# Influence of dispersed generation (DG) on distribution system protection

- What to expect from DG-units (island, S.C.-contribution, protection)
- Distribution System Earthfault Protection
- Distribution System Short Circuit Protection
- Challenges
  - Far-end fault (Ikmin), current suppression, side-infeed
  - Two-sided current flow vs. selectivity and blocking logic
  - Energising feeders – voltage check

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# Dispersed Generation (DG) in the Distribution Power Grid

- Dispersed generation (DG)
  - Decentralized power plants
  - Feeding into the distribution level power-grid
  - Typically sized below 10 MVA
  - A booming business in the new millennium, due to legislation changes
  - NVE has approx. 500 DG – applications

- The Norwegian distribution power grids (5 – 22 kV)
  - Radial networks traditionally buildt to feed, not to receive, power
  - The short circuit protection scheme based on «one-way» short circuit current
  - Isolated grounded network or compensated netw. with parallell resistor

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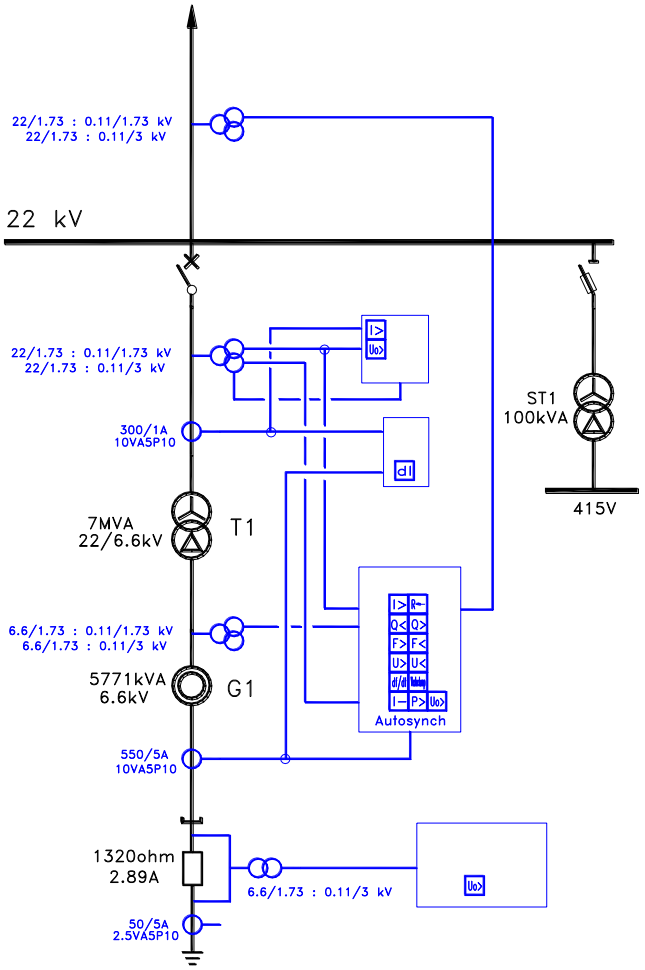
# What response to expect from DG-unit protection?

To be expected / requirements:

- Instantanous tripping of internal short circuits (dI> protection)
- Tripping of short circuits in the 22 kV system
  - Non selective, U<-relay with time delay 100 ms
  - Or selective, U<-relay with time delay higher than feeder –S.C. relays
- Tripping of earthfaults in the 22 kV system (3Uo> -relay, time delay < 10 s)
- Non-island (U<> and f<> relays)

To be «feared»:

- Failure of tripping
- Island mode or slow island detection
- Transient instability



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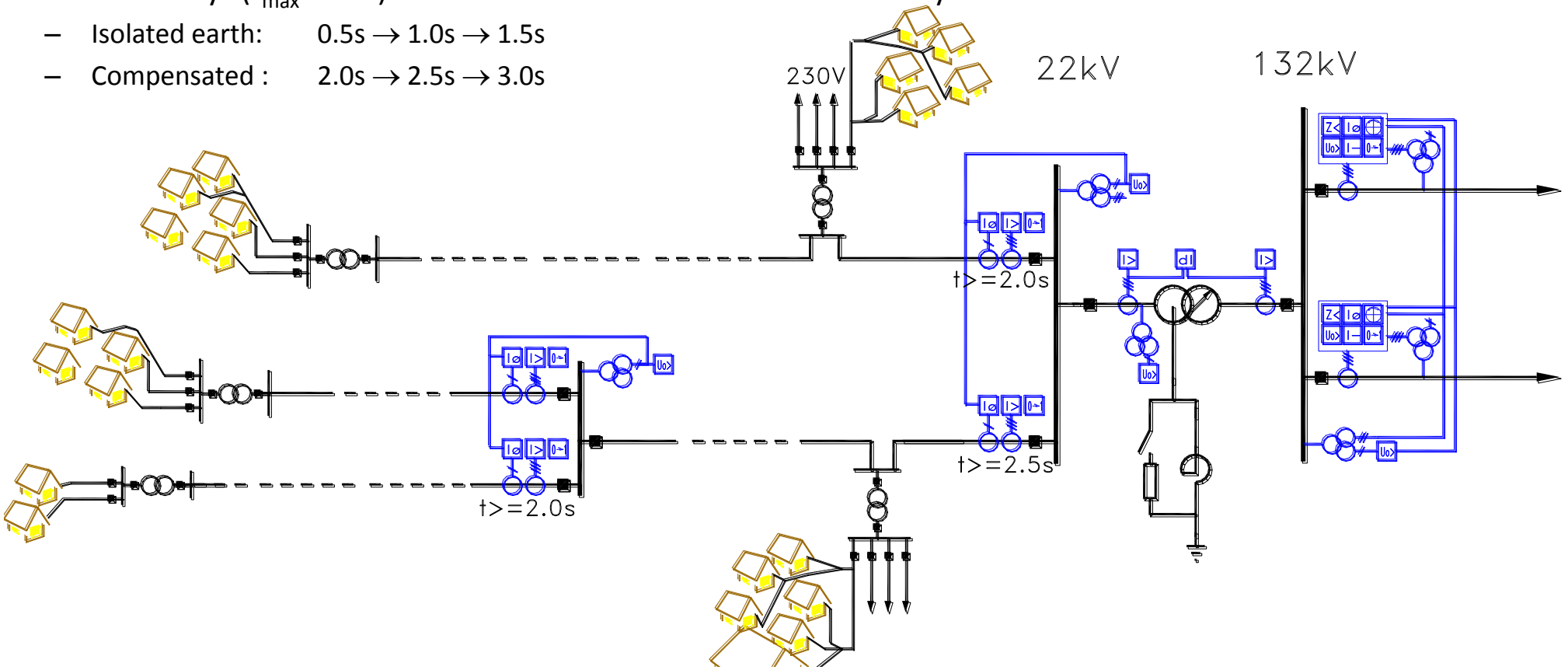
# Traditional EF Protection Scheme in Distribution Systems

## Earthfault protection feeders

- Directional earthfault relays (Iø>)
- Time delays ($t_{max}$ = 10s)
  - Isolated earth: 0.5s → 1.0s → 1.5s
  - Compensated : 2.0s → 2.5s → 3.0s

