AC Microgrid protection utilizing IEC 61850 based communication

Case study of adaptive protection of radial AC Microgrid in PSCAD (Grid-connected and islanded mode scenarios)

Protect-DG

New techniques for the management of power system faults and distributed generation

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Programme for Sustainable Growth and Jobs

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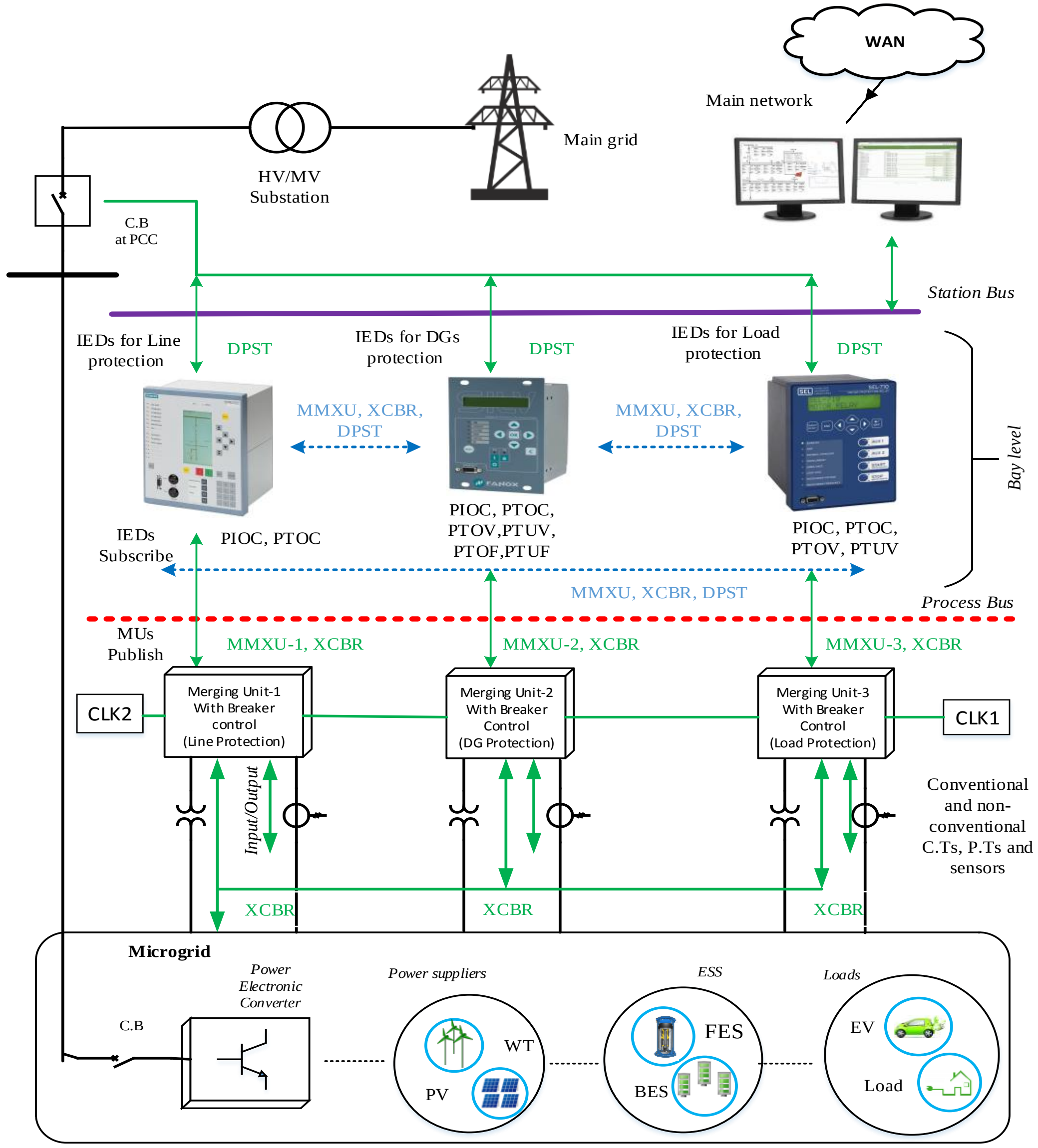
Adaptive protection of AC Microgrid based on IEC 61850 Standard



IEC 61850 Standard offers:

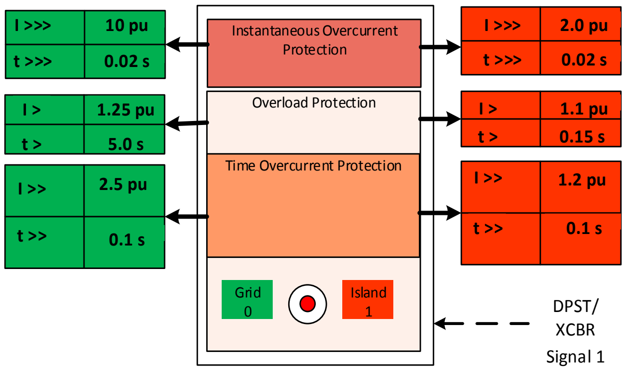
- interoperability
- cost reduction by replacing hard-wired connections by fiber optics between C.Ts and relays and other parts
- lower installation costs
- Process bus: SV protocol, 1-10 GB Ethernet
- Station bus: GOOSE and MMS protocols, 10-1000 MB Ethernet

For mission-critical fast events and reliability:

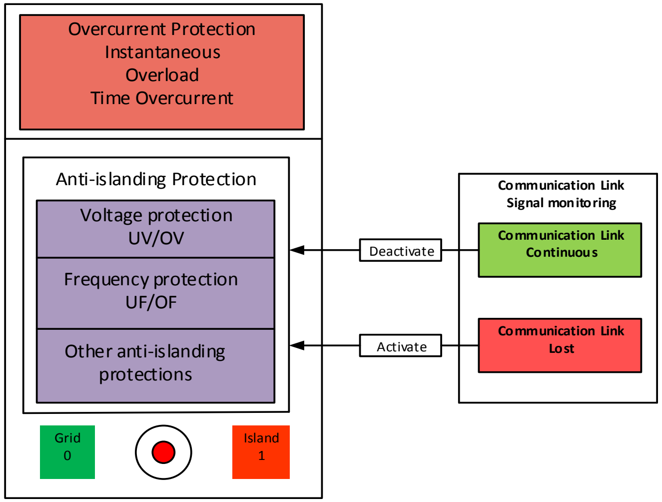
- redundant comm. channels
- redundant synch clocks

Adaptive Protection IEDs

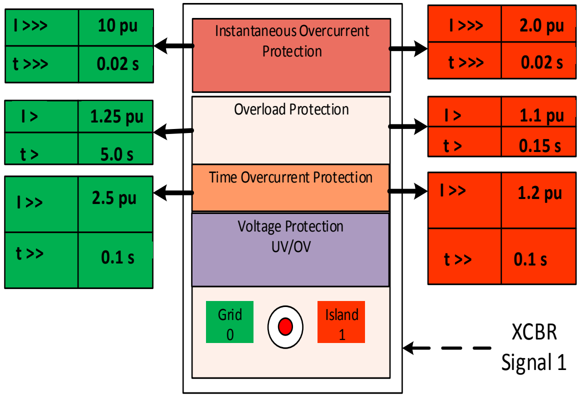
I>>>, t>>> Close in faults
I>,t> Overload protection
I>>, t>> Back-up coordination



Adaptive OC protection IED (Line/Load/DG)



