Inverter Dominated Island Power Systems

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Inverter Dominated Power Systems

- Transition from conventional fossil fuel based electrical generation to sustainable solutions, e.g. renewable energy sources, battery storage systems, etc.
- Storage Systems and most RES are interfaced to the grid through power electronics

Conventional Power Systems

Inverter Dominated Systems

Inverter Dominated Power Systems

Challenges

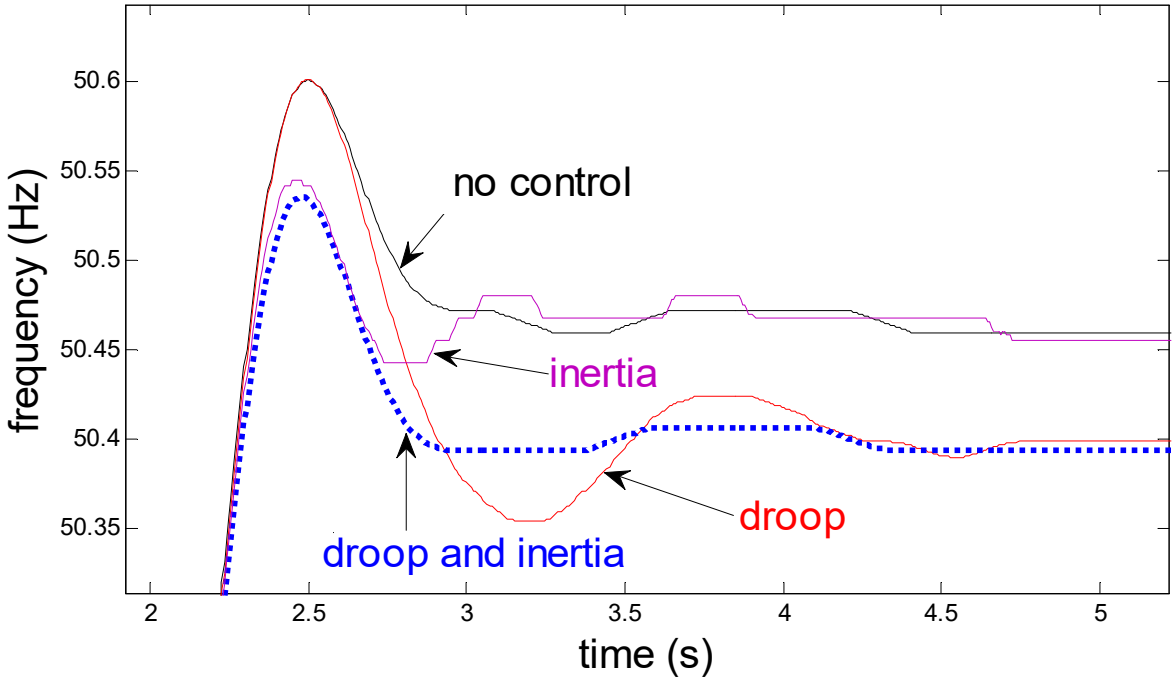
- Less system inertia (reduced number of synchronous generators - high RES penetration)
- Less units contributing to frequency and voltage support
- Less fault current contribution compared to SG with same rating (or even disconnection) during faults by inverters
- Inverter Stability issues
- Cooperation issues with existing installed equipment (e.g. protection devices)

Special considerations must be given in inverter's functionalities and design to address the above challenges

Inverter Dominated Power Systems - Frequency and Voltage stability

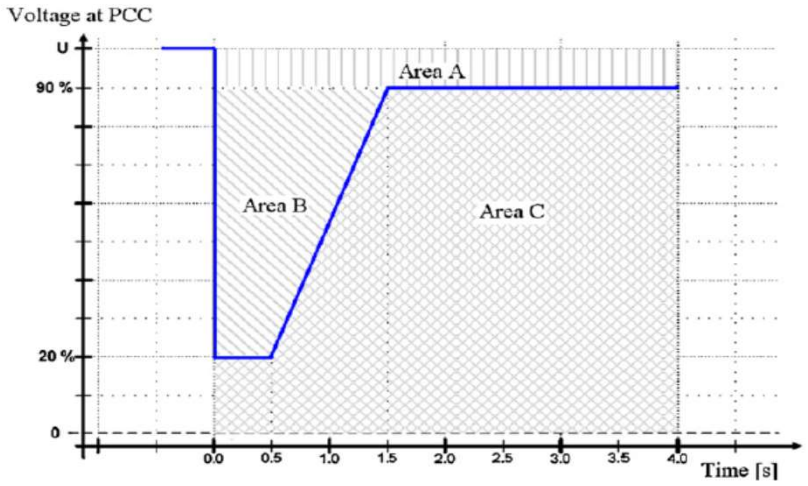
- Contribution to frequency and voltage support with proper inverter functionalities (e.g. Q(V), P(f) droop curves)
- The inverters can emulate the system inertia and support the frequency during the transient

