3DMicroGrid

DESIGN, DEVELOPMENT AND DEMONSTRATION
OF A SMART MICRO GRID

Framework Design for Smart Micro-Grids

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SEVENTH FRAMEWORK PROGRAMME

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Agenda

- The 3DMicrogrid Framework
- Pilot Site Models
- Key Performance Indicators (KPIs) for Microgrids
- Baseline Performance Investigation
- Flexibility Constraints and Impacts
- Outlook and Conclusions
- Acknowledgments

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The 3DMicroGrid Framework: Overview

The framework comprises "3D":

MicroGrid Design (first D)

- Description and analysis of use cases
- Collecting and defining requirements
- Sketching out a suitable control architecture

MicroGrid Development (second D)

- Development of software components
- Modeling and simulation for testing purposes
- Data collection and pilot site constraint assessment

MicroGrid Demonstration (third D)

- System performance evaluation

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August 2019

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The 3DMicroGrid Framework: Architecture

MG centralized control

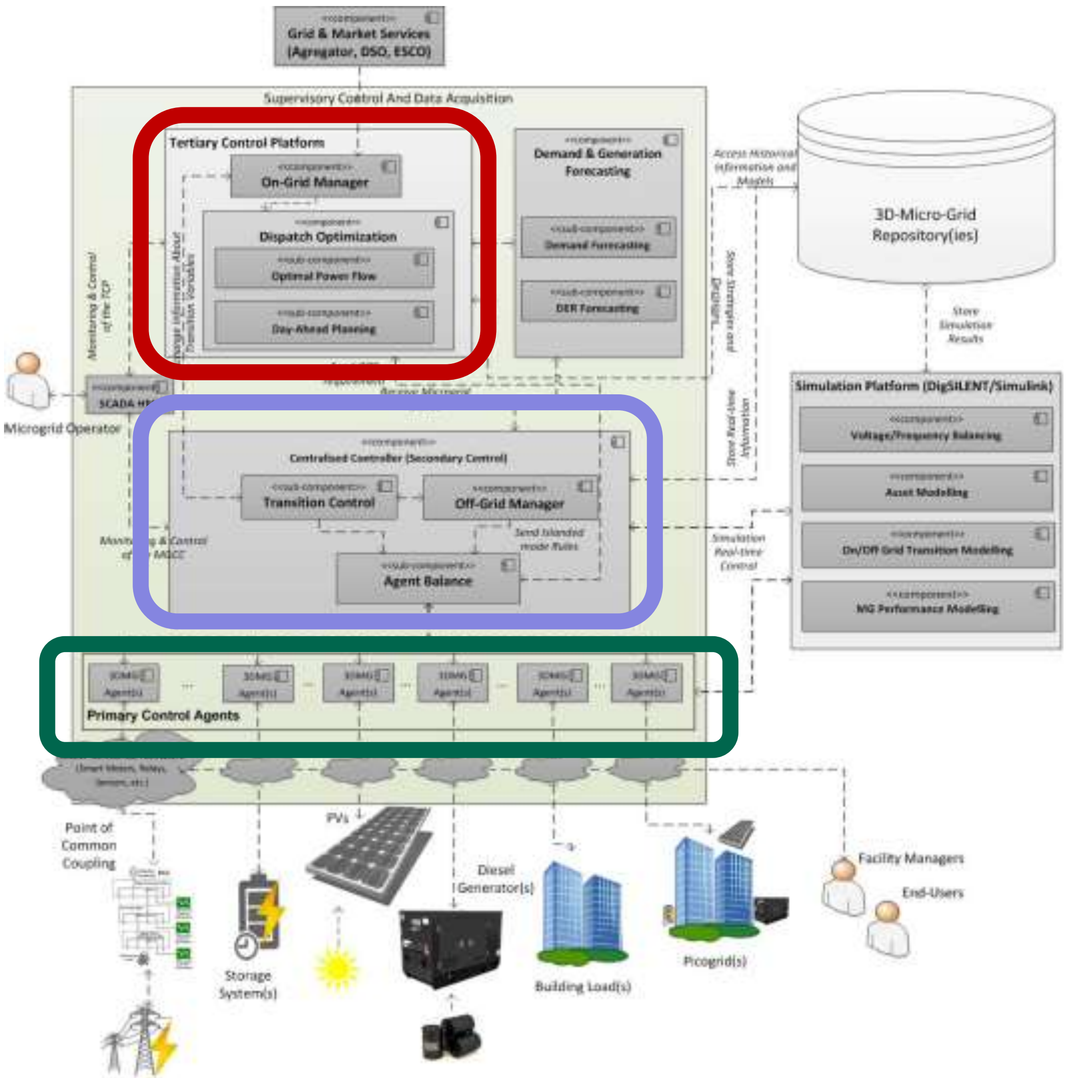
+ Real-time knowledge of system state (MG supervision),
+ enables efficient stability management
+ Easy implementation and deployment of new high-level functions
+ Easy interoperability (external communication)
- Single point of failure
- Scalability issues with increasing number of assets

