Preliminary research regarding impacts of GFCs introduction in DSO Nets: Enel’s Studies

ESC-GC Meeting 2024.12.09

REASONS FOR THE STUDIES

Foreword

- RfG 2.0 draft introduced GFCs and National Roadmaps
- ENEL considered that heavy impacts on a full automated distribution network could be possible
- To better discuss a possible National Roadmap preliminary investigations have been defined

Preliminary considerations

- Detailed capabilities/requirements of GFC inverters are not yet defined by any National /European/ International Standard
- To date, only high-level functionalities are defined in the draft of the new RfG 2.0 grid code. Further details are currently under definition within ESC-TG-GFG, started in 2024, while studies started before (2023)
- Apart from extremely simplified generic models available in simulation SW libraries, there is no public GFC detailed models: These are exclusive to manufacturers who do not disclose them
- Simulation with generic models give, therefore, unrepresentative results

Scope

- To define how to operate correctly GFCs in a DSO's network (Protection & CBs ; Islanding; voltage quality , etc) . Comparison with current and state of art solutions. Gaps to be filled.
- To evaluate an evolved distribution system able to take synergic advantage from all features of inverter-based generators
- To define possible improvements of inverter-based generators capabilities/standardization to optimize overall distribution system performances

<u>TBN: target does not include any evaluation on choices behind and on the overall Electric System security. Outcomes for RfG 2.0 draft and TG-GFC applied as far as possible to distribution networks</u>

BACKGROUND

Integration of generators (including GFCs) in a fully automated distribution network considering also intentional islanding

Two studies performed, with different detail levels according to each specific dealt issue:

- Study 1: models developed in the DigSilent PowerFactory 2023 software environment (RMS simulation) with the aim of carrying out medium to long term verifications
- Study 2: models developed in PSCAD environment, fast transients

Critical aspect 1: all GFC digital models have been hypothesized, no standardized/shared model with proper detail level available.

Critical aspect 2: only one Manufacturer was be disposal to supply detailed real time digital models but it resulted extremely difficult to “translate” PSCAD models into DigSilent models. Currently DigSilent real time models under development for further deeper analyzes

ENEL-POLITECNICO OF MILAN:

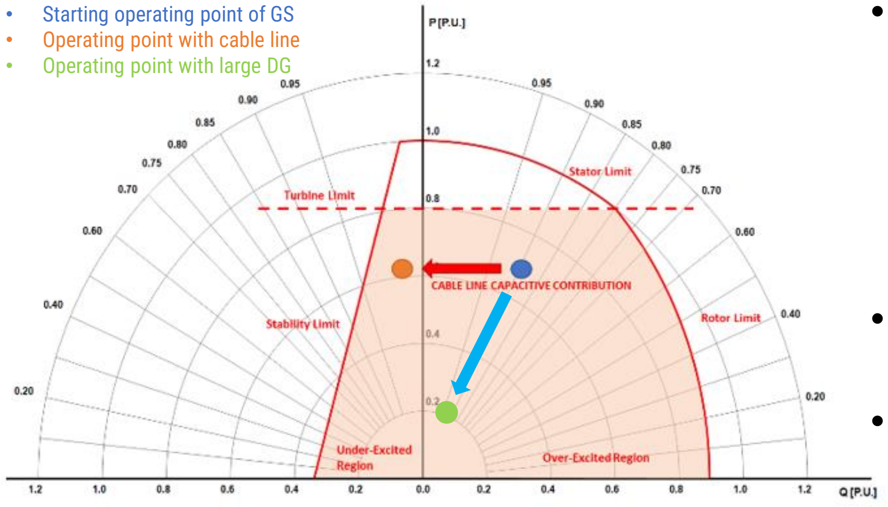
- ADVANCED VOLTAGE REGULATION ON MV/LV DISTRIBUTION NETWORK
- INTENTIONAL ISLANDING

INTENTIONAL ISLAND OPERATED BY A SYNCHRONOUS GENERATOR

According to an IT NRA request intentional islanding sustained by a sync. generator was analized.
The study was aimed to:

- evaluate the dynamic stability (f & Q) of an islanded electrical grid powered by a diesel GenSet (GS)
- define specifications required for the GS in relation to the grid electric characteristics

Gen Set during provisional operation



Variation of the operating point of the GS after events

Study evidence milestone 1

- Important decrease of selectivity and reliability of traditional protection relays in case of earth faults (related to network phase to earth capacitances-zero sequence bypole)
- Network instability in case of appreciable cable lenght
- Instability in presence of appreciable inverter based generation
- Instability also in case of inverter generation reconnection even if lower than load

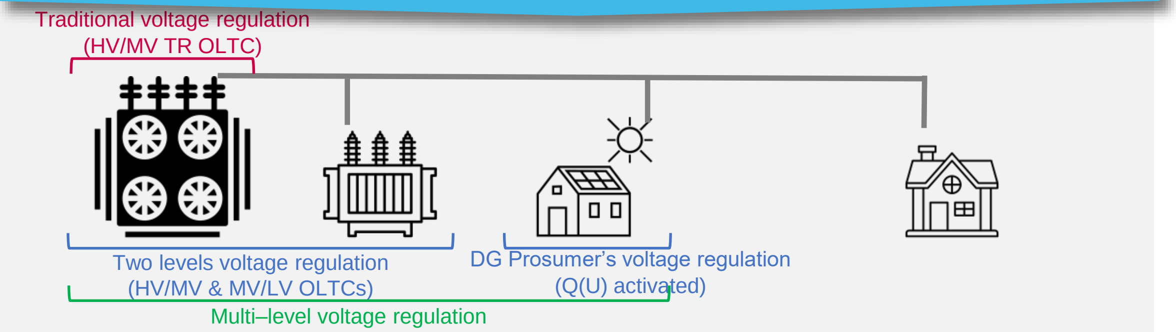
Solution individuated

- Earth faults protection based on 51N relay PLUS an earthing TR
- Case by case selection of the generator according to features of the island

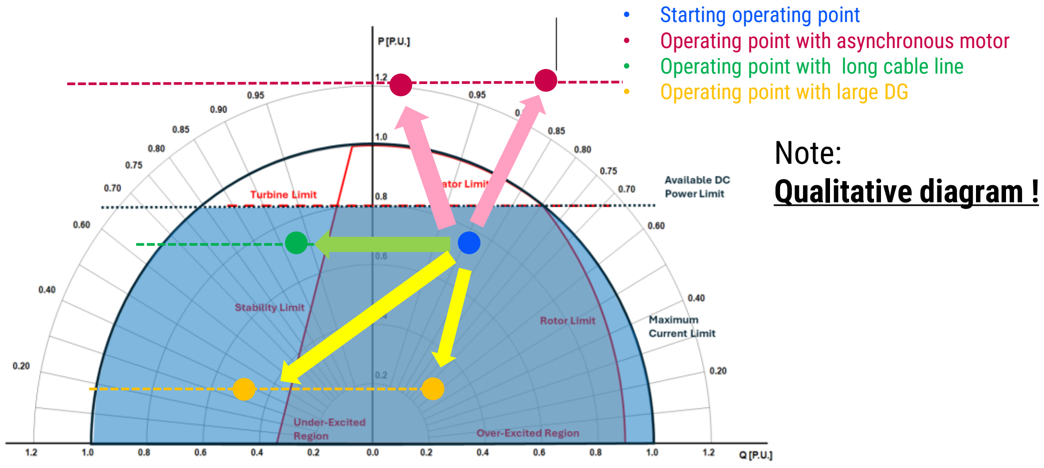
Conclusion: **island can be stable and safety operated ONLY IF COMPLETELY PLANNED IN ADVANCE AND WITH LOW VARIABILITY**. To allow a dynamic island management new technical solutions have to be defined, tested with pilots regarding also scalabilty, then standardized

MULTI-LEVEL VOLTAGE REGULATION & ISLANDING POWERED BY GFCs

Multi-level voltage regulation



Intentional islanding sustained by GFCs



Note:
Qualitative diagram !

Study evidence milestone 2

- MV/LV OLTCs improve voltage profile influenced from feeder length and/or presence of DG (RER)
- **Q(U) activation helps OLTCs reducing operations,** and, in case of long feeders, also support AVR in maintaining voltage profile within limits
- **But**, the beneficial effect in **reducing operations number is maximum when DG is located at feeder beginning, while decreases with the increase of DG POC distance, becoming counterproductive for important feeders length and DG located close to their end. Q(U) and OLTCs regulation laws are not coordinated !**
- **Furthermore,** possible **shunt reactors installed in MV/LV station** (HV and/or LV connected) used to control reactive power exchange with transmission system side **increase the number of OLTC maneuvers**, affecting life duration. Continuous regulation Q exchange devices (synchronous condensers, SVCs) may reduce/eliminate this phenomena. **To be evaluated with further studies.**

Study evidence milestone 3

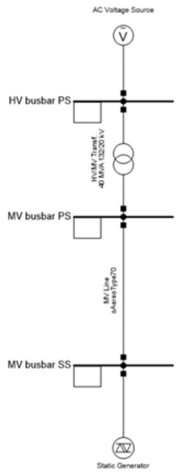
- Island operation of a distribution grid by using a GFC is generally feasible in static conditions
- Island stability is primarily influenced by the load and the reactive power need, mainly related to type and length of the MV conductors in the system
- GFCs can energize without stability issues:
  - overhead MV lines exceeding tens of kms
  - static loads up to their rated power
  - Islands with generated power up to 80% from traditional DG (not GFCs)
- **But,** GFCs can have stability problems with asynchronous motors if exceeding 20%-25% of their nominal power during transients (island energization, reclosing cycles, motor starting, etc.)

