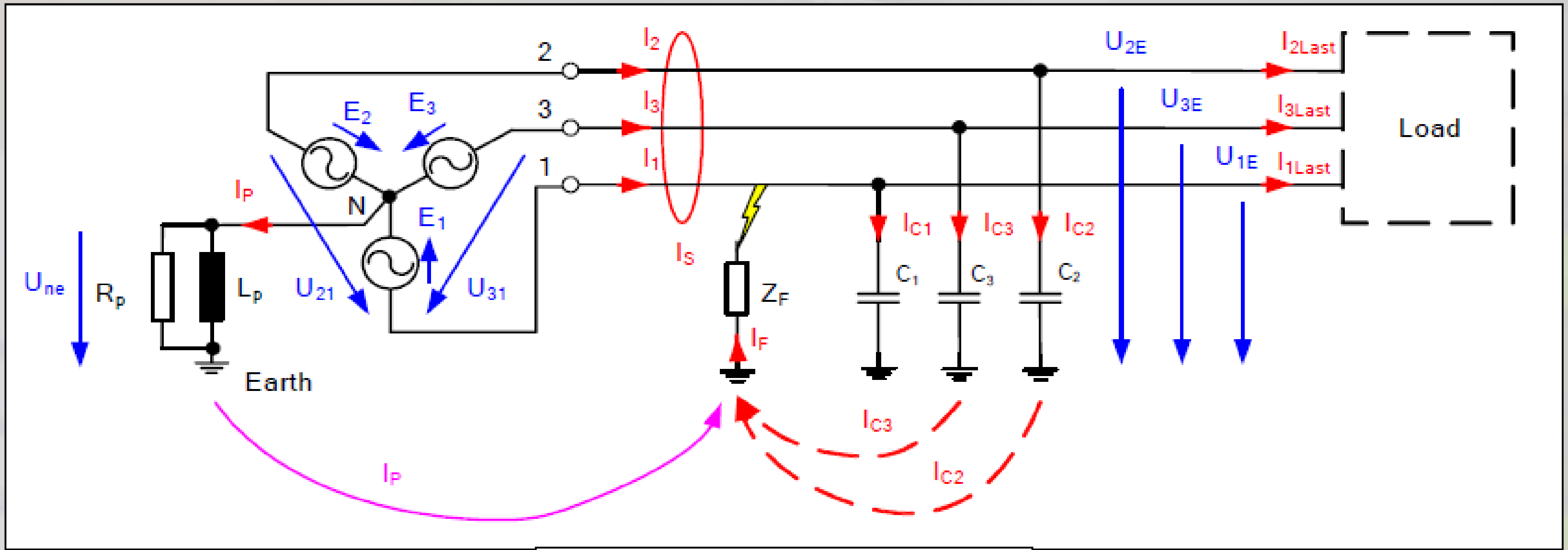
- Increased phase voltages
  - Increased risk of earth-faults
- It can block the tuning of the Petersen coil (because of high U_0)
  - Petersen coil is not tuned
  - Earth-fault current is increased
  - Earth-fault is continuous
  - Risk of dangerous step voltage is high
  - Protection trip is needed

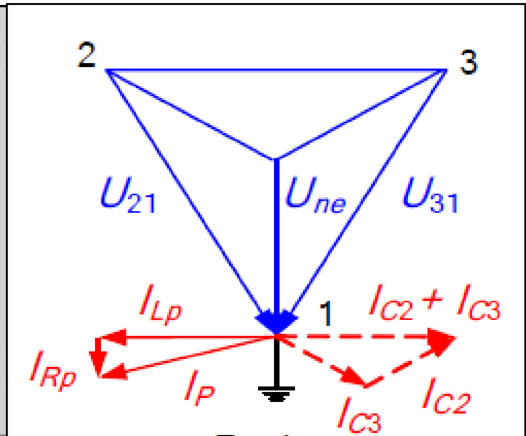
SYMMETRIZATION METHODS

- Cyclic transposition of the phase conductors
  - Needs reconstruction of the network
  - Mounting on several locations
  - Long time without power supply
- Continuous grounding resistor
  - Several disadvantages
- Added symmetrizing capacitors (provided by Protecta)
  - Mounting at the substation only
  - Lower costs
  - Short time without power supply

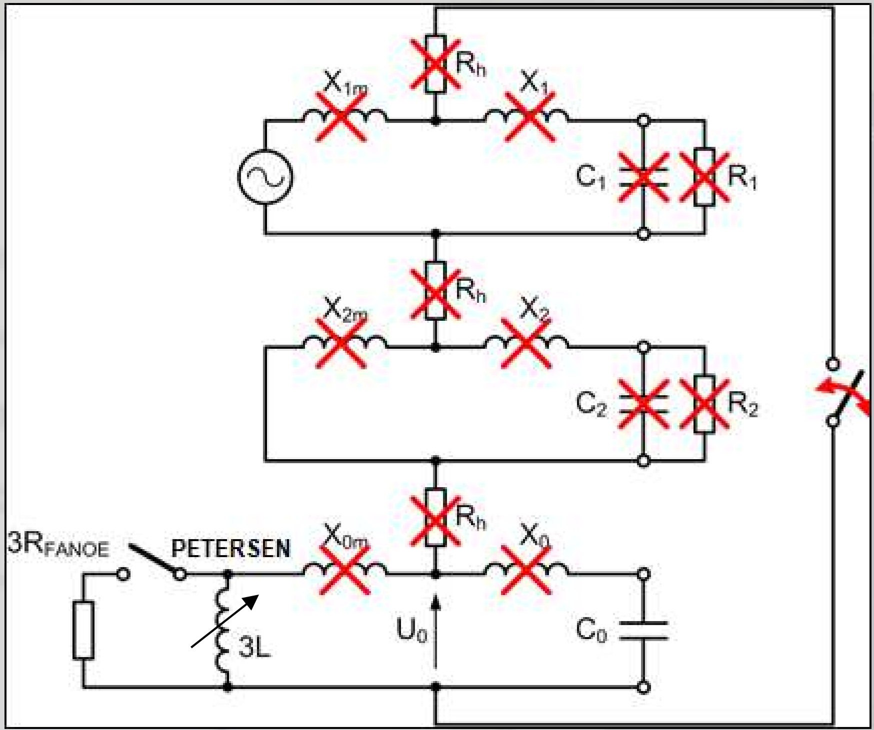
USAGE OF PETERSEN COIL CONTROLLER

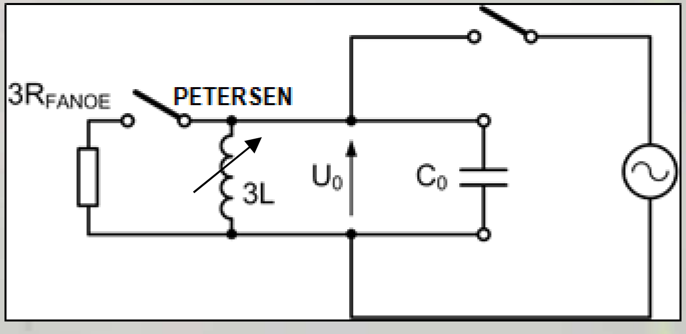
PRINCIPLE OF COMPENSATION (PETERSEN COIL)





PRINCIPLE OF COMPENSATION (PETERSEN COIL)