MG decentralized control

- Difficulties with stability management
- Implementing new high-level functions is hard
- External communication interface?
+ DER asset features immediately usable (plug and play)
+ No single point of failure
+ Robust against network segment disconnection when segments retain sufficient power balance

Approach: Hierarchical control architecture implementing both centralized and decentralized concepts

The 3DMicroGrid Framework: Architecture



Tertiary Control Platform

On-grid manager: communication

Dispatch optimization: optimal power flow, day-ahead planning

Central Secondary Control

Off-grid manager, agent balance, transition control

Primary Control Agents

Active balancing: voltage and frequency control or active/ reactive power control

Pilot Site Models

Modeling and simulation based on pilot sites

MATLAB/Simulink, Homer, DIgSILENT PowerFactory

- Test
- Evaluate
- Validate the proposed framework

JADE

- Multi Agent System (MAS) implementation
- Communication between developed components and simulation models

Three Pilot Sites

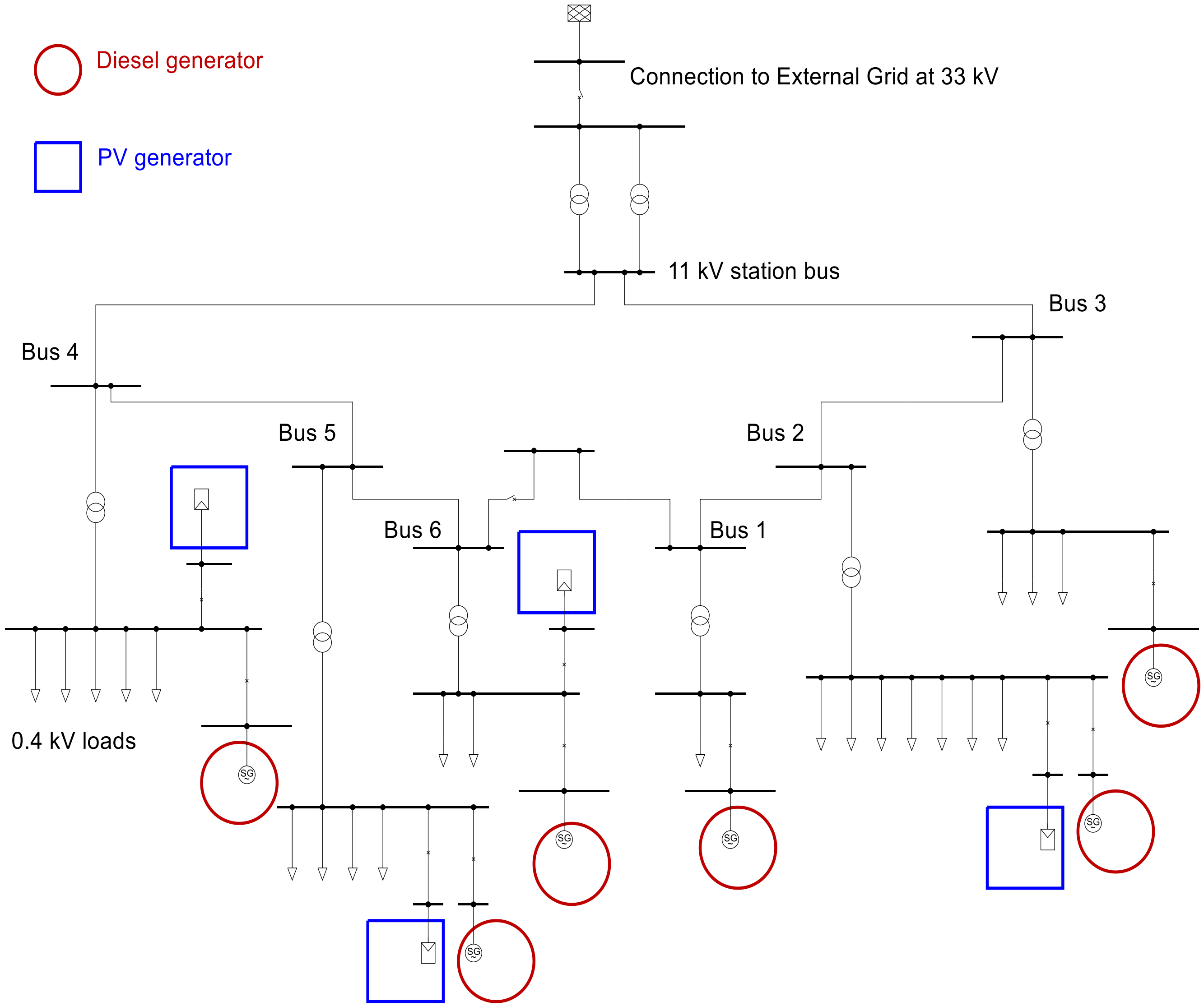
- CERTH Smart house, Greece
- MCAST University campus, Malta
- GJU University campus, Jordan

Selected Case Study

Assets Employed

- PV Generators
- Batteries
- Diesel Generators
- Building Loads

Pilot Site Models: GJU campus grid



One 11 Kilovolt ring with 7 buses

One external grid connection

6 Diesel Generators (total capacity 2.5 MW)

4 PV Generators (total capacity 1.8 MW)

Load aggregated at 0.4 kV buses (assumed peak load 1.6 MW)

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Key Performance Indicators for Micro-Grids

Measuring the performance of a MG entails quantification of key aspects:

a) Economy,

b) Environment,

c) Reliability,

d) Resiliency,

e) Power Quality, and

f) Efficiency.

Key Performance Indicators (KPIs) have been defined in all of these categories.

Selected performance criteria investigated in simulations and presented here:

- voltage limits,
- frequency limits,
- greenhouse gas (GHG) emissions, and
- integration of variable renewable energy sources (VRES)

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Baseline Performance Investigation: Voltage

Voltage limits: Analyse impact of PV on 11 kV and 0.4 kV bus voltages in winter/summer with island operation (worst case).

