Details of Microgrid Test Bed System

I. Sources Specifications

1. **Wind Emulator Specifications: The PMSG and DFIG are coupled through the DC motor shaft.**
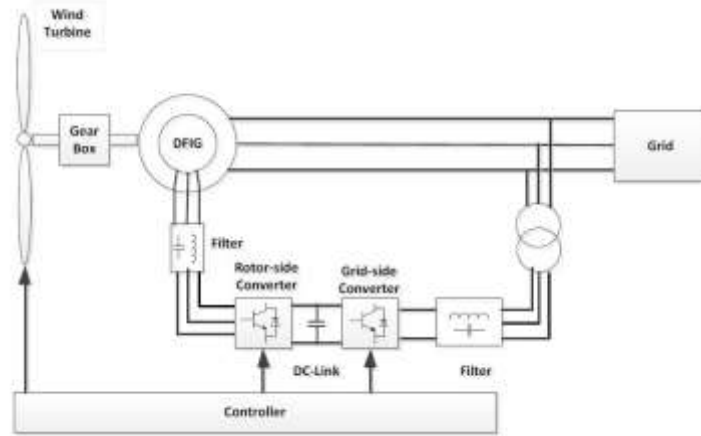
A. DFIG based WECS (Nos: 1)

Fig. 1 DFIG based WECS

DFIG specifications: (Nos.: 1)

Power	2 kVA
Stator voltage	415 V
Current	5 A

B. PMSG based WECS (Nos: 1)
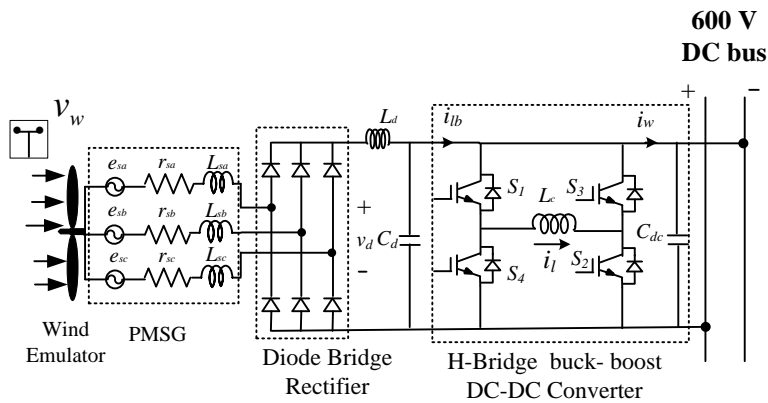
Fig. 2 PMSG based WECS

PMSG specifications: (Nos: 1)

Power, P_o	2.5 kW
Output Voltage, V_0	415 V
Speed in rpm	1000
Current	5 A
Torque	30 N-m
Connection	Star
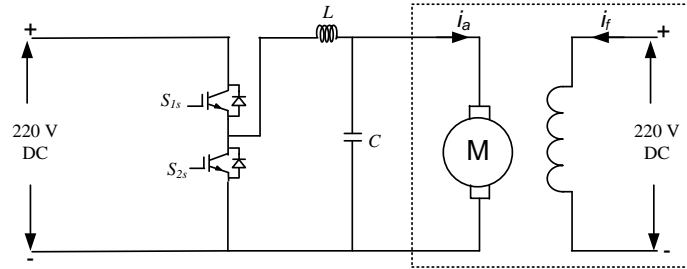
Fig. 3 DC Motor for Wind Emulator

C. DC Motor specifications: (Nos: 1)

Power, P_o	3 kW
Input voltage, V_{in}	220 V
Speed in rpm	1500
Current	13 A
Field voltage	220 V
Field current	0.5 A

II. Converters Specifications

1. Battery Converter (Nos:1)

Conv-Bat/Conv-Scap Specifications:

Power, P_o	1 kW
Output Voltage, V_o	96 V
Minimum Input Voltage, $V_{bat,min}$	44 V
Switching Frequency, F_{sw}	40 kHz
Output Voltage Ripple, ΔV_o	2% of V_o
Input Current Ripple, Δi_L	20% of I_L
Charging current	10 A
Discharging Current	30 A

Suggested Topology: Conventional Bi-directional Boost converter as shown in Fig. 4.