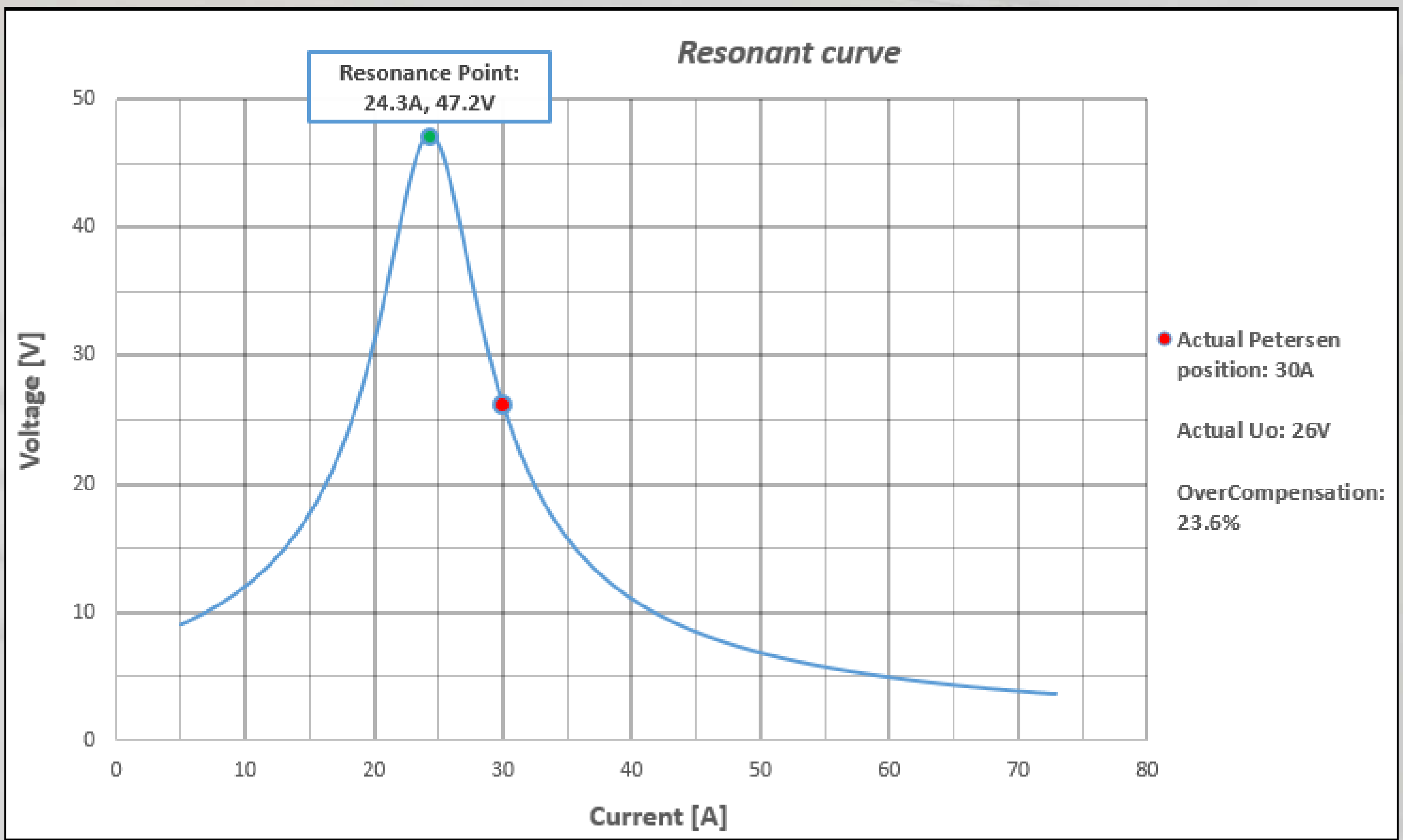


$$Z = \frac{j3\omega L \dfrac{1}{j\omega Co}}{j3\omega L - j\dfrac{1}{\omega Co}}$$

ADVANTAGES OF USING PETERSEN COIL CONTROLLER

- Why is it important to use an automatical controller for the Petersen coil?
  - To check the level of compensation whenever it is needed
  - The network always changes: feeders can be connected or disconnected to the busbar any time
  - Because the capacity of the zero sequence network can change any time, the Petersen coil must follow the change of the capacity
  - It always keeps the Petersen coil in a well-tuned position

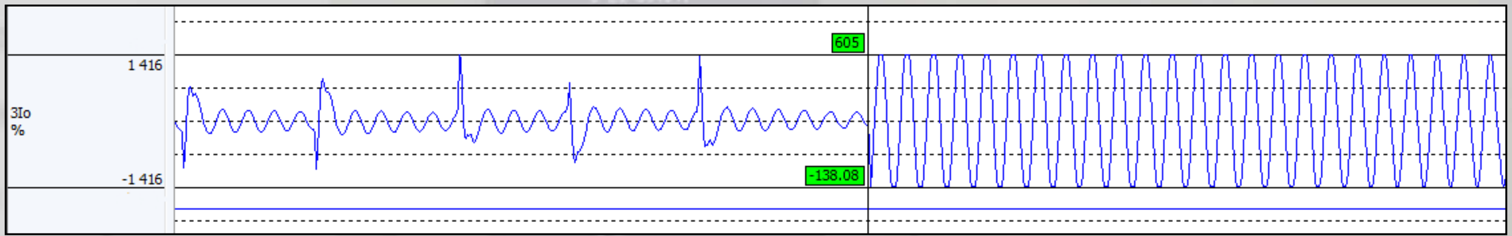
RESULT OF THE MEASUREMENT: THE RESONANT CURVE



PREVENTION OF EVOLVING PERMANENT EARTH FAULTS

WHAT CAN INCREASE THE RISK OF EVOLVING PERMANENT EARTH FAULTS?

- Use of grounding (shunt) resistor → it increases the fault current, so the fault becomes stable

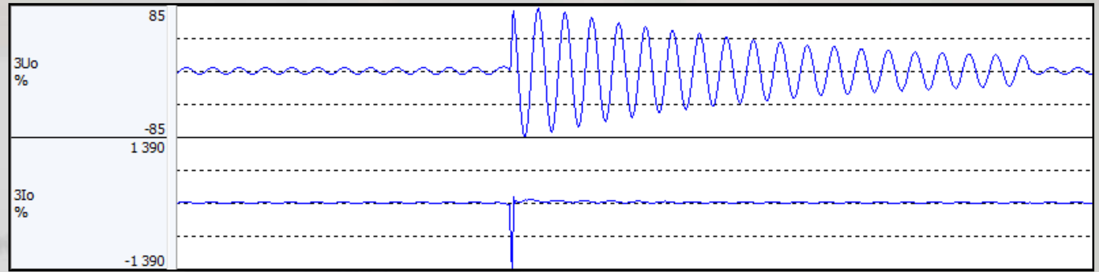


- The Petersen coil is not well tuned → High under- or overcompensation
- Short time for using the Petersen coil alone

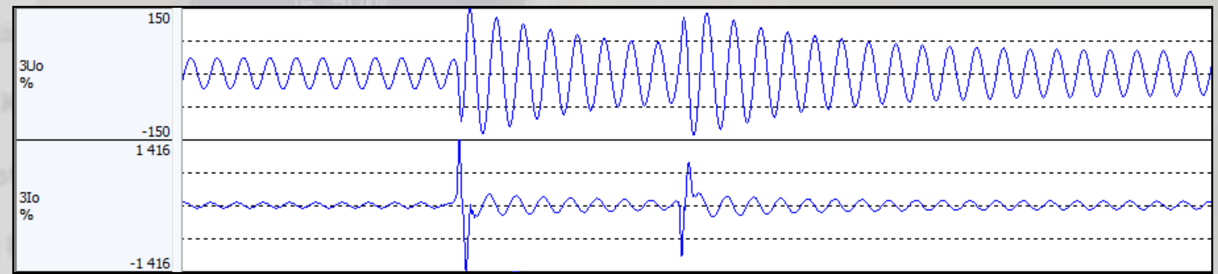
AN EFFECTIVE WAY OF PREVENTION

- Well-tuned Petersen coil

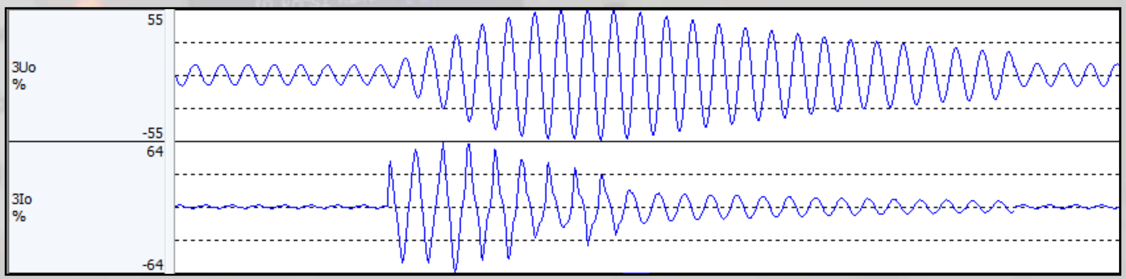
Example 1:



Example 2:



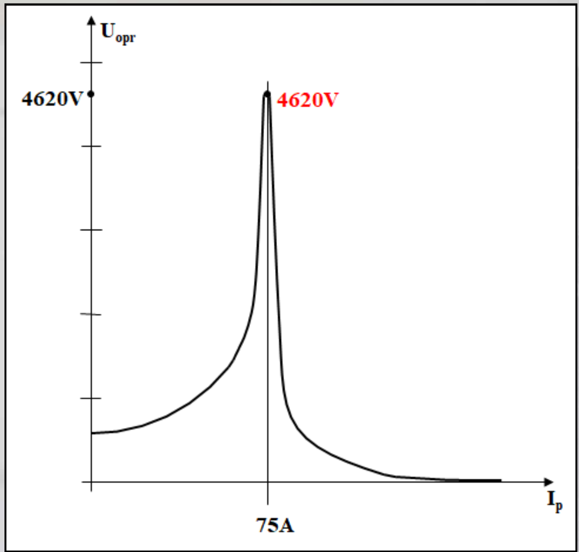
Example 3:



WHY "EXACT" COMPENSATION CAN CAUSE PROBLEMS?

PROTECTA HUNGARY

- The U_0 is relatively high:

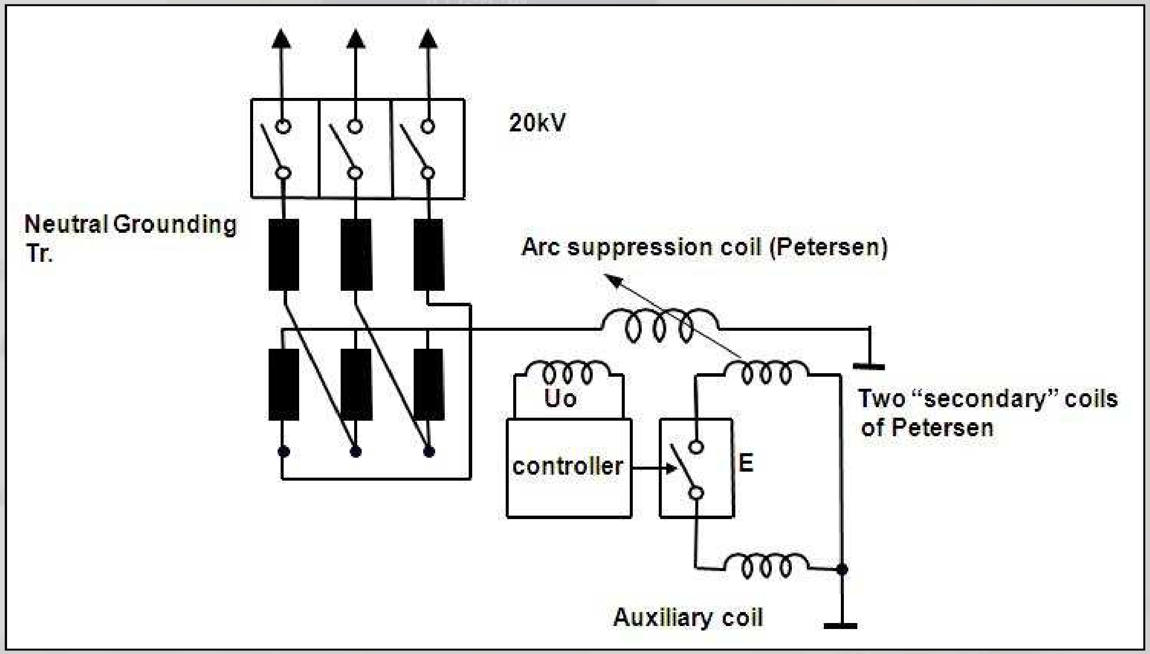


- Increased phase voltages
- Problems of Petersen tuning procedure

WHAT CAN BE THE BEST SOLUTION? (IDEA OF PROTECTA)

PROTECTA HUNGARY

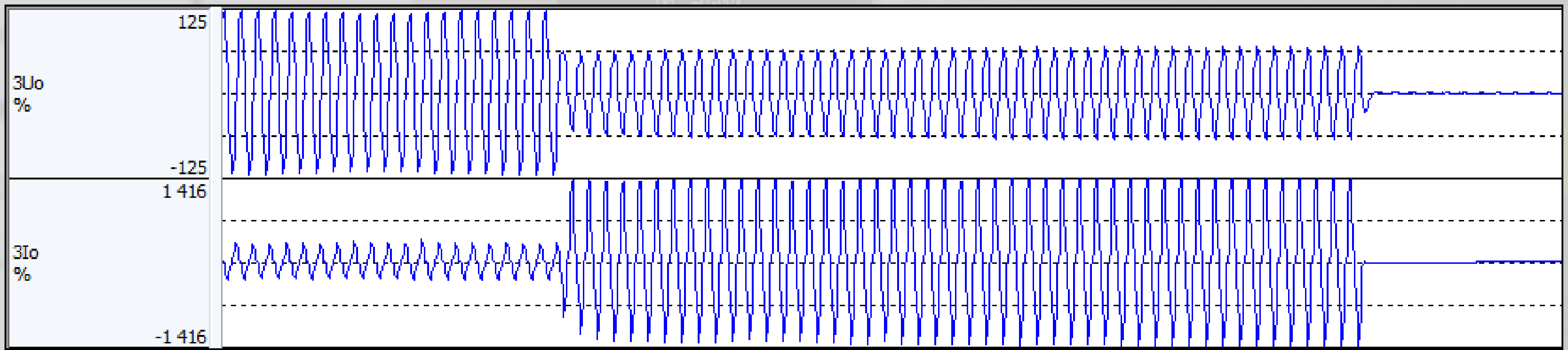
- Use of shunt inductance, which is connected parallel to the Petersen coil → in case of possible earth fault the ”exact” compensation can be approached: ADAPTIVE COMPENSATION



MAIN TYPES OF PERMANENT EARTH FAULTS

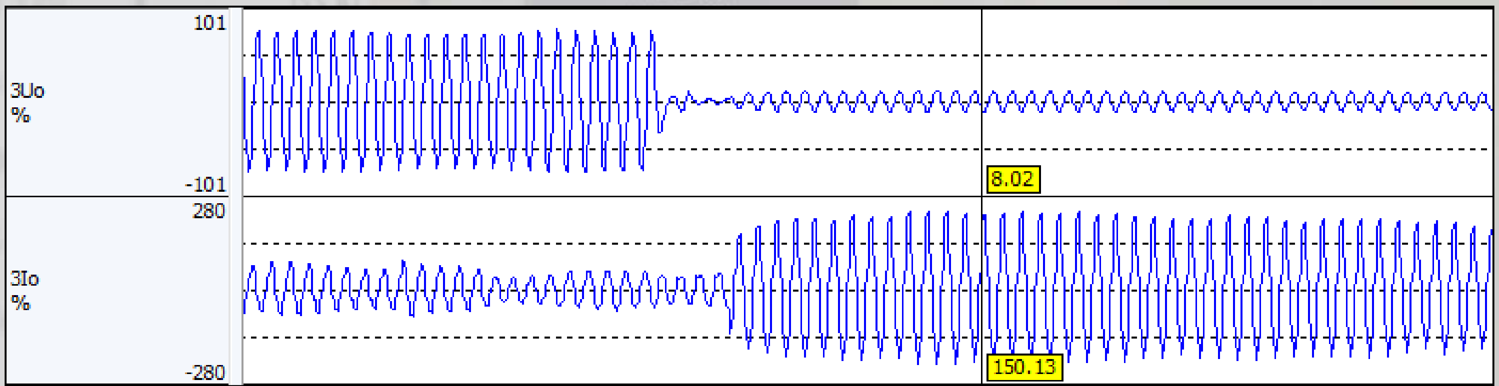
STABLE EARTH FAULTS WITH LOW FAULT RESISTANCE

