FISUEL GAM 2019
Beirut - Lebanon

Evolvement of Electrical Safety

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Impact of Technology Progress on Safety

- Shed Lights on the evolvement of : safety , earthing system , protection design in four domains :
  - Communication
  - Industrial
  - Health Care Unit
  - Renewable energy

High Speed Transmission Data

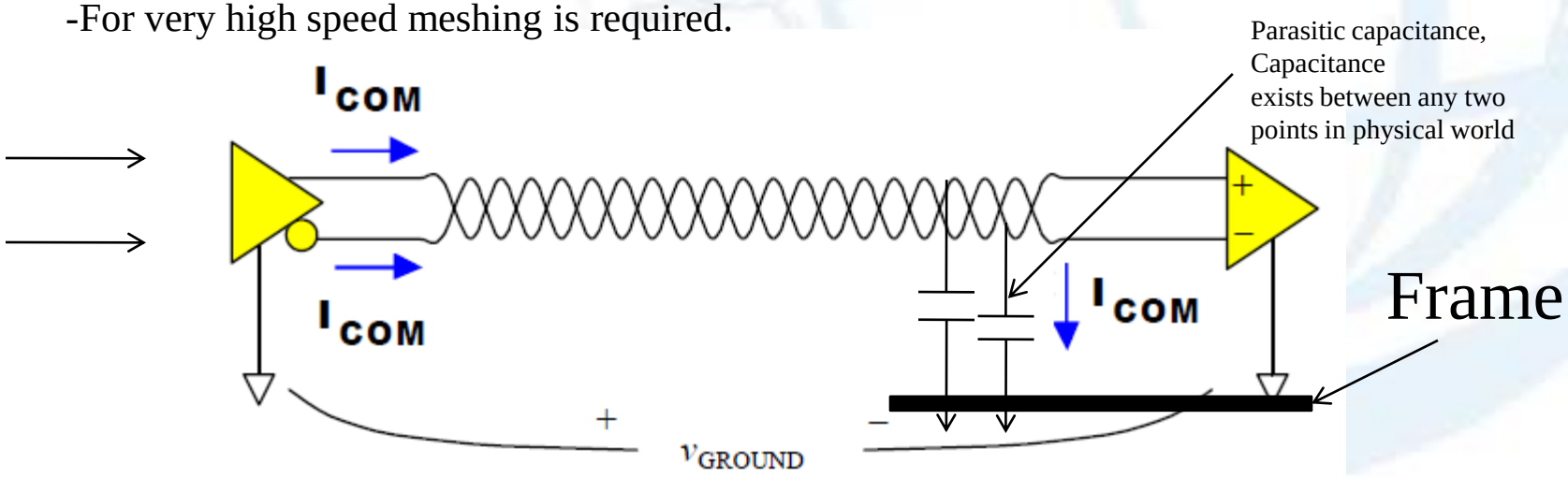
-As the transmission frequency increases and approaches several GHZ the common mode current cannot be negligible .

-If V_{GROUND} Large, Vc at the receiving device will be high , malfunctioning of the electronic device.

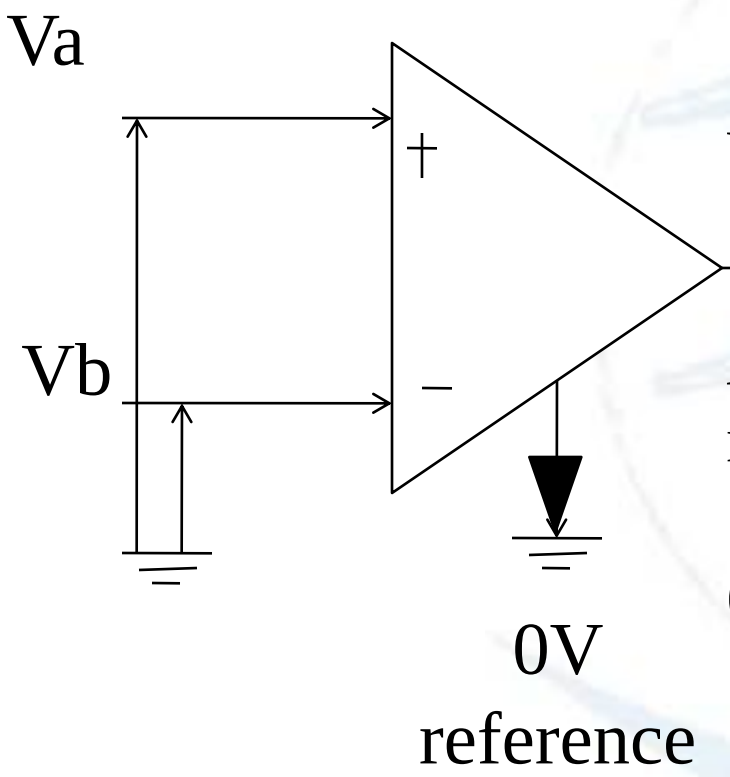
-TT earthing system is not recommended anymore fore communication system.