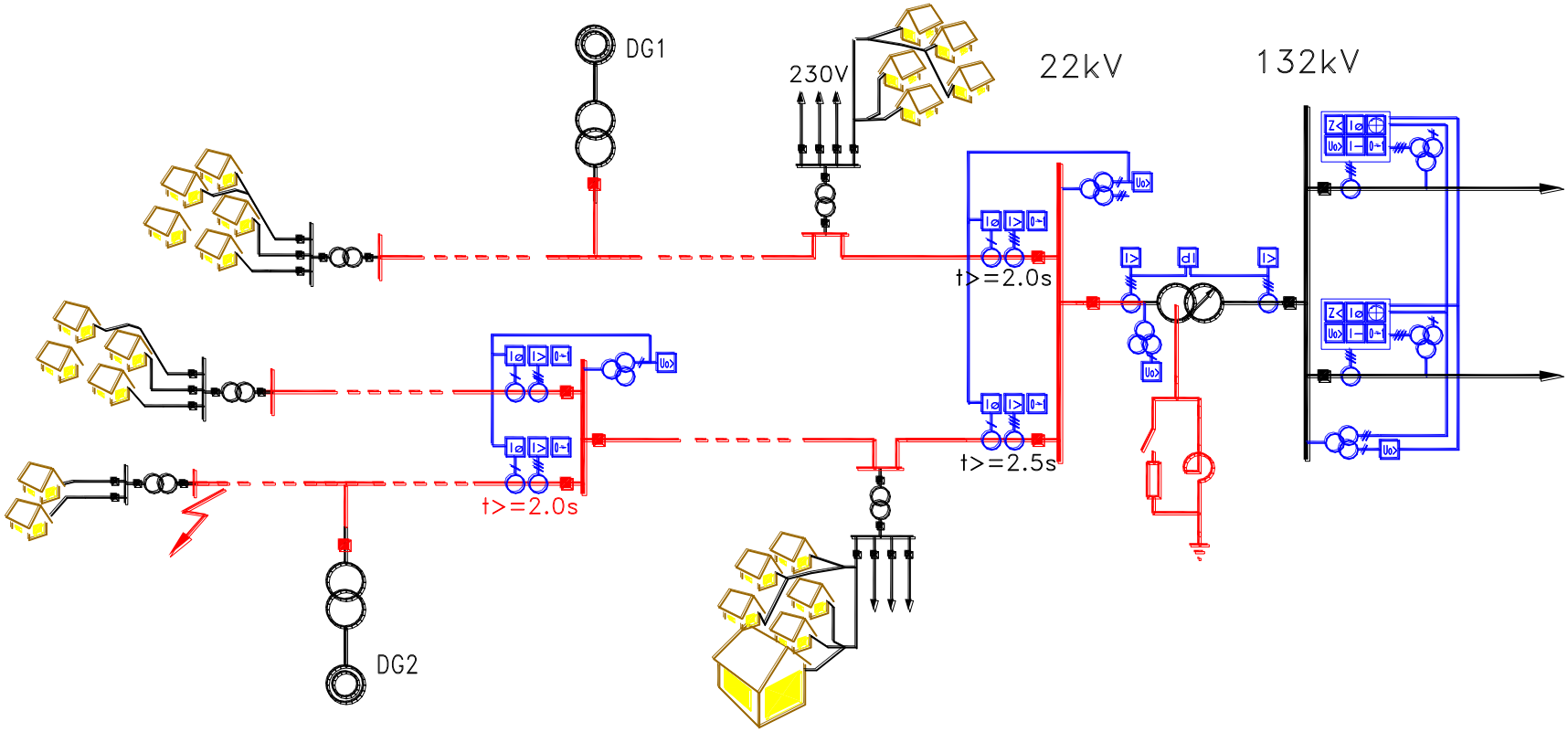
## Earthfault protection busbars

- Non - directional earthfault relays (3Uo>)
- Alarm only ?



# Traditional EF Protection Scheme

Direction of EF-current not dependent on DG-units



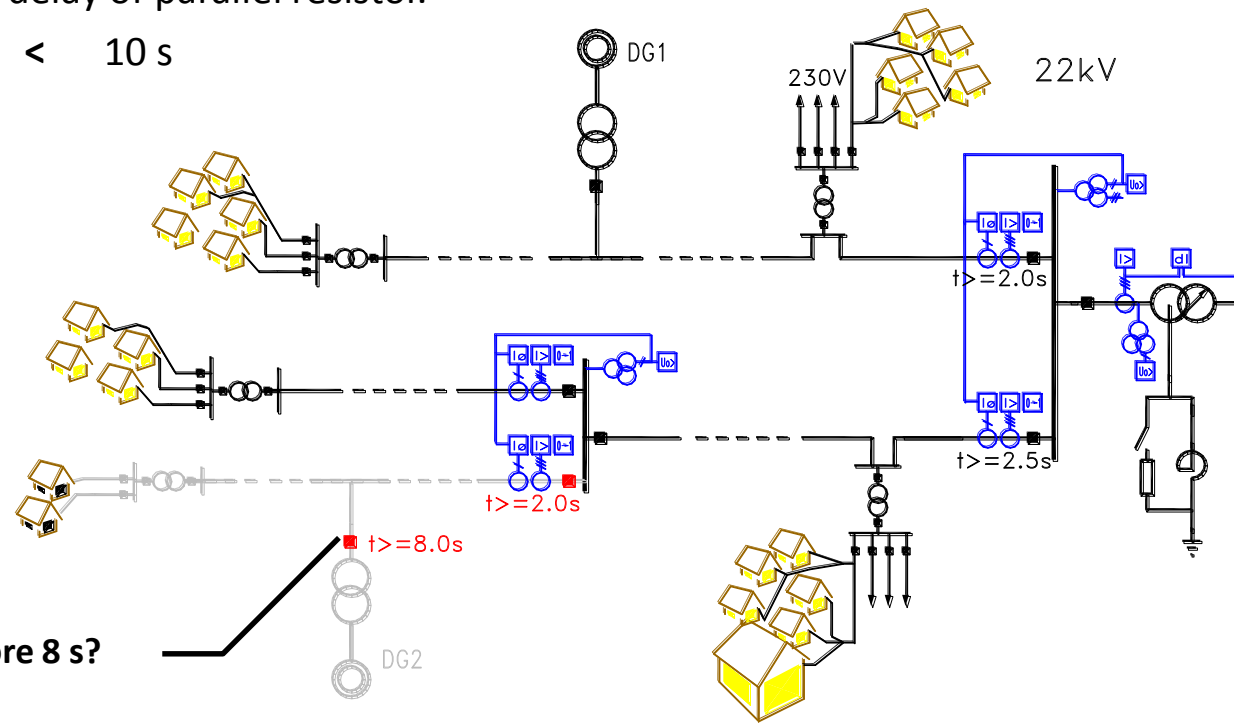
# EF Protection Scheme With DG

## Dispersed Generation (DG) - Influence

- Earthfault voltage relays located at HV side at DG-units must trip the DG-units (3Uo>)
- Time delay higher than the max. delay of any directional earthfault relay (tø>) + closing time delay of parallel resistor.