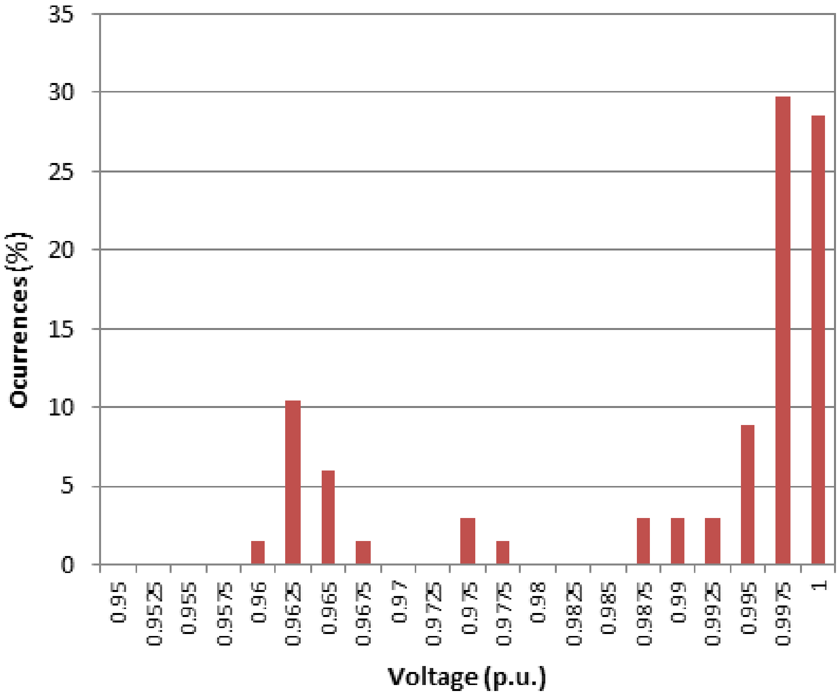
Scenario	Mode	Load & Irradiance	Gen set online
U1	Island	Summer week	2x 703 kVA weekdays 2x 150 kVA weekend
U2	Island	Winter week	2x 703 kVA weekdays 2x 150 kVA weekend

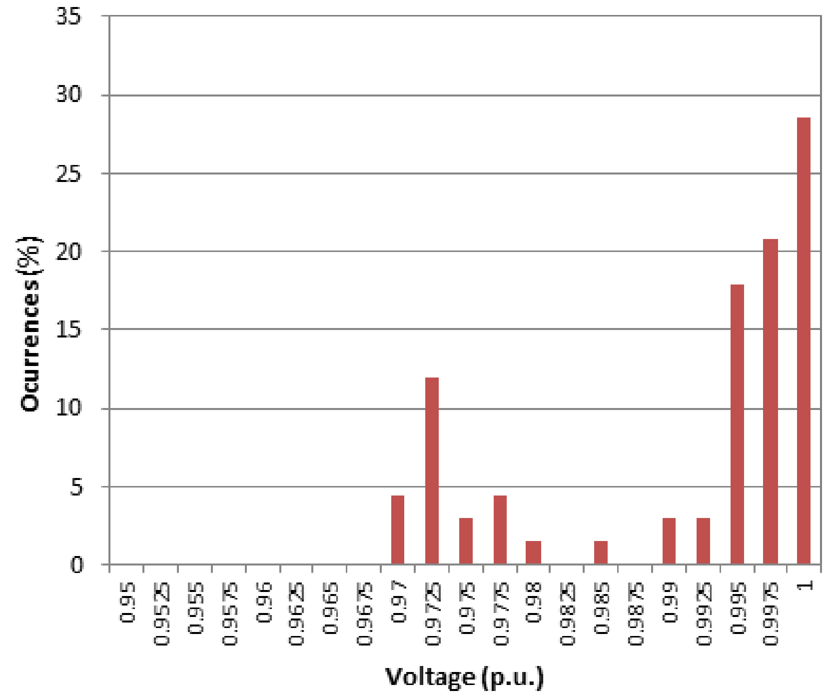
Assumptions:

- Generator dispatch considers (i) demand, (ii) spinning reserve requirements, (iii) Diesel generators' minimum loading levels.
- At least one Diesel generator must be running at each point in time to provide voltage and frequency control (grid forming capability).
- Otherwise PV generation is always preferred when available.
- PV units use a Q(V) voltage droop characteristic to mitigate voltage deviation.

Baseline Performance Investigation: Voltage

Summer week Voltage histograms for bus 2 (simulation results) Winter week





KPI Supply voltage variations	GJU Microgrid	EN 50160
Summer week	100% week voltage: [0.96,1]	95% week Voltage [0.9, 1.1] p.u.
Winter week	100% week voltage [0.97,1]	100% week Voltage [0.85,1.1] p.u.

