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PRIORITY 6.1, Sustainable energy systems
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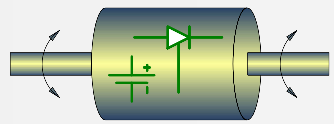
Project VSYNC - Contract no: FP6 – 038584

Virtual Synchronous Generators



- VSYNC project and VSG concept -

Klaas Visscher – Project manager

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Energy research Centre of the Netherlands (ECN)

Overview

- The VSYNC project
- The VSG concept
- The Application Cases
- Implementation of VSG's
  - Phase 1: Laboratory testing
  - Phase 2: Demonstration
- Many Questions To Be Addressed

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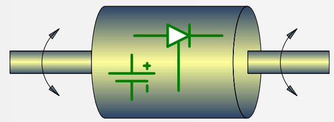
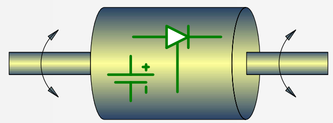
THE VSYNC PROJECT



THE VSYNC PROJECT



Virtual Synchronous Machines For Frequency Stabilisation In Future Grids With A Significant Share Of Decentralized Generation.

- **Duration:** 3 years (Oct 2007 till Oct 2010)
- **Budget:** € 3.25 million
- **Aim:** Give distributed energy resources the character of Virtual Synchronous Generators that solve stability problems in future grids.
- **Phase 1:** Laboratory testing (6 x 5 kW VSG)
- **Phase 2:** Demonstration
  - 10 x 5 kW VSG; The Netherlands (Continuon)
  - 1 x 100 kW VSG; Romania (Electrica)
- **Coordinator:** ECN, The Netherlands
- **Project manager:** Dr. K. Visscher, visscher@ecn.nl

Project partners

1	ECN	NL
	Energy research Centre of the Netherlands	
2	TUE	NL
	Technical University of Eindhoven	
3	TUD	NL
	Delft University of Technology	
4	KUL	BE
	Catholic University of Leuven	
5	UPB	RO
	Universitatea Politehnica Bucuresti	
6	LABEIN	ES
	Fundación LABEIN	
7	3E	BE
	3E NV	
8	UfE	DE
	UfE Umweltfreundliche Energieanlagen Handelsgesellschaft mbH	
9	Electrica	RO
	Electrica SA	
10	Continuon	NL
	Continuon NV	

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FUTURE GRID SCENARIO

FUTURE CONDITIONS

- Large share of decentralised generation
- Central generation is diminished
- Partial near-islanding operation

CONSEQUENCES

- Less rotational mass in the system
  - Larger frequency variations
- Shorter response time to fault situations
  - for safety devices and for grid operators
- A less stable grid

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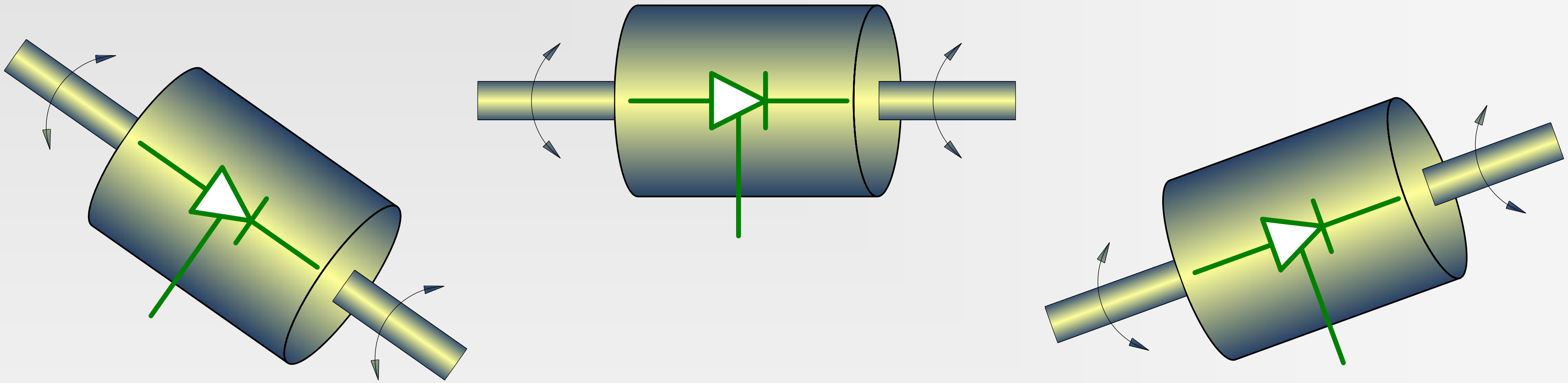
PROBLEM APPROACH

