Annexure-1

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) PMSG based WECS (Nos: 1)

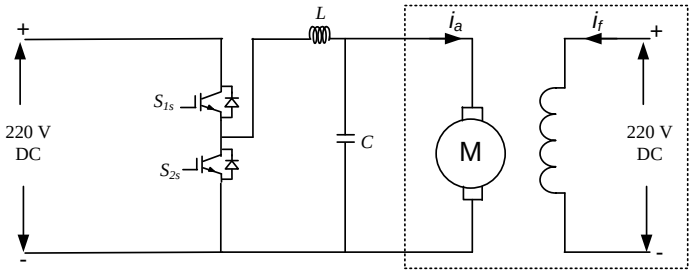

Fig. 1 Wind Emulator

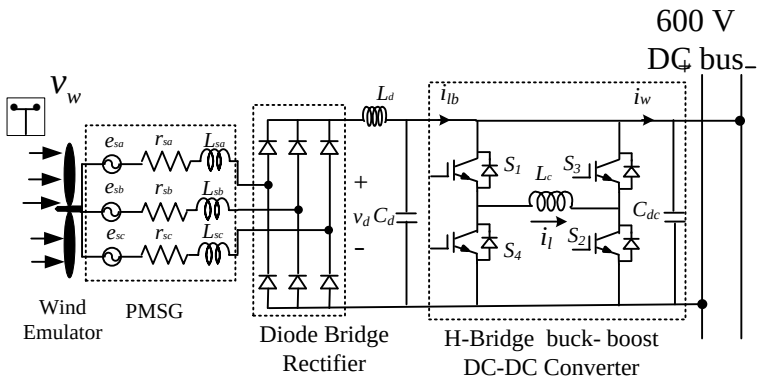

Fig. 2 PMSG based WECS

b) DFIG based WECS (Nos: 1)

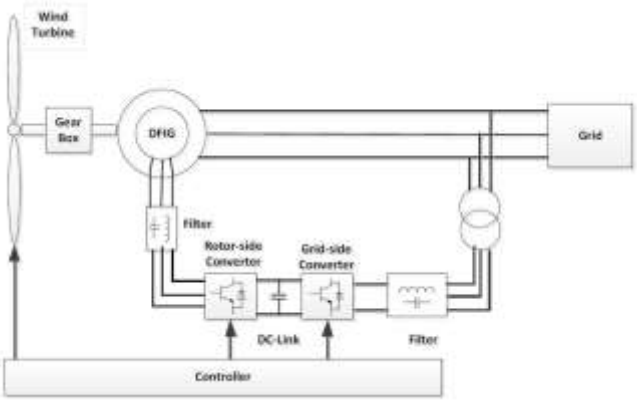

Fig. 3 DFIG based WECS

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

d) 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

e) DFIG specifications: (Nos.: 1)

Power	2 kVA
Stator Voltage	415 V
Current	5 A

II. Converters Specifications

1. PV Converter (Nos:1)

Conv-PV Specifications:

Power, P_o	5 kW
Output Voltage, V_o	96 V
Input Voltage, V_{in}	60 V to 120 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: H-Bridge Buck-Boost converter as shown in Fig. 4.

Design Values: Inductor, L_{PV} = 50 µH / 120 A

Output Capacitor, C = 330 µF / 150 V

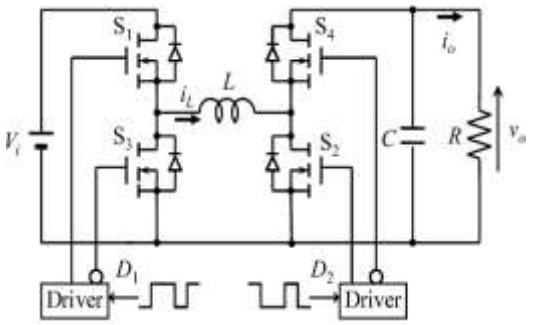

Fig. 4 Conv-PV Topology

2. Battery Converter (Nos:2)

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. 5.