MULTI-LEVEL VOLTAE REGULATION & ISLANDING POWERED BY GFCs

Line length relatively short (moderate impedance between RER generators and HV/MV TR)

Network operation:

- **multi-level autonomous regulating voltage systems**
- **high presence of RER, in particular with inverter based generators (GFL-GFC) (preliminary analysis)**



HV/MV transformer:
- Rated power: 40 MVA
- On-Load Tap Changer and tap changer actuation delay: 0.1 s
- Automatic Voltage Regulator

MV line:
- Typology: 4 lines in parallel (naked conductor in copper)
- Length: 10 km
- Cross-section: 70 mm^2
- Ampacity: 248 A x 4

DG unit:
- Maximum active power (*Pmax*): 40 MW
- Actual active power delivered: 36 MW
- Q(V) control logic thresholds:
  - V2i: 0.90 p.u.-
  - V1i: 0.95 p.u. -
  - V1s: 1.05 p.u -
  - V2s: 1.10 p.u

Number of daily maneuvers of OLTC in Primary Substation

Scenarios		1 Low variability	2 Med-Low variability	3 Med-High variability	4 High variability
EVALUATED CONDITIONS: #A (GFL/GFC in MV)	**AVR in PS**	**4**	**7**	**13**	**41**
	AVR in PS+AVR in SS	**4**	**7**	**13**	**43**
#B (GFL/GFC in LV)	**AVR in PS+Q(U) DG**	**4**	**7**	**13**	**41**
	AVR in PS+AVR in SS+Q(U) DG	**4**	**7**	**13**	**43**

Maneuver number stable with Q(U) ON or OFF

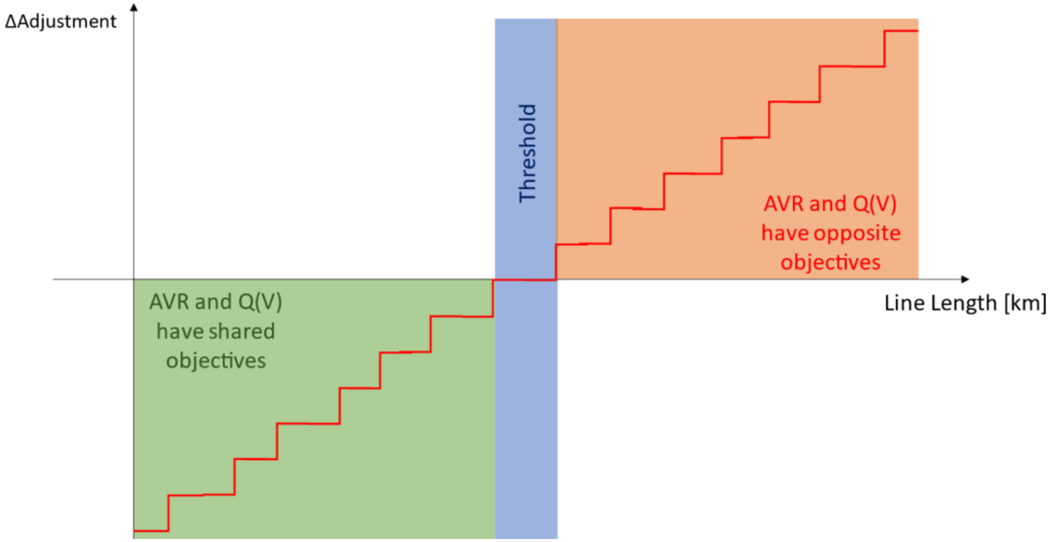
Number of daily maneuvers of OLTC in Secondary Substation

Scenarios		1 Low variability	2 Med-Low variability	3 Med-High variability	4 High variability
EVALUATED CONDITIONS: #A (GFL/GFC in MV)	**AVR in PS**	**0**	**0**	**0**	**0**
	AVR in PS+AVR in SS	**8**	**0**	**29**	**43**
#B (GFL/GFC in LV)	**AVR in PS+Q(U) DG**	**0**	**0**	**0**	**0**
	AVR in PS+AVR in SS+Q(U) DG	**8**	**0**	**17**	**35**

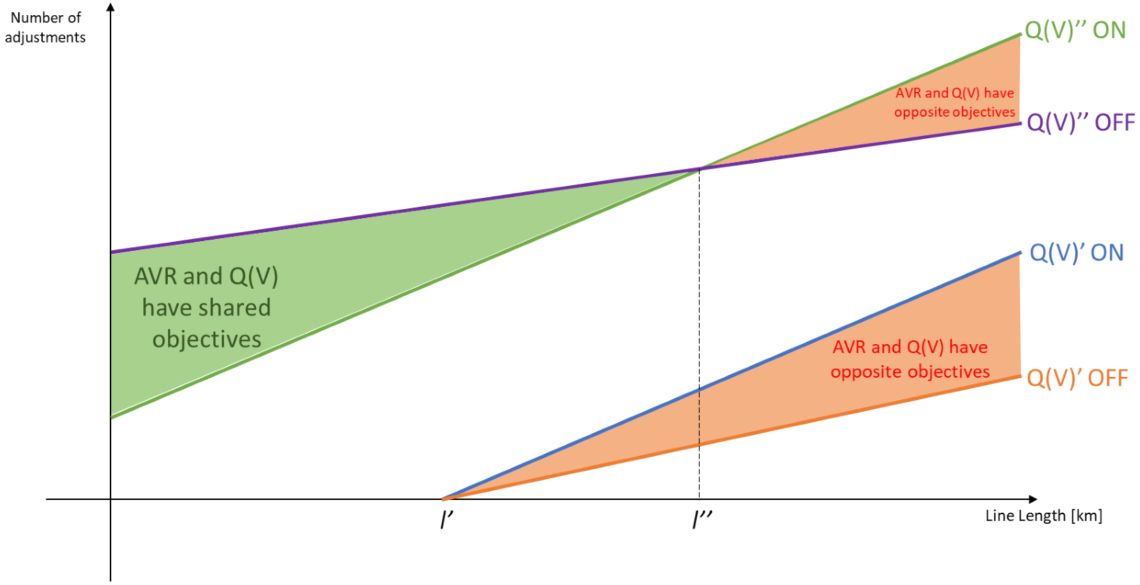
Maneuver number decreasing with Q(U) ON

MULTI-LEVEL VOLTAGE REGULATION & ISLANDING POWERED BY GFCs

Effect of line length (electric impedance between RER generators and HV/MV TR)



Difference in the number of tap adjustments between short and long electrical distances with Q(U) ON



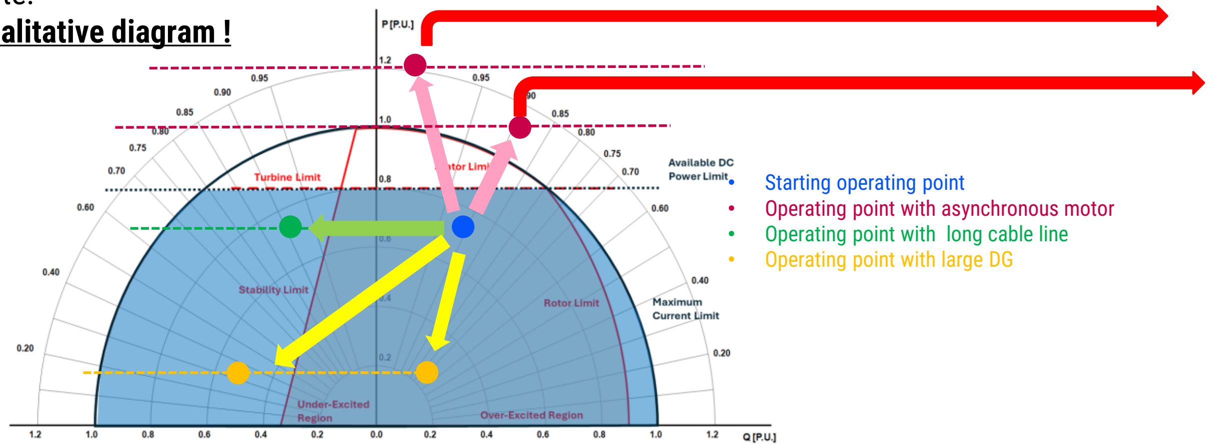
Behavior of the multi-level voltage regulation:
a) active power variability of the DG unit + primary side voltage variability
b) active power variability of the DG unit

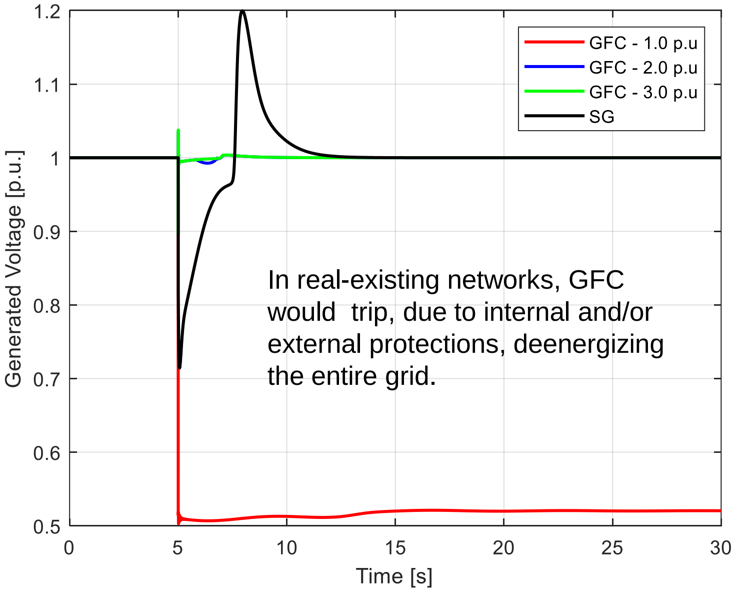
<u>Voltage support by reactive power in Standardization is currently not completely defined. Some improvements (daytime variable U setpoints, time delays, Q@night, etc.) could easily improve the overall behaviors</u>

MULTI-LEVEL VOLTAGE REGULATION & ISLANDING POWERED BY GFCs

Intentional islanding sustained by GFCs

Note:
Qualitative diagram !

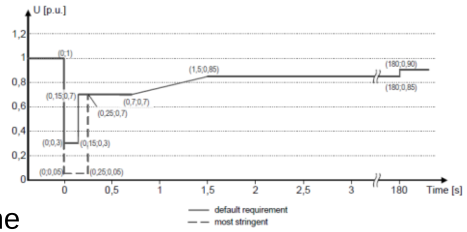


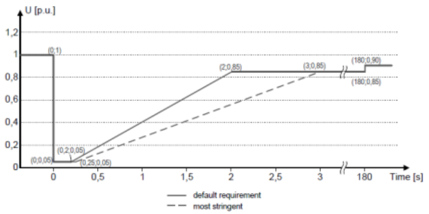


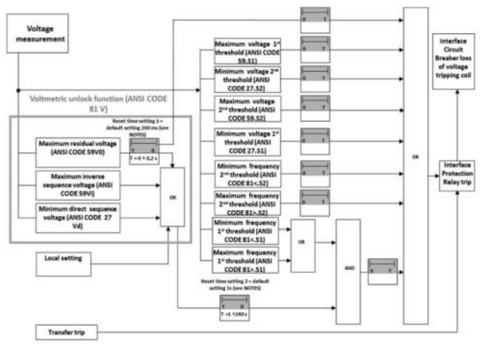
Synchronous generator is able to start asynchronous motors of larger size with respect to GFCs, if max I is equal to 100% In.
If GFC current would be higher (200 or 300% nominal value), GFC would be able to avoid these problems and to start the motor in a shorter time due to the higher dynamic..
Synchornous generator and 200%/300% In GFC curves are very similar, because the current limits are not reached.

