

# *SUPERGEN Wind*

## *2011 General Assembly*

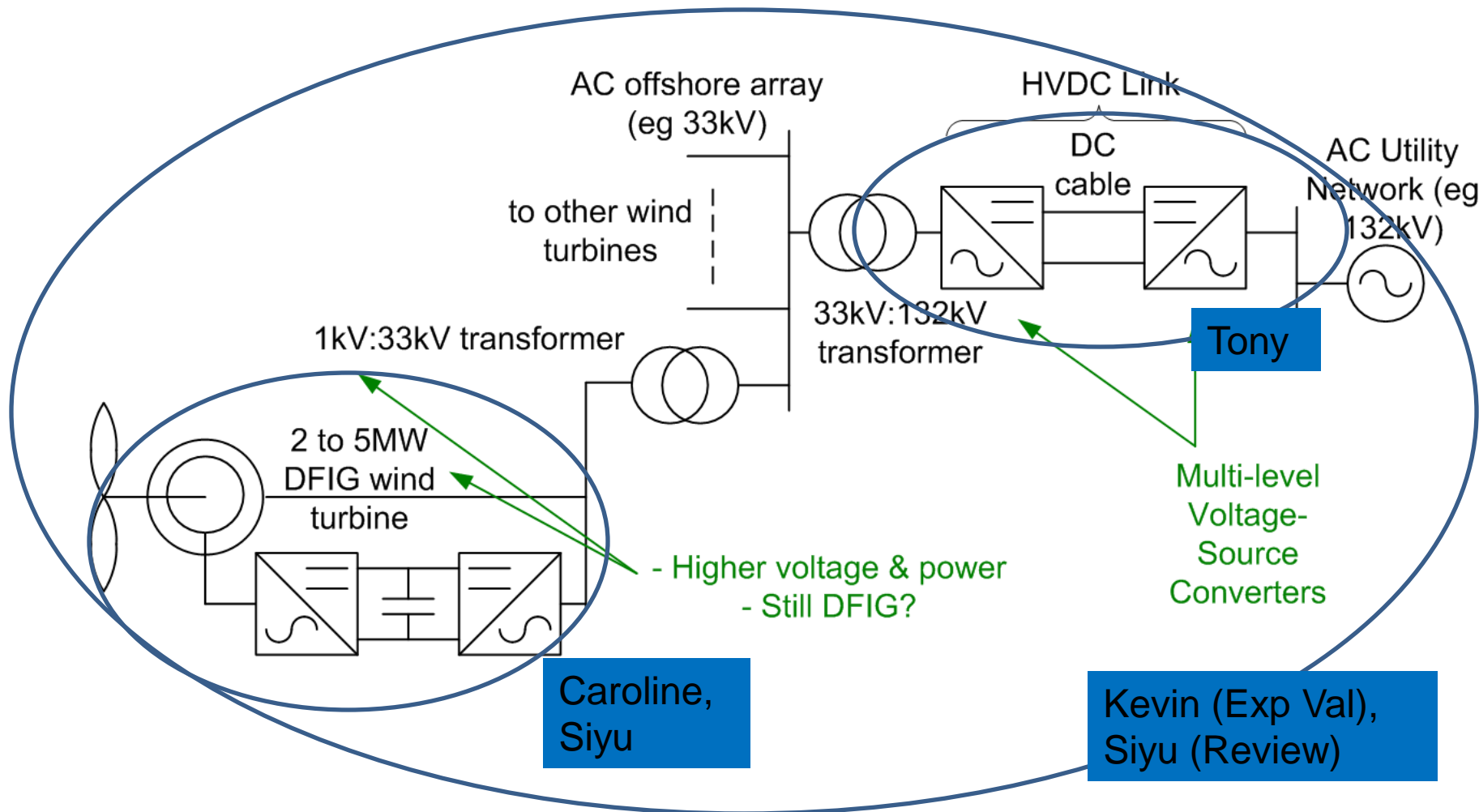
**Connecting offshore wind farms to the  
onshore grid**

**by Dr Mike Barnes, University of Manchester**  
20<sup>th</sup> March 2011, Durham University

# Overview:

- **Improving system reliability**
- **Key focus at this stage:**
  - **Power electronic converter interactions**
    - **with machine**
    - **with other converters**
    - **with VSC HVDC converter**
    - **with cable and system protection**
- **Goal: better more integrated system design**