-TNS is more robust.

-For very high speed meshing is required.



Common Mode Voltage



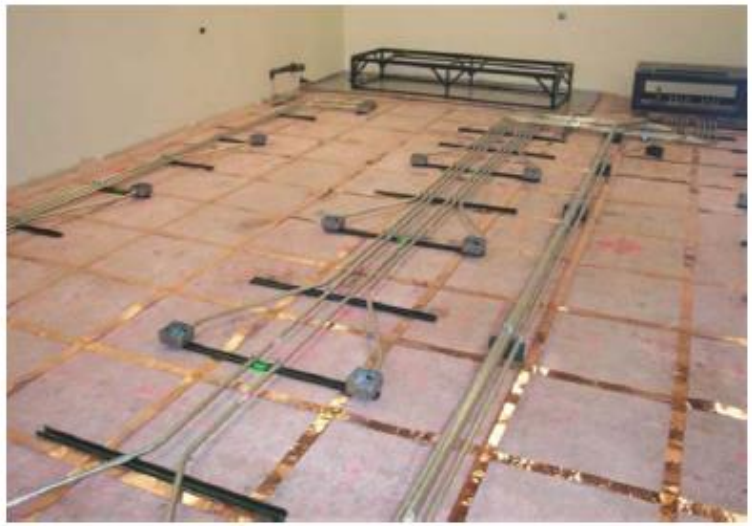
$V_{out} = A_d(V_a - V_b) + A_c(V_a + V_b)/2$