✓ Islanded MG system with PV complies with EN 50160 voltage limits.

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Baseline Performance Investigation: Frequency

Frequency limits: Microgrid assets only have measurable impact on the frequency during island operation. A critical task is to transition to island operation without violating frequency limits.

Parameters impacting frequency during the transition:

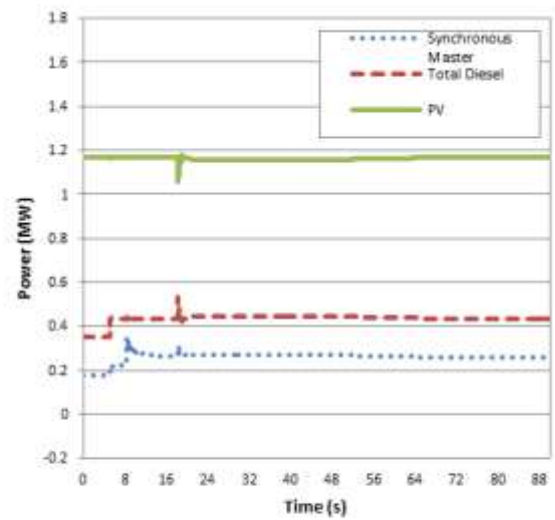
- Power flow across the breaker prior to the transition
- MG asset inertia
- Speed of the frequency control system (including controller and engine power output)

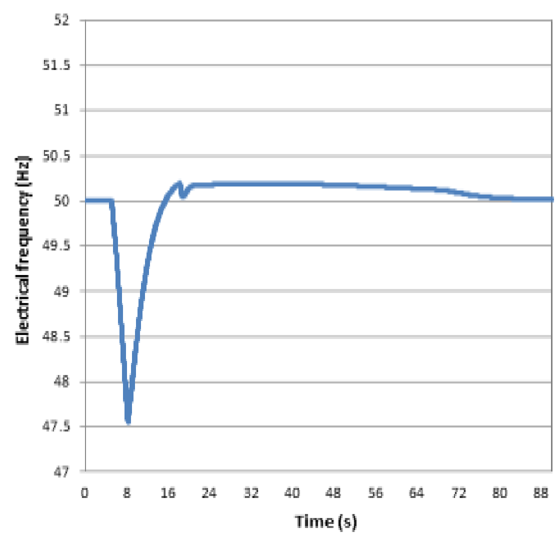
What is the maximum power import (or export) of the pilot MG prior to the transition that still allows staying within generator frequency protection limits?

Baseline Performance Investigation: Frequency

Underfrequency:

- Protection limit is 47.5 Hz
- Critical in case of power import prior to the transition
- Addressed by increasing power output of Diesel generator(s) (which therefore need to run below their maximum output before the transition)





The GJU model indicates an import power limit of 0.1 MW (6.25% of peak demand)