# The System

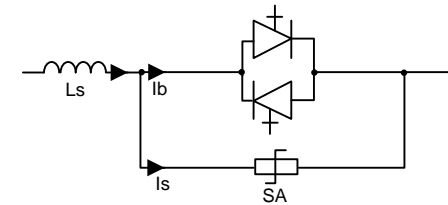
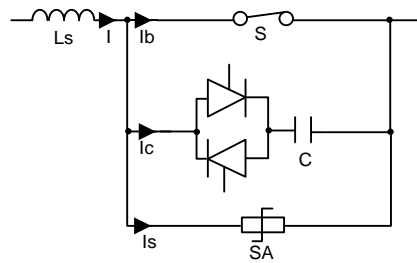
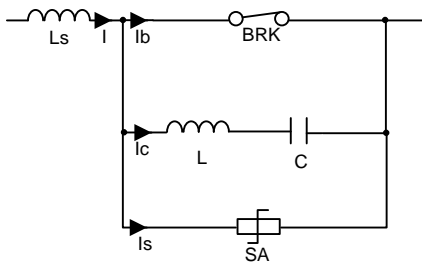


# Tasks to Date:

- 1. DC Link (A Beddard)
  - DC Breaker review/modelling
  - Cable modelling
- 2. DFIG (Ting Lei)
  - FMEA of system
  - System modelling
- 3. PMSG / System (Siyu Gao)
  - Wind farm system review (context)
  - PSCAD PMSG modelling
- 4. Experimental Evaluation (K Dyke)

# 1. Tony - HVDC Circuit Breakers

- Required to clear dc side faults without de-energising grid
- Designs generally fall into one of the following categories:-



(i) Resonance circuit breaker    (ii) Hybrid circuit breaker    (iii) Solid-state circuit breaker

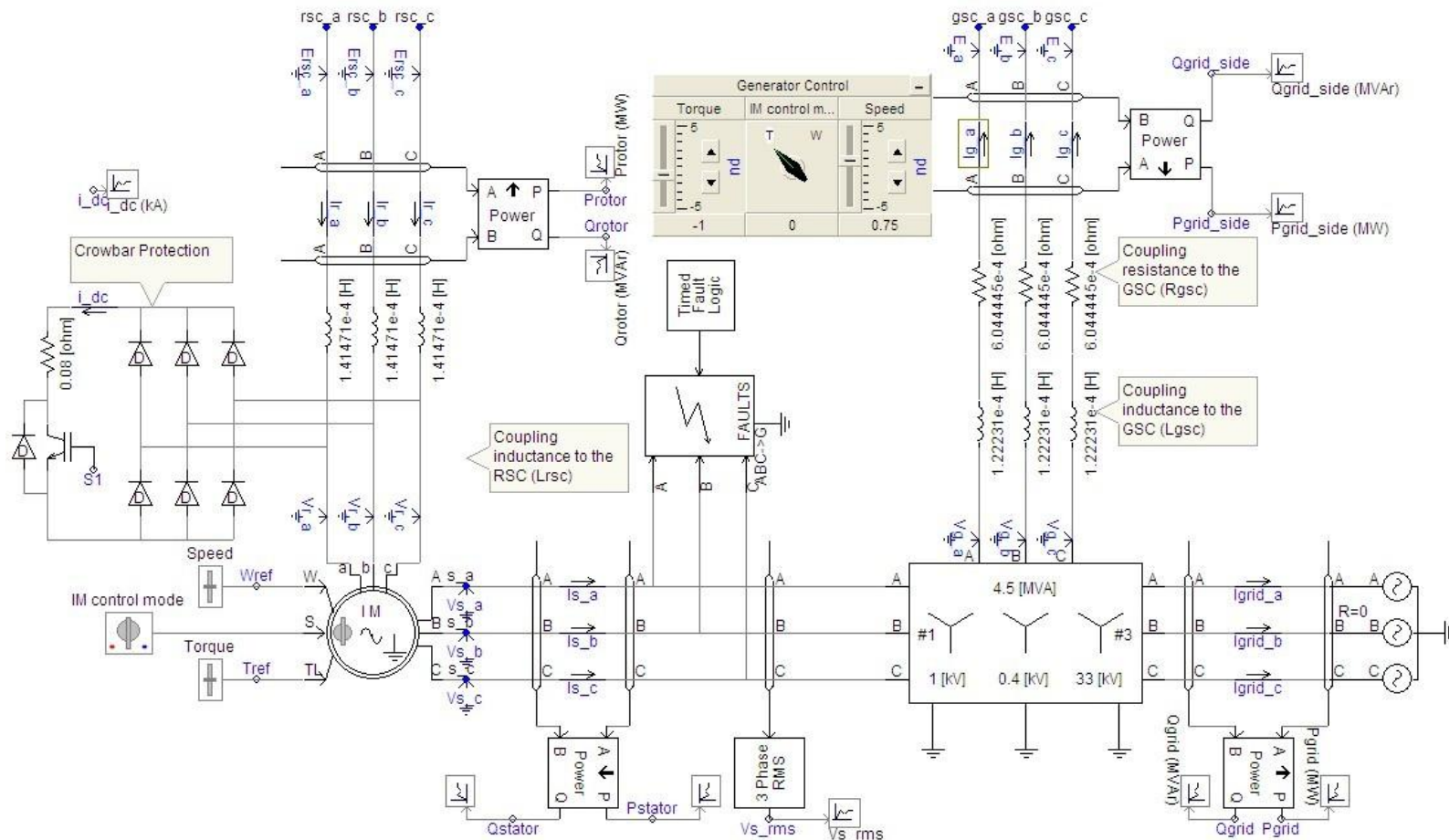
- Resonance & Hybrid – Low on-state losses but slow operation
- Solid-state – Fast interruption speed but high losses
- New design – Compromise between losses and speed