Design Values: Inductor L_B = 300 µH / 30 A

Output Capacitor C_B = 110 µF / 150 V.

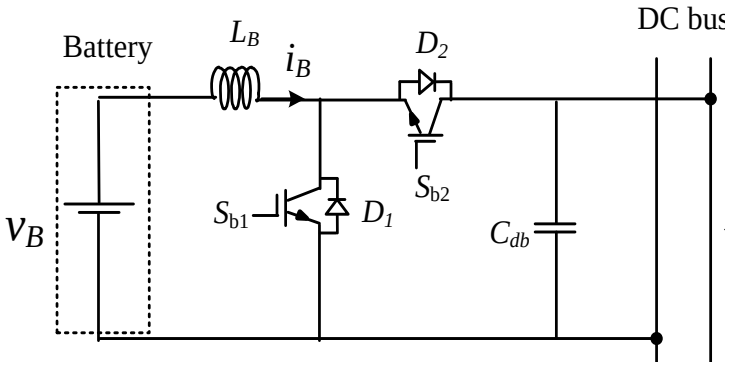

Fig. 5 Conventional Bi-directional Boost converter

3. 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. 6

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

Transformer turns ratio: (N_S/N_P) = 8 (with tapping)

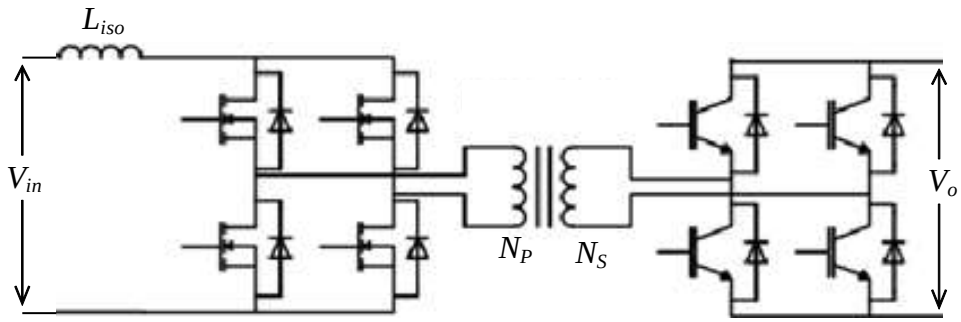

Fig. 6 Isolated Boost Converter

5. Buck Converter for DC motor (Nos.:1)

Specifications:

Output Voltage, V_o	50 V to 200 V
Input Voltage, V_{in}	220 V rms
Converter Switching Frequency, F_{sw}	15 kHz
Input Current Rating	20 A

Suggested Topology: Conventional Buck Converter as shown in Fig. 7

Design Values: Inductor L_{iso} = 10 mH / 50 A

Output Capacitor C_{SC} = 220 µF / 200 V

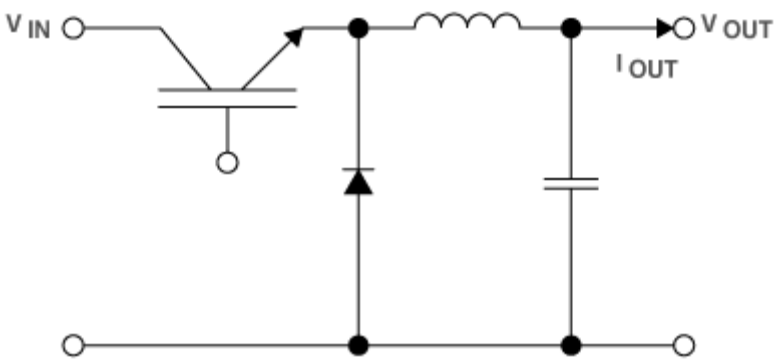

Fig. 7 Conventional Buck Converter

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

Conv-DVR:

Design Values: Inductor L = 10 mH / 20 A

Output Capacitor C = 100 µF / 1000 V.