$$t_{ø}> + t_{Par,Res} < t_{Uo}>_{setting} < 10\ s$$

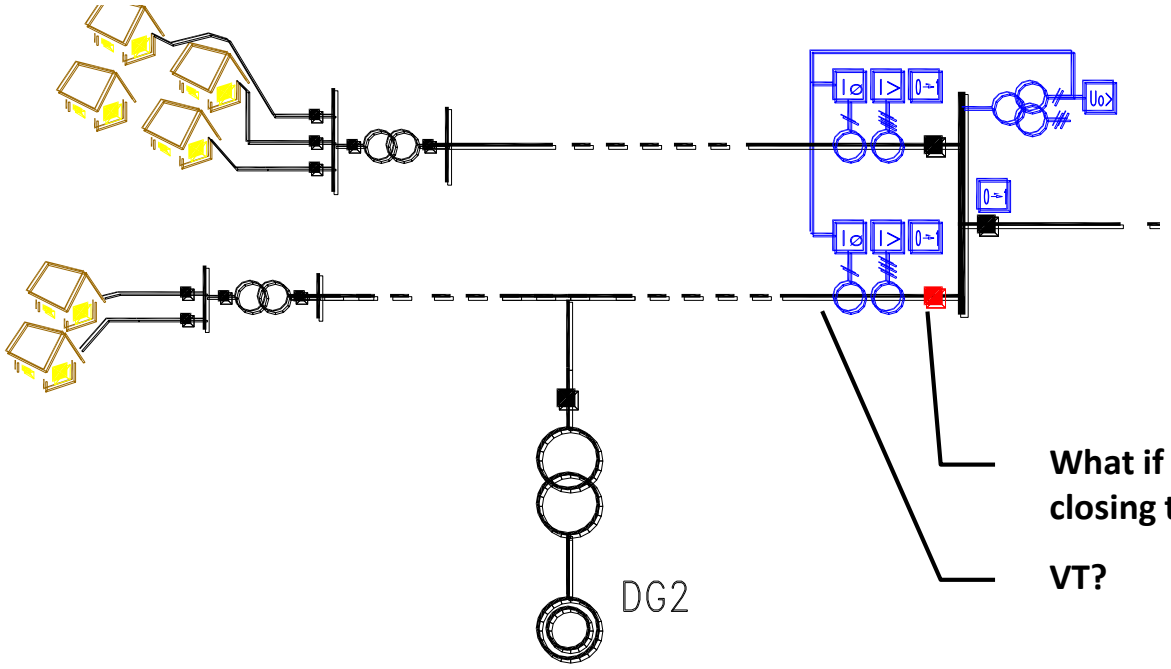
- 3Uo> - level according to FEF 2006




**What if the EF disappear before 8 s?**

# Reclosing Circuit Breaker

- Voltage check or synchro check to allow closing of breaker
- VT on feeder side of breaker



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## Short circuit protection – Higher & Lower level networks

Distribution transformers

- HV-fuses with typical arcing times
  - HV – fault → 0.005 - 0.05 s
  - LV – fault → 1 s – 10 s
  - 50 % - fault → 0.1 s – 0.3 s

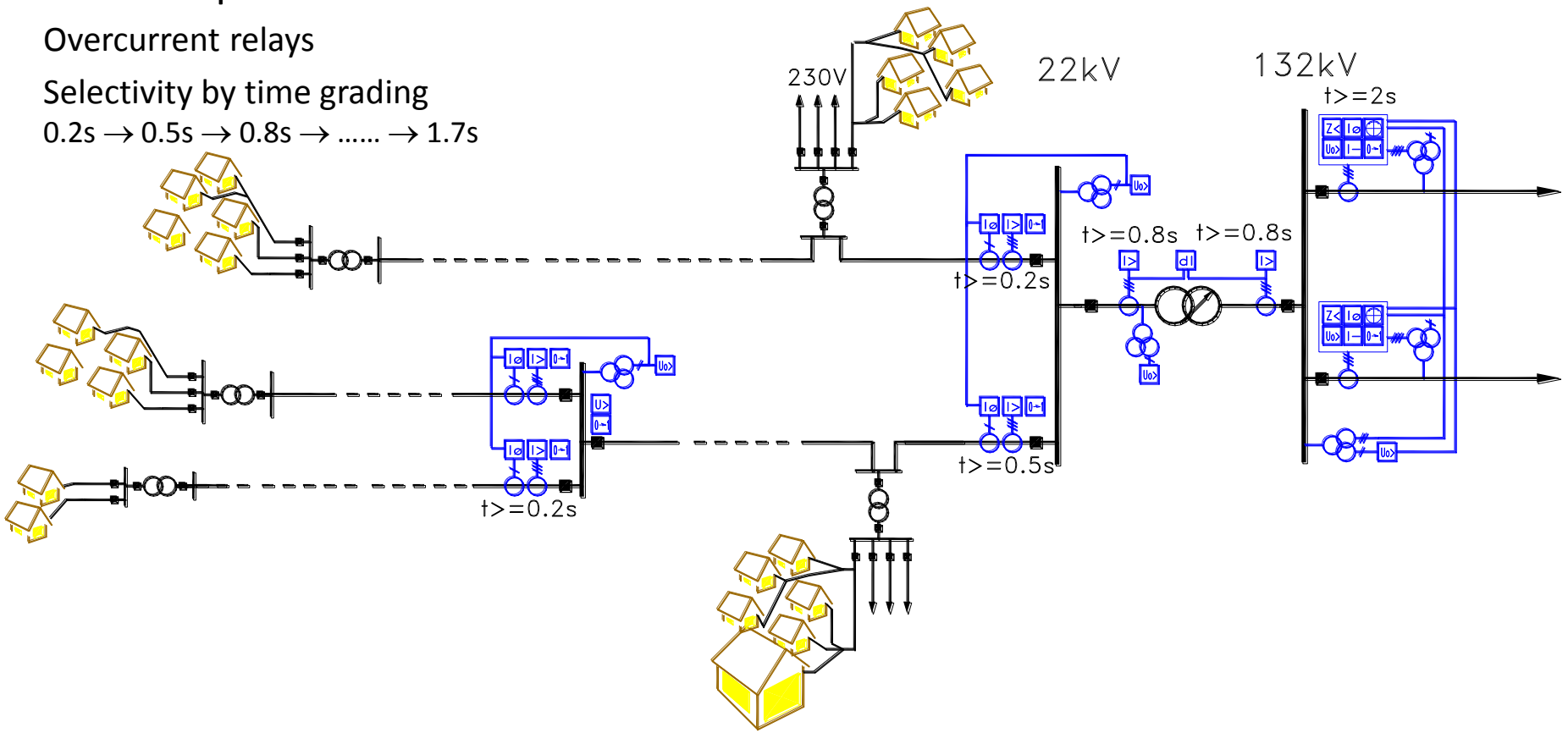
Transmission network

- Distance relays trips:
  - Faults in transmission netw. → t ≤ 0.7s
  - Faults in HV-distribution netw. → t = 1.2 - 3s