Add Virtual Synchronous Generators (VSG's)



Expected Result: A more stable grid

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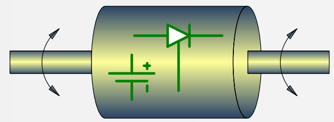
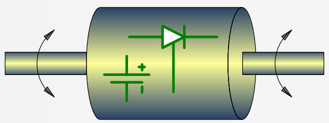
THE VSG CONCEPT



OPERATION PRINCIPLE OF VSG's

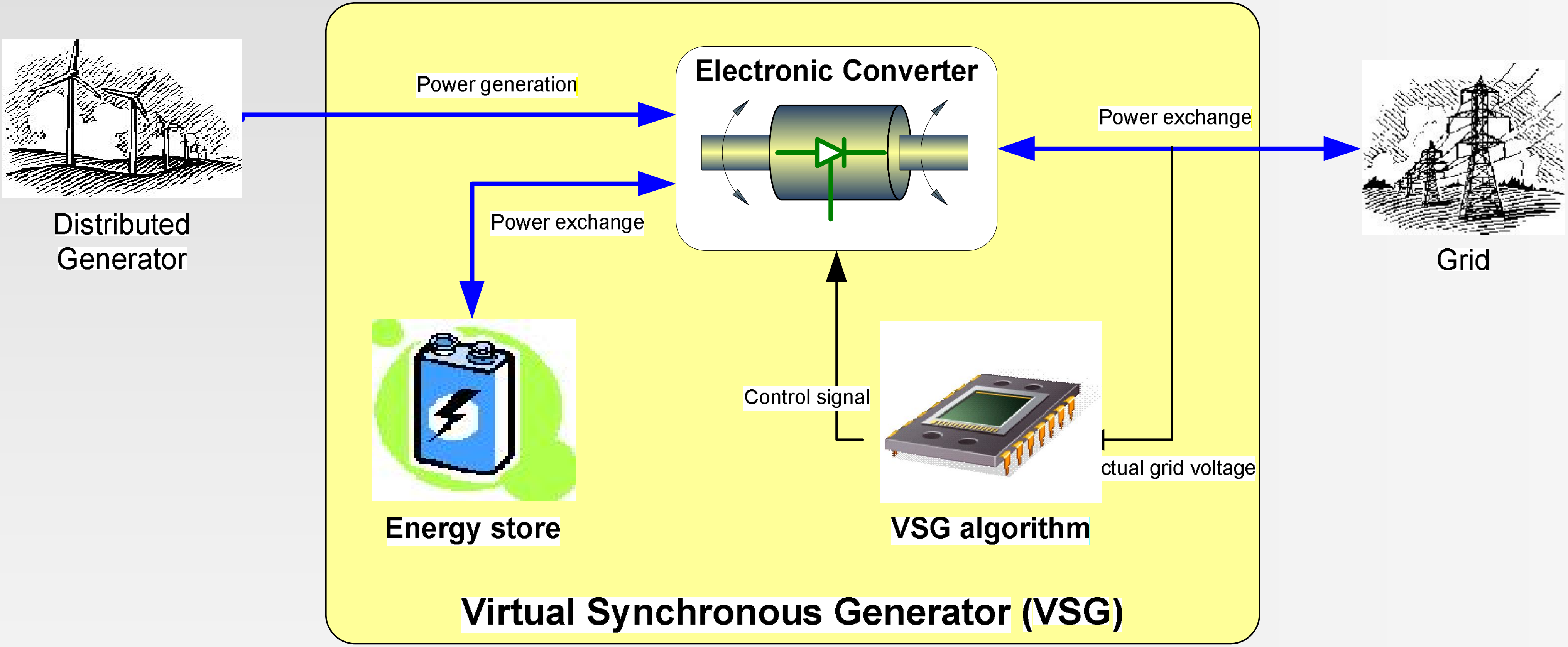


- Many VSG's together behave like one large rotating mass
- Short lasting power exchanges between grid and energy stores counteracting changes in
  - Frequency
  - Voltage

EXPECTED RESULTS:

- Reduction of variations in frequency and voltage
- Improved fault clearance due to slower response of power system

THE VSG CONCEPT



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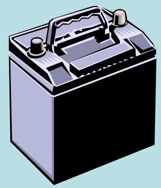
ENERGY ESTIMATES

$$\delta t = (1 \quad 5 \quad 15)\ \text{min}$$

$$P_{nom} = \begin{pmatrix} 5 \\ 50 \\ 100 \end{pmatrix} \text{kW} \qquad E = \begin{pmatrix} 0.1 & 0.4 & 1.3 \\ 0.8 & 4.2 & 12.5 \\ 1.7 & 8.3 & 25 \end{pmatrix} \text{kWh}$$