GFC Rating [kVA]		Maximum Current [p.u.]	AM Ratings [kVA] 11	55	132	200	250	500	630	710
	160	1.2								
		2								
		3								
	500	1.2								
		2								
		3								
	1000	1.2								
		2								
		3								

- Green: AM's sizes that can be powered in any load condition (mechanical power applied to the shaft equal to 100% of the motor's rated power);
- Yellow: AM's sizes that can be partially powered (not reaching the full-load condition);
- Red: when starting of the motor is not feasible in any condition;
- Grey: cases not investigated







IMPEDANCE CHANGES AT TERMINALS OF A GENERATING UNIT

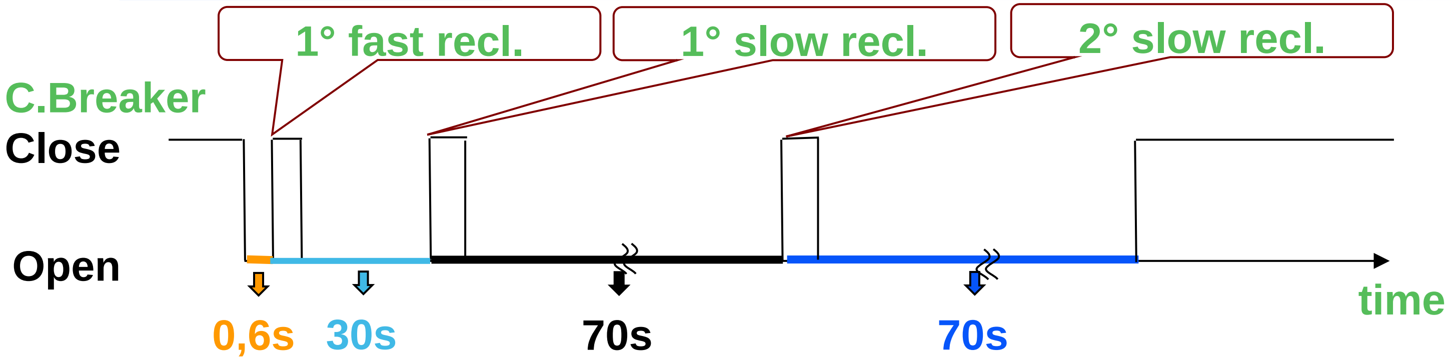
Reclosing cycles and network impedance variations according to fault tipologies

E-DISTRIBUZIONE,Year 2022
Number of MV feeders: about 23.000

FAULT TYPOLOGY	CONSEQUENT INTERRUPTION: SHORT (1s < d<3 m), up to 4 subsequent CB trips	CONSEQUENT INTERRUPTION: LONG I (d >3m)), up to 4 subsequent CB trips	CONSEQUENT INTERRUPTION: TRANSIENT (d ≤1 s)), 1 CB trips
3-phase/2-phase, overcurrent/voltage dip	17347	13799	1745
Cross country fault, overcurrent/voltage dip	3110	4512	301
Earth fault, depending on MV neutral point operation	12763	17724	1426
Overload, moderate voltage dip	941	678	88
TOT	34161	36713	3560

Average values:
- 7,11 impedance variations per feeder per year associated to voltage dips
- 5,36 impedance variations per feeder per year associated to earth faults. Effects according to MV neutral point operation (isolated, resonant, solidly grounded, etc)

10 feeders per each HV/MV TR !



Typical E-DISTRIBUZIONE reclosing cycle
Cycle usually independent from fault typology, number of reclosures depending on conductors tipology (cable, naked)

E-DISTRIBUZIONE,Year 2023
Number of MV feeders: about 23.000

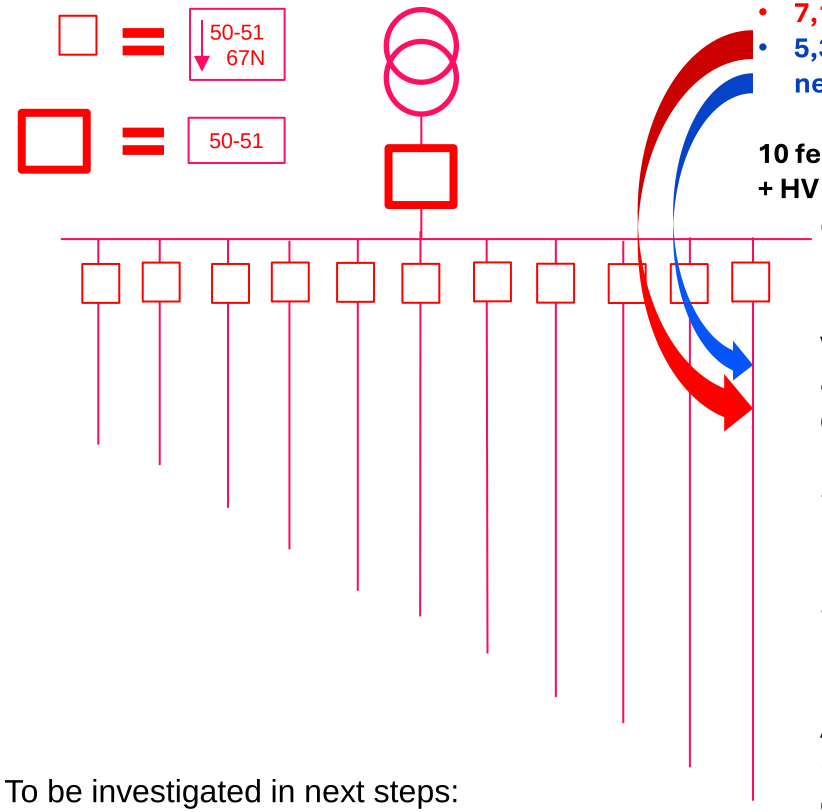
FAULT TIPOLOGY	CONSEQUENT INTERRUPTION: SHORT (1s < d<3 m), up to 4 subsequent CB trips	CONSEQUENT INTERRUPTION: LONG I (d >3m)), up to 4 subsequent CB trips	CONSEQUENT INTERRUPTION: TRANSIENT (d ≤1 s)), 1 CB trips
3-phase/2-phase, overcurrent/voltage dip	11455	8800	1227
Cross country fault, overcurrent/voltage dip	2544	3134	256
Earth fault, depending on MV neutral point operation	7701	10406	1030
Overload, moderate voltage dip	655	482	33
TOT	22355	22822	2546

Average values:
- 4,78 impedance variations per feeder per year associated to voltage dips
- 3,19 impedance variations per feeder per year associated to earth faults. Effects according to MV neutral point operation (isolated, resonant, solidly grounded, etc)

10 feeders per each HV/MV TR !

IMPEDANCE CHANGES AT TERMINALS OF A GENERATING UNIT

Reclosing cycles & fault tipologies



Average values:

- **7,11 impedance variations per feeder per year associated to voltage dips at G.U. terminals**
- **5,36 impedance variations per feeder per year associated to earth faults. Effects according to MV neutral point operation (isolated, resonant, solidly grounded, etc) at G.U. terminals**

10 feeders per each HV/MV TR !
+ HV events

Considerations:
Most of industrial plants and/or devices, industrial or domestic, have no immunity to voltage dips. Even in case of immunity class 3 about 50-60% of events would result in a disconnection of loads, with subsequent restart.

- **GFCs requirements should have to consider fast and subsequent impedance changes at unit terminals.**
- **GFC Imax should be higher than 1 p.u., expecially in case of intentional islanding,**

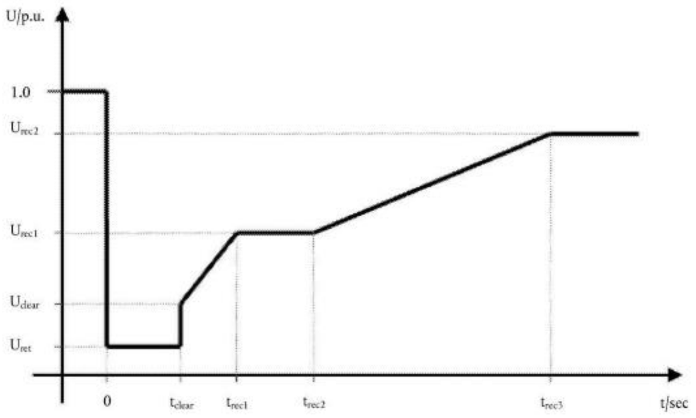
Additional: immunity to voltage dips in IEC (adopted in EN 50160) is different from the curve in DCC for V1G

Immunity to voltage dips according to EN 50160

	Durata t [ms]				
	10 ≤ t ≤ 200	200 ≤ t ≤ 500	500 ≤ t ≤ 1000	1000 ≤ t ≤ 5000	5000 ≤ t ≤ 60K
90 > u ≥ 80	Cell A1	CELL A2	CELL A3	CELL A4	CELL A5
	HIGH IMPEDANCE FAULTS (PARTIAL ISOLATION DEGRADATION or LONG DISTANCE)				
80 > u ≥ 70	CELL B1	CELL B2	CELL B3	CELL B4	CELL B5
	HIGH IMPEDANCE FAULTS (PARTIAL ISOLATION DEGRADATION or LONG DISTANCE)				
70 > u ≥ 40	CELL C1	CELL C2	CELL C3	CELL C4	CELLA C5
	HV AND/OR MV EVENTS	MV FAULTS	MEDIUM DEPTH FAULTS OF DIFFERENT ORIGIN		
40 > u ≥ 5	CELL D1	CELL D2	CELL D3	CELL D4	CELLA D5
	HV AND/OR MV EVENTS	MV FAULTS	HIGH DEPTH FAULTS OF DIFFERENT ORIGIN		
5 > u ≥ 0	CELL X1	CELL X2	CELL X3	CELL X4	CELLA X5
	HV AND/OR MV EVENTS	IMPORTANT FAULTS OF DIFFERENT ORIGIN (POOR STATISTIC)			

IMMUNITY CLASS 2 (CELLS A1,A2,B1,B2)

IMMUNITY CLASS 3 (CELLS A1,A2,A3,A4,B1,B2,C1)



Sudden disconnection/reconnection of loads, expecially of asynchronous type, seems not to be an optimal solution for grids based on a high share of inverter based generators. Electronic self regulated loads seem to be a better solution: higher immunity to sudden voltage changes and controlled starting current easily achievable

<u>N.B.: frequency transients not explicity evaluated!</u>

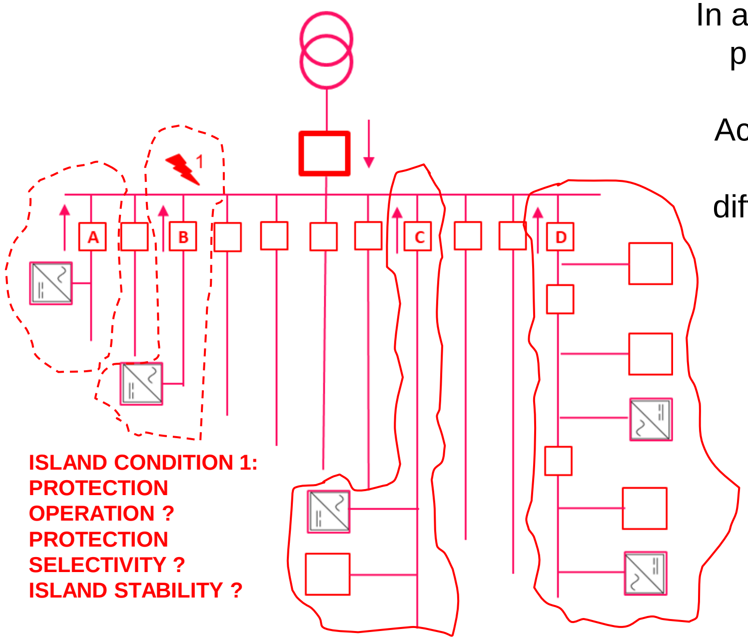
To be investigated in next steps:

- **Earth faults, according to specific DSO neutral status operation, just impedance change or also voltage dip ?**
- Island protection system. Well known problems for earth faults, no protection and selectivity against overcurrents with GFCs with Imax= 1.p.u.