# Traditional Short Circuit Protection Scheme Without DG

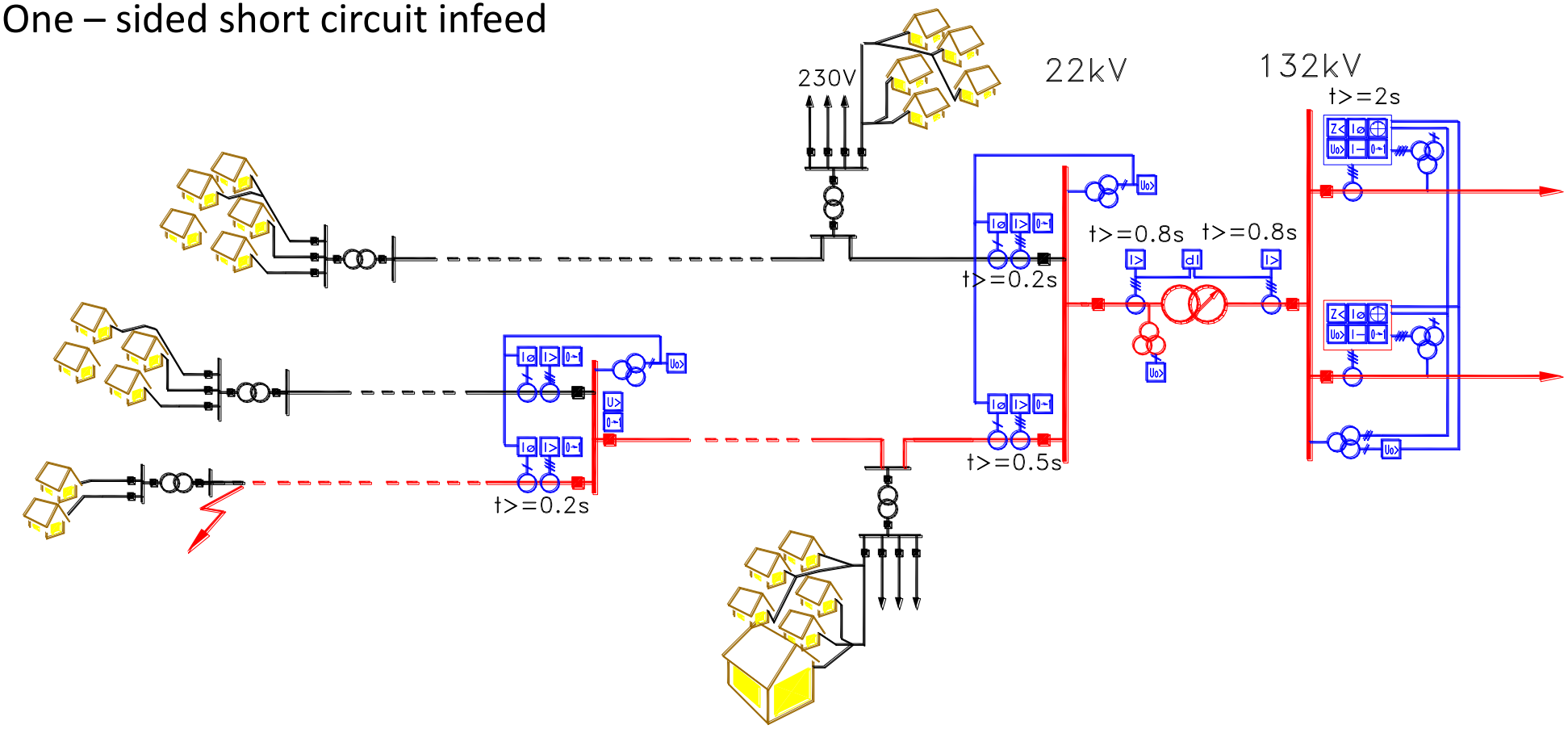
Short circuit protection of feeders

- Overcurrent relays
- Selectivity by time grading
  0.2s → 0.5s → 0.8s → ..... → 1.7s