# Modelling HVDC Cables

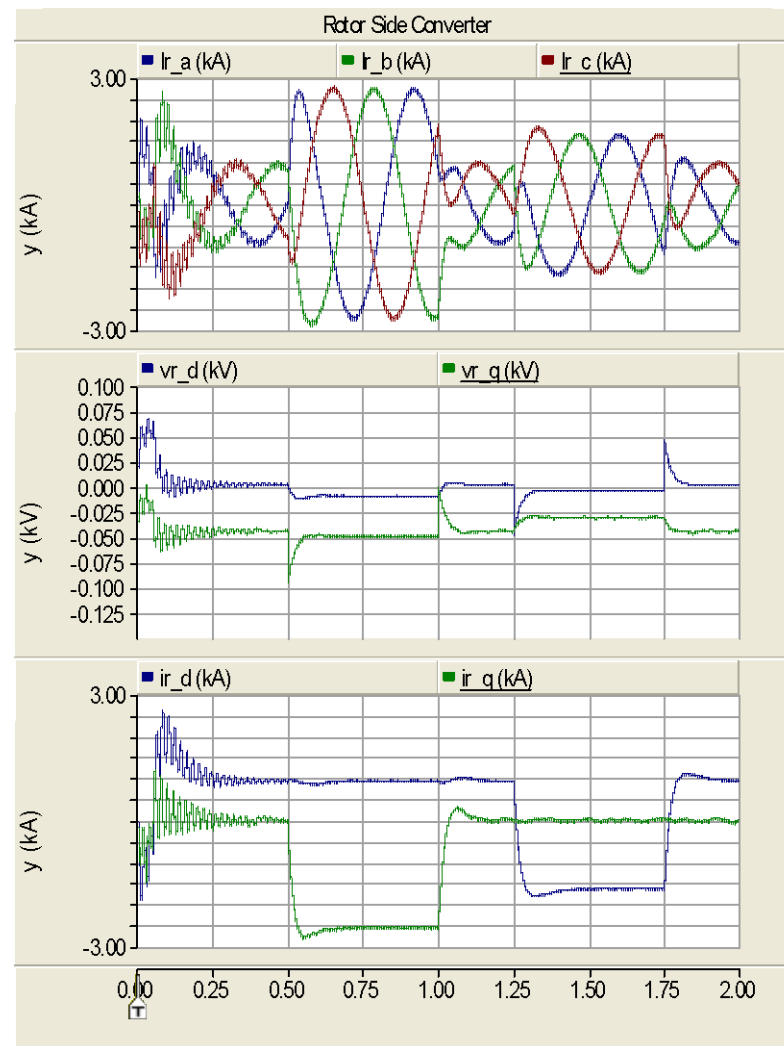
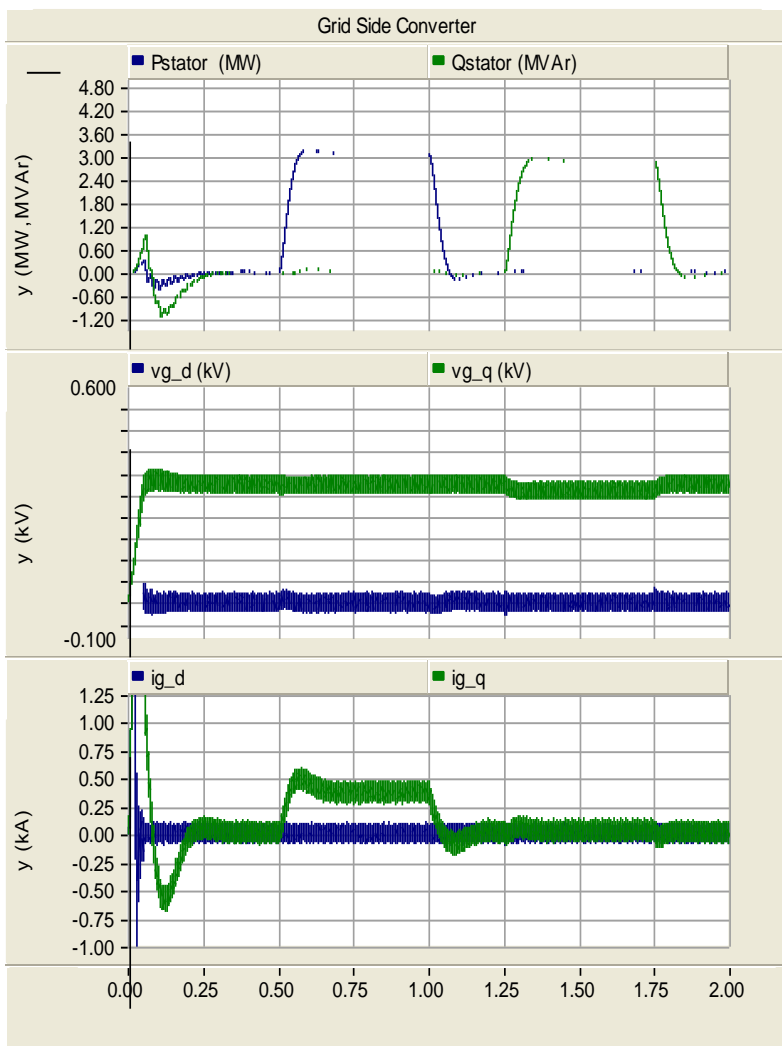