SOME EXAMPLES OF POSSIBLE ISLANDING

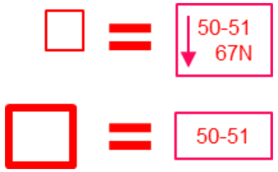
Future use cases (not exaustive)

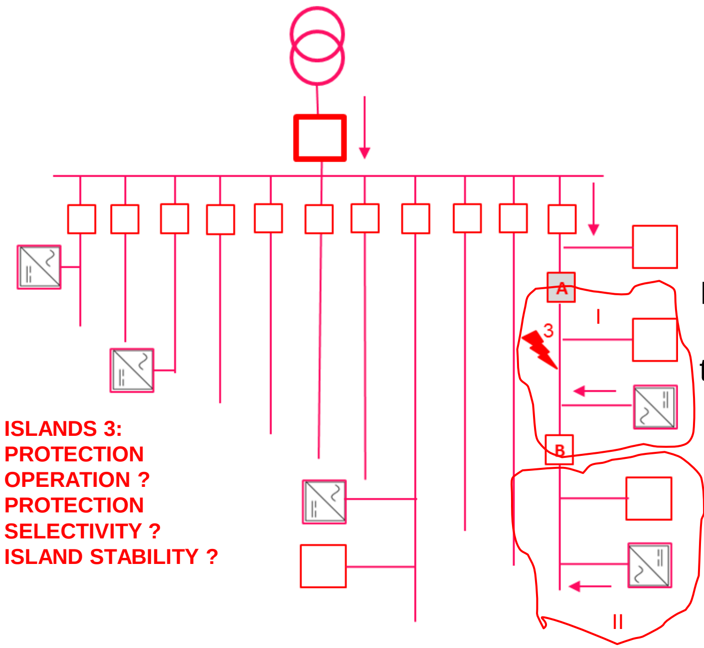
In an automated distribution network it's not possible to foresee a limited number of possible situations.
According to «required performances» of islands and to specific phenomena, different transients and issues have to be investigated



ISLAND CONDITION 1:
PROTECTION OPERATION ?
PROTECTION SELECTIVITY ?
ISLAND STABILITY ?

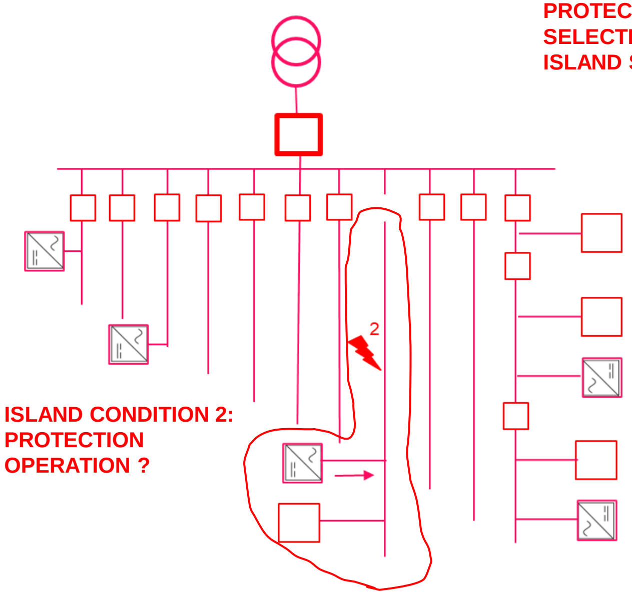
Islands should have to survive to FAULT 1
Protections should have to detect the fault, according to the tipology, and to open CBs
GFCs and loads should have to stay connected, surviving to transients, maintaining stability.
In this case:
Earth fault protections: OK
Overcurrent protections: KO





ISLANDS 3:
PROTECTION OPERATION ?
PROTECTION SELECTIVITY ?
ISLAND STABILITY ?

Island II should have to survive after **FAULT 3**.
Both in case I+II are already in island or not.
Protections should have to detect the fault in island I, according to the tipology, and to open CBs A & B, GFC in island I has to be switched off immediately
GFCs and loads in island II should have to stay connected, surviving to transients, maintaining stability.
In this case:
Earth fault protections: KO
Overcurrent protections: KO



ISLAND CONDITION 2:
PROTECTION OPERATION ?

Island (already present) has to be switched off immediately for **FAULT 2**.
In this case:
Earth fault protections: KO
Overcurrent protections: KO

STUDY NEXT STEPS

Considering outcomes of preliminary study, a future study is under definition.

TARGETS

• to refine the operating GFC control strategies according to data from manufacturers (current limitation-including possible overcurrent time decay constant, inherent energy storage value, operation without primary energy source-Q(U), etc..);
• to tune model parameters through simulations on realistic test networks;
• to implement additional controls to handle specific GFC operating conditions (TG-GFC deliverables).

NECESSARY INFORMATIONS

• GFC models (open or black-box) developed in DigSilent PowerFactory or other software environments (Simulink, EMTP, etc.);
• Description of the control logics implemented on commercially available GFCs (e.g. block diagrams and relevant transfer functions);
• Outputs of the numerical simulations performed by manufacturers on their legacy models to validate by comparison the ones obtained.

POSSIBLE NEXT APPLICATION SCENERY

- 2-3 real networks interested from important Q exchange with TSO and relevant presence of inverter based generators
- Replacement (simulated) of GFLs with GFCs
- Implementation (simulated) of Q@night function to control reactive power/voltage
- Residual Q exchange with transmission system regulated through synchronous condensers with flywheel and/or SVCs with energy storage (GFCs). Full cost CBA to be considered
- Dynamic simulations considering typical system events (possibly also HV ones, if available).

ENEL-UNIVERSITY OF PADOVA- POWER ELECTRONICS RESEARCH GROUP: STABILITY AND INTERACTIONS OF GRID-FORMING CONVERTERS

ESC-GC Meeting 2024.12.09

SIMULATION OF GFCS DINAMIC BEHAVIOR IN DISTRIBUTION GRIDS (PSCAD ENVIRONMENT)

Reasons for the study and first considerations

Reasoning:

1. To define more detailed time domain models accordingly to RfG 2.0 and related subsequent technical discussions (TG GFC)
2. To evaluate GFCs behavior and consequences in case of massive introduction in a distribution network
3. To evaluate, if necessary, possible contermeasures to be detailed in future

Evaluated issues and preliminary indications (study started before TG GFC):

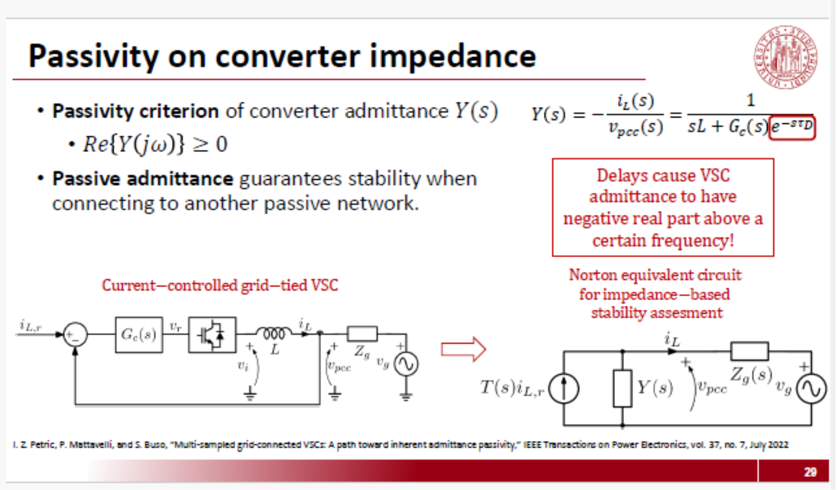
1. Dynamic Interactions of Grid Forming Converters
   When multiple GFM (from different vendors) and synchronous machines are present, possible instability and interactions may arise.
2. Impedance specifications
   Need of individual impedance specifications for each converter in the grid, so that stability of the whole system is guaranteed. Specifications for each converter dependent on grid parameters and independent of other converter parameters

SIMULATION OF GFCS DINAMIC BEHAVIOR IN DISTRIBUTION GRIDS (PSCAD ENVIRONMENT)

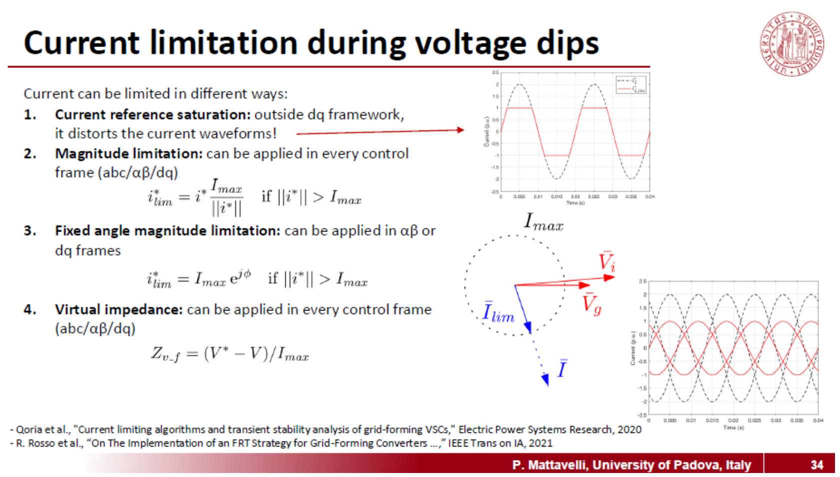
Reasons for the study and first considerations

Evaluated issues and preliminary indications:

3. Impedance passivation
   Definition of a passivity criterion to guarantee stability when connecting to another passive network



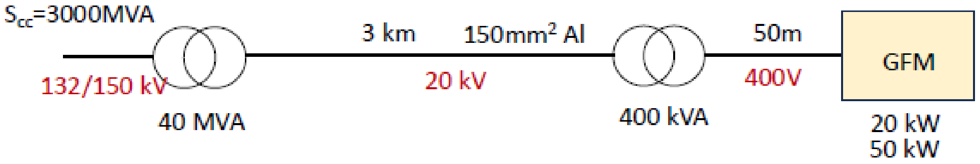
4. Operation under grid fault conditions-current limit
   The same functionalities/capabilities can be implemented in different ways, the output of these functionalities depends on the modelling approach used for a particular functionality, so the expected result and its impact on the network can be very different depending on the manufacturer / model / size / etc. Topic currently under discussion in TG GFC. In case of temporary overcurrents exceeding 1 p.u., time decay constant has to be defined.