- The fault current flows continuously
- If the grounding resistance is switched on, the increased fault current is high enough for overcurrent protections to detect the earth fault



STABLE EARTH FAULTS WITH HIGH FAULT RESISTANCE

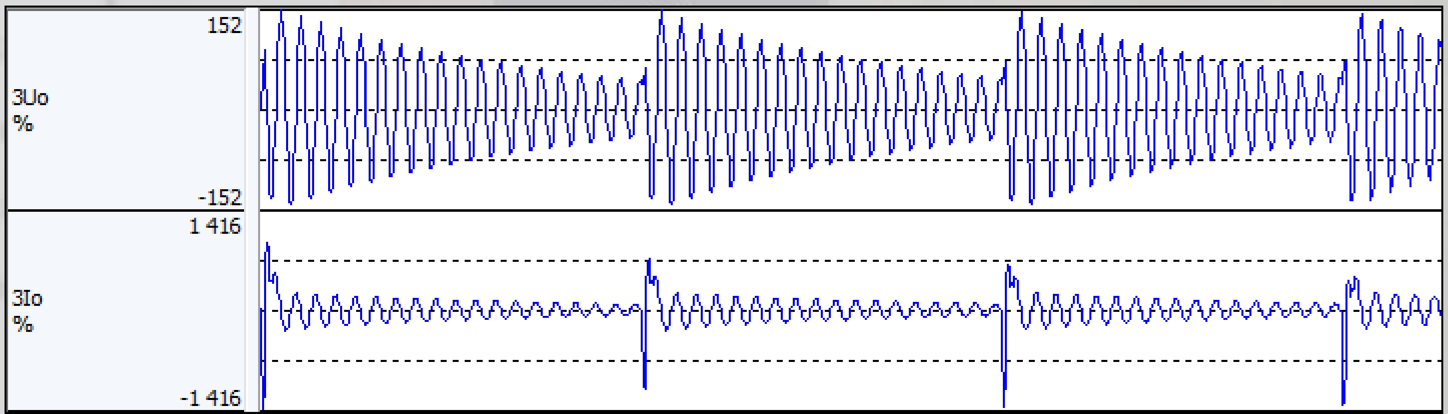
- The fault current flows continuously
- If the grounding resistance is switched on, the increased fault current is NOT enough for overcurrent protections to detect the earth fault



The primary $3I_0$ is 18A!

INTERMITTENT EARTH FAULTS

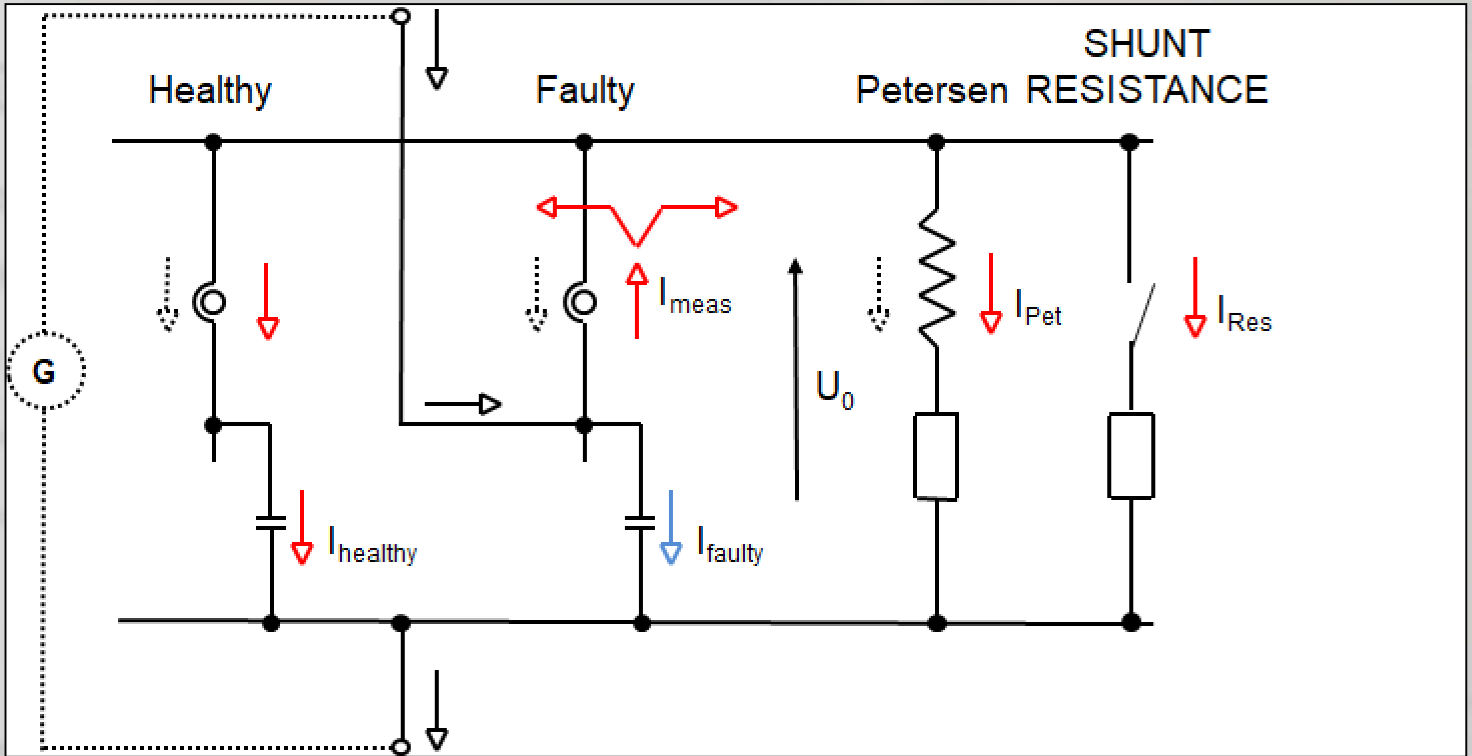
- The fault current does not flow continuously
- The exact fault time is around 5-10msec, then the fault is cleared for many periods
- The time between faults can be 100msec – 500msec



RESIDUAL DEFINITE TIME OVERCURRENT PROTECTION

Earth fault current-booster method

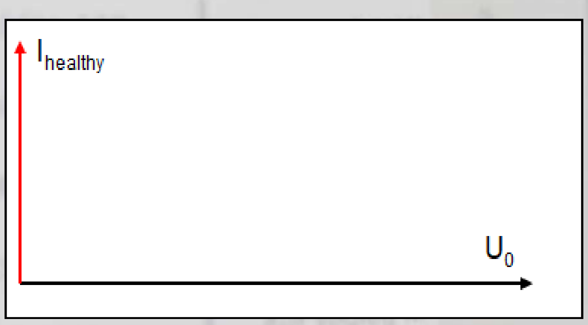
- The symmetrical component network:



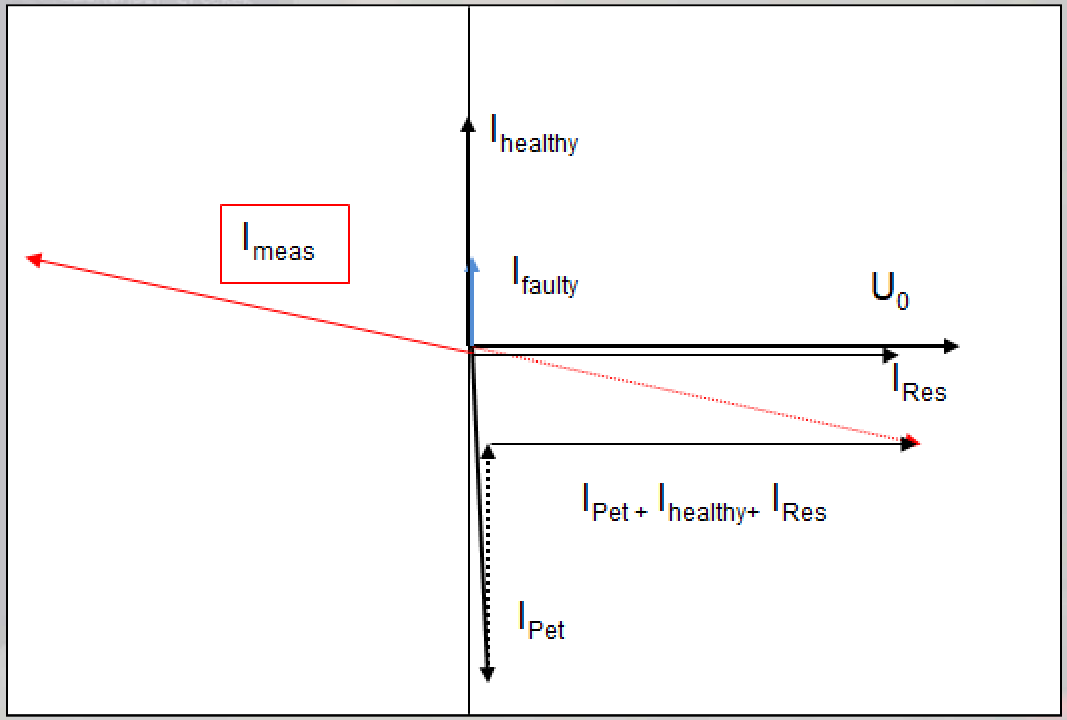
EARTH FAULT CURRENT-BOOSTER METHOD

- The zero sequence voltage and currents during the earth fault:

Healthy feeder:



Faulty feeder:



RESIDUAL DEFINITE TIME OVERCURRENT PROTECTION

- The setting parameters are:
  - Starting current (I_{start})
  - Definite time delay (T_{delay})

RESIDUAL DEFINITE TIME OVERCURRENT PROTECTION

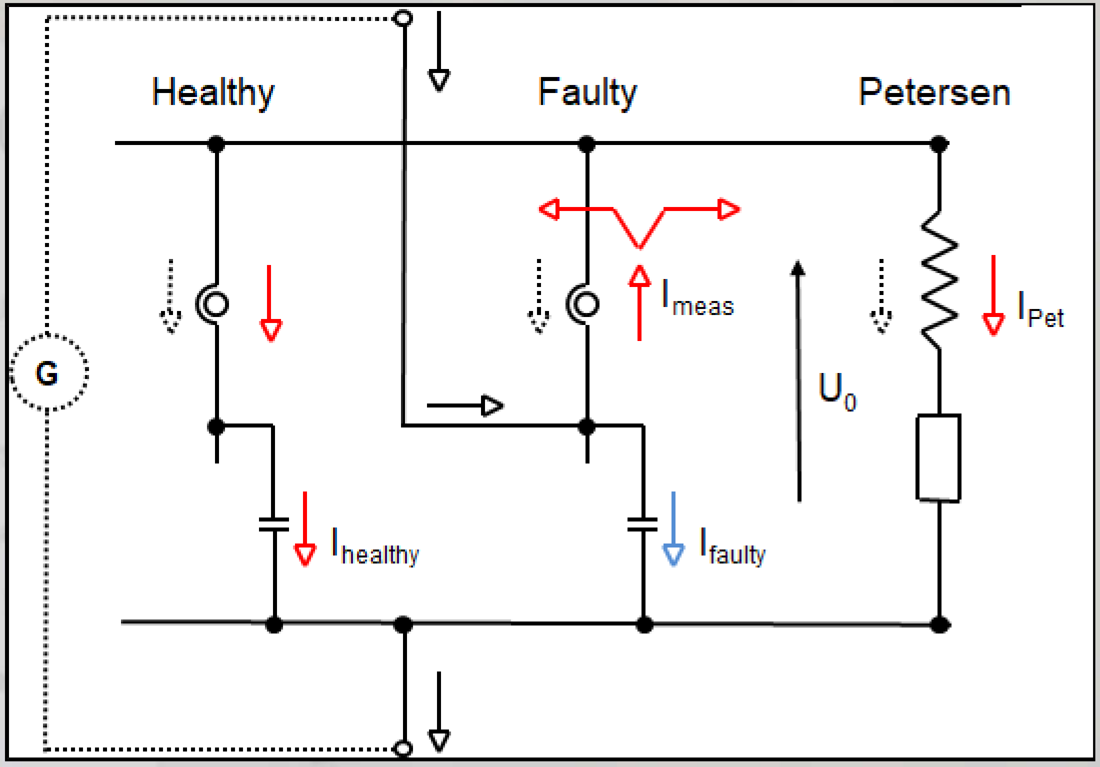
PROTECTA HUNGARY

- Advantages
  - Very simple solution
  - The list of parameters is short
  - It does not require U_0 voltage
- Disadvantages
  - Maintenance of the resistance is expensive
  - It cannot detect earth faults with high fault resistance
  - If the resistance is switched on, then the chance of clearing the earth fault by the Petersen coil is zero
  - Dangerous step and touching voltage: the IEC-50522 standard does not allow to keep the increased fault current for a long time (the fault time can be maximum 100-200ms)

DIRECTIONAL RESIDUAL DELAYED OVERCURRENT PROTECTION

WATTMETRIC METHOD

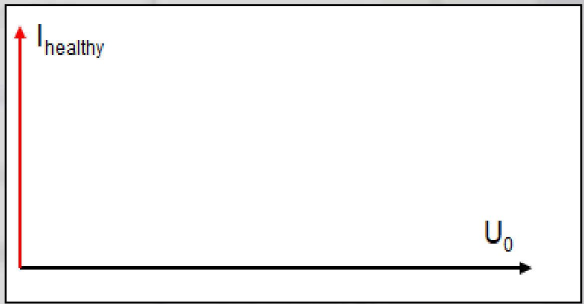
- The symmetrical component network:



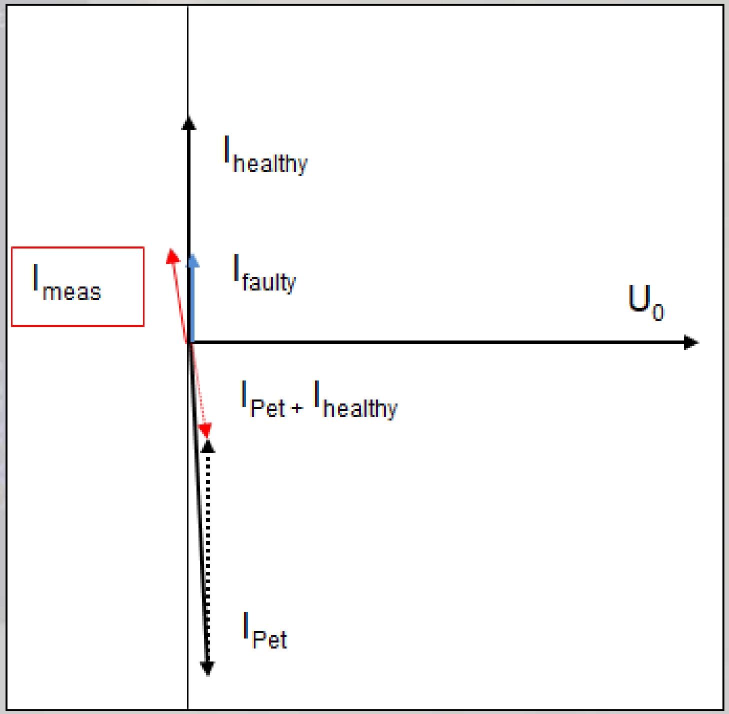
WATTMETRIC METHOD

- The zero sequence voltage and currents during the earth fault:

Healthy feeder:

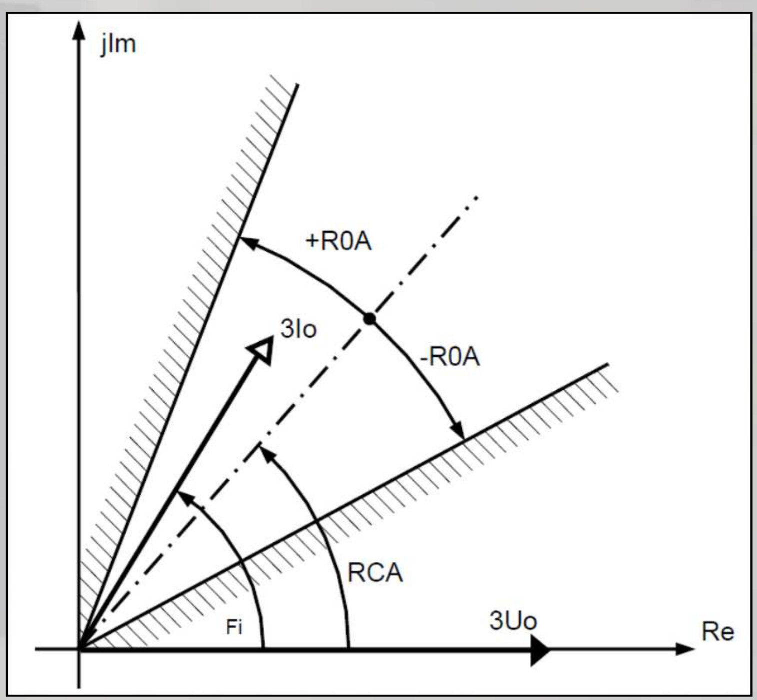


Faulty feeder:



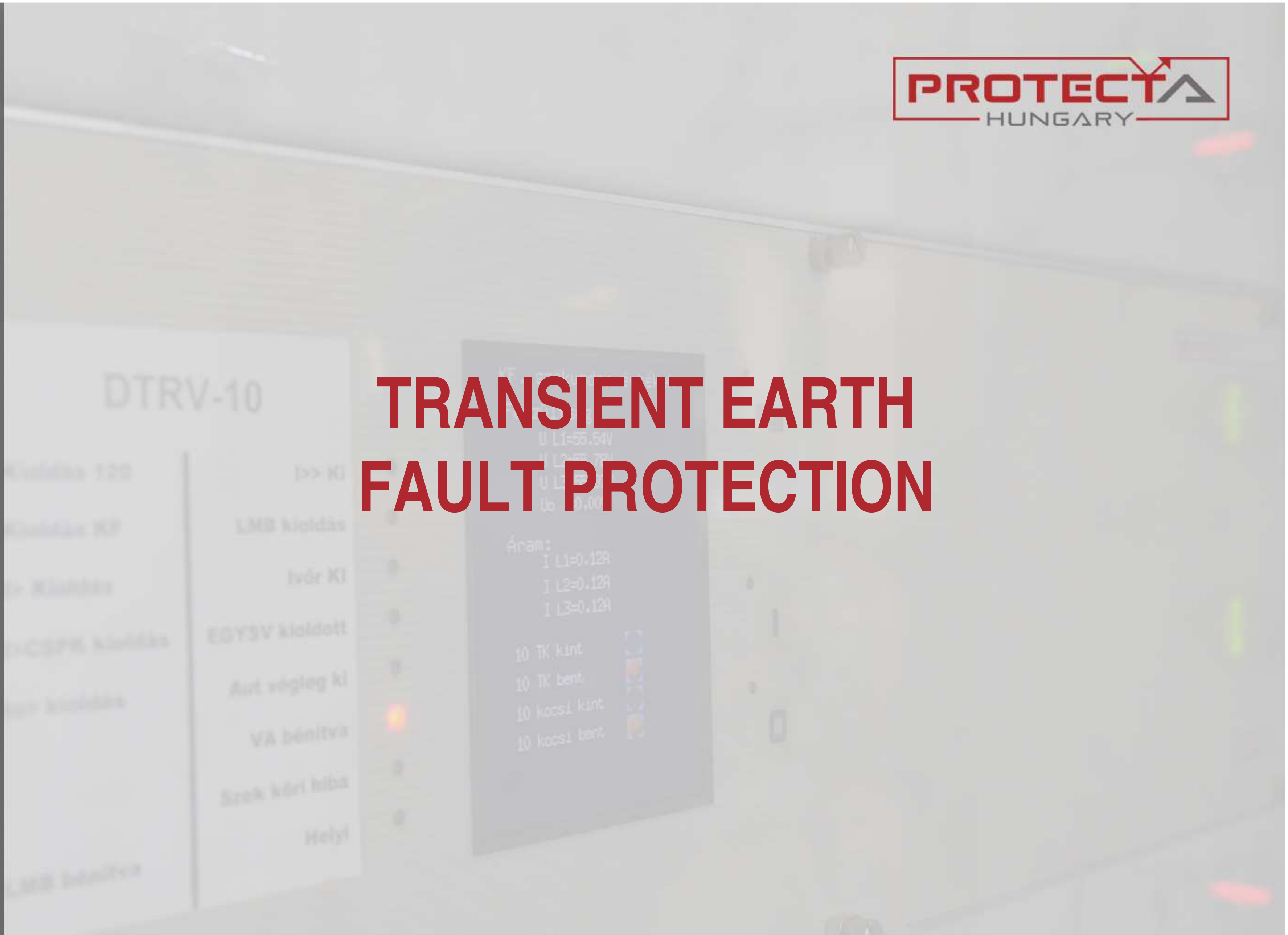
DIRECTIONAL RESIDUAL DELAYED OVERCURRENT PROTECTION

- The setting parameters are:
  - Starting current (I_{start})
  - Characteristic angle (RCA)
  - Operating angle (ROA)
  - Operating characteristic



DIRECTIONAL RESIDUAL DELAYED OVERCURRENT PROTECTION

- Advantages
  - It does not require any added primary or secondary element
  - The earth fault current is not increased
- Disadvantages
  - It cannot detect intermittent earth faults
  - If the resistance of the Petersen coil is low, then the wattmetric component of the fault current is too low → it is hard to set the characteristic well
  - It requires U_0 voltage (and of course I_0 current)