Multifunctional adaptive protection IED for DGs

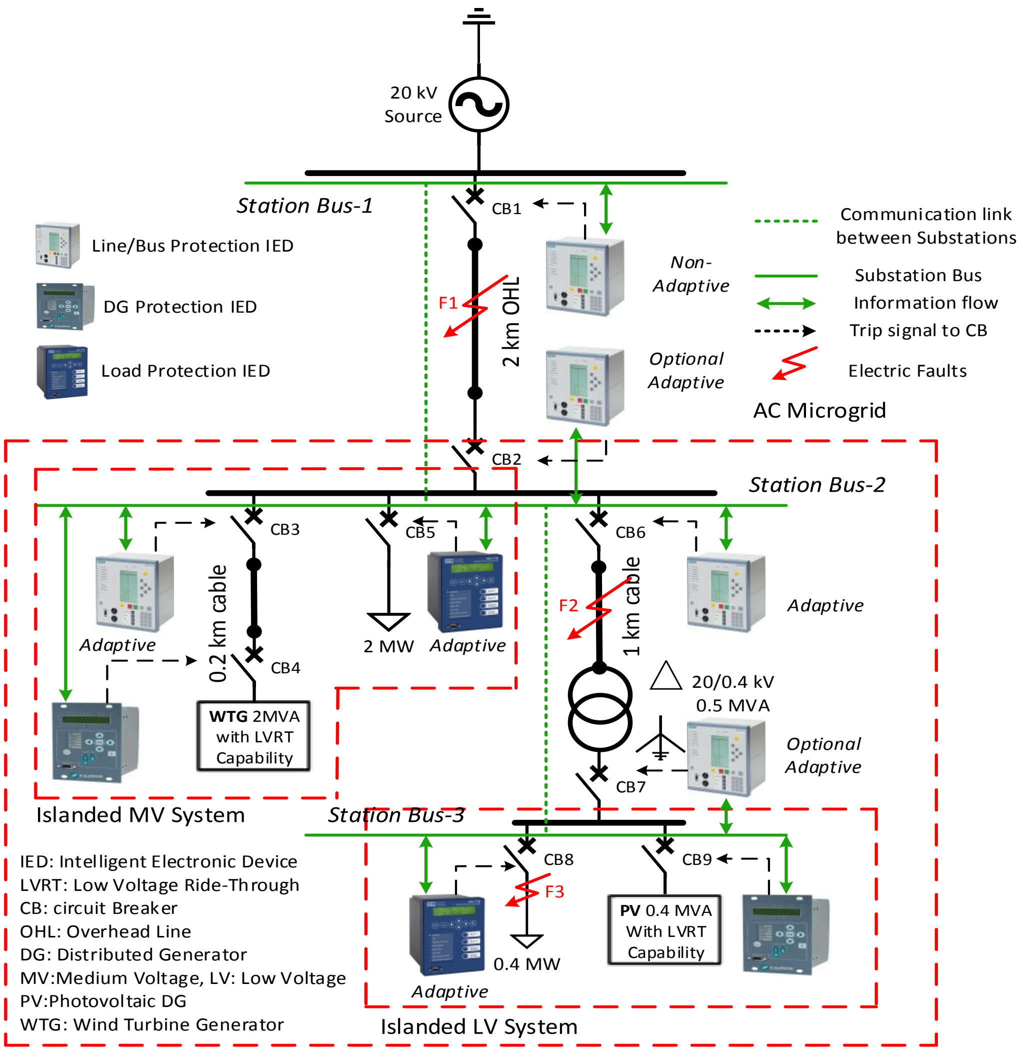


Adaptive OC protection with backup voltage protection for AC Microgrid loads

- Adaptive OC protection has been studied
- Focus only on 3-Ph faults in distribution lines and LV load
- Generic DG models have been used
- DG models provide LVRT up to any fault duration by default, any value of Igmax can be selected (1.2 pu selected)
- Decision of adaptivity made by IEDs based on CB status transfer

Radial AC Microgrid System under study (20/0.4 kV, 2.4 MW):

- Load and generation assumed balanced with additional energy storage



Grid-connected:

Fault F1:

Method-A:

1) Non-adaptive IED1 detects fault and trips CB1 in 20 ms.
2) After tripping CB1, IED1 sends GOOSE message to IED2 and all IEDs within AC Microgrid (20-40 ms two-way transfer time)
3) CB2 will transfer trip to isolate fault F1 completely (20 ms)

Method-B:

1) IED1 detects fault and send GOOSE message to IED2. CB1 tripping and message transmission occurs at the same time (20 ms)
2) IED2 trips CB2 after receiving GOOSE (20 ms)

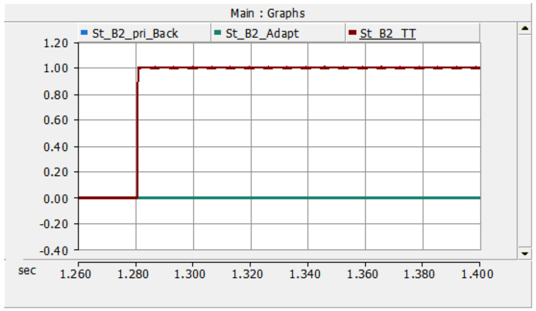
-After receiving CB1 status signal, DGs set-points change to islanded mode and all adaptive IEDs change to islanded mode settings.)