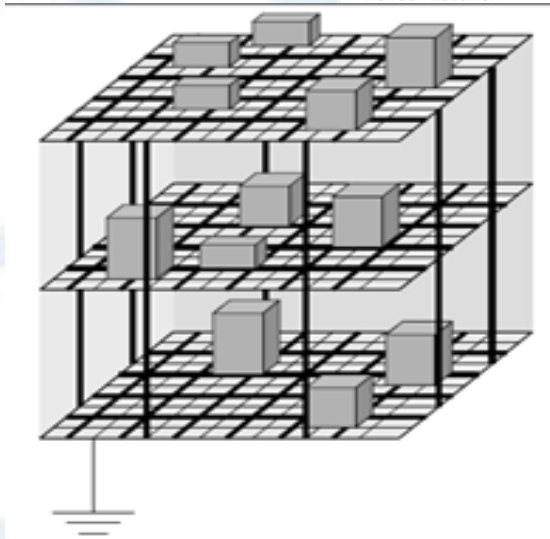
A_c <<< CMR common mode noise rejection

$(V_a + V_b)/2$: Common mode voltage

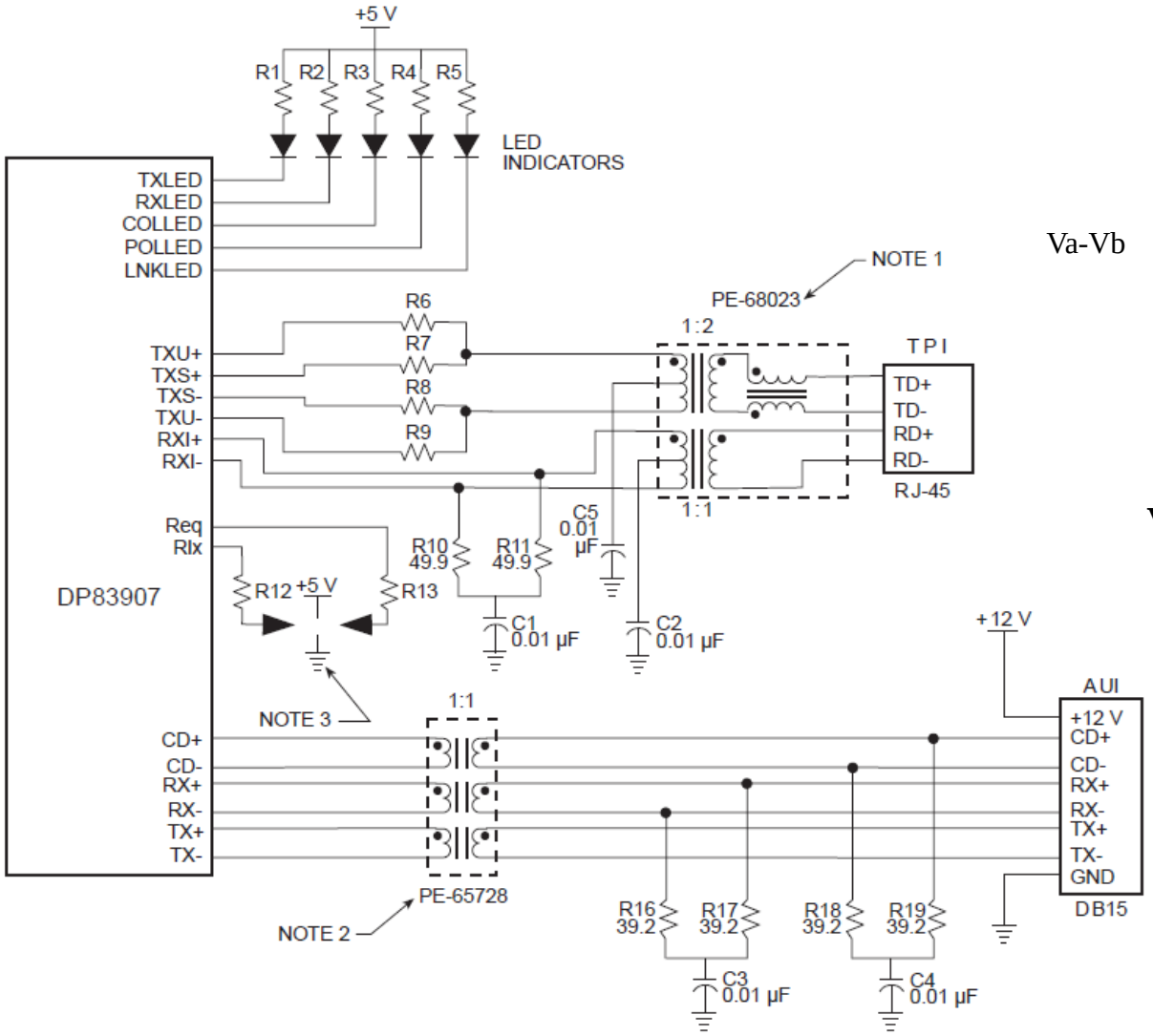
Signal Reference Grid Meshing

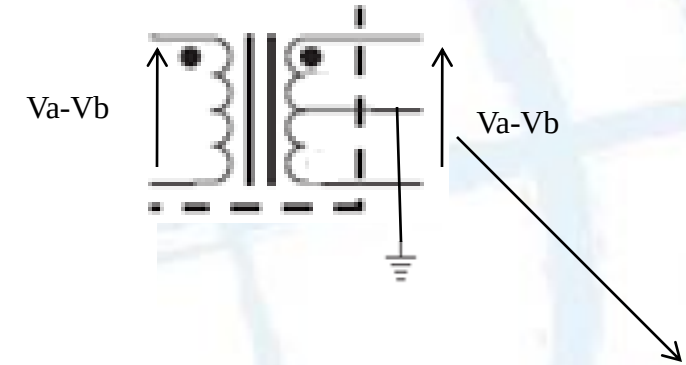
To Minimize voltage differences between interconnected equipment by providing a low impedance equipotential ground plane for high frequency, low voltage noise.