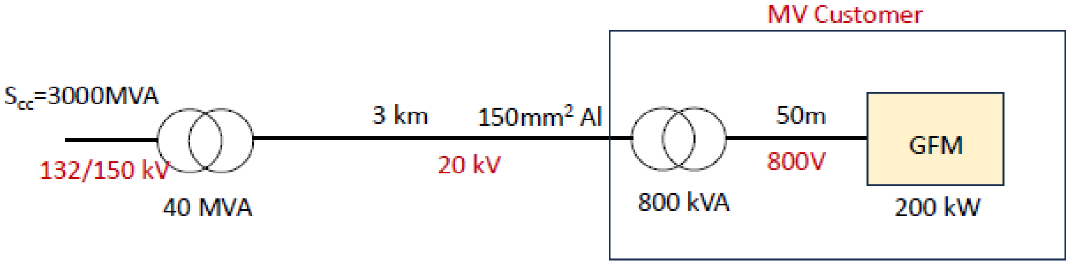


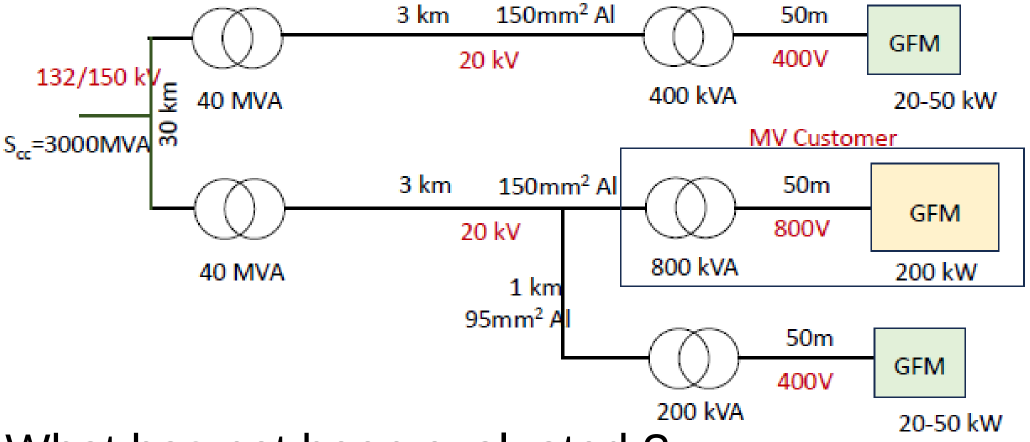
SIMULATION OF GFCS DINAMIC BEHAVIOR IN DISTRIBUTION GRIDS (PSCAD ENVIRONMENT)

Reasons for the study and first considerations

5. Application of preliminary analysis on some DSO application scenarios (typical simplified network configurations).







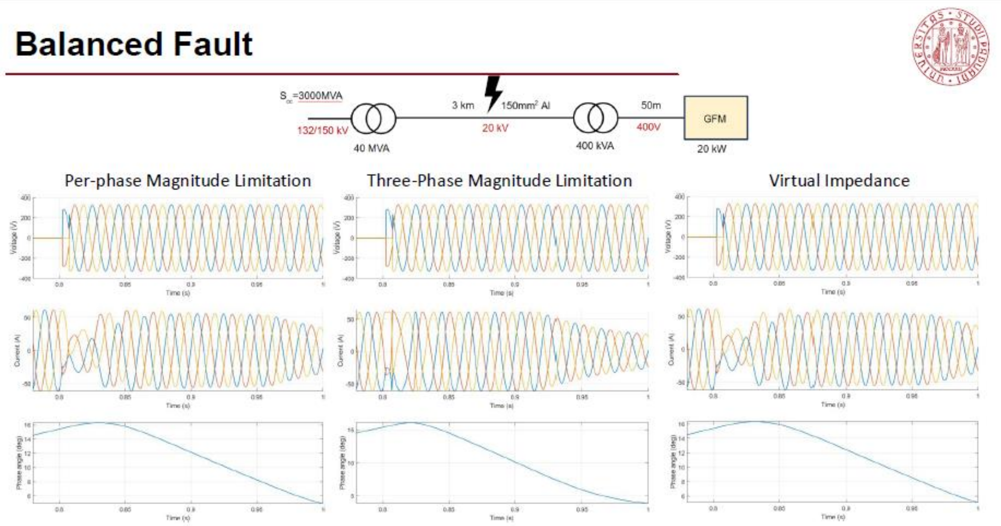
What has been evaluated ?

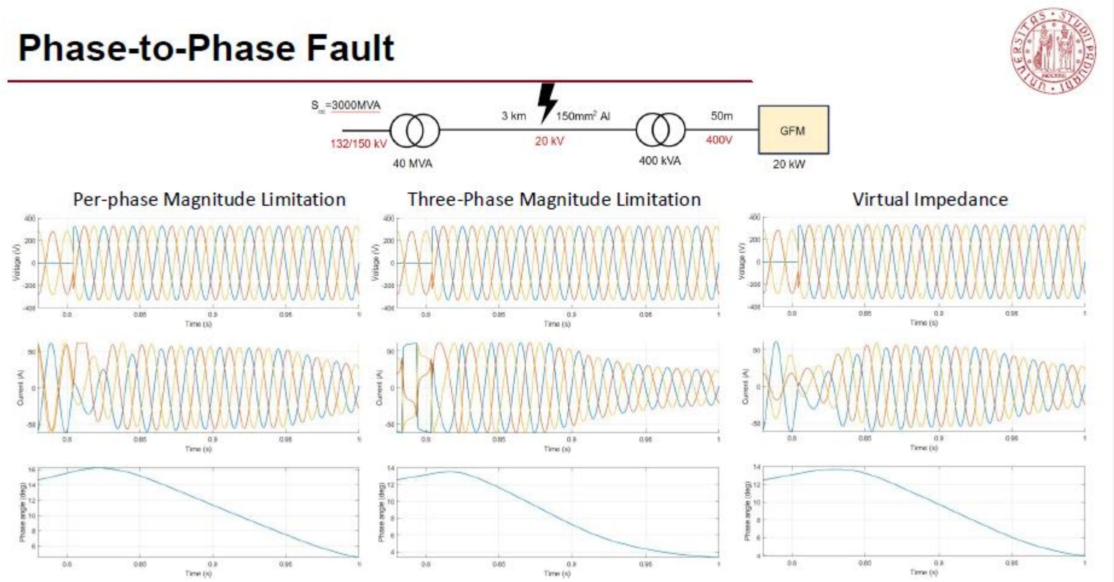
1. Dynamic behavior after 3Φ and 2Φ faults (with a single reclosing operation or without)
2. Effect of network impedance
3. Islanding condition after a fault

What has not been evaluated ?

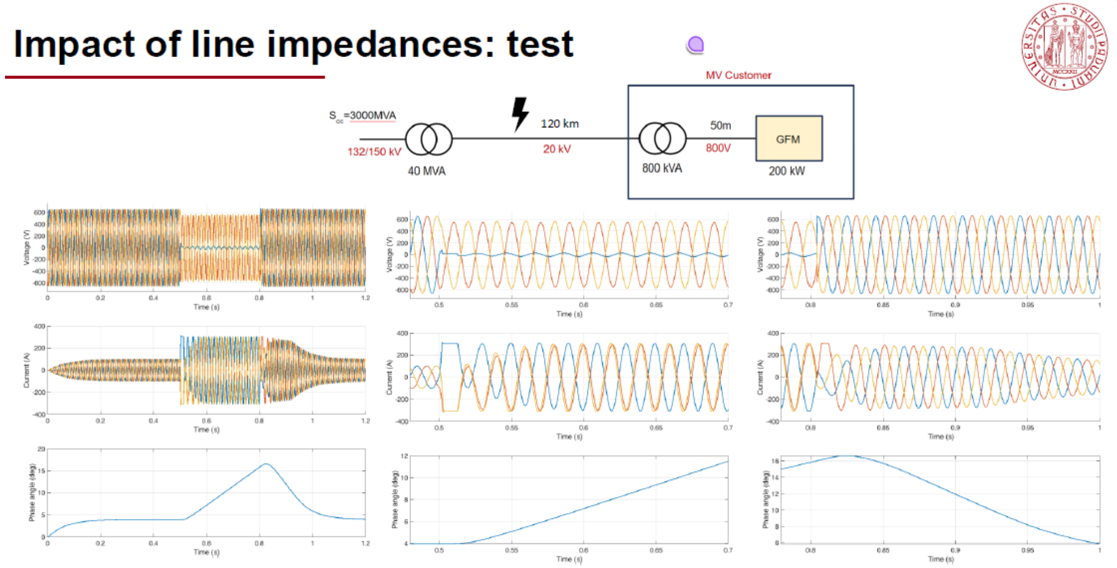
1. Inherent energy storage
2. Protection relays operation (overcurrent-50/51, earth fault-51N/67N/59V_0, frequency and δf/δt, etc.)
3. **F**ault **P**assage **I**ndicators operation
4. Network automation and automatic supply restoration with all MV fault typologies