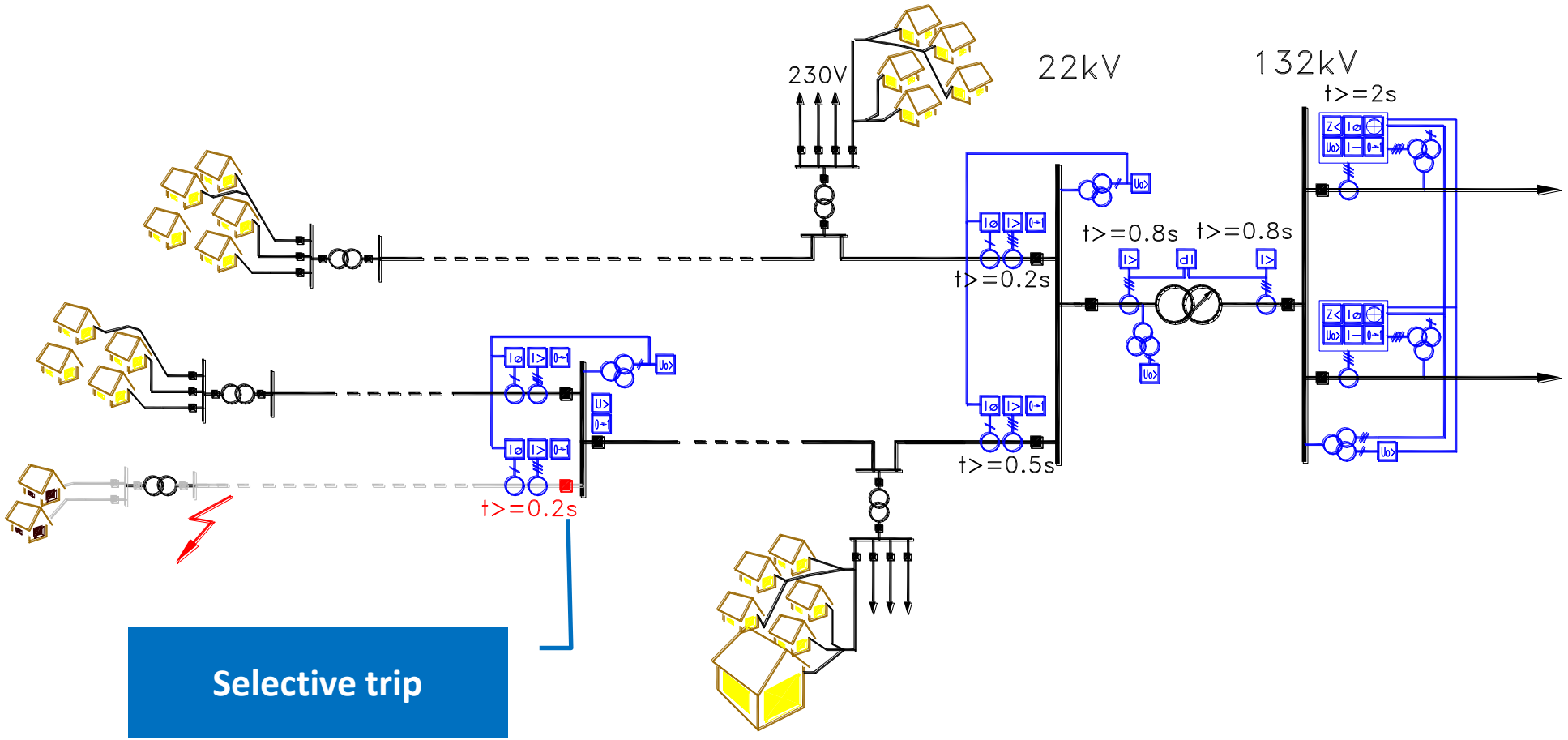


# Traditional Protection Scheme Without DG

One – sided short circuit infeed

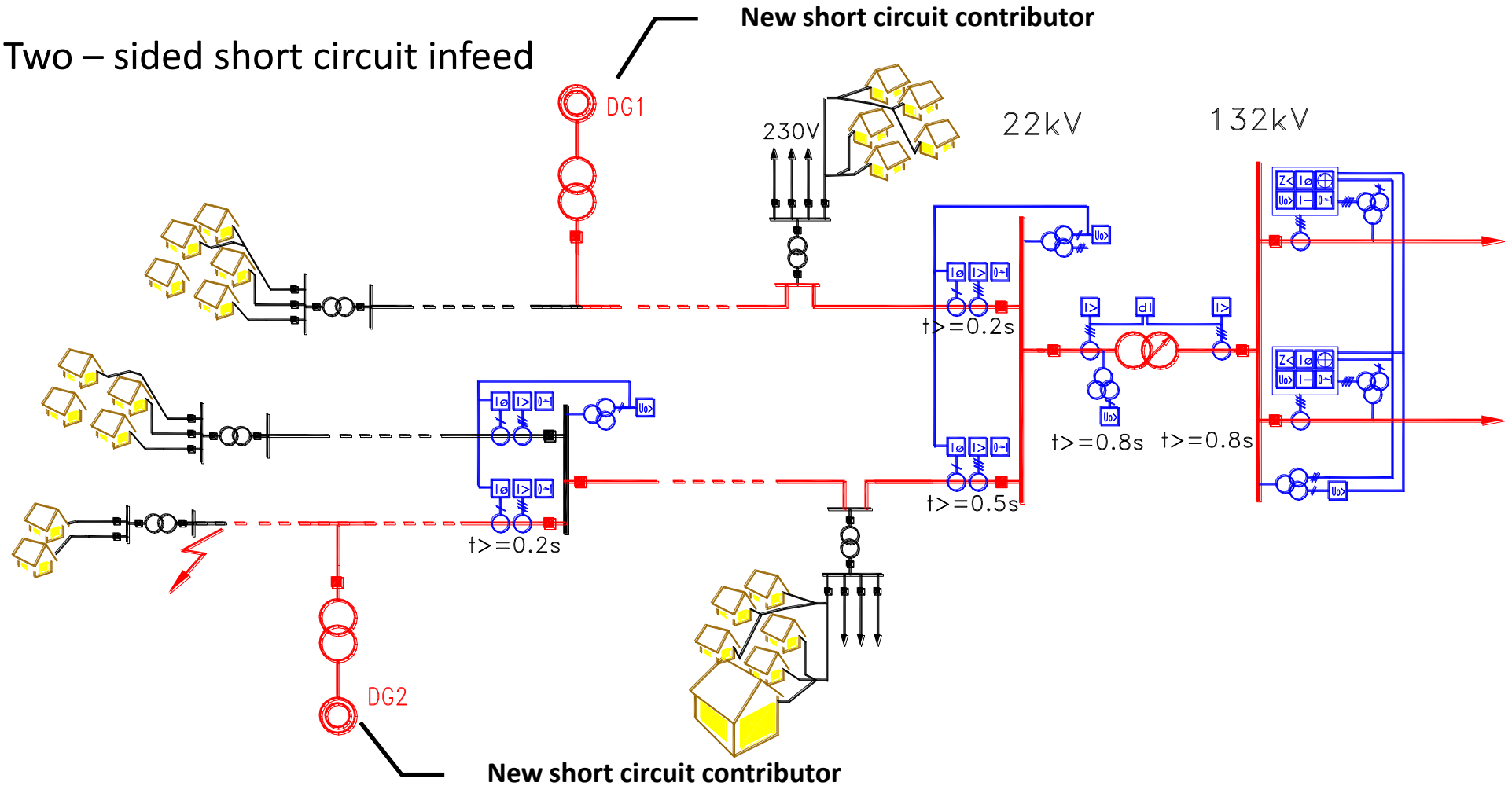


# Traditional Protection Scheme Without DG



# Introducing DG

Two – sided short circuit infeed



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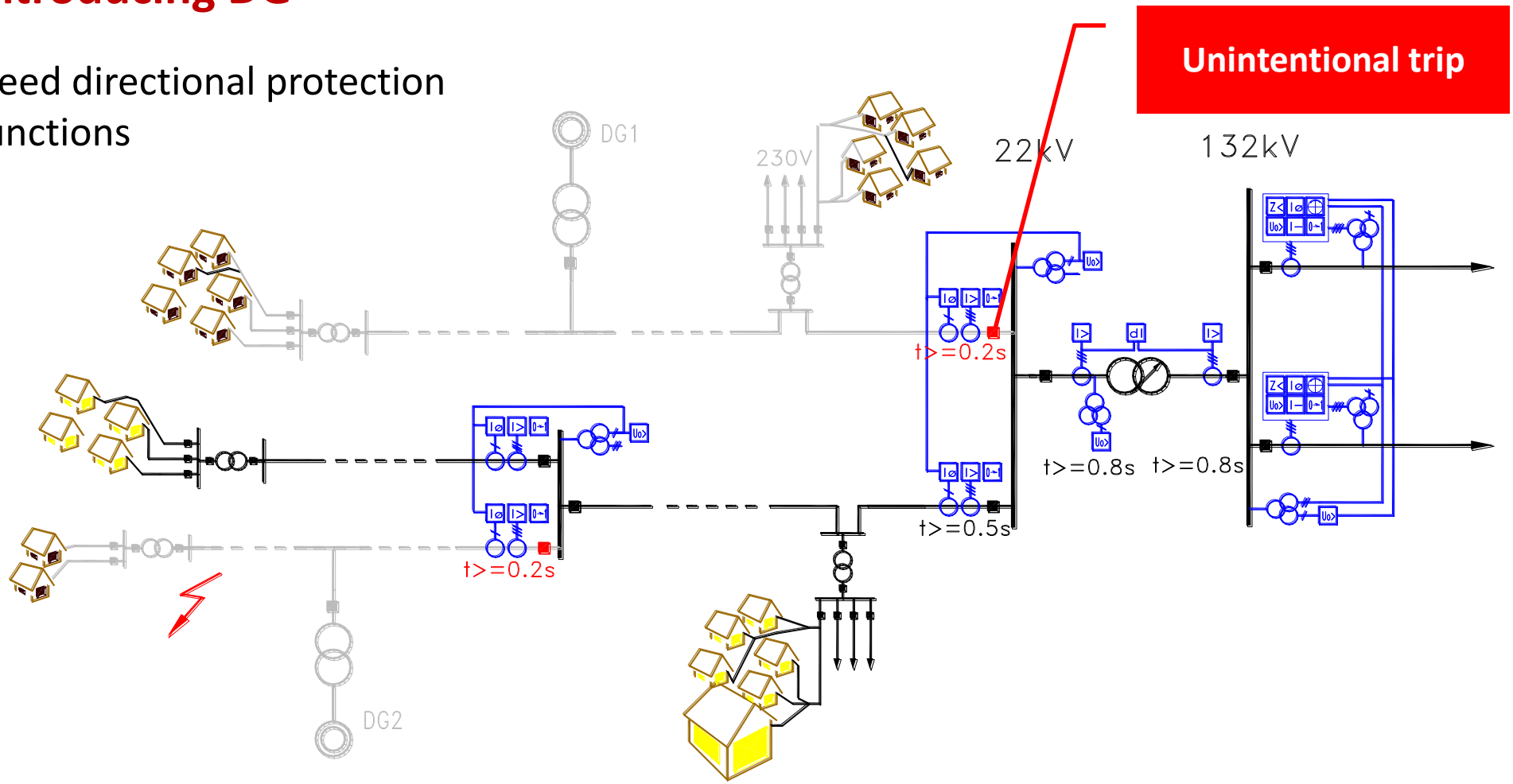
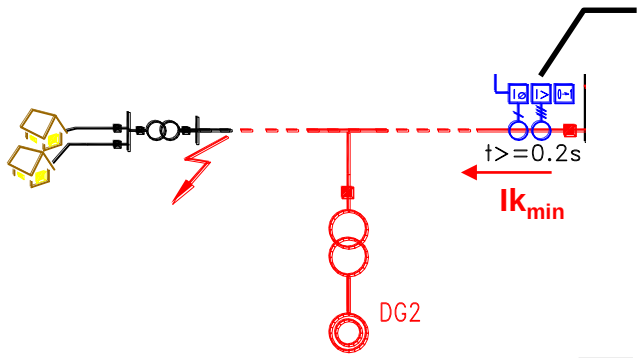
# Introducing DG