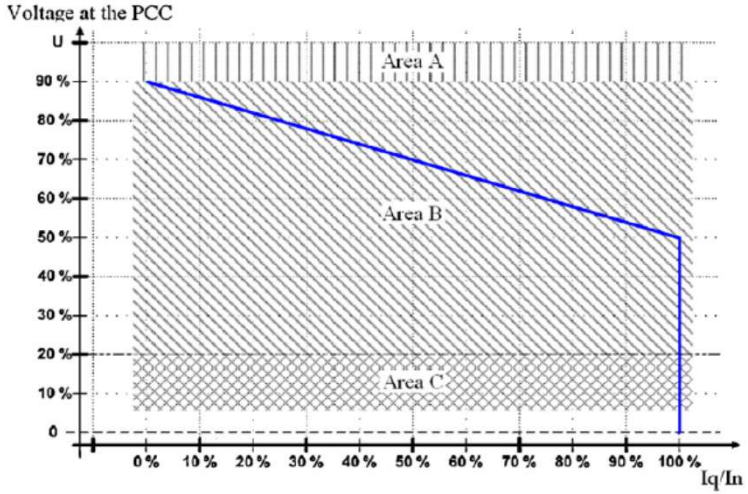
Stability issues could arise if the inverters functionalities aren't coordinated properly: e.g. voltage instability due to poor reactive power sharing among DERs in small isolated systems.



Inverter Dominated Power Systems – Faults

- Inverters (especially of large generating units) should remain connected during the fault and also contribute to the fault current.
- Fault Ride Through capabilities of inverters specifies the time that the inverter remains connected during the fault and the amount of reactive power that it provides to the fault.



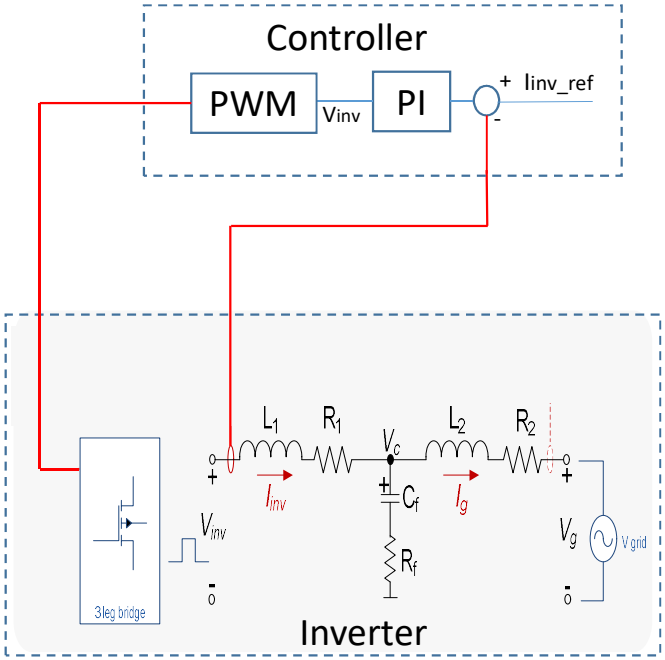


- **Existing protection devices in the grid have been designed for SGs based systems. This equipment might not work properly on inverter based systems, e.g. reduced fault current could result in higher tripping time of protection devices.**

Inverter Dominated Power Systems – Inverter Stability

The controller of the inverter (e.g. voltage and current control loops, PLLs) could be a major concern for the stability of the system in inverter dominated systems. Invert stability issues can be caused by:

- interaction of inner current and voltage control loops (may cause high harmonic-frequency oscillations, in the range of hundreds of Hz to several kHz)
- high-frequency switching can trigger the parallel and series resonance introduced by LCL power filters or parasitic capacitors of feeders.
- The presence of several inverters at close distance also generates interaction problems resulting in multi-resonance peaks
- PLLs in grid-following/feeding inverters modify the impedance and admittance matrices of the power system, which may lead to instabilities
- **Harmonic instability can be prevented and/or mitigated by so called active damping strategies.**
- **The proper design of the inverter filter and tuning of the controls to address the above issues.**