Suggested Topology: Conventional Three Phase Diode Bridge Rectifier.

7. 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.

8. Voltage Source Inverters (VSI-Inv)

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

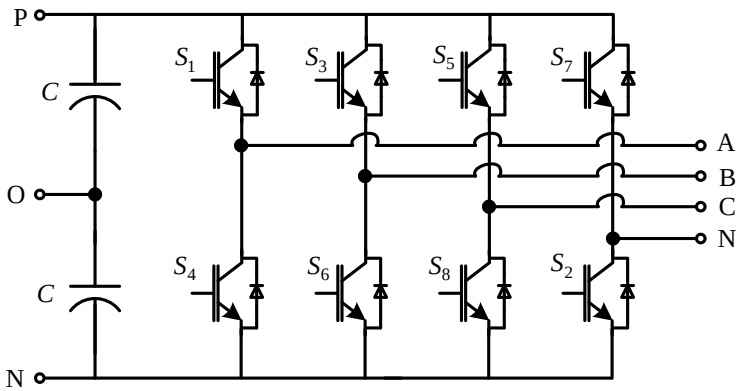

Fig. 8 Four leg inverter topology.

Suggested Topology: Four Leg Split Capacitor Inverter as shown in Fig. 8.

Conv-DFIG Specifications: (Nos.:1)

Inverter Rating	5 kVA
Suggested Topology:	3 leg back to back converter
DC link voltage	500-700V
DC link capacitor (C_{dc})	3600 µF / 600 V
No. of Capacitors	2
Switching frequency	10 kHz - 20 kHz

a. Design Values: (1) LCL Filter with following specifications. L_1= 3 mH/ 25 A

L_2= 1 mH/ 25 A and Capacitors, C= 10 µF / 250 V.

(2) Two LC Filters for DFIG WECS with L_1= 5 mH/ 2.5 A and Capacitors, C= 20 µF .

b. Other Requirements: (1) Isolation Transformer of rating 10 kVA.

(2) Inductors are needed with tapings.

III. Control Platform Specifications

- **Number of ADCs = 64**, (≥ 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 ≥100 kHz is desirable.
- The sampling of ramp signal in PWM block: 20 times the PWM frequency (≥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.

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

V. 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 and CB4	96 V; 65 A
CB3 and CB4	96 V; 13 A
CB4 and CB26	500-700 V; 5-6 A
CB6 and CB10	500-700 V; 10-16 A
CB27	96 V; 25 A

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

Breakers	Ratings
CB7-9	440 V (RMS); 5 A (peak)
CB11-13 and CB23-25	440 V (RMS); 12 A (peak)
CB14-16, CB17-19, and CB20-222	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. **Solar Emulator**
2. **Battery Bank**
3. **Supercapacitors**
4. **AC Load**
5. **Voltage and Current transducers / sensors**