Need directional protection functions

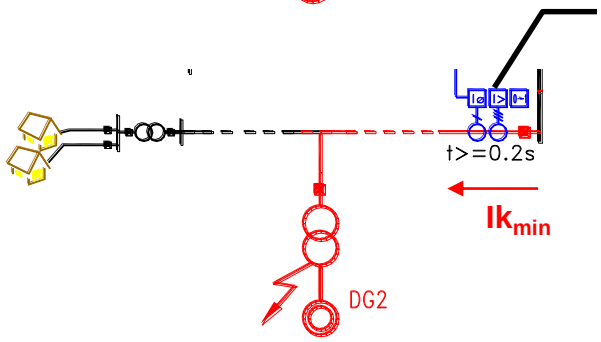


# Introducing DG

New $Ik_{min}$ considerations


**Current suppression -> smaller $Ik_{min}$**




**Backup of transformer fault at DG-unit?**

# Ways of Determining Direction of S.C. Current

1. Current grading if possible
   - Overcurrent (I>) can determine «forward direction» when:
     $1.5 * Ik_{max\ reverse} < \mathbf{I>_{setting}} < 0.7 * Ik_{min\ forward}$
   - The criteria must be verified each time new DG-units are installed/planned

2. Relay types with directional decision
   - Distance relays (Z<)
   - Directional overcurrent ($I_{dir}$>)
   - Requires voltage measurement

3. Other
   - Differential protection (dI>)
     Suitable for cable feeders whithout tap-offs

# Protection of far-end fault (Ikmin)

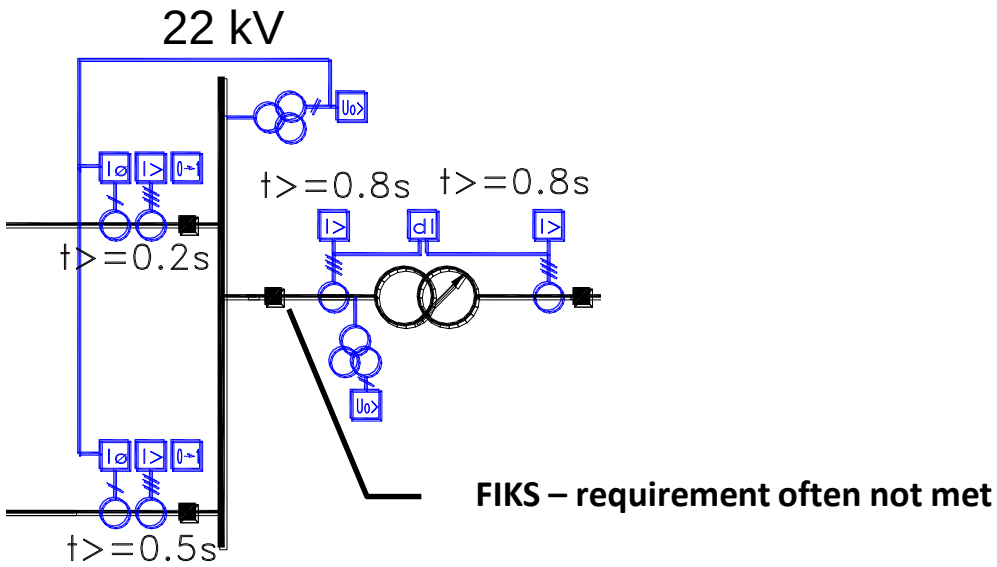
Short circuit protection must cover far-end fault.

- I>-relays cannot be set lower than max-load current.
  - Side-infeed from DG → relay measures smaller $Ik_{min}$
- Z<-relays can cover faults, even with low currents (as low as 10 % of In).
  - Side-infeed from DG → relay measures higher impedance

# Typical Busbar Protection Scheme Without DG

## Requirements Statnett – FIKS (grid code)

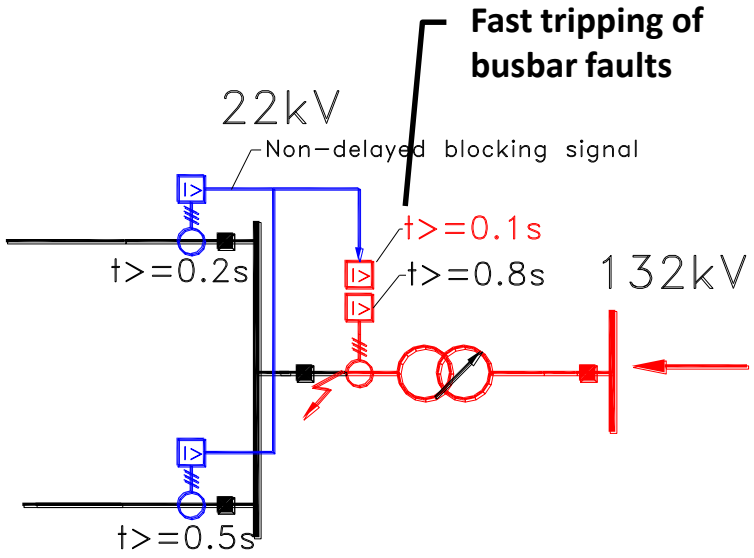
- Max fault clearance time for faults between LV-CT and LV-CB (Practically speaking LV bus-fault)
  - 0.4 s if HV voltage = 132 kV
  - 0.5 s if HV voltage = 33kV…110 kV