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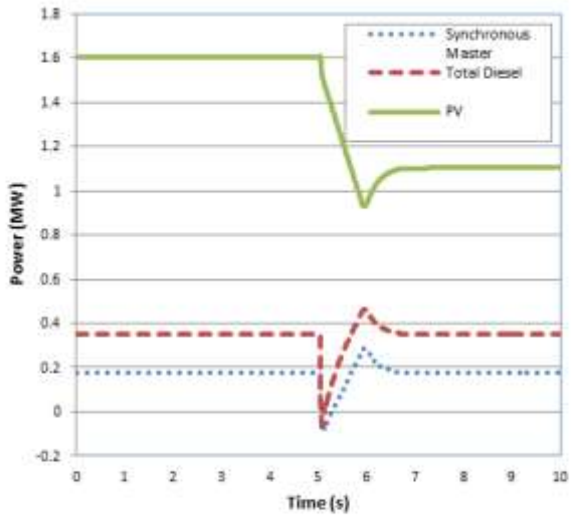
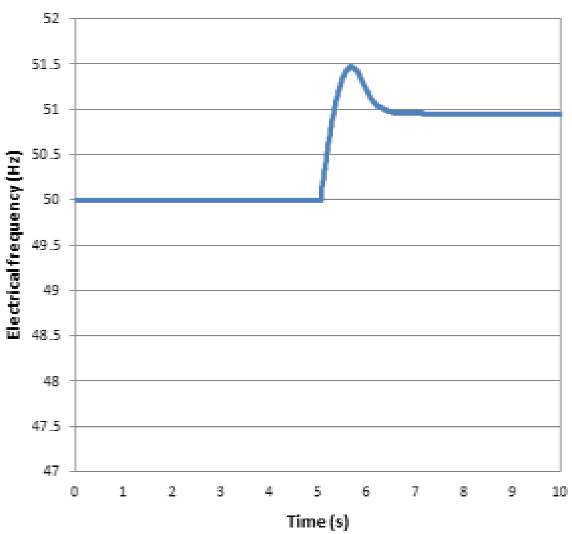
Baseline Performance Investigation: Frequency





Overfrequency:

- Protection limit is 51.5 Hz
- Critical in case of power export prior to the transition
- Addressed by decreasing power output of PV generator(s) (assuming significant generation from PV before the transition)

The GJU model indicates an export power limit of 0.65 MW (50% of momentary demand of the given scenario)

Baseline Performance Investigation: GHG and VRES

Scenario	Mode	PV (MWp)
H1	Island	0
H2	Grid	0
H3	Island	1.84
H4	Grid	1.84

Grid CO_2 emissions (g/kWh)	675
Diesel Generators CO_2 emissions (g/kWh)	715-870
Minimum active power limit for diesel generators (%)	25

Greenhouse gas emissions and variable renewable energy sources (VRES) penetrations are calculated using Homer software.

Same generator dispatch mechanism as in previously presented cases

Lack of storage and flexible loads causes reduced VRES utilization in island operation.

Generator loading level and grid emissions also have an impact on GHG emissions.

Scenario	Mode	CO_2 emissions (tons)	CO_2 emissions (% rel. to scen. H2)	VRES available (% of demand)	VRES curtailed (% of demand)	VRES Fraction (% of GJU demand met by VRES)	Diesel Generation (% of demand)	Grid Sales (%)	Grid purchases (%)
H1	Island	3220	98.5	0	0	0	100	0	0
H2	Grid	3270	100	0	0	0	29.9	0	70.1
H3	Island	2140	65.5	74	29.7	44.3	55.7	0	0
H4	Grid	2124	65	74	0	44.9	29.9	29.1	25.2

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Flexibility Constraints and Impacts

When aiming for the highest possible levels of VRES penetration, flexibility is very important.

Sources of Flexibility:

- Generators with wide power output adjustment ranges
- Electricity storage systems
- Sector coupling: heating and cooling, electric vehicles
- Flexible loads (in terms of consumption time and power)

Flexibility sources vary widely in availability and efficiency.

Implementation of Smart Micro-Grid services, and their service ranges, strongly depend on availability of flexible resources.

Reminder: The presence of VRES generation alone is not sufficient for implementation of a smart Micro-Grid.

Outlook and Conclusions

The simulation results presented in this work represent a baseline case in terms of MicroGrid performance of the GJU pilot, and illustrate the site constraints.

Once the developed control framework can be applied to the GJU pilot, its combined performance will be benchmarked against this baseline.

Models and control framework components are under development by the project partners.

Simulations of Components in Various Frameworks

- JADE <-> MATLAB/Simulink
- OPAL-RT
- GAMS
- DIgSILENT PowerFactory
- Homer

More results will be presented in further publications.

Acknowledgments

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MCAST

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eSDL

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Thank you!

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Questions ?