For comparison only:

One car battery = 0.5 kWh



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ESSENCE OF VSG OPERATION

- Virtual Synchronous Generators emulate rotating inertia for limited time intervals,
- with the aid of complementary control algorithms to sustain operation in case of faults or contingencies,
- thereby giving balancing algorithms, control and protection devices ample time to restore normal operation in the system.

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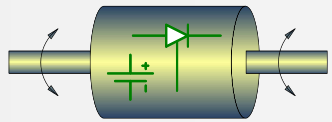
THE APPLICATION CASES

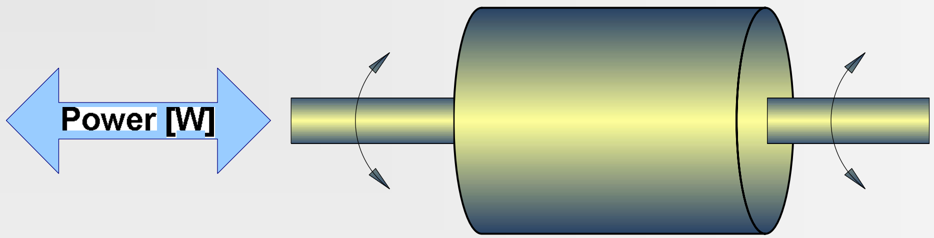


CASE 0: Normal operation

Frequency following VSG

- For simplicity:
  - DER switched off
  - without secondary algorithm for voltage stabilisation

$$P_{mech} = \omega_{grid} \cdot J \cdot \left(\frac{d}{dt} \omega_{grid}(t) \right)$$



Result:

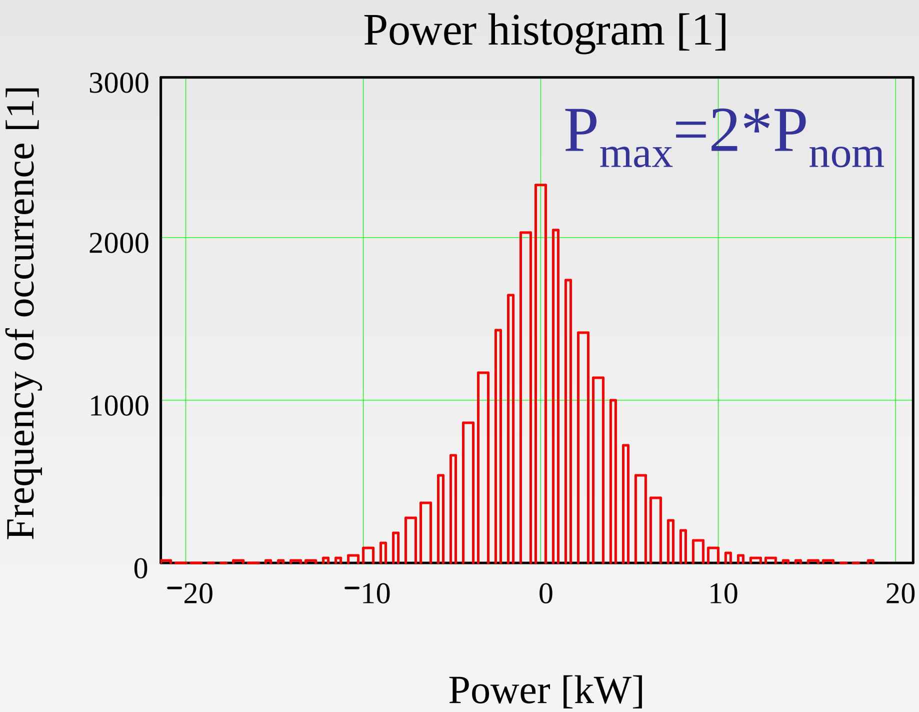
- Short lasting power exchanges between grid and energy store counteracting changes in frequency

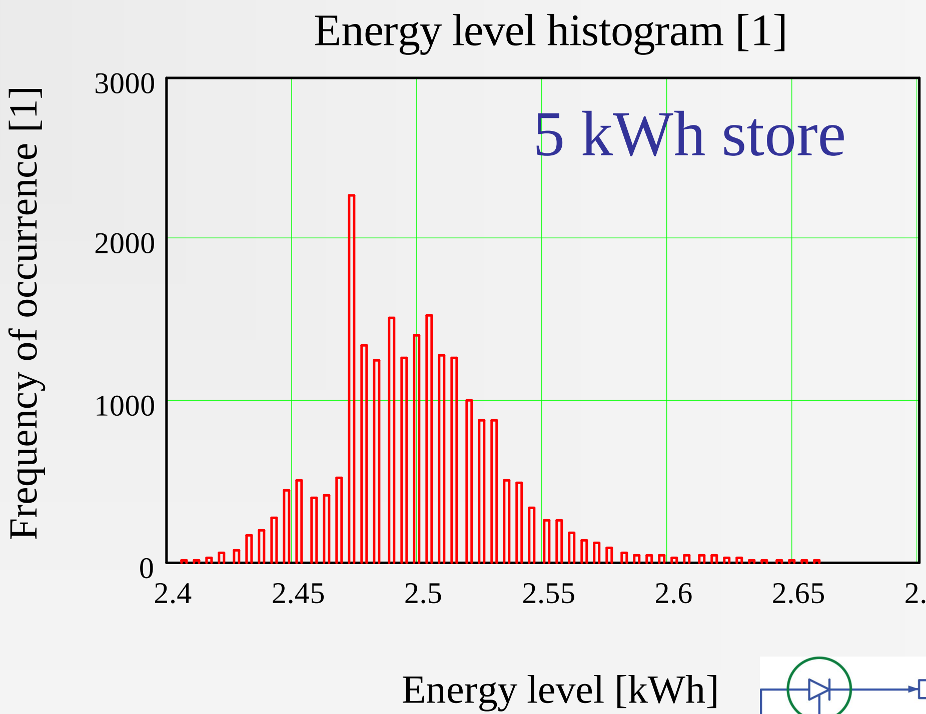
Normal operation of 10 kW VSG (10 April 2008)

$J_{rot} = 608\,\mathrm{kg \cdot m^2}$

Calculation from grid frequency data

(4 sec samples, 24 hr series. Source: TenneT)





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CASE 1: Primary balancing

Isolated small grid as a model for a future grid with significant intermittent generation.