Inverter Dominated Power Systems– The Greek non interconnected Island Power Systems

- 100 Inhabited Islands
- 60 of them non-interconnected to the mainland
- 32 isolated electrical systems (some of them with more than 1 island and 21 single island systems)
- 2 islands (Rhodes and Crete) with more than 100MW average peak demand

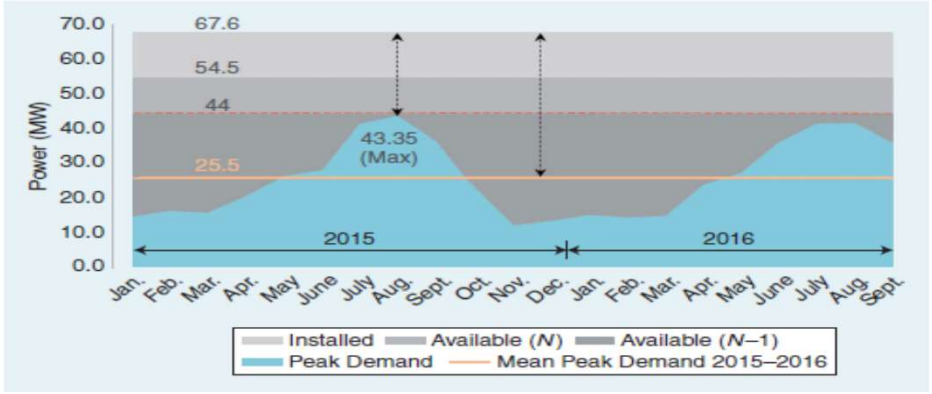
Power Generation characteristics on NIIPS:

- Supplied by autonomous power stations
- Generators running on light fuel oil (LFO) or heavy fuel oil (HFO)
- Severe constraints on the exploitation of the significant renewable energy system (RES) potential
- RES mainly wind and solar

Inverter Dominated Power Systems– The Greek non interconnected Island Power Systems

- High seasonal variability in load demand (peak demand in summer due to islands' high dependence on tourism)

- Power produced by RESs covers around 20% of the annual electric energy demand of the NIIPSs.
  - *97 wind farms (323 MW)*
  - *1,758 ground photovolatic (PV) stations (136 MW)*
  - *3,242 rooftop PV systems (24 MW)*
  - *one small hydroelectric station (0.3 MW).*



- **Given the excellent wind and solar potential in the Aegean Sea islands, a challenging goal remains the achievement of very high RES energy penetration levels (beyond 60%).**

- **To this end, a new pilot project has been considered utilizing storage units and RES in order to increase RES penetration levels.**

Inverter Dominated Power Systems– Non interconnected Island Power Systems pilot project

- The implementation of this pilot project will modify the non interconnected power system to an inverter dominated system
- At certain periods (e.g. high RES power production and reduced load consumption) the non interconnected island power system should **operate solely with the storage and the RES units**.
- The storage and RES units should have specific characteristics in order to ensure secure power supply