SOME EVALUATED CASES

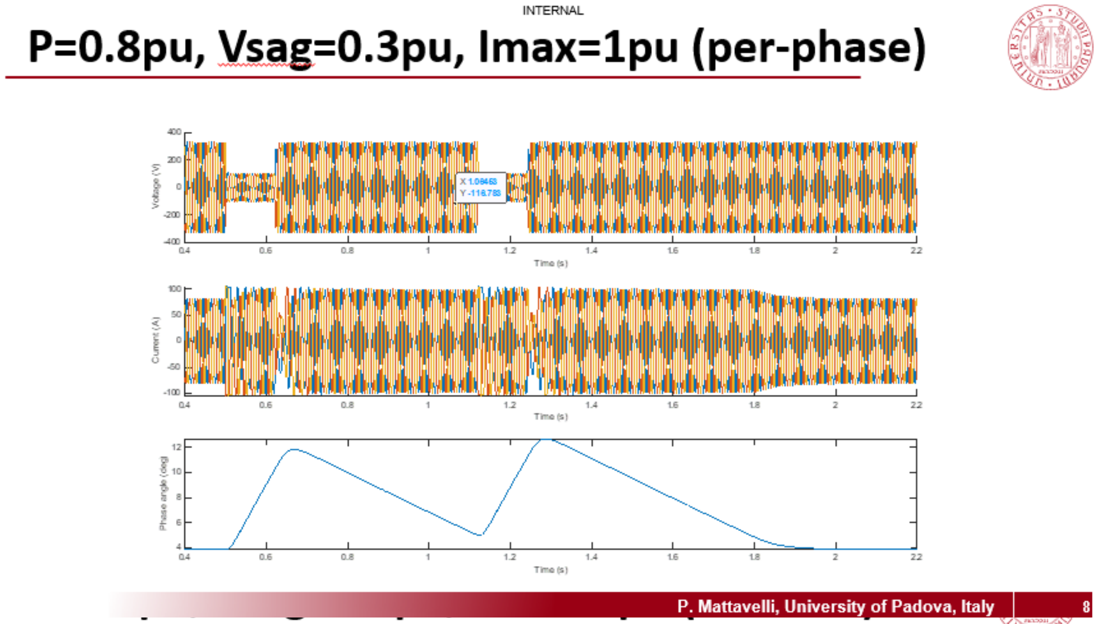


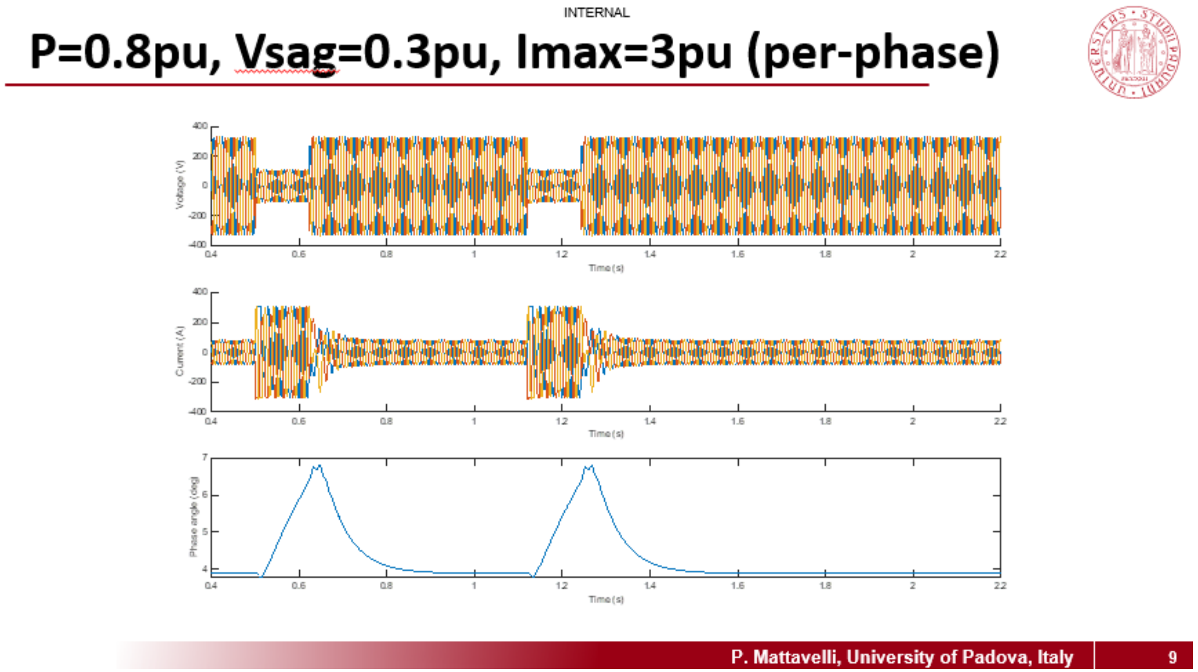


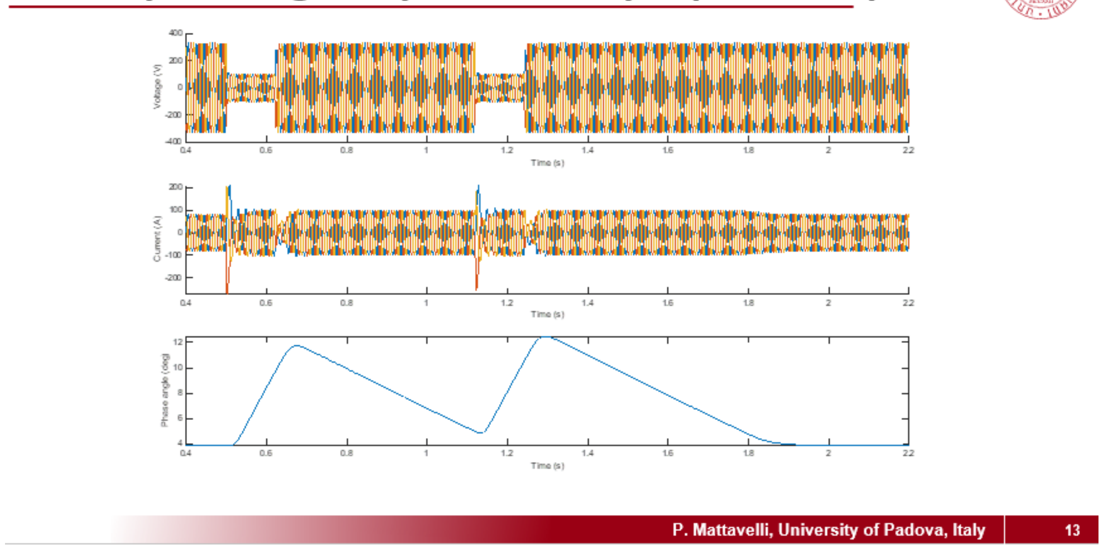
Behavior differences are extremely time limited (~1÷2 periods). Anyway short-circuit current limitation should be clarified in an unambiguously as different approaches give different results
Possible effect on protections to be deeper investigated.
Rough evalution of network impedance influence. To be deeper investigated considering extreme conditions of typical distribution networks
Evaluation performed with GFC maximum current = 1 p.u.



SOME EVALUATED CASES
Transients with connection to main grid



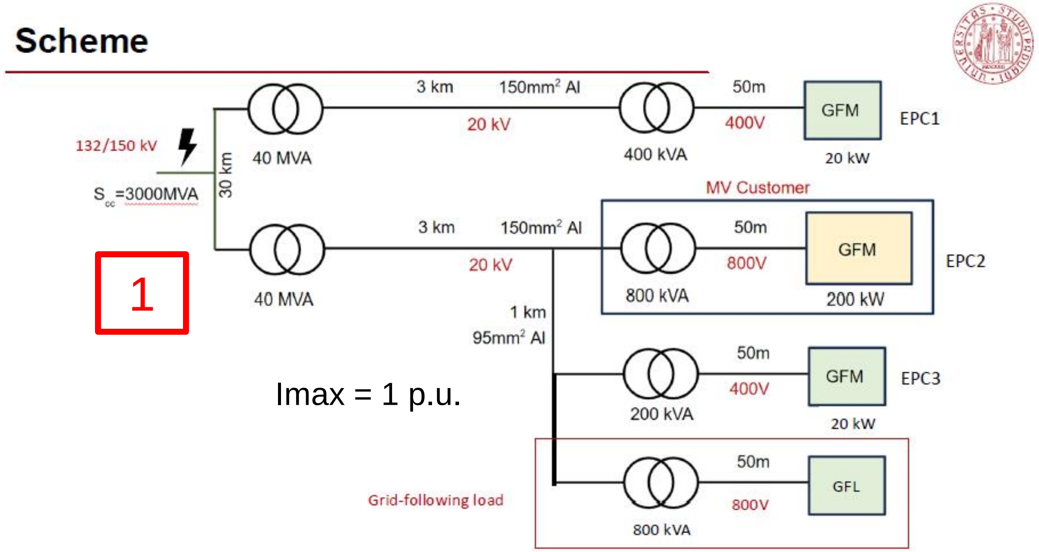


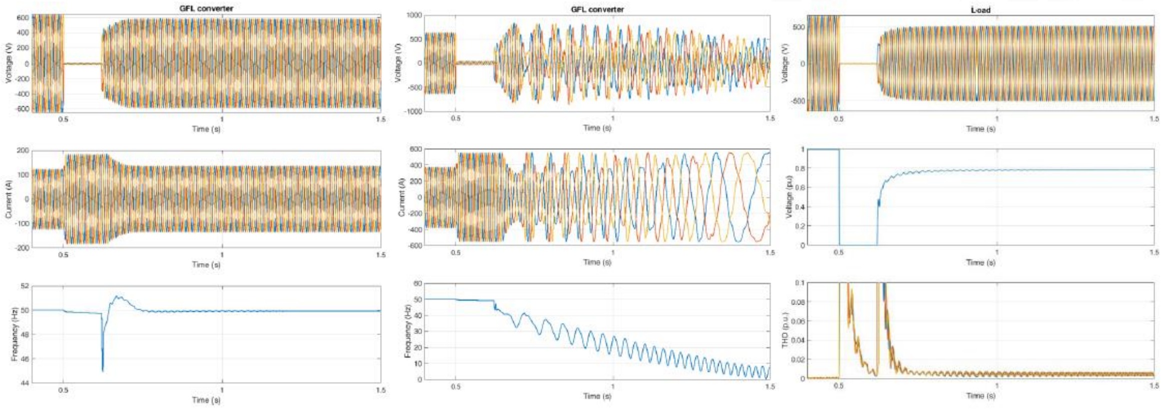


Fast inverter reaction times seem to render them immune to possible negative effects of reclosing cycles.
Anyway Standardization should consider this
Higher values of Imax assure better dynamic performaces
Current time decay constant in case of 3 p.u. not considered (unknown). The effect on simulations considered should be negligible (no asynchronous motor)

SOME EVALUATED CASES

Island Transients (1-island generation – 2-fault in island condition)