- Aims
  - Ascertain required levels of model fidelity for different study types.
  - Determine which model provides necessary fidelity while minimising simulation time
- HVDC Modelling Report
  - Calculation of cable parameters ✓
  - Transmission line theory ✓
  - Representation of cables (pi-section, distributed parameter, etc) ✓
  - Interface cable models in PSCAD (Dommel's method)- in progress
  - Simulations
  - Analysis of results
  - Conclusions and recommendations

# 2. Caroline - DFIG Model



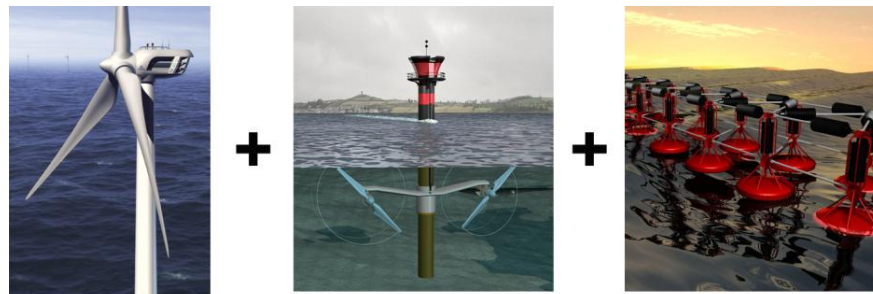
# Response to Set Demand Changes



### 3. Siyu - Survey on offshore wind power technologies



- Types wind turbines summarized and compared.
- Developments of power electronics and grid links summarized.
- Installation of different offshore wind turbine foundations and substations have been studied.
- Different generations of offshore substations have been summarized.
- Projections on offshore energy have been made.