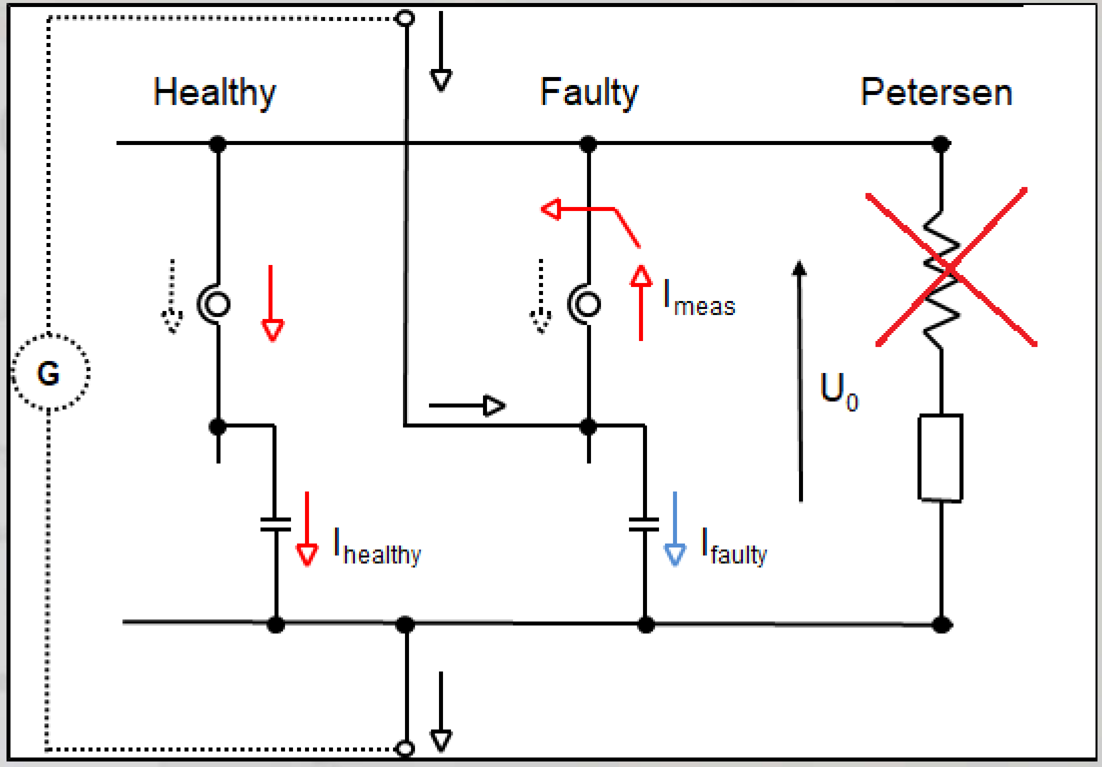


TRANSIENT EARTH FAULT PROTECTION

TRANSIENT METHOD

PROTECTA HUNGARY

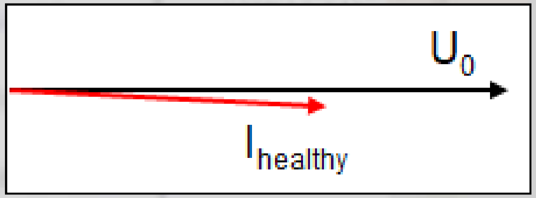
- The symmetrical component network at the transient:



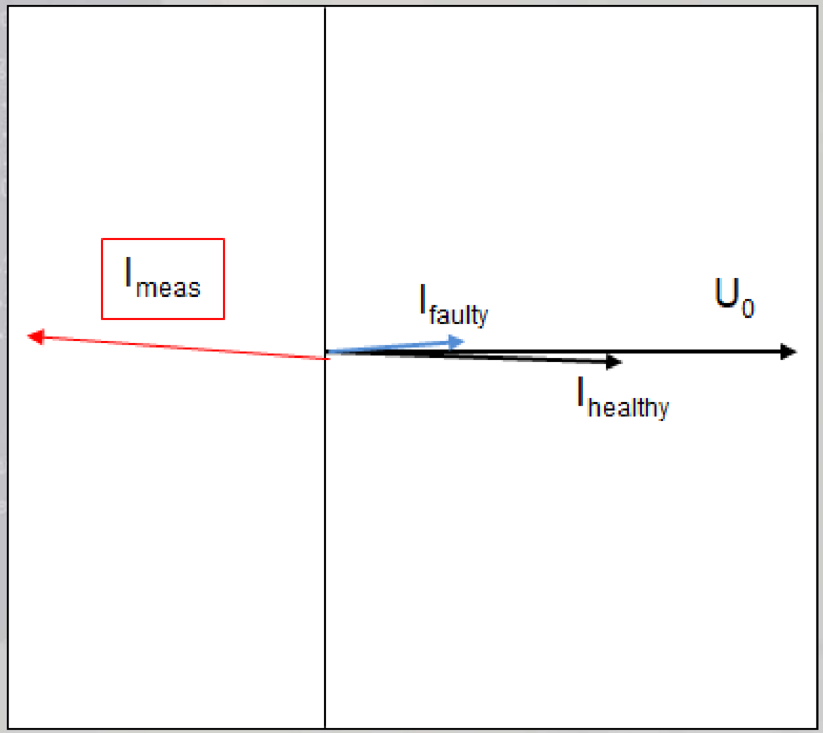
TRANSIENT METHOD

- The zero sequence voltage and currents at the faulty moment:

Healthy feeder:



Faulty feeder:



TRANSIENT EARTH FAULT PROTECTION

- The setting parameters are:
  - Minimal residual voltage ($U_{0,min}$) and current ($I_{0,min}$)
  - Number of the counted peaks
  - Reset time after the last detected peak (T_{reset})

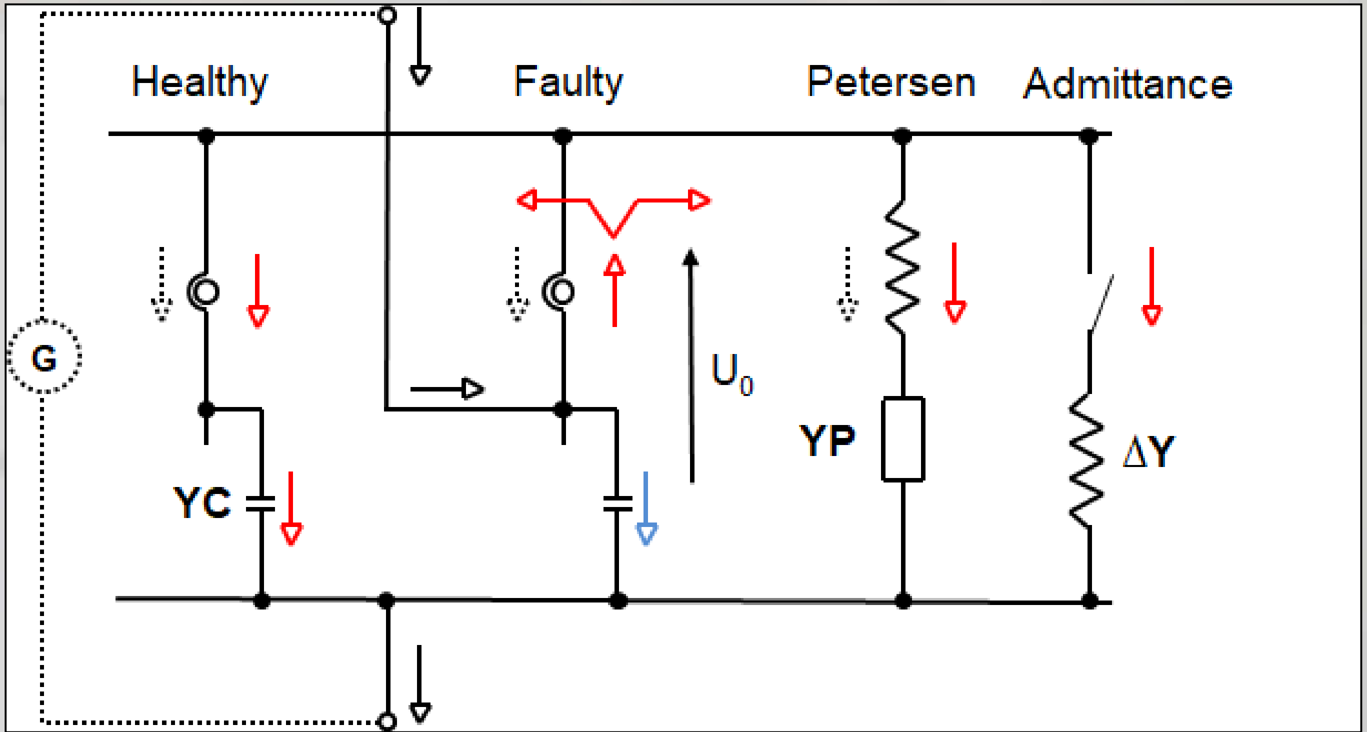
TRANSIENT EARTH FAULT PROTECTION

- Advantages
  - It does not require any added primary or secondary element
  - The earth fault current is not increased
  - Very simple solution
  - The list of parameters is short
- Disadvantages
  - It cannot detect the stable earth faults with high fault resistance
  - It requires U_0 voltage (and of course I_0 current)