Wind turbine and one central generator

1. Wind catches up
2. Power balance disturbed
3. Generator speeds up (frequency increases)
4. Operator takes measures (load increase or power decrease)

Scenario 1: No VSG

5. System goes into critical condition
6. Generator trips

Scenario 2: VSG added to the wind turbine

5. VSG buffers the excess wind power for a short time period
6. Balance restored

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CASE 2: Safety & Security of supply

Solar array with inverter

1. Normal operation
2. Nearby short circuit fault (not in the main feeder)
3. Voltage drops (tens of percent)

<u>Scenario 1: No VSG</u>

4. Inverter trips
5. Safety device kicks in, and fault is cleared

<u>Scenario 2: VSG added to the inverter</u>

4. VSG empties its buffer to slow down the voltage drop
5. Safety device kicks in, and fault is cleared

CASE 3: Reconnection of microgrid

Micro grid with decentralised generators

1. Normal operation
2. Main grid voltage drops for a short time interval (minutes)

<u>Scenario 1: No VSG</u>

1. Decentralised generators trip
2. Main grid voltage restored

<u>Scenario 2: VSG's added to the generators</u>

1. Main grid connection broken (islanding mode)
2. VSG's balance the micro grid (active & reactive power)
3. Main grid voltage restored
4. VSG's synchronise to main grid (UCTE sync/ grid voltage)
5. Micro grid reconnection

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Case 4: Coordination of electricity stores

- Grid or micro grid with a mix of traditional power plants, DG's and VSG's
- Without coordination, the stores may get exhausted or filled completely
- VSG's and/or the DSO have to participate in a coordinated action to maintain the power balance for longer duration (e.g. 50% SOC)

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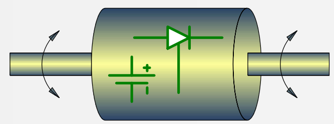
IMPLEMENTATION OF VSG'S