Method-C: Communication failure/data loss

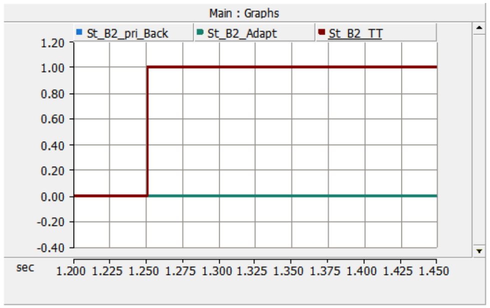
-IED2 trips with adaptive settings with AC Microgrid already islanded.
-Islanding detected by DG undervoltage.

Results:Grid-connected Mode:Fault at location F1

With Communication link

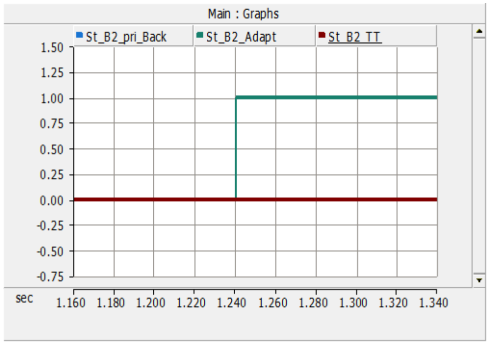


Transfer trip from CB1 to CB2
(1.2 + 0.06s +0.02s = 1.28 s)
With extended delay 20 ms
(one-way communication)

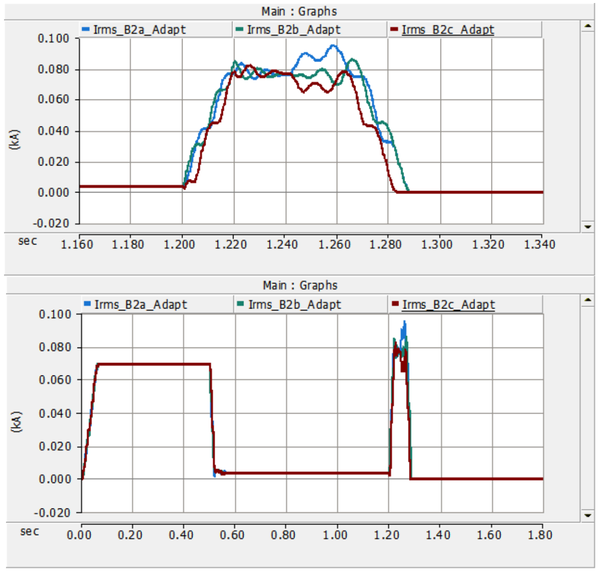


Transfer trip from CB1 to CB2
(1.2 + 0.03s +0.02 = 1.25 s)
With reduced delay 10 ms
one-way communication

Without Communication link



Adaptive IED2 trips CB2
(1.2s + 0.04s = 1.24 s)
with instantaneous trip
setting of 0.02 s (DGs
automatically providing LVRT)