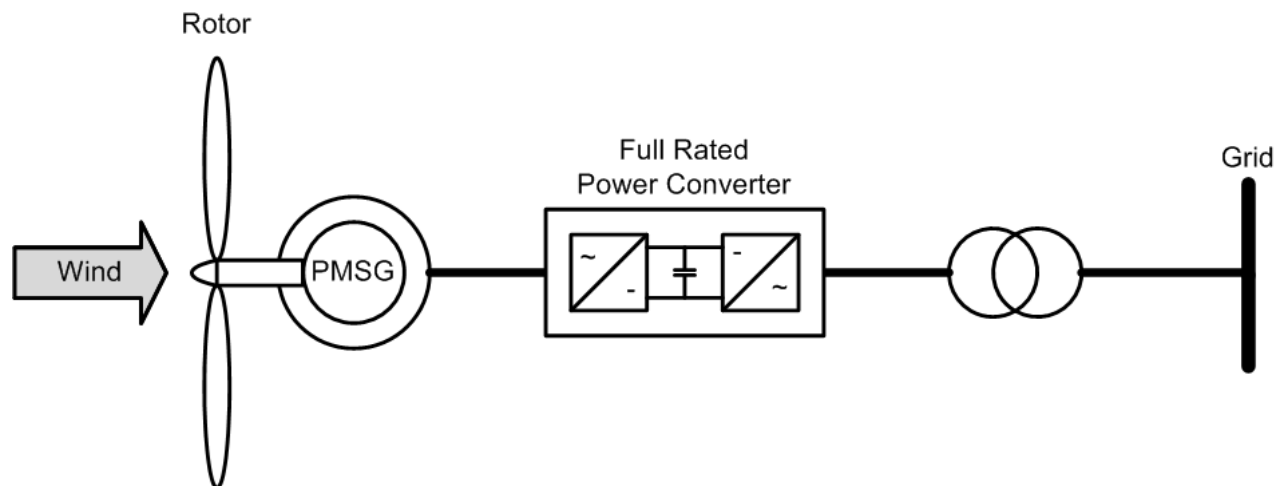


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**Future Offshore Hybrid Power Generation?**

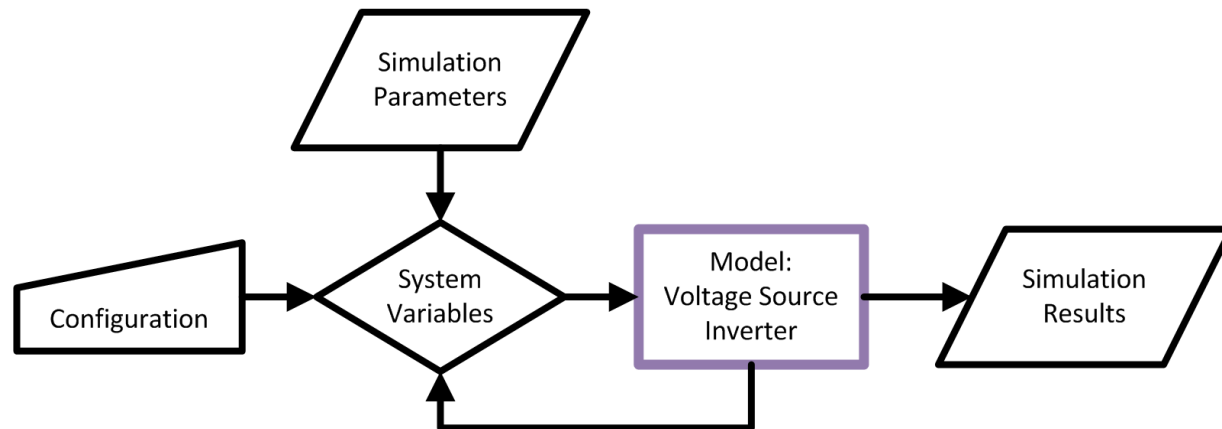
# Modelling a Direct Drive PMSG wind turbine

- Direct drive permanent magnet synchronous wind turbine is now the favoured design since it is able to provide better support for the utility network than conventional DFIG wind turbines.
- The model aims to combine the mechanical and electrical properties of the wind turbine together to give comprehensive simulation results.



## 4. Kevin - MIL to HIL

- Establish behaviour of HVDC using PSCAD
- Use Matlab<sup>®</sup> Simulink<sup>™</sup> to provide simulations for a model-in-loop voltage source inverter
- Validate Simulink<sup>™</sup> model-in-loop against Hardware-in-loop voltage source inverter