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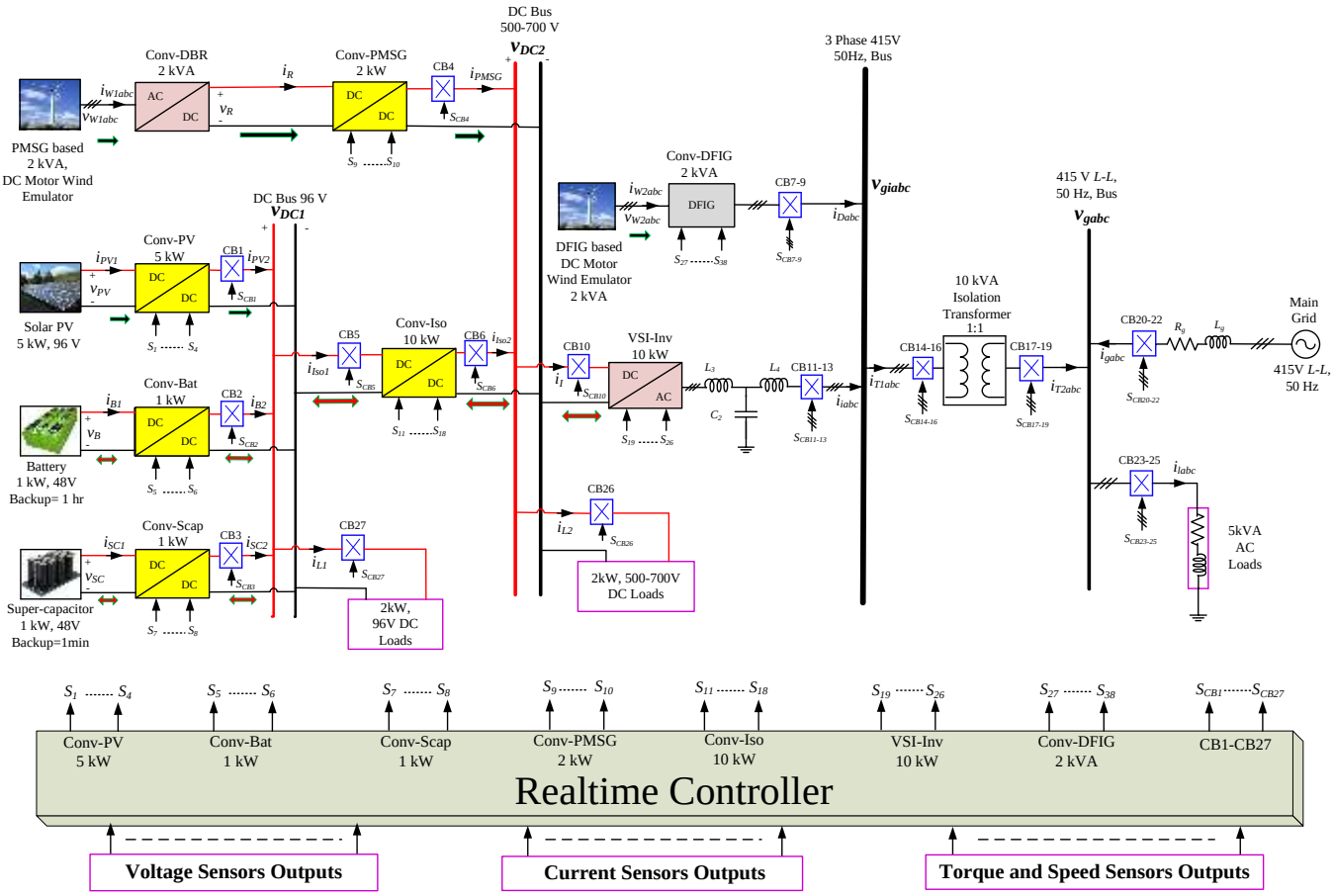
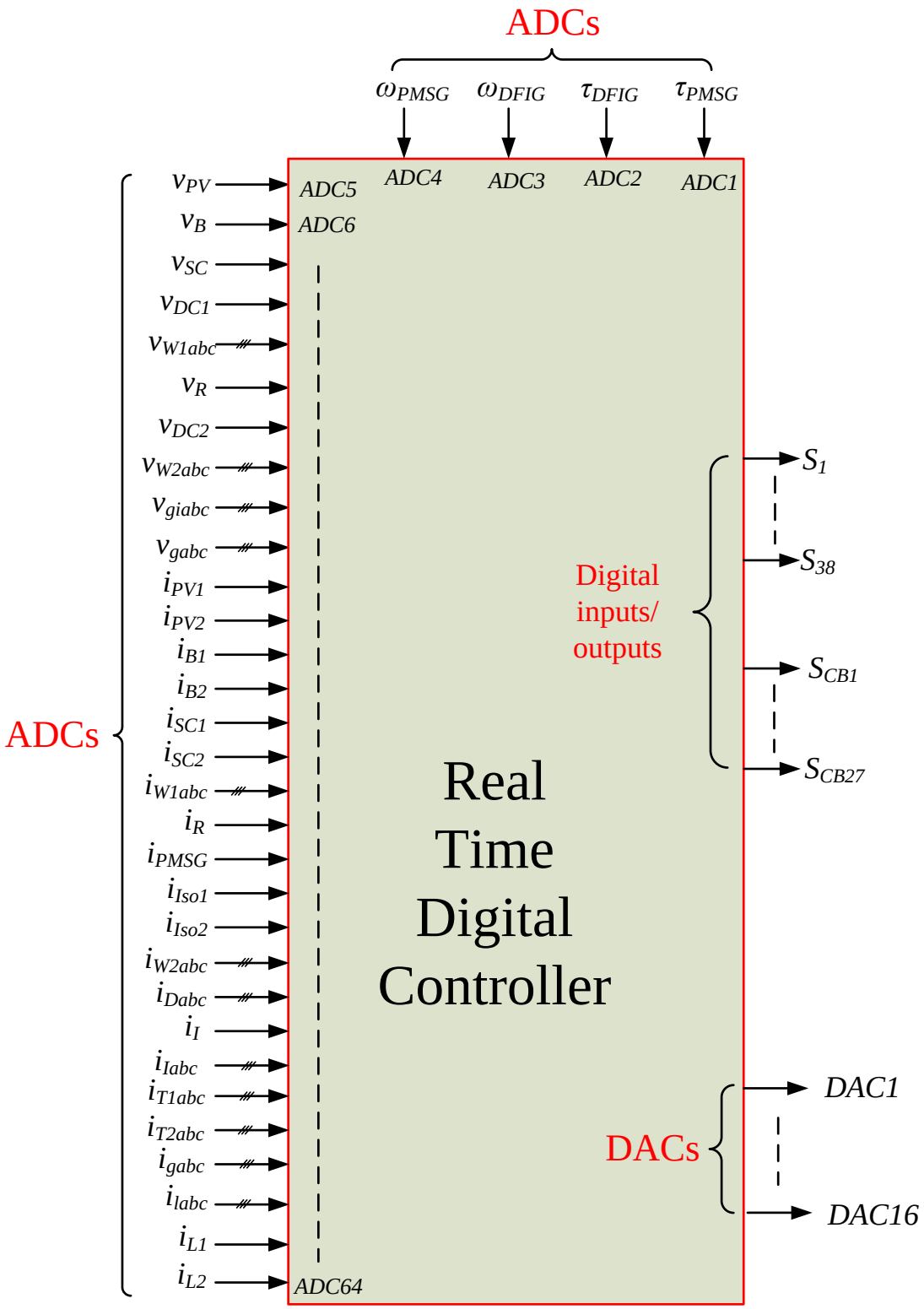
Development of Microgrid Test-bed Set-up




ADCs
ω_{PMSG}
ω_{DFIG}
τ_{DFIG}
τ_{PMSG}
ADC4
ADC3
ADC2
ADC1
ADC5
ADC6
ADC64
v_{PV}
v_B
v_{SC}
v_{DC1}
v_{W1abc}
v_R
v_{DC2}
v_{W2abc}
v_{giabc}
v_{gabc}
i_{PV1}
i_{PV2}
i_{B1}
i_{B2}
i_{SC1}
i_{SC2}
i_{W1abc}
i_R
i_{PMSG}
i_{Iso1}
i_{Iso2}
i_{W2abc}
i_{Dabc}
i_I
i_{Iabc}
i_{T1abc}
i_{T2abc}
i_{gabc}
i_{labc}
i_{L1}
i_{L2}
ADCs
Real Time Digital Controller
Digital inputs/ outputs
S_1
S_{38}
S_{CB1}
S_{CB27}
DACs
DAC1
DAC16