Design Values: Inductor L_B = 300 µH / 30 A; (with 5-7 tapings from 0.1 mH to 1 mH)
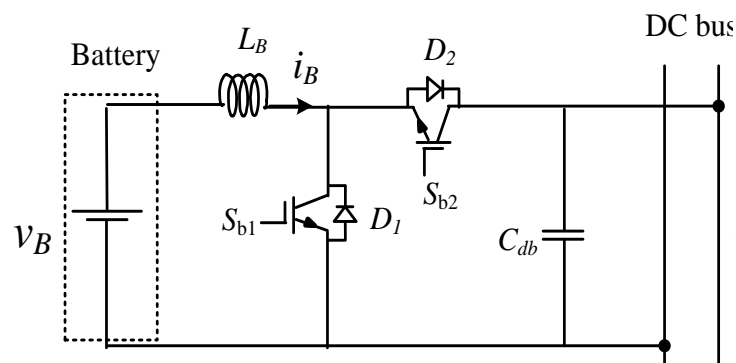
Output Capacitor C_B = 110 µF / 150 V.

Fig. 4 Conventional bi-directional boost converter

2. Isolated DC−DC Converter (Nos:1)

Conv-Iso Specifications:

Power, P_o	5 kW
Output Voltage, V_o	500-700 V
Input Voltage, V_{in}	96 V
Switching Frequency, F_{sw}	40 kHz
Output Voltage Ripple, ΔV_o	2% of V_o
Input Current Ripple, Δi_L	20% of I_L

Suggested Topology: Isolated Boost Converter as shown in Fig. 5.

Other Requirements: Transformer tapings on secondary side (Left side of microgrid test-bed set-up diagram) for 200/400/600/800 V.

Design Values: Inductor L_{iso} = 10 µH / 65 A (with 5-7 tapings from 1 µH to 50 µH)

Transformer turns ratio: (N_S/N_P) = 8 (with tapping)
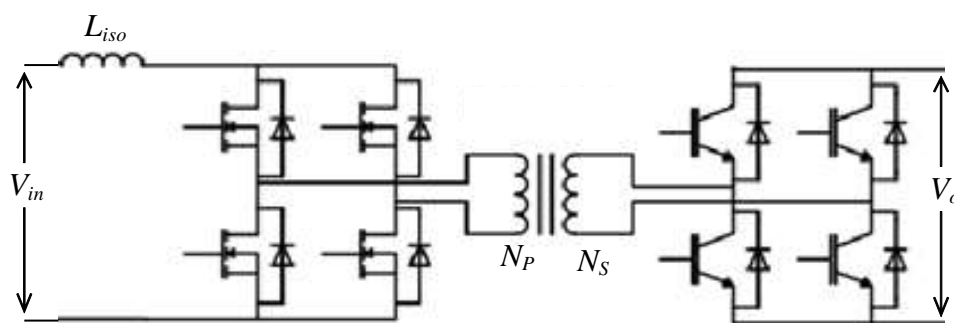
Fig. 5 Isolated boost converter

3. Conv-DFIG Specifications: (Nos.:1)

Inverter Rating	5 kVA
DC link voltage	500-700V
DC link capacitor (C_{dc})	3600 µF / 600 V
No. of Capacitors	2
Switching frequency	10 kHz - 20 kHz

Suggested Topology: 3 leg back-to-back converter as shown in Fig. 1

   a. Design Values: Two LC Filters (with 5-7 tapings ranging from 0-10 mH) for DFIG WECS with L_1= 5 mH/ 2.5 AC= 20 µF as selected values.

4. Three Phase Diode Bridge Rectifier (Nos.:1)

Conv-DBR:

Design Values: Inductor L = 10 mH / 20 A

Output Capacitor C = 100 µF / 1000 V.

Suggested Topology: Conventional Three Phase Diode Bridge Rectifier as shown in Fig. 2.

5. Buck Boost Converter for MPPT Tracking of PMSG based WECS (Nos.:1)

Specifications:

Output Voltage, V_o	500-700V
Input Voltage, V_{in}	50 V to 540 V
Switching Frequency, f_{sw}	20 kHz
Output Current	6.5 A

Suggested Topology: H-bridge Buck Boost converter as shown in Fig. 4

Design Values: Inductor $L = 10$ mH / 30 A

Output Capacitor $C = 100$ µF / 600 V.