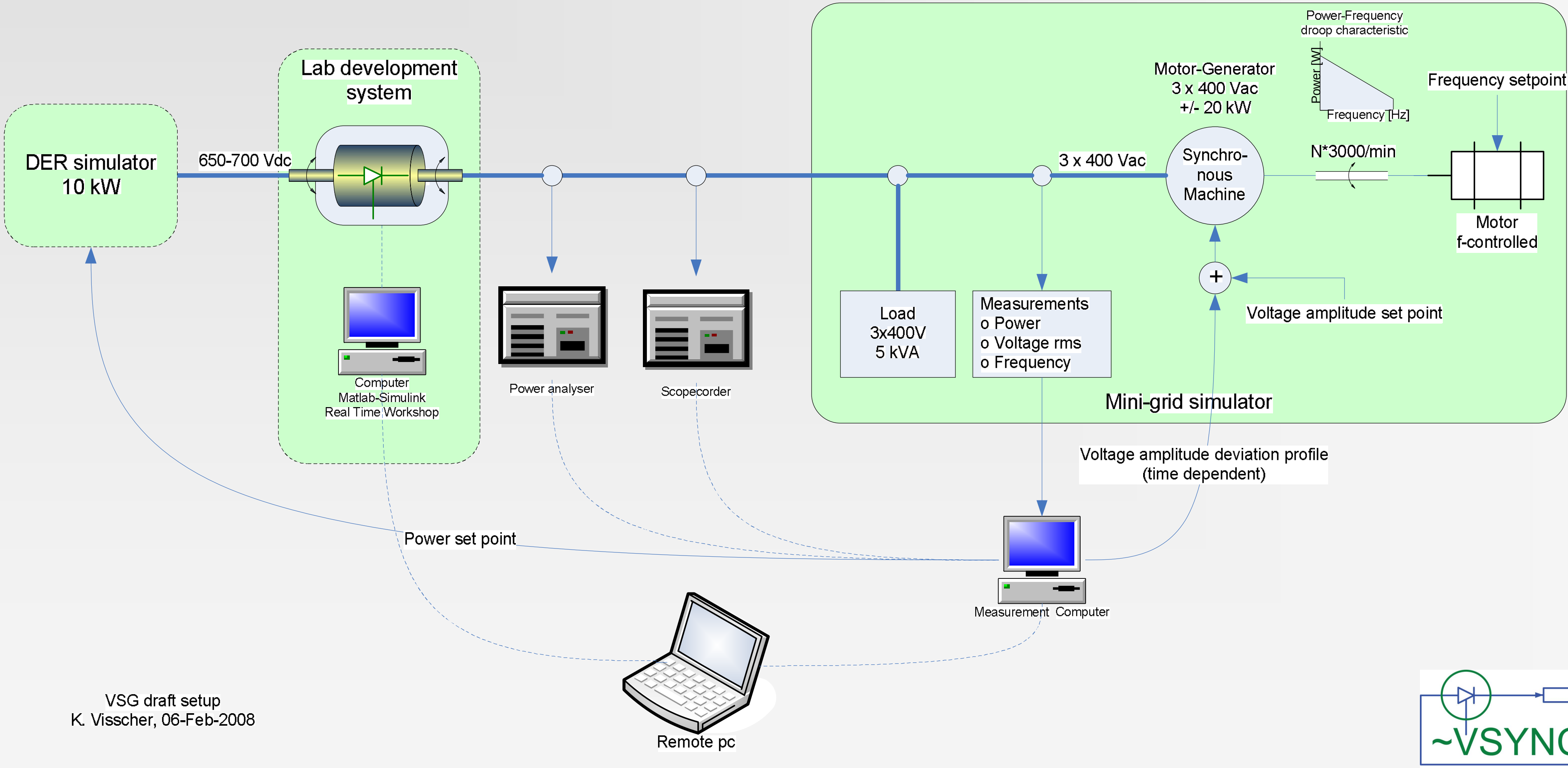
Phase 1: Laboratory testing (6 x 5 kW VSG)

Laboratory equipment

- Triphase development system
  - Rapid prototyping of power electronics applications
  - Controlled by pc (Matlab-Simulink)
  - Same equipment at 6 partners
- Mini test grid 20 kW @ 50 Hz
  - Motor / synchronous generator
  - RLC-loads
  - DER simulator

Laboratory system lay-out

DRAFT - Laboratory set-up for tests of:
a) VSG control algorithms
b) Interaction of VSG with mini-grid events