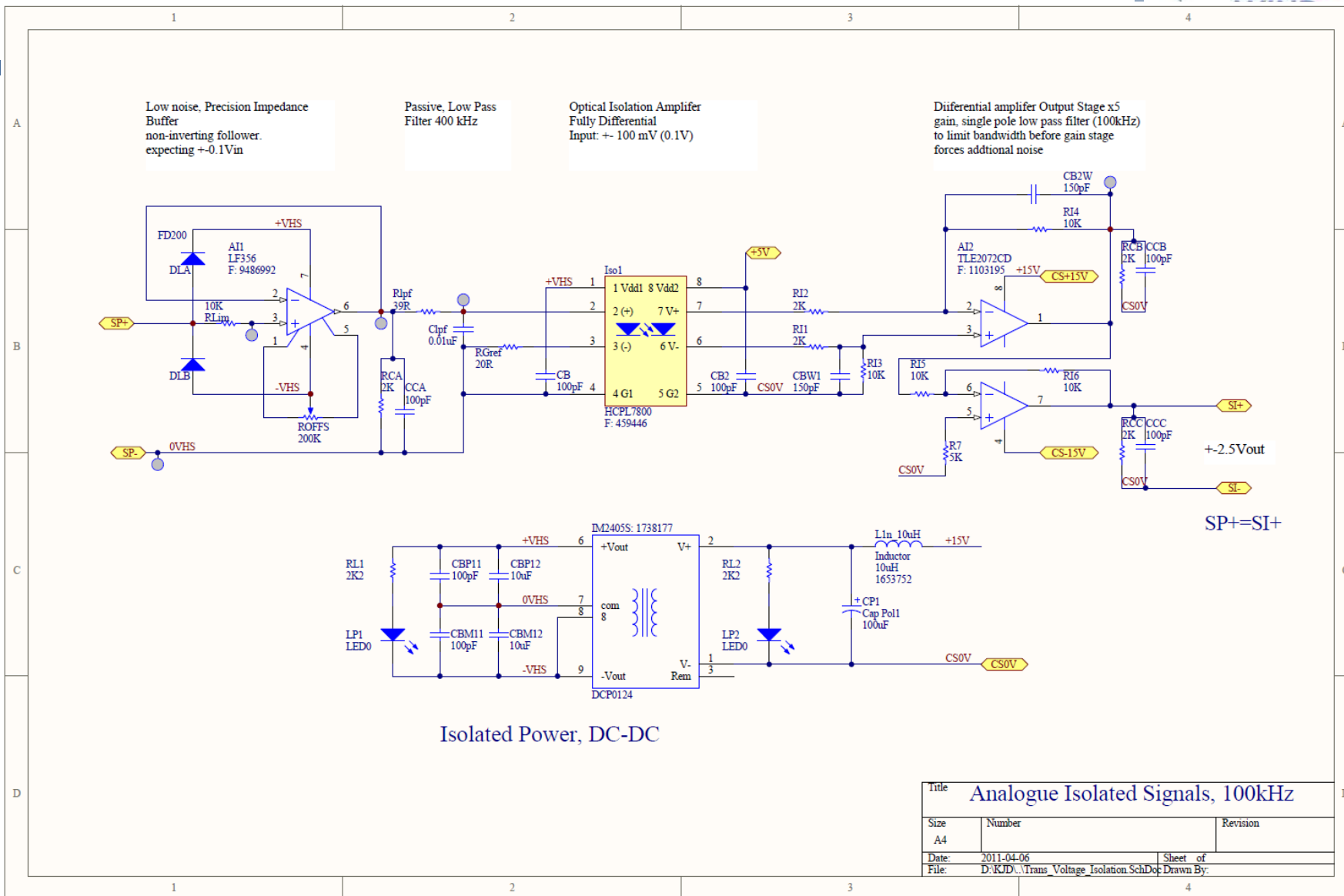


# VSI for HIL

## Design requirements

- Isolated High-bandwidth transducers (voltage, current and temperature) for use in hardware control (DSP) and data acquisition (dSpace)
- Isolated High-speed digital lines
- Thermal management and protection for flexible control schemes and high speed operation.
- Hardware (DSP) managed safety critical control.
- CAN bus interface for dSpace commands.

# Isolation

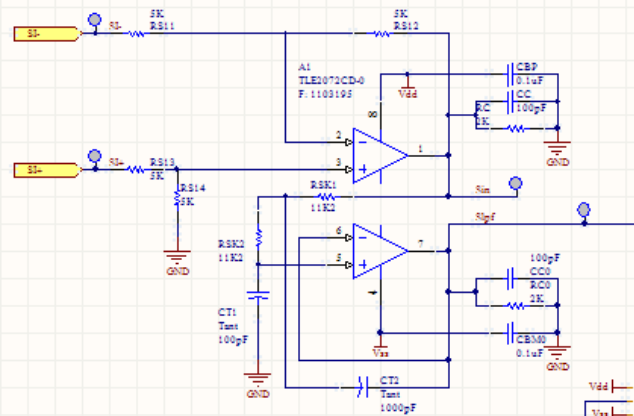


Title		
Analogue Isolated Signals, 100kHz		
Size	Number	Revision
A4		
Date:	2011-04-06	Sheet of
File:	D:\KJD\Trans_Voltage_Isolation_SchDoc	Drawn By:

# Signal Conditioning

## S0: Buffer and Filter

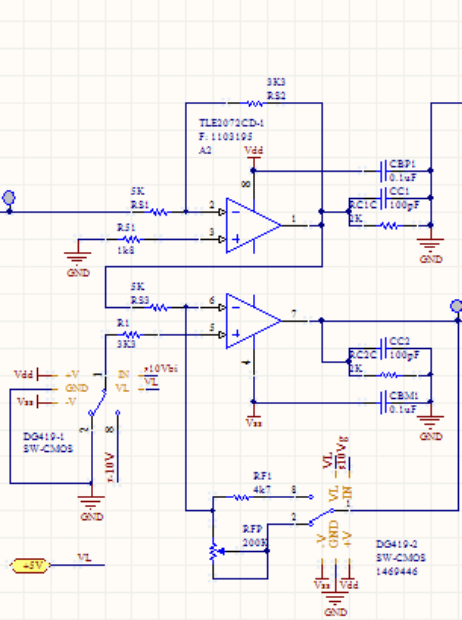
OP1: Unity Buffer (differential)  
OP1: Sallen-Key 5 kHz



Sallen Key  
 $R3K = 0.707 \sqrt{2} \sqrt{C1 \cdot f_c}$   
 $C1 = 2 \cdot C1$   
 ... 50 Hz

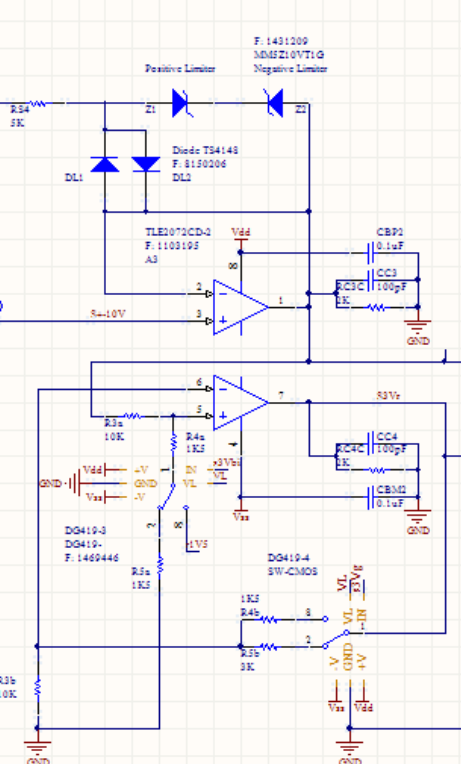
## S1: Scale Signal (+10V)

OP1: Unity Buffer Inverting  
 OP2: Gain(x60)/Offset(10V)/Protection(+10V-10V)



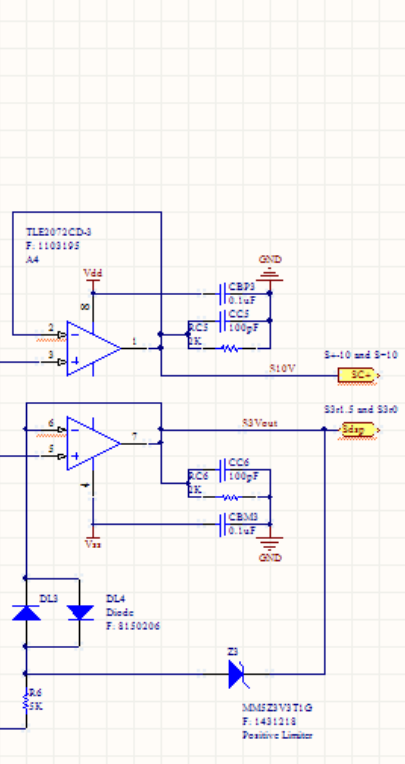
## S2: Scale Signal (+3V)

OP1: Unity Buffer  
 OP2: Gain(3v)/Offset(1V5)/Protection(3V)