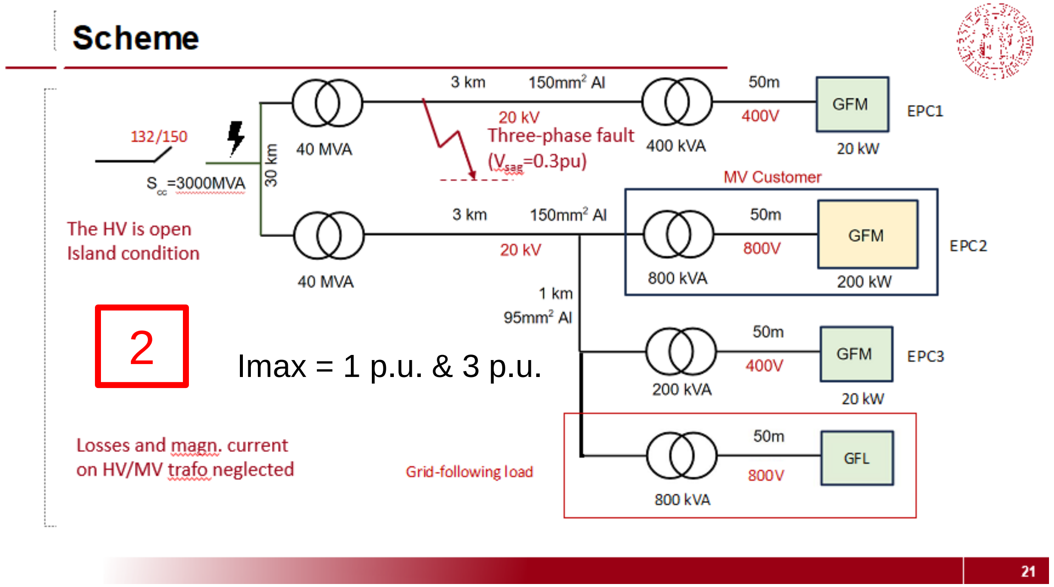




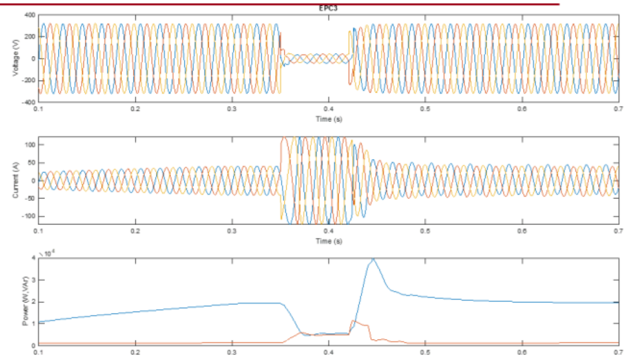
GFL load set to 50% of island total power capability.

GFL load set to 150% of island total power capability.

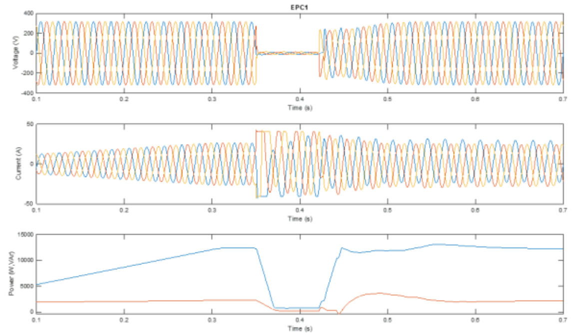
Resistive load set to 150% of island total power capability.



EPC3: Vsag=0.3pu, Imax=3pu



EPC1: Vsag=0.3pu, Imax=1pu



No significative difference due to presence of electronic driven load

Simulation of GFCs dinamic behavior in distribution grids (PSCAD environment)

Open points

- Digital models: the study confirms that negligible added value is obtainable in carrying out simulations with simplified/generic models or with literature more detailed models. Shared models with sufficient details are necessary, both in trequency and time domain, preliminarily for network planning, subsequently to define operation. A case by case approach it's not feasible for mass market products.
- Intentional island operation: in dynamic distribution networks it seems to be problematic, resulting in a not stable long term island without additional devices and/or higher GFCs capabilities and/or higher presence of electronic driven self-regulating loads
- Protection system: earth fault and overcurrent. Not considered in this study. To be evaluated in time domain environment
- System stability. To be better investigated as network impedance is variable depending on:
  - Network set-up
  - Variability during reclosing cycles
  - HV events (not at all considered, reference HV events should have to be defined)
  - During short-circuit faults
  - Depending on the state of the neutral (and thus also during related earth faults)
- Short-circuit current limitation: should be clarified. An unambiguous method should be adopted as different approaches give different results. TG-GFC is working actively on this.

Main conclusions

The study, as the previous one, has shown that negligible added value is obtainable in carrying out simulations with simplified/generic models and with literature more detailed models. Also definition of detailed custom models result in a low added value effort. Shared models with sufficient details are necessary, for network planning and consequent operation. A case by case approach it's not feasible for mass market.

PRELIMINARY RESULTS OF STUDIES

ESC-GC Meeting 2024.12.09

Simulation of GFCs dinamic behavior in distribution grids (PSCAD environment)

- Being the issues in constant evolution, studies are aimed only to perform preliminary evaluation of GFC introduction in distribution networks. Further analysis are necessary.
- At present, synergy among different studies at EU level will be limited, with poor generalization of results. Requirements/capabilities definitions are in evolution, standardization is not sufficiently present
- Without additional research/solutions it seems that islanding on distribution networks does not offer significative advantages, despite it creates problems:
  - RER GFCs in absence of a primary source can not sustain any island and/or provide ancillary services
  - Imax close to 1 p.u. may be critical. In case of islands sustained from GFCs with a current limit close to 100%*In both in normal operation and during short circuits, no distinction between standard operation and fault operation is present (max I relays 50/51 can not detect any fault). In addition, starting of asynchronous motors may cause island collapse
  - All protection system in island condition has to be defined (overcurrent and earth fault), present solutions are no more reliable without important improvements (to be evaluated and tested before industrialization and consequent massive introduction).

  Intentional islanding has to be well planned in advance (BESS, Q@night, TLC net, protections, higher GFCs capabilities, etc.). Final architecture is likely to be DSO specific, after proper CBA, but more Standardization seems to be necessary
- Frequency domain and time domain simulations are necessary, but a case by case approach is not realistic for mass market, due to the huge numbers involved and to the time variability of the networks. For instance, PSCAD isn’t commonly used by DSOs. It would be appropriate to develop Standardized sufficiently detailed digital models of GFCs both in frequency and in time domains, to be tuned on the specific devices after testing. Models could be used also for large units and/or plant compliance.

TG GFC Priority topics list

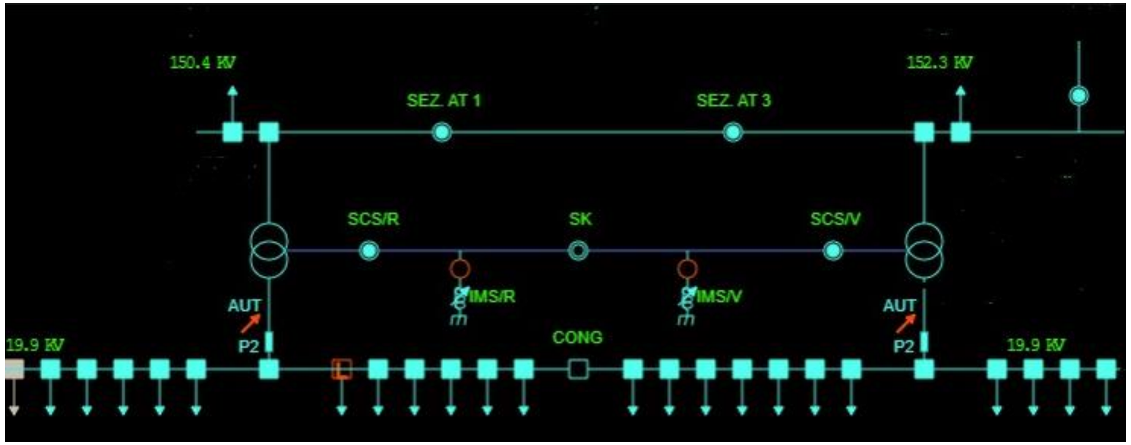
Application to distribution networks

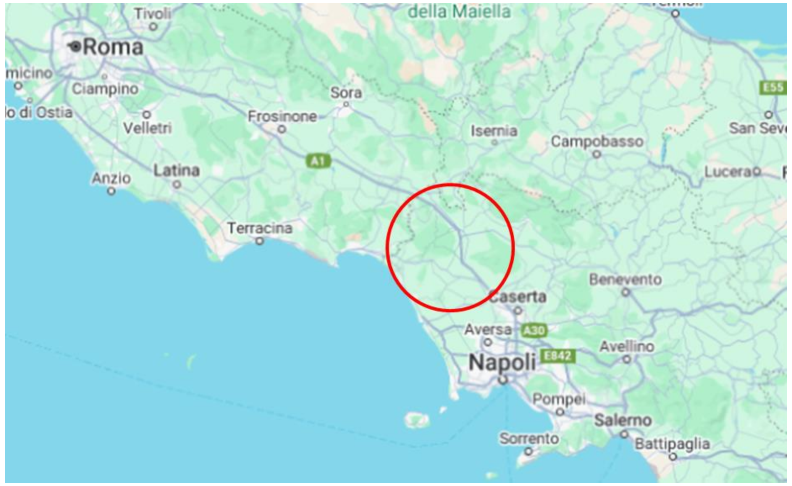
Priority Number	Priority Topic TOR TG GFC	Addressed in the studies (started in 2023)	Notes
1	Power generating unit level requirements	CONSIDERED.	Not fully aligned with ongoing TG-GFCs ongoing activities, as hypothesized in 2023. Critical issue: absence of any shared digital model both in frequency and I time domain
2	Inherent energy storage of the power generating unit for both power park modules (PPM) and electricity storage modules (ESM)	NOT YET CONSIDERED To be considered for stable intentional islanding operation	Critical issues: Transient conditions; Primary energy source variability; night
3	Current limiting/ overload requirements and effective impedance of the power generating unit for cases of voltage drop and angle jumps	CONSIDERED	Partially aligned with ongoing TG-GFCs ongoing activities, as hypothesized in 2023. Critical issues: Protection system & selectivity, island stability
4	Synthetic inertia requirement and sub-cycle measurable quantities of the PPM (with focus on type B, C and D PPM)	PARTIALLY CONSIDERED	Not fully aligned with ongoing TG-GFCs ongoing activities, as hypothesized in 2023.
5	Dynamic response expected to RoCoF and time domain requirements	NOT YET CONSIDERED	
6	Compliance verification and certification recommendations	NOT CONSIDERED	Out of the scope of the studies
7	Impact of existing anti-islanding protections in islanded grids	CONSIDERED	Critical issues: Protection system & selectivity

ENEL
ISLAND EVENT 2024-11-19

BRIEF EVENT DESCRIPTION

Involved HV/MV station:
Typical e-distribuzione HV/MV station double MB busbars, 2 HV/MV TRs 40 MVA
South Italy