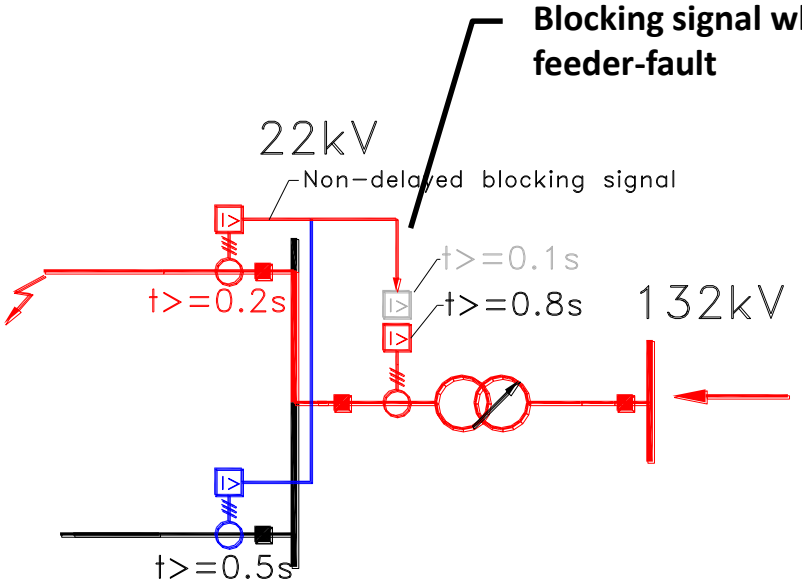


# Fast Busbar Protection Without DG

## Overcurrent (I>) blocking scheme

- Dedicated I>-function at transformer bay provides fast clearance of busbar faults
- The fast I>-function is blocked by I>-start signal from relays at feeder bays

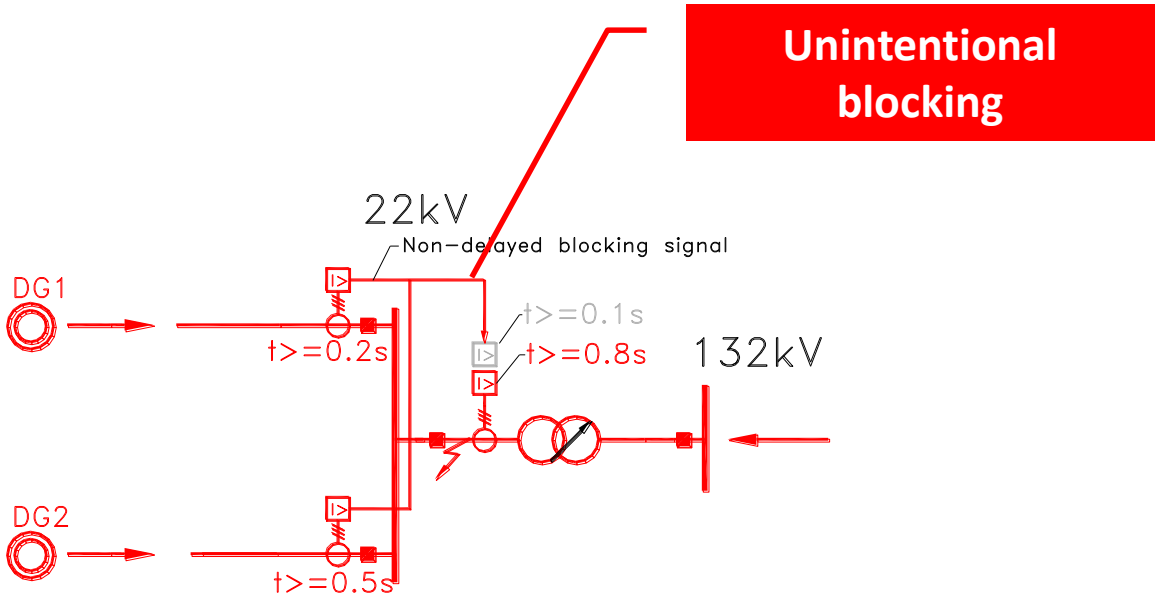


# DG- influence on Busbar Blocking Schemes

Two side infeed requires directional decision in blocking scheme

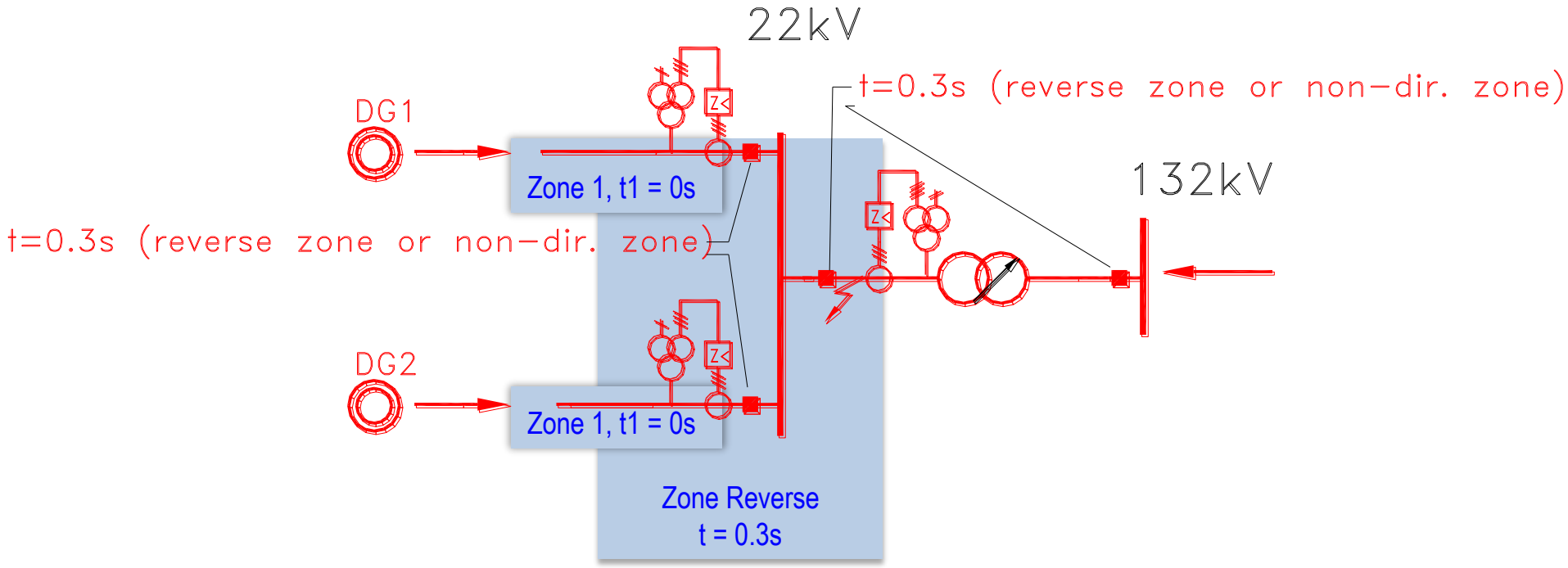
- Directional decision at feeder bays to avoid false blocking of busbar faults
- Directional decision at transformer bay to avoid non-selective fast tripping of HV-faults.