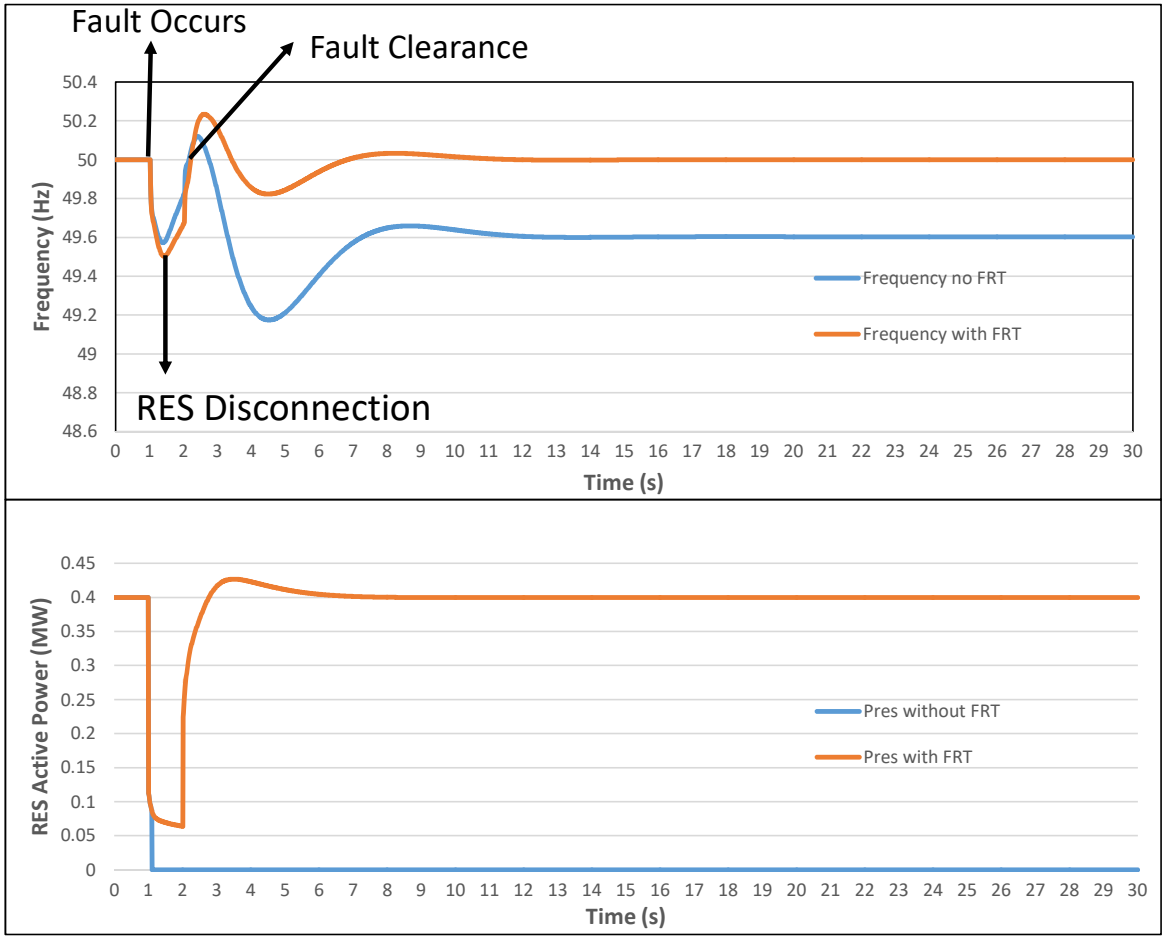
Technical Considerations – Parallel operation with the Thermal Station

- RES and storage units should remain connected to the grid during fault for a period of time.
- In case of disconnection those units should be able to reconnect and reach their power production (or consumption for the storage unit) in a short period of time.
- Specific measures might need to be taken in order to reduce the inrush current of the transformers connecting the units to the grid (during the RES and storage units connection to the grid) in order to avoid unwanted protection tripping
- The storage system should be able to contribute at system restoration when a blackout occurs.

Inverter Dominated Power Systems– Non interconnected Island Power Systems pilot project

Fault Ride Through Capability Case:

- During a fault in a non-interconnected Island Power System the voltage drops significantly to the whole system (due to the small length of lines that exist in a non-interconnected island power system).
- If RES and Storage units don't remain connected for a period of time (Fault Ride through capability) significant amount of the total production could be disconnected
- If the RES are disconnected, a severe transient could occur in frequency jeopardizing the stability of the whole system.
- FRT capability allows RES to remain connected for a period of time avoiding massive power generation disconnection



Inverter Dominated Power Systems– Non interconnected Island Power Systems pilot project

Technical Considerations – Stand alone operation

- The storage system must be able to operate in grid forming mode in order to ensure that the voltage and frequency of the non interconnected island system remain within limits.
- When faults occur the storage system should remain connected and provide fault current.
- Storage inverter(s) should contribute up to their nominal current (thermal ratings of inverter filter and switching devices).
- The fault current of the inverter must be adequate to ensure proper operation of the protection devices.
- Since most of non interconnected islands power systems have only distribution system network, load unbalances might exist between the phases of the system. The storage system should be able to support those unbalances.
- The storage system should ensure secure operation of the system during transient phenomena such as RES disconnection, inrush currents of transformers, etc.
- Seamless transition should be ensured when the thermal station is disconnected or connected.