Ethernet
Isolating Transformer or Photovoltaic isolator





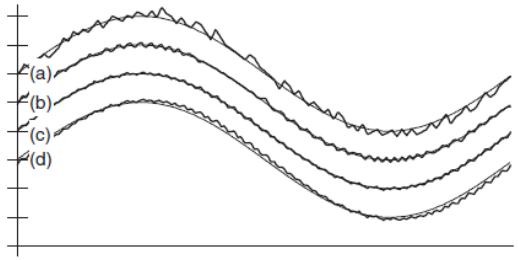
Va+Vb=0 with respect to the local earth

Modern Data Center

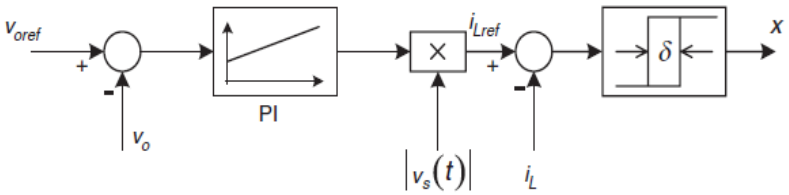
Total immunity	High immunity	Partial immunity	Low immunity
•Fiber-optic •Wireless	•Ethernet	•Modbus •RS-485 •SCSI	•Parallel ports •RS-232 ports •Proprietary backplane •Video cables

Industrial Sector

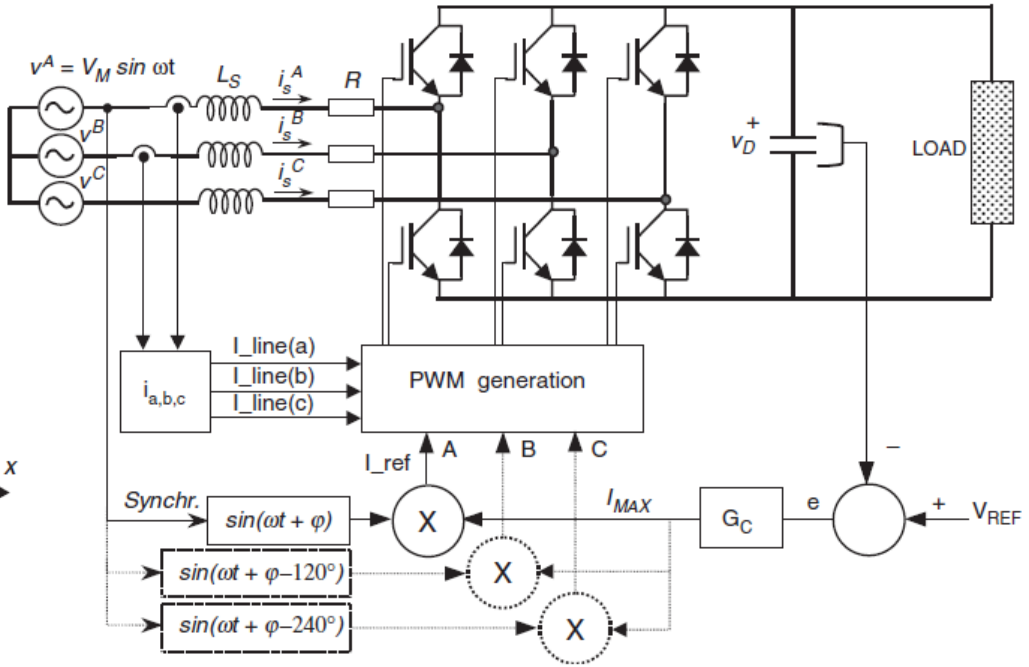
No More Harmonics !!!



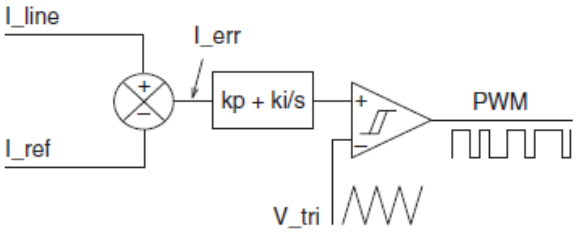
Waveforms obtained using 1.5 kHz switching frequency and $L_S = 13$ mH: (a) PS method; (b) HB method; (c) TC method ($K_P + K_I$); and (d) TC method (K_P only).