6. Voltage Source Inverters (VSI-Inv)
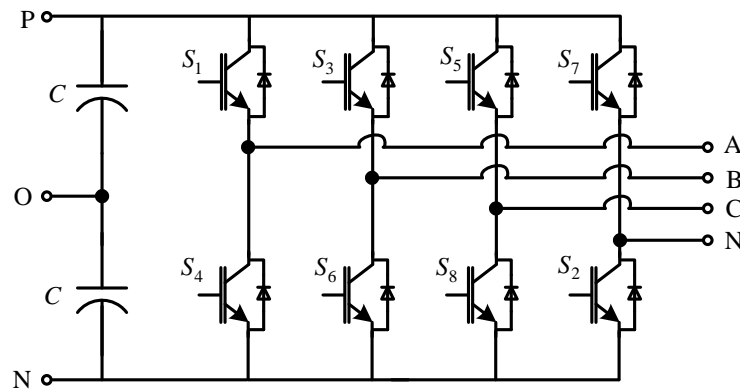
Fig. 6 Four leg inverter topology

VSI Specifications: (Nos.:1)

Inverter Rating	10 kVA
Topology	Four leg split capacitor
DC link voltage	500-700 V
DC link capacitor (C_{dc})	3600 µF / 600 V
No. of Capacitors	2
Switching frequency	20 kHz

b. Suggested Topology: Four Leg Split Capacitor Inverter as shown in Fig. 6.

c. Design Values: LCL Filter with following specifications:

$L_1 = 3$ mH/ 25 A (with 5-7 tapings from 1 mH to 10 mH);

$L_2 = 1$ mH/ 25 A (with 5-7 tapings from 0.5 mH to 5 mH) and

C= 10 µF / 250 V.

III.   Control Platform Specifications

❖ **Number of ADCs = 64**, ($\geq$ 250 kSPS) simultaneous high-speed acquisition of the channel signals.

> ➢ ADC input signal range = ±10 volts
> ➢ Availability of check/testing points at the output of every ADC.
> ➢ Provision to add/access additional ADCs externally.

❖ **Number of DACs = 16**

> ➢ DAC Output voltage range = bipolar with ±10 volts

❖ **Encoder: 04**

❖ **Number of Digital I/Os = 96**

> ➢ Range= 0 to 5 volts (OR) Optically isolated ±15 volts output

❖ PWM generation blocks with speeds around $\geq$100 kHz is desirable.

❖ The sampling of ramp signal in PWM block: 20 times the PWM frequency ($\geq$2 MHz)

❖ **Loop Speed**

> ➢ A system with 2 three-phase inverters, 7 DC-DC converters with fairly medium size algorithm to control them with sampling time of 10 μs (100 kHz).
> ➢ All hardware setup is outside the digital platform such as transducers, inverters and DC-DC converters.
> ➢ The digital platform should acquire all necessary input signals, process them fast in the loop speed of 1-10 μs.
> ➢ All the control signals (sensor outputs) should able to access with the necessary check points.

❖ **Communication Platform**

> ➢ Communications between different DSP / dSPACE / OPAL-RT/ FPGA or any other controllers are required while interacting various Microgrids.

❖ **Other Requirements:** The control platform should have additional switches ready to use as shown in Microgrid test bed set-up figure.

❖ **Miscellaneous: Necessary software, cables, connectors and other accessories should be provided.**

IV.   Sensors and Protection Circuit Specifications

1. Sensors

a) No. of Voltage sensors = 24

> i.   1000 V-Rating = 2
> ii.   500 V-Rating= 21

b) No. of Current Sensors = 42

      i.   50 A-Rating= 35
    ii.   75 A- Rating= 5
   iii.   150 A- Rating = 1

2. Protection Circuit

a) DC Circuit Breakers and Solid-State Relays:

Breakers	Ratings
CB1, CB2, CB4	96 V; 65 A
CB3, CB5	500-700 V; 10-16 A
CB6	500-700 V; 5-6 A

b) AC Circuit Breakers (3-Phase 4- pole type) and Solid-State Relays:

Breakers	Ratings
CB7-9	440 V (RMS); 5 A (peak)
CB 10-12	440 V (RMS); 12 A (peak)
CB13-15, CB16-18	440 V (RMS); 25 A (peak)

Note: Relays input DC voltage must be in the range of 5 to 10 volts

Note: No need to quote following items in the above description.

1. Battery Unit

2. AC and DC Loads

3. Voltage and Current transducers / sensors

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Schematic of Microgrid Test-bed Set-up

S_1	S_2	S_3 ...... S_{10}	S_{11} ...... S_{22}	S_{23} ...... S_{30}	S_{CB1} ...... S_{CB17}	S_{24}	S_{25}	S_{22}	S_{23}	S_{18} ...... S_{21}	S_{CB18} ...... S_{CB27}

Conv-Bat 1 kW | Conv-Iso 10 kW | Conv-DFIG 2 kVA | VSI-Inv 10 kW | CB1-CB17 | Conv-PMSG 2 kW | Conv-Scap 1 kW | Conv-PV 5 kW | CB18 - CB27

Realtime Controller

Voltage Sensors Outputs

Current Sensors Outputs

Torque and Speed Sensors Outputs