# Busbar protection

Using Z<-relays

- Z< - relays <u>with</u> blocking scheme → trip delay 50 - 100 ms
- Z< - relays <u>without</u> blocking scheme using short reverse or non-directional zones.
  - Reverse zones must be shorter than, and time selective above, Zone 1 of all feeder bays
  - Trip delay 300 – 400 ms



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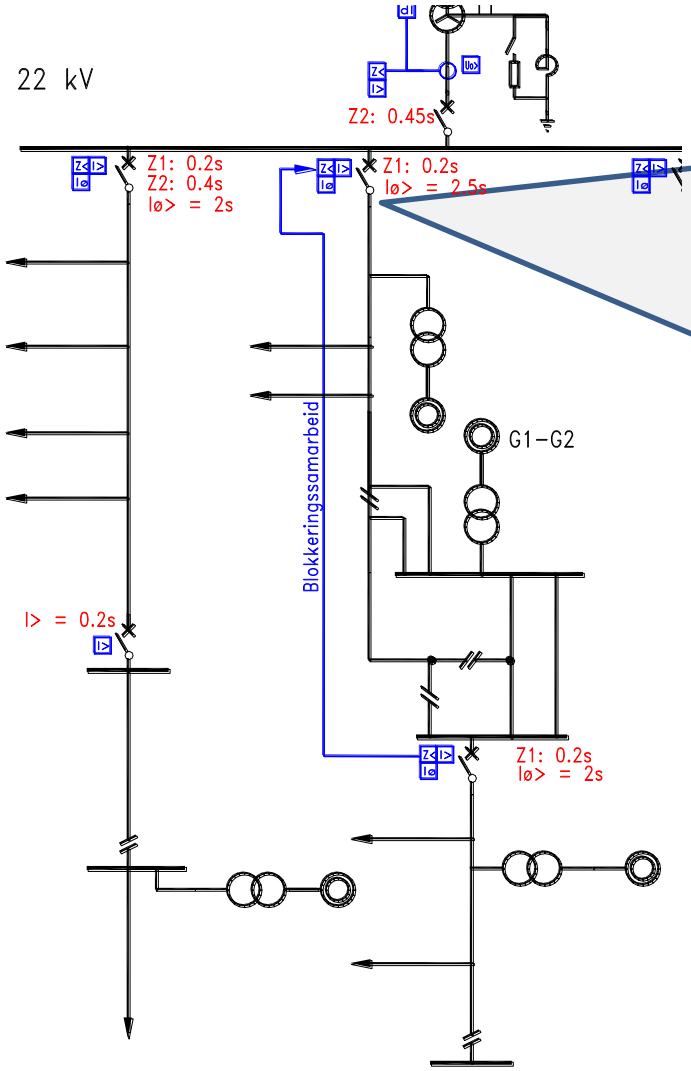
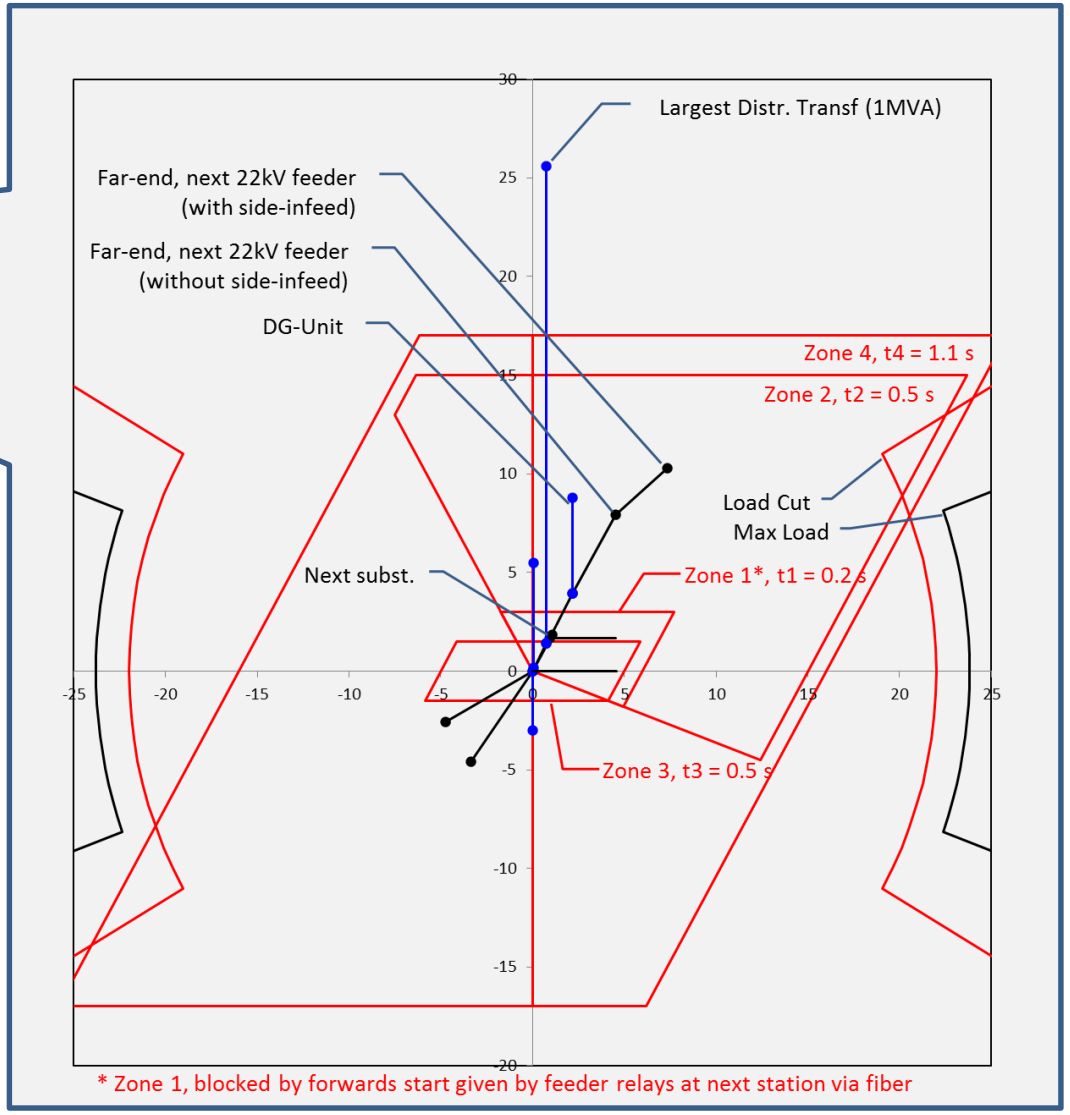
# Example Z<-relays w/communication



# Summary

New Units Initiated by Dispersed Generation