Irms at CB2 location

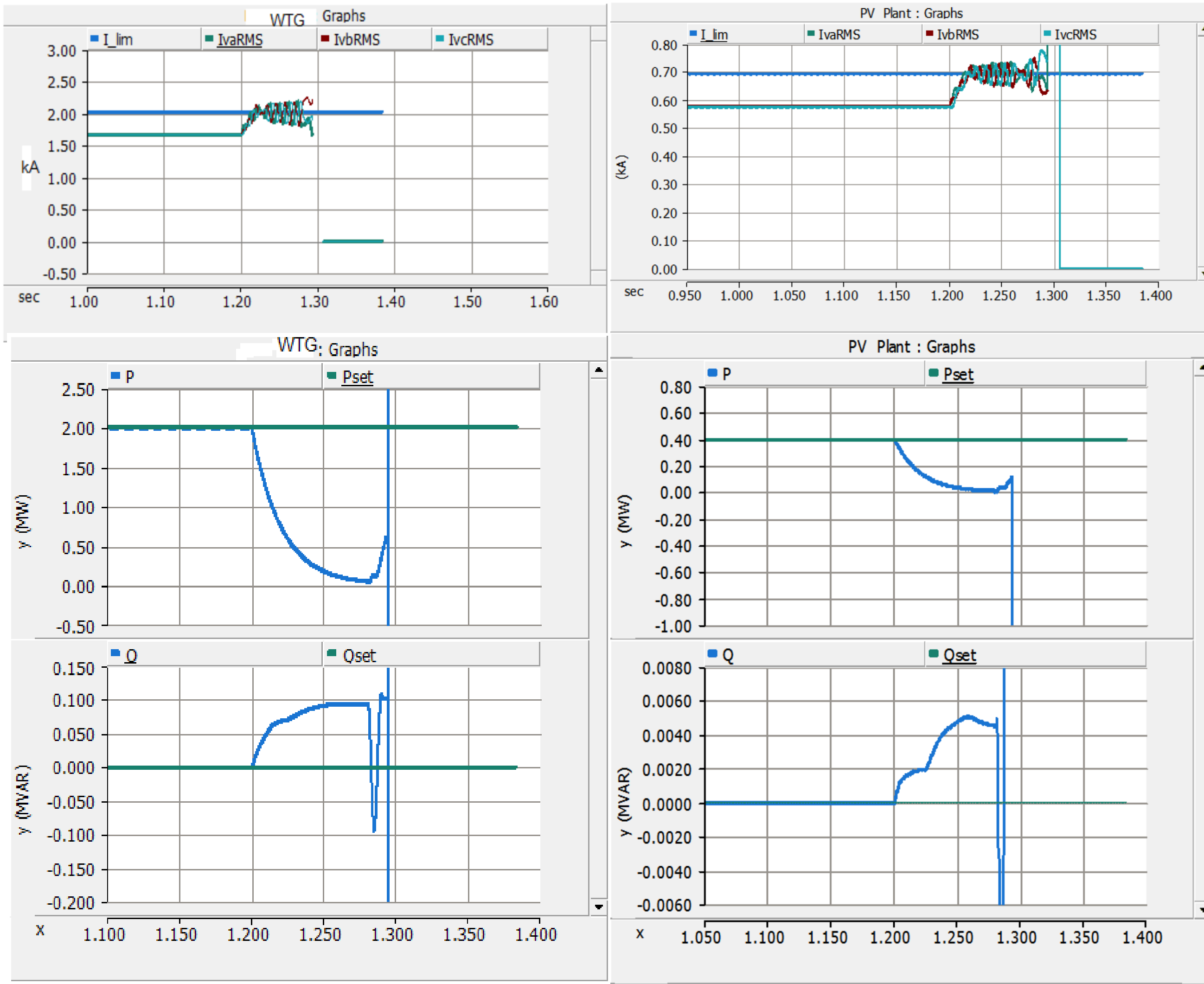
-Events are as follows:

1) IED1 detects fault and sends GOOSE to IED2
2) IED2 acknowledges and sends back ”no fault” GOOSE
3) IED1 trips and sends back trip status to all IEDs including IED2
4) IED2 trips CB2 to isolate fault F1 within extra 20 ms

- With adaptive settings of IED2 when no comm between IED1 and IED2, same trip times are obtained as with transfer trip with Comm. delay of 10 ms. IED2 detects fault with lower settings. However, direct transfer trip from IED1 to CB2 <u>excluding step No. 2-3</u> will be much faster depending on delay.

Results:Grid-connected Mode:Fault at location F1

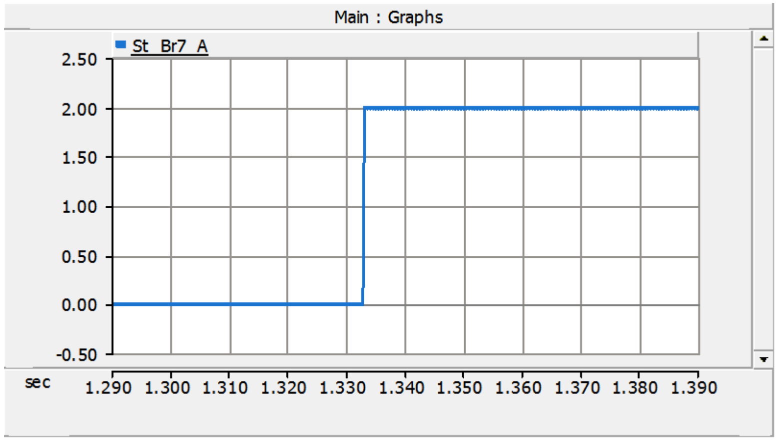
DGs behaviour during fault: Output currents and powers