Control system of the boost rectifier.

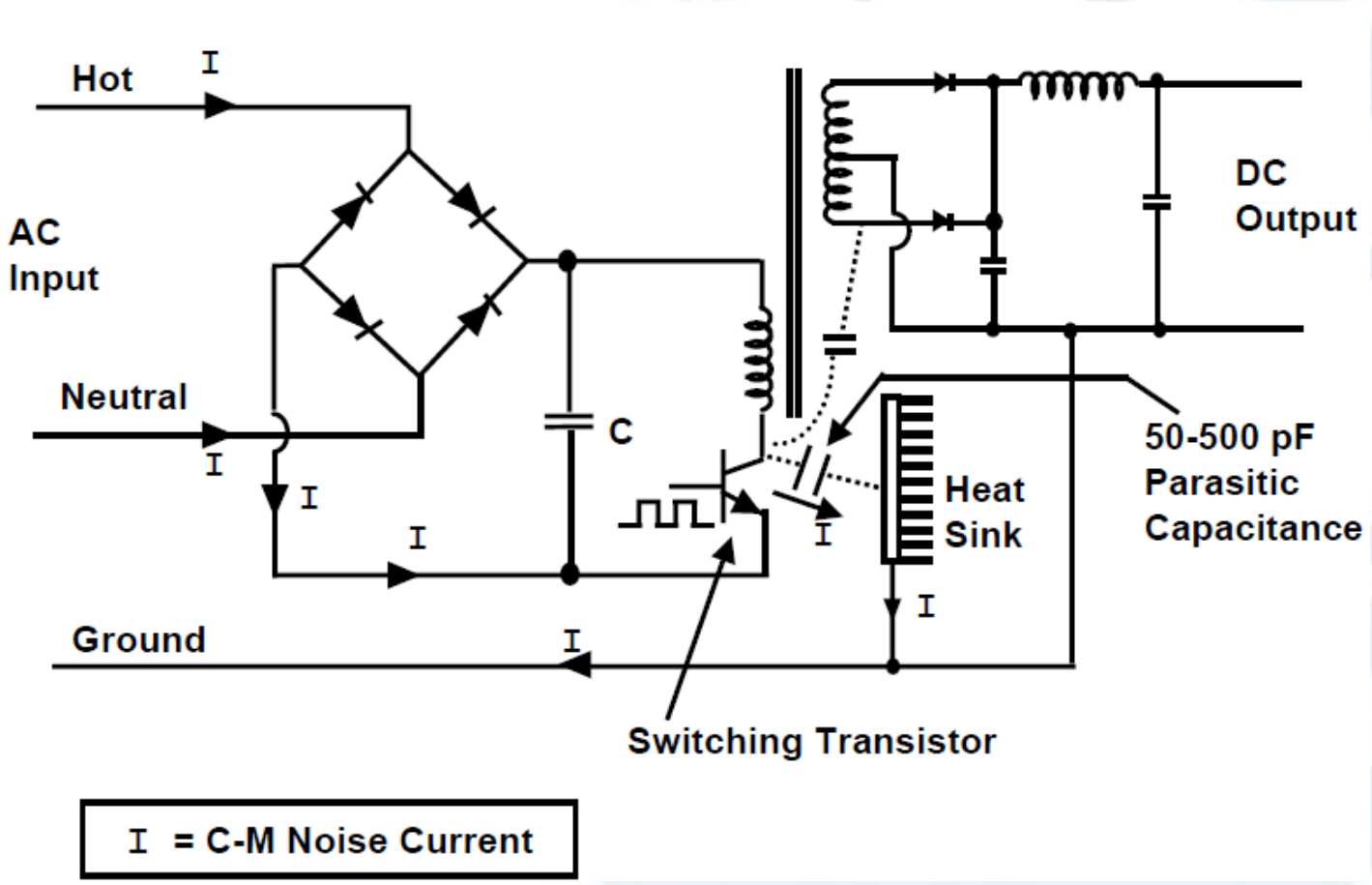


Voltage-source current-controlled PWM rectifier.