VSG draft setup
K. Visscher, 06-Feb-2008

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Triphase Development System

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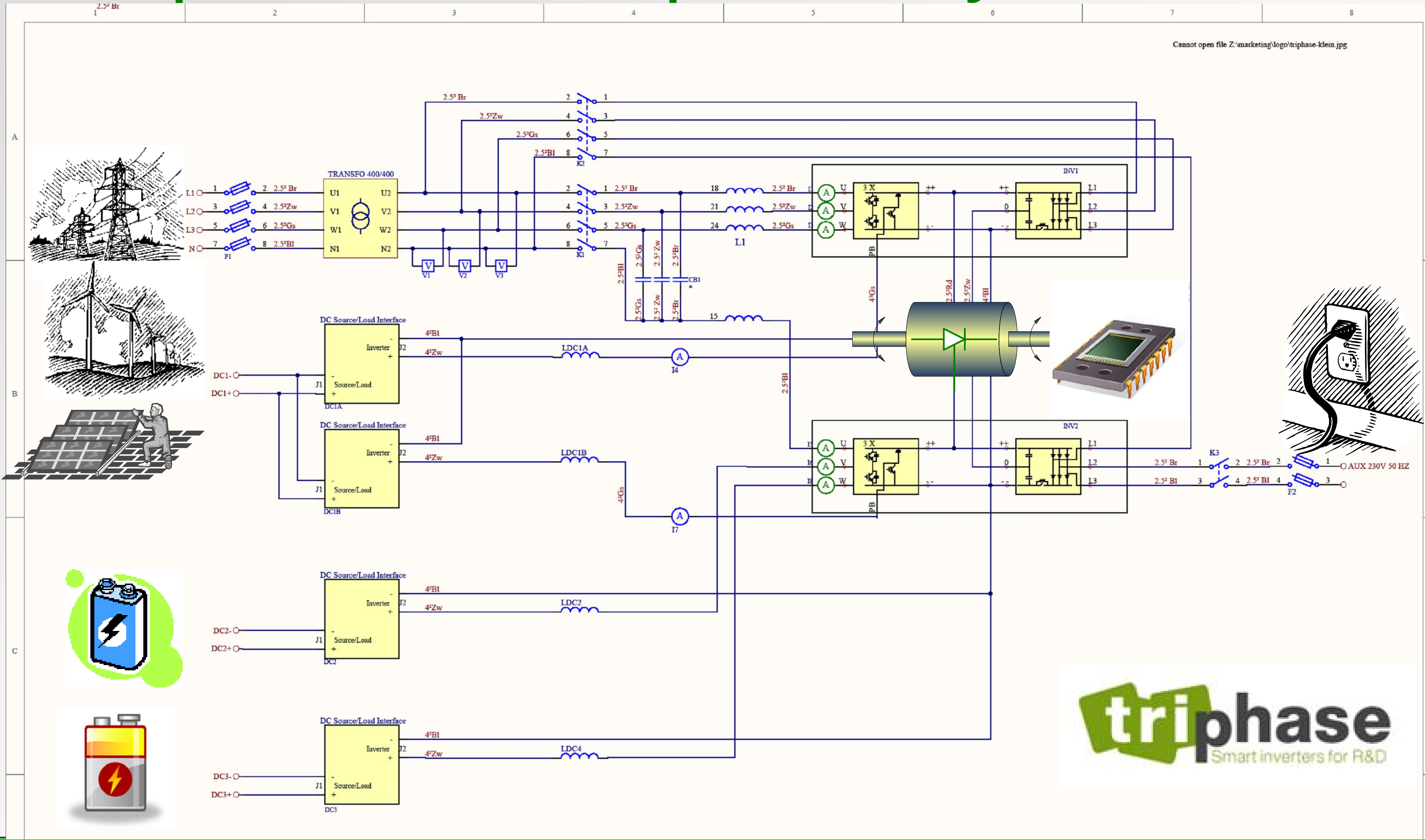
Triphase Development System



Selected battery system

- LiFeBatt battery pack:

Fotos of safety device and battery pack(s) to be included

Selected battery for ECN's system

- **LiFeBatt battery pack specifications:**

  Each battery (two parallel packs required)

  – 3 x 10810-HPS in series gives 3,2kWh storage
  – Minimum capacity = 9Ah
  – Nominal voltage = 356V
  – Maximum voltage = 394V
  – Cutt off voltage = 227V
  – Maximum charge current = 30A
  – Maximum discharge current = 120A

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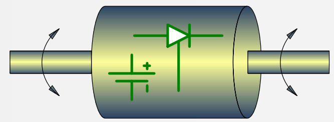


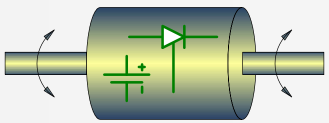
Phase 2: Demonstration

Field Tests (Planned)

- 10 x 5 kW VSG; The Netherlands (Continuon)
- 1 x 100 kW VSG; Romania (Electrica)
- (....?)

Many Questions To Be Addressed

1. To what extent will VSG's improve the stability of future grids?
2. What are the limitations of VSG's?
3. Are the application cases also good laboratory test cases?
4. How to measure the effect of one VSG in a field test?
5. To what extent doe the use of VSG's increase the amount of DG allowed in the grid?
6. Is a VSG a cost effective solution?
7. (….)



Thank you for your attention