NEW METHOD: ADMITTANCE EARTH FAULT PROTECTION

ADMITTANCE CHANGE METHOD

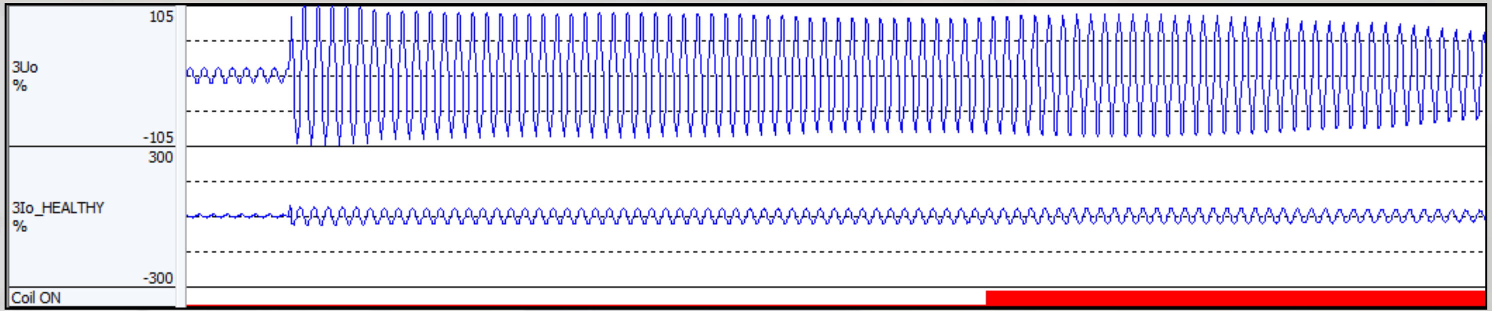
- The symmetrical component network:



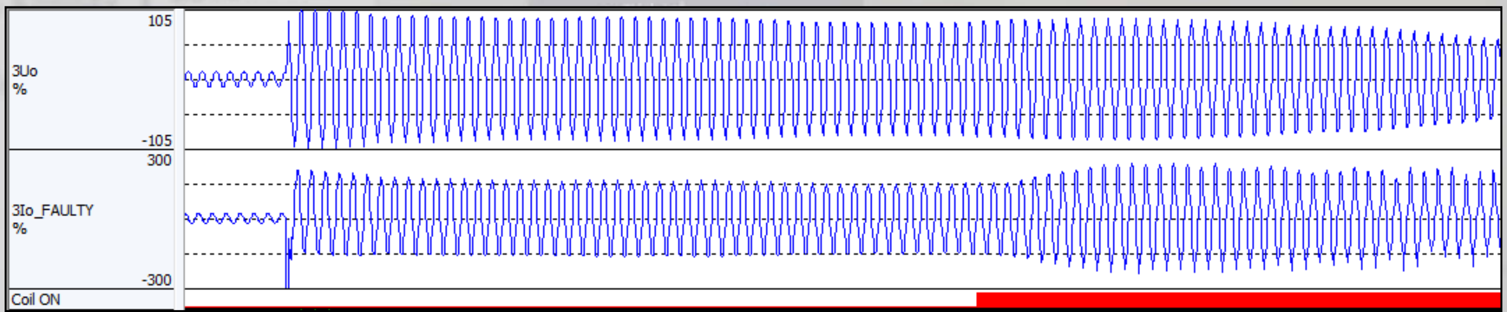
ADMITTANCE CHANGE METHOD

- The zero sequence voltage and currents

Healthy feeder:



Faulty feeder:



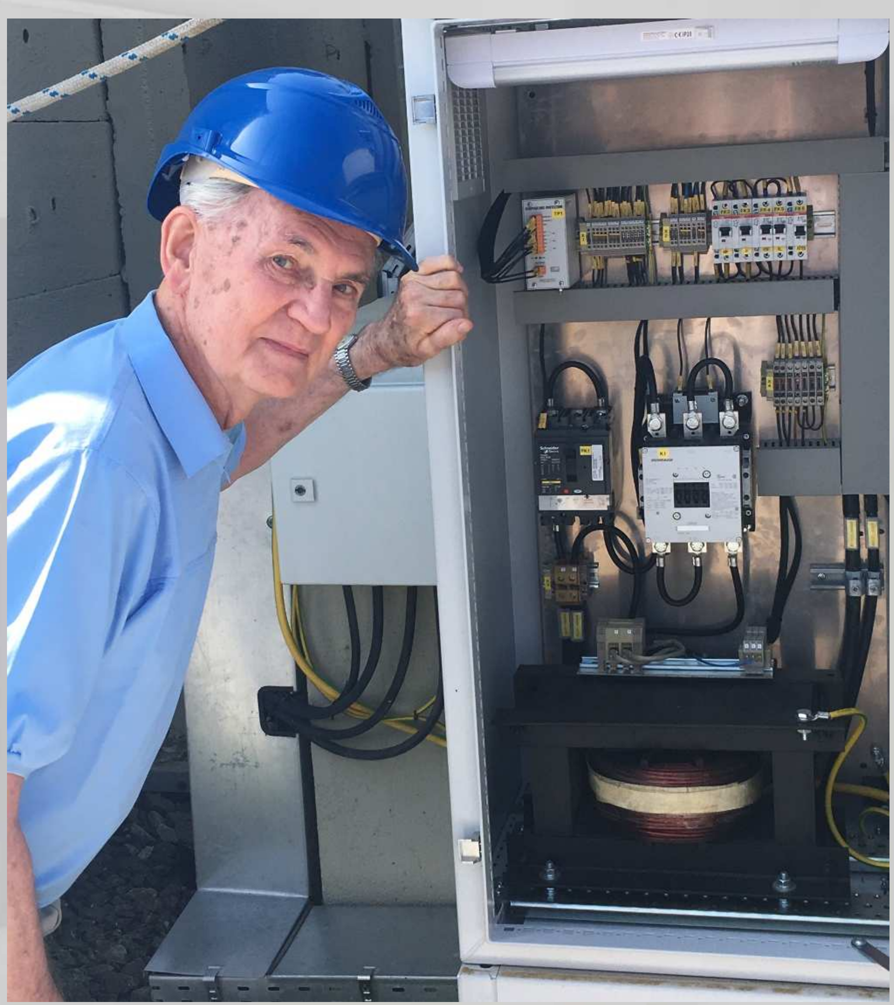
Admittance Change Method

- The measured zero sequence admittances ($3I_0/3U_0$):

	ΔY switched OFF	ΔY switched ON	Difference
Healthy feeder	YC	YC	0
Faulty feeder	-(YC+YP)	-(YC+YP+ΔY)	ΔY

Admittance change method

- The application:



ADMITTANCE EARTH FAULT PROTECTION

- The setting parameters are:
  - Minimal residual voltage ($U_{0,min}$) and current ($I_{0,min}$)
  - Voltage and current transformer ratios
  - Admittance value of the added coil
  - Line parameters (for calculating the fault location only)

ADMITTANCE EARTH FAULT PROTECTION

PROTECTA HUNGARY

- Advantages
  - It can detect stable faults with high fault resistance
  - The earth fault current is not increased
  - It can calculate the exact fault resistance
  - It can separate the earth faults (all the three types)
  - It can be used for adaptive compensation (mentioned earlier)
- Disadvantages
  - It cannot detect the intermittent fault: it requires a different method. This different method is built to the admittance protection
  - It requires U_0 voltage (and of course I_0 current)

THANK YOU FOR YOUR ATTENTION!

www.protecta.hu