Brief event description:
«GREEN» HV/TR TR not in operation for maintenance, bus coupler closed, «RED» HV/TR supplying both MV busbars
H 11:40:29: MV CB of «RED» TR trip, no electric fault (SF6 low pressure alarm), with following uncontrolled islanding (mismatch generation/load about 60 A absorbtion)
H 11:43:47: starting of automatic load shedding relays ($\delta f/\delta t$) on 14 MV feeder. Starting & trip due to positive values of $\delta f/\delta t$, associated with voltage variations. No other protection tripping !
Subsequent disconnection of 6 MV feeders.Disconnection (not simultaneous) of generating plants due to IPRs interventions
H 11:44:07: end of uncontrolled islanding phenomena
Duration of uncontrolled island: 3:38 m, generation/load of the island ~ 16 MW
N.B. 1: measurements in the following slides are calculated as average in a 10 m not-sliding window. Therefore are affected by islanding and interruption durations. Selected values refer to window 11:40 – 11:50.
<u>N.B. 2: just preliminary information, futher analyses on course on protection interventions !</u>

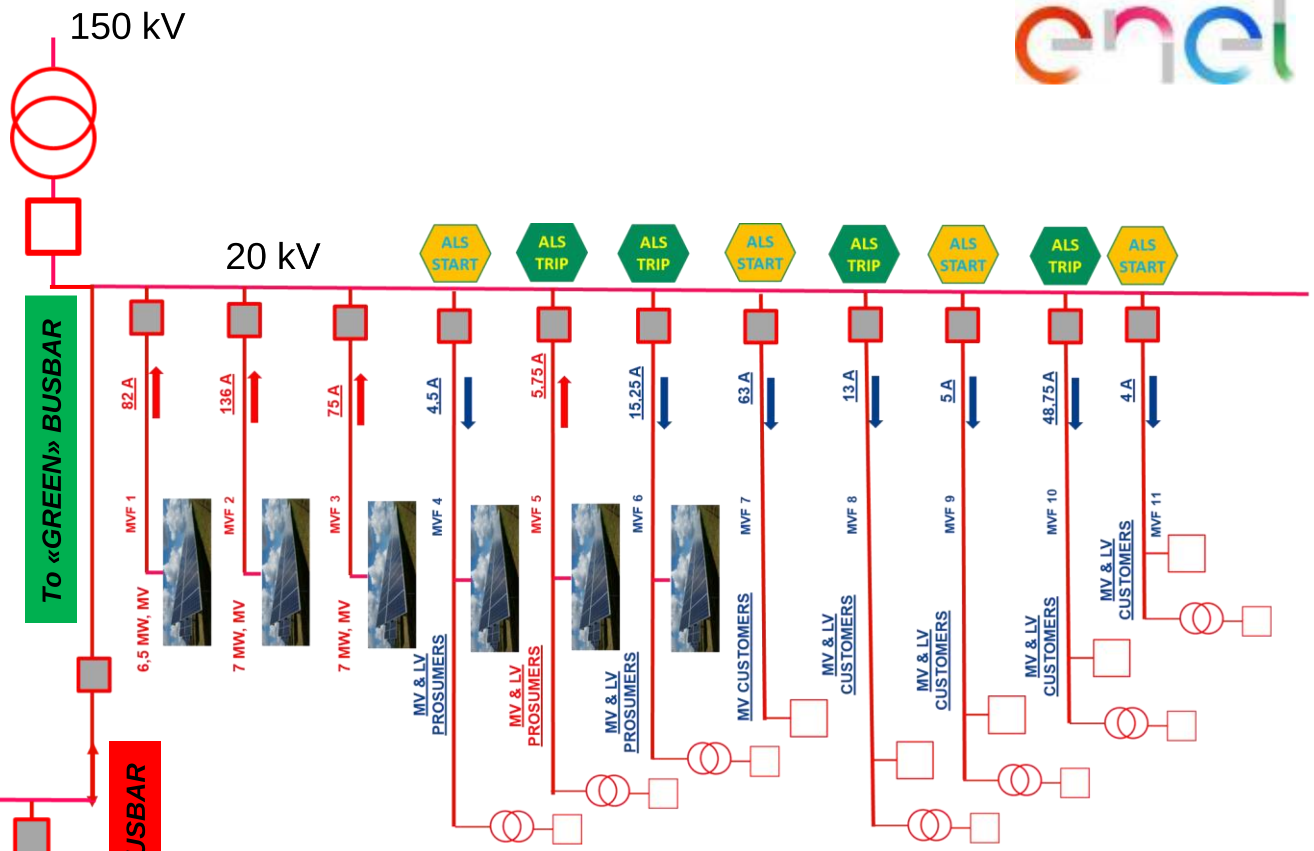
BRIEF EVENT DESCRIPTION

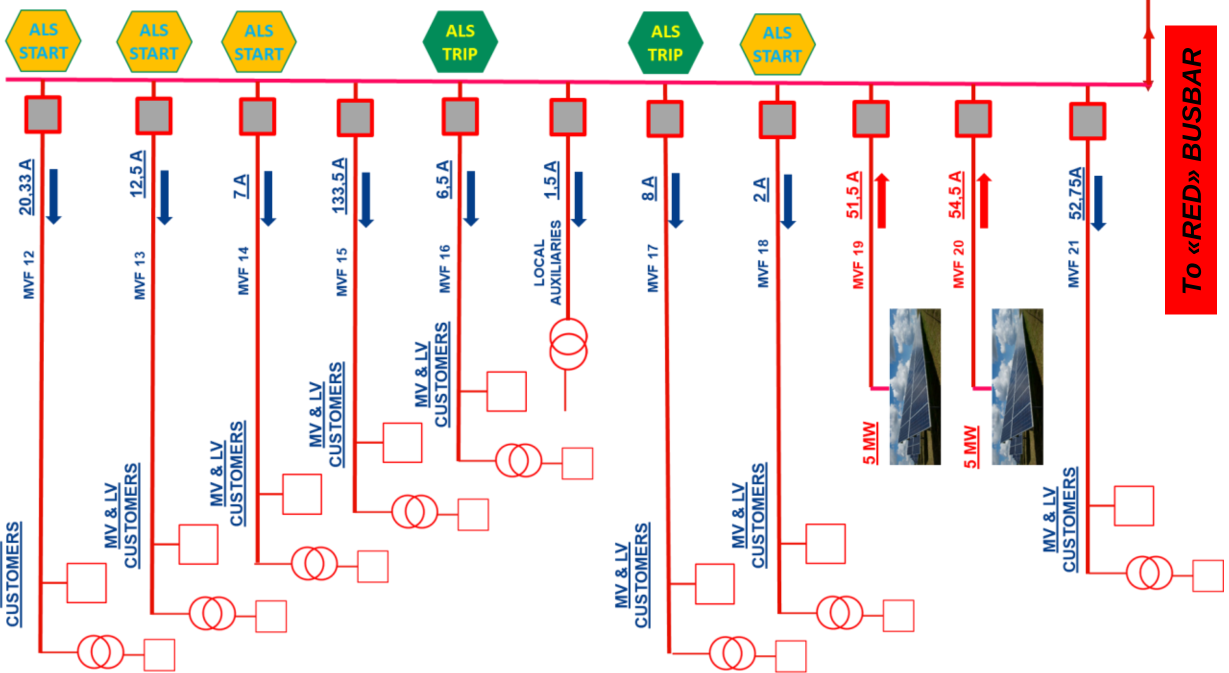
ALS START — Automatic load shedding relay (δf/δt) starting

ALS TRIP — Automatic load shedding relay (δf/δt) tripping

«GREEN» BUSBAR

«GREEN» busbar MV network:
127 km, 37% in underground cables





«RED» BUSBAR

«RED» busbar MV network:
111 km, 57% in underground cables

MVF 1,…,…: Medium Voltage Feeders
HV: 150 kV
MV: 20 kV

BRIEF EVENT DESCRIPTION

proceedings of public event UNCONTROLLED ISLANDING 14th April 2014 – discussion of RfG 1.0

- Islandig stable – high probability
- Islanding stable- - medium probability
- Islanding not stable for more hundreds ms

Best possible "compromise" solution on the basis of performed studies and evalutions (not accepted from ENTSOE)

As P(f) delay was not accepted from TSOs, Q(U) was not activated to reduce islanding probability.

A small delay would have significatively increased IPR selectivity.

Conclusion: minimal additional modifications in parameter settings and in inverter-based generator requirements/capabilities would allow a more comfortable hosting of RER in distribution grids without affecting operation and requiring heavy interventions.

P(f) with hysteresis Italian TSO request

	Q(V)&P(f) fast	Q(V)&P(f) fast, 10% rotating gen. , no reg, H = 1 s		Q(V) fast, P(f) delay 300 ms	Q(V) fast, P(f) delay 500 ms	Q(V) delay 3 s, P(f) delay 300 ms	Q(V) delay 3 s, P(f) delay 500 ms
P_G-P_L [kW]	0	0	-9 / *+6*	0	0	0	0
Q_L-Q_G [kVAr]	21,3	21,3	25,1 / *18,7*	21,3	21,3	21,3	21,3
(0,85-1,15Vn) time [s]	-	-		-	-	0.31↓ (0.78)	0.51↓ (0.98)
(49,5-50,5 Hz) time [s]	1,38↓ (1.55)	-	0.45↓ / *0,87↑* (0,62) / *(1,04)*	0.08↑ (0.25)	0.08↑ (0.25)	0.1↑ (0.27)	0.1↑ (0.27)
(47,5-51,5 Hz) time [s]	-	-	2,83↓ / - (6,90) / -	0.32↓ (4.79)	0.52↓ (4.99)	0.14↑ (1.21)	0.14↑ (1.21)

P(f) without hysteresis – according to RfG

	Q(V)&P(f) fast	Q(V)&P(f) fast, 10% rotating gen., no reg, H = 1 s		Q(V) fast, P(f) delay 300 ms	Q(V) fast, P(f) delay 500 ms	Q(V) delay 3 s, P(f) delay 300 ms	Q(V) delay 3 s, P(f) delay 500 ms
P_G-P_L [kW]	0	0	-9 / *+6*	0	0	0	0
Q_L-Q_G [kVAr]	21,3	21,3	25,1 / *18,7*	21,3	21,3	21,3	21,3
(0,85-1,15Vn) time [s]	-		-	-	-	0.45↓ (0.92)	
(49,5-50,5 Hz) time [s]	-		0.83↓ / *0,86↑* (1.00) / *(1,03)*	0.07↑ (0.24)	0.07↑ (0.24)	0.06↑ (0.23)	
(47,5-51,5 Hz) time [s]	-		9,50↓ / - (13.57) / -	-	-	0.1↑ (1.17)	

Application to GFCs: possibility to exclude some GFC capabilities at least during commissioning (for instance V2G EV3 LV connected). Issue at research stage, too stringent and limiting requirement would create useless problems, require useless intervention and negatively affect GFC adoption on DSO nets