Inverter Dominated Power Systems– Non interconnected Island Power Systems pilot project

During a Fault when the storage inverter forms the grid:

- The fault current is provided from the battery inverter (up to its nominal current)
- It provides less current compared to a synchronous generator of the same rating
- Protection devices (e.g. relays) might require different settings
- RES inverters could also contribute to the current according to the FRT curves (provide reactive power)

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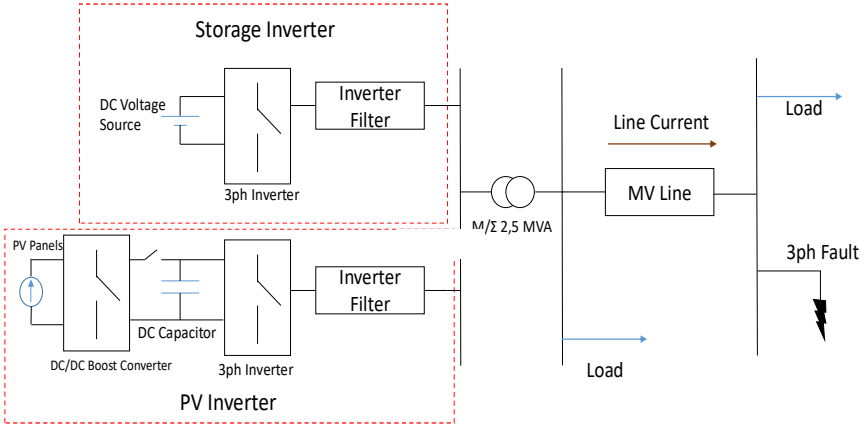

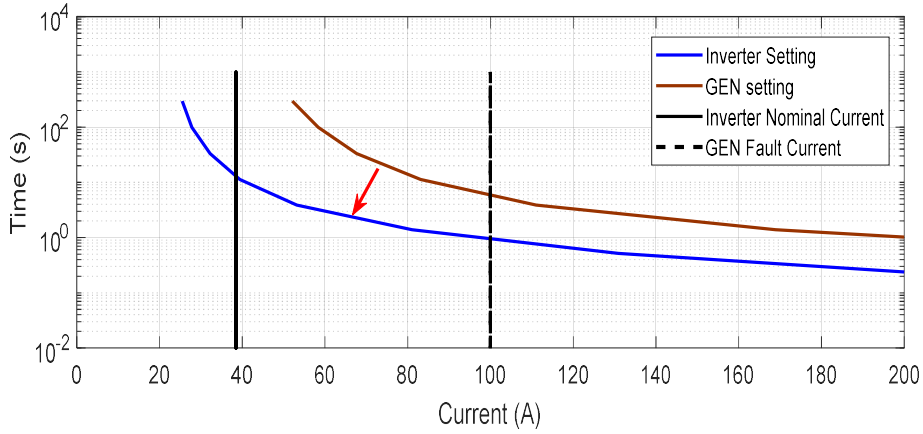

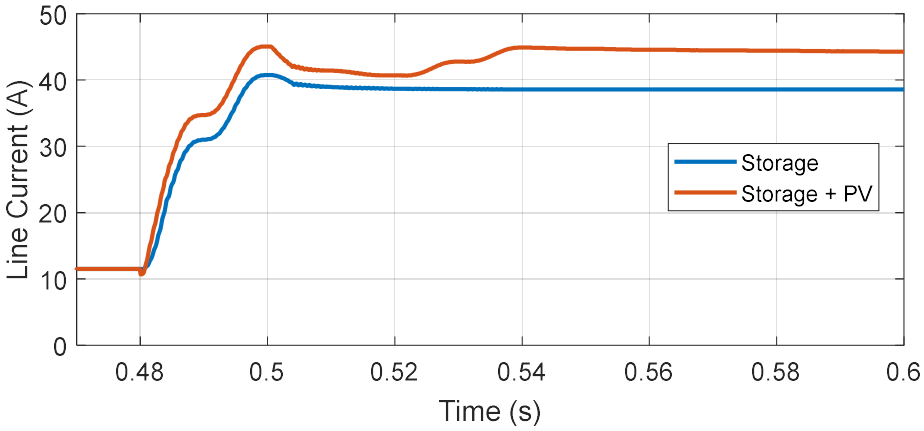

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WU1 Αφού δίνουν μόνο άεργο ισχύ ουσιαστικά λειτουργούν σαν Statcom. Οπότε και κατά τη διάρκεια της νύχτας ένας PV inverter μπορεί να συνεισφέρει στο βραχυλύκλωμα

Dimitris Lagos (ICCS), 10/11/2018

Thank you for your attention!

Questions?

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