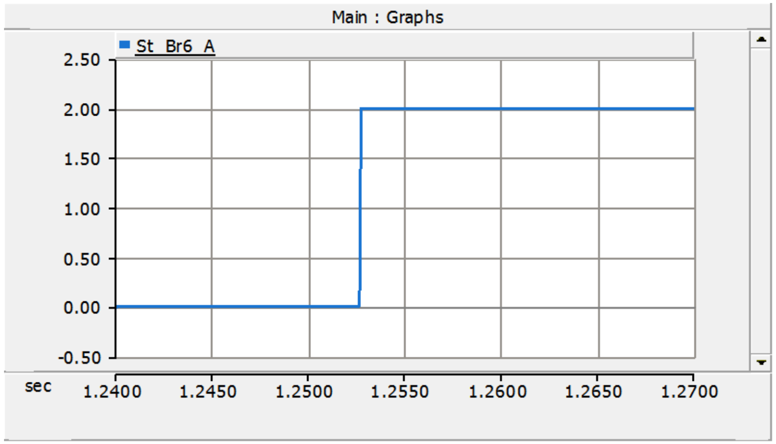
Simulation stability is lost after both CB1 and CB2 are tripped to clear fault F1 at 1.28 s

(Island operation failed in this simulation due to an error in the model)

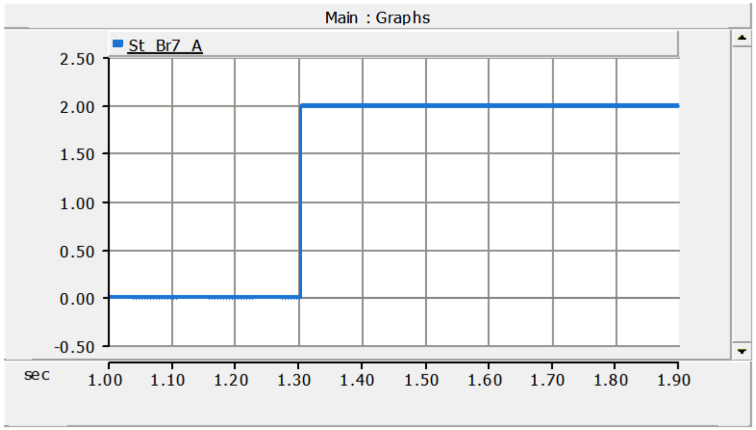
Results:Islanded Mode:Fault at location F2



Transfer trip from CB6 to CB7
(1.25s + 0.06s + 0.02s = 1.33 s)
With extended delay 20 ms (one-way communication)



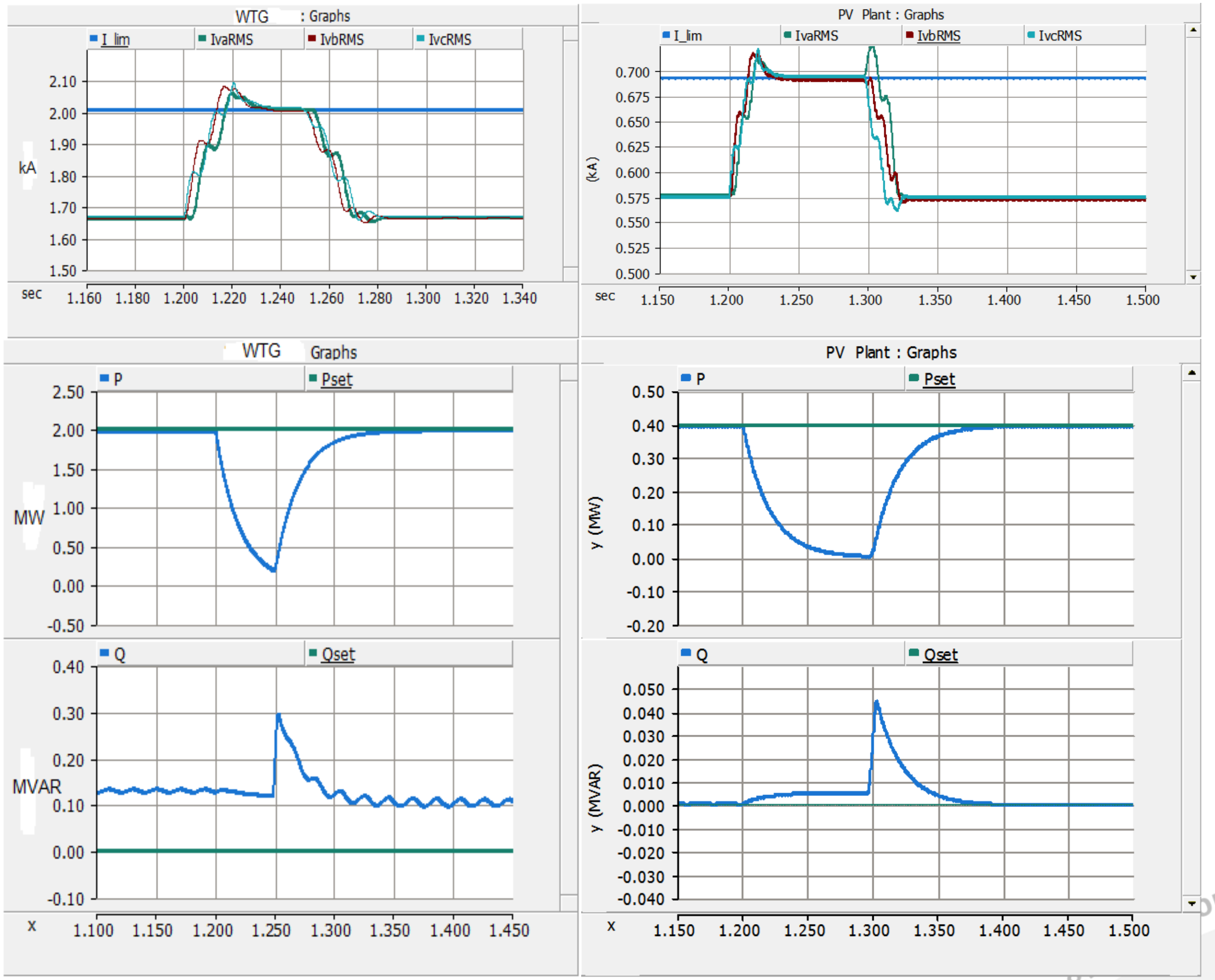
CB6 trips instantaneously within 1.2s + 0.04s = 1.24s after fault (only sensing and tripping delay)



Transfer trip from CB6 to CB7 (1.25s + 0.03s +0.02s = 1.3 s)
With reduced delay 10 ms one-way communication

Results:Islanded Mode:Fault at location F2

DGs behaviour during fault: Ouput current and powers



Islanding is created by opening only CB1, CB2 is closed and OHL section is still energized…….!

VCO control instead of PLL for DGs in islanded mode

After fault F2 is removed, DGs seemlessly continue to supply their own loads (Two islands within AC Microgrid)

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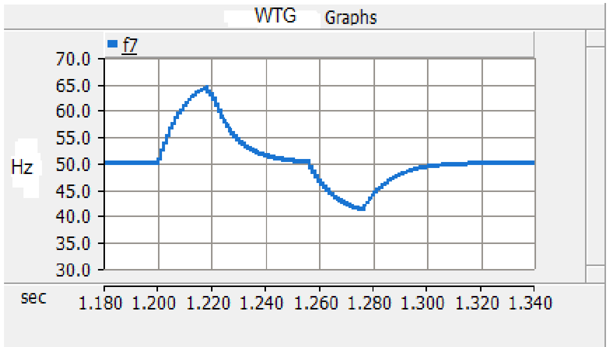
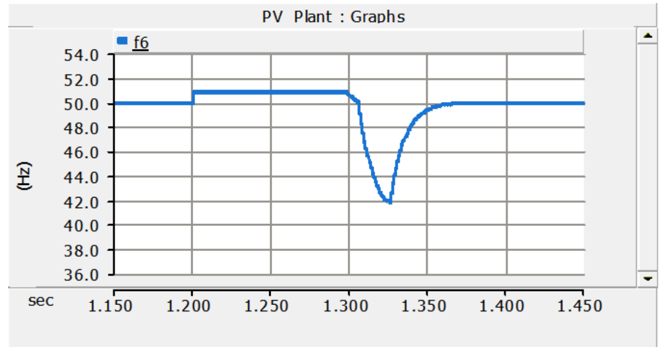
Results:Islanded Mode:Fault at location F2

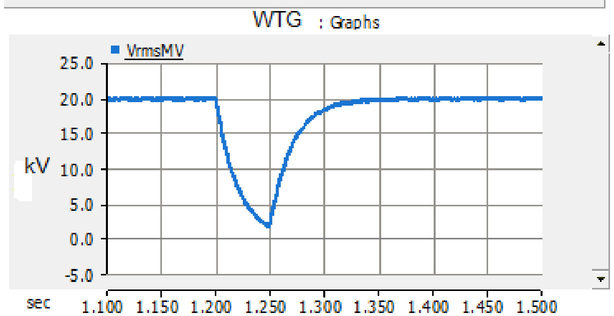
DGs behaviour during fault: Frequency and voltages

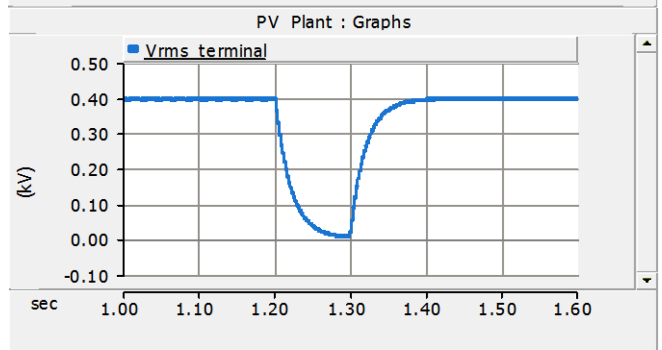


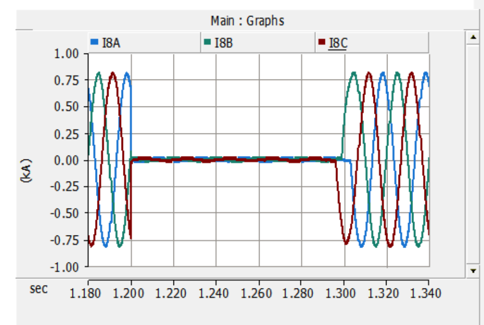


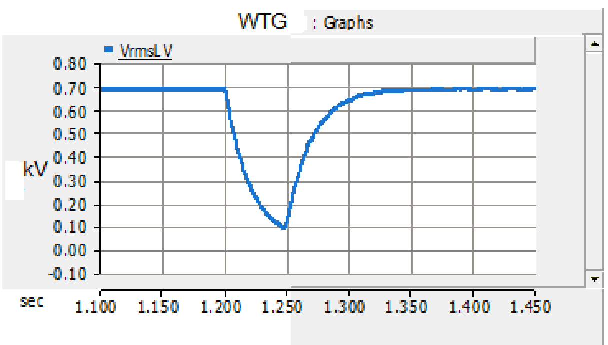
-Slight frequency change of DGs during fault duration

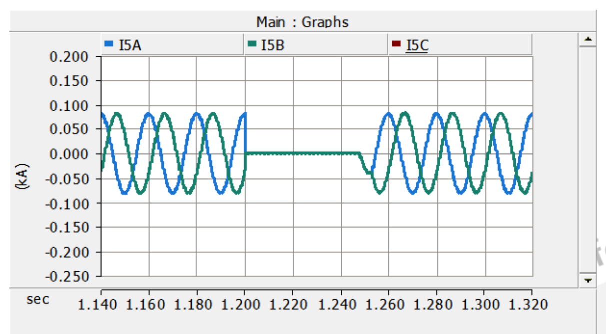
-No problem since loads get interrupted during fault due to low voltage.











Load currents during fault F2

Conclusions:

- Adaptive protection can be realized in AC Microgrid using IEC 61850 Communication Standard but have many challenges.
- Undefined and unpredicted communication delays between IEDs create challenges for adaptive protection settings/coordination, since fault current by DGs can be supplied for limited time (150 ms or less).
- Monitoring of communication channel continuity at each IED is a must.
- Passive anti-islanding protection of DGs should be activated when comm. link fails.
- DGs with well defined LVRT are needed for adaptive OC protection to work even if communication links are interrupted.
- High speed transfer trips (CB status signals) via GOOSE messages are useful for seamless operation of AC Microgrids.
- Fault current magnitude before and after fault at fault location shared with other IEDs will help finding fault location quickly.
- OV/UV voltage protection may be required for back-up of adaptive OC protection.
- For AC Microgrid with many parallel feeders, adaptive directional OC will be required.

Future work

- Real-Time simulation of the AC Microgrid model in MATLAB/Simulink (OPAL-RT) for implementation of IEC 61850 IEDs (developed by Mike Mekkanen from our group).
- Observation of other adaptive protection schemes (combinations).
- AC Microgrids with different types of grounding schemes.
- Adaptive protections for high impedance and grounding faults.
- Back-up protection schemes.

Thank you!
Kiitos!

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Sähkötutkimuspooli

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