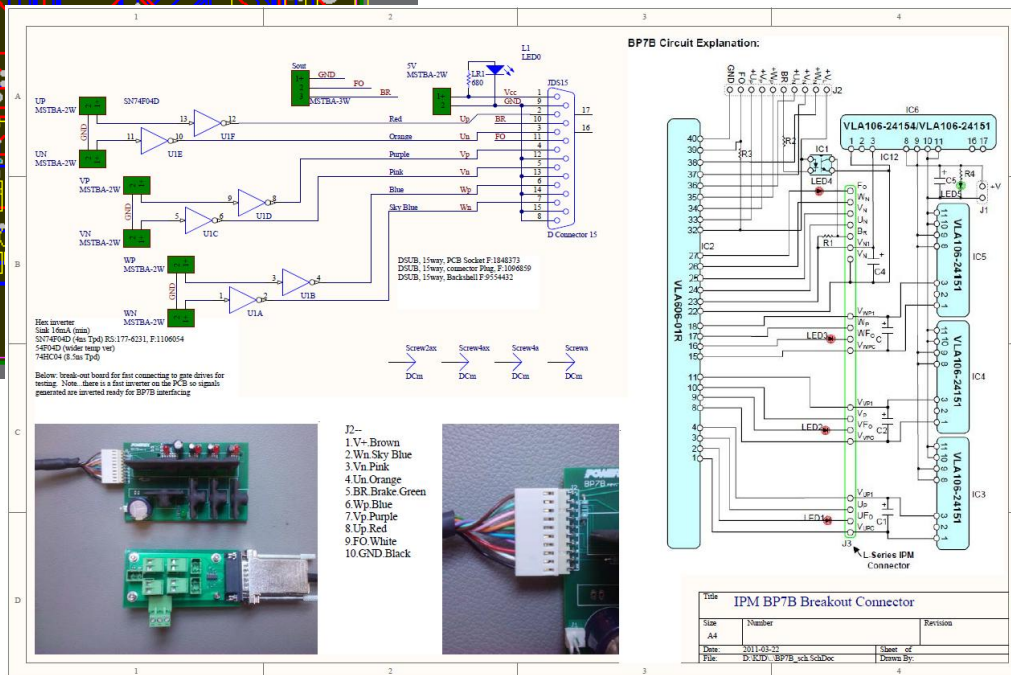
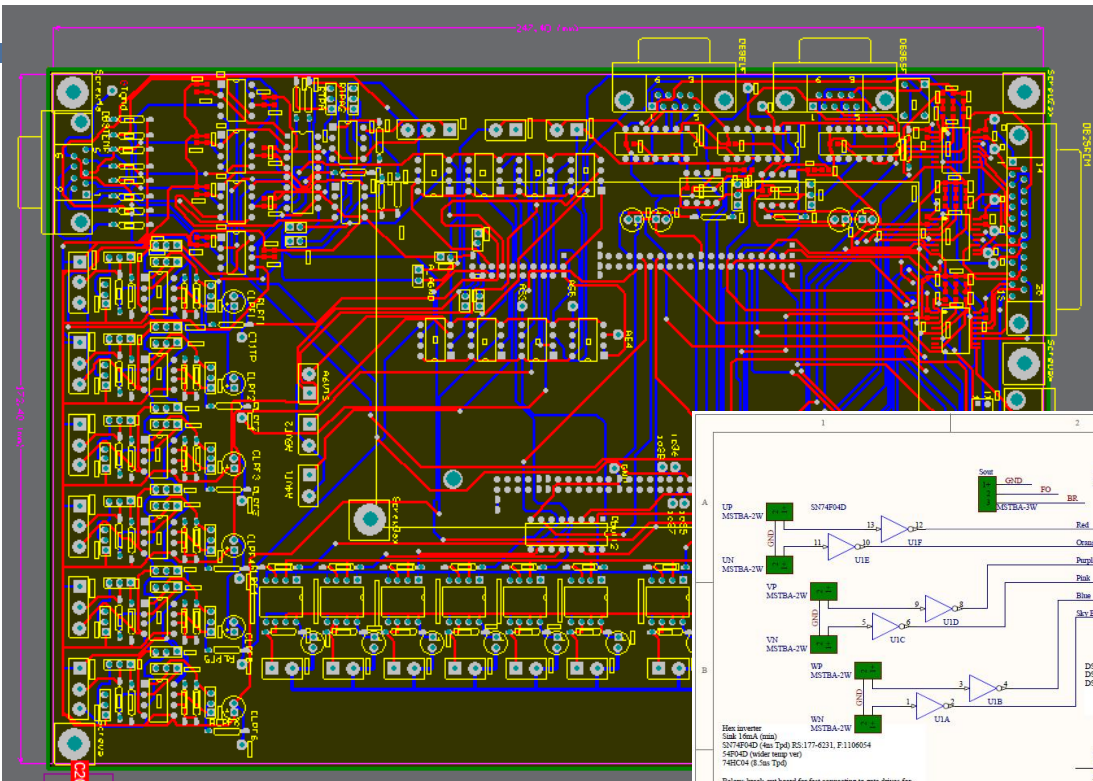


## S3: Buffer and Filter

OP1: Unity Buffer  
 OP2: Unity Buffer



# Hardware Design



# Milestones

- Thermal analysis of 6-switch SPWM complete
- Thermal solution acquired, forced air cooled bonded fin heat sink
- All analogue designs complete
- All system critical hardware procured

# 5. Summary

- Progress:
  - Background review on multiple areas complete
  - Models of DFIG and PMSG progressing
  - Validation hardware progressing
  
  - Good interaction with partner companies (Siemens, Alstom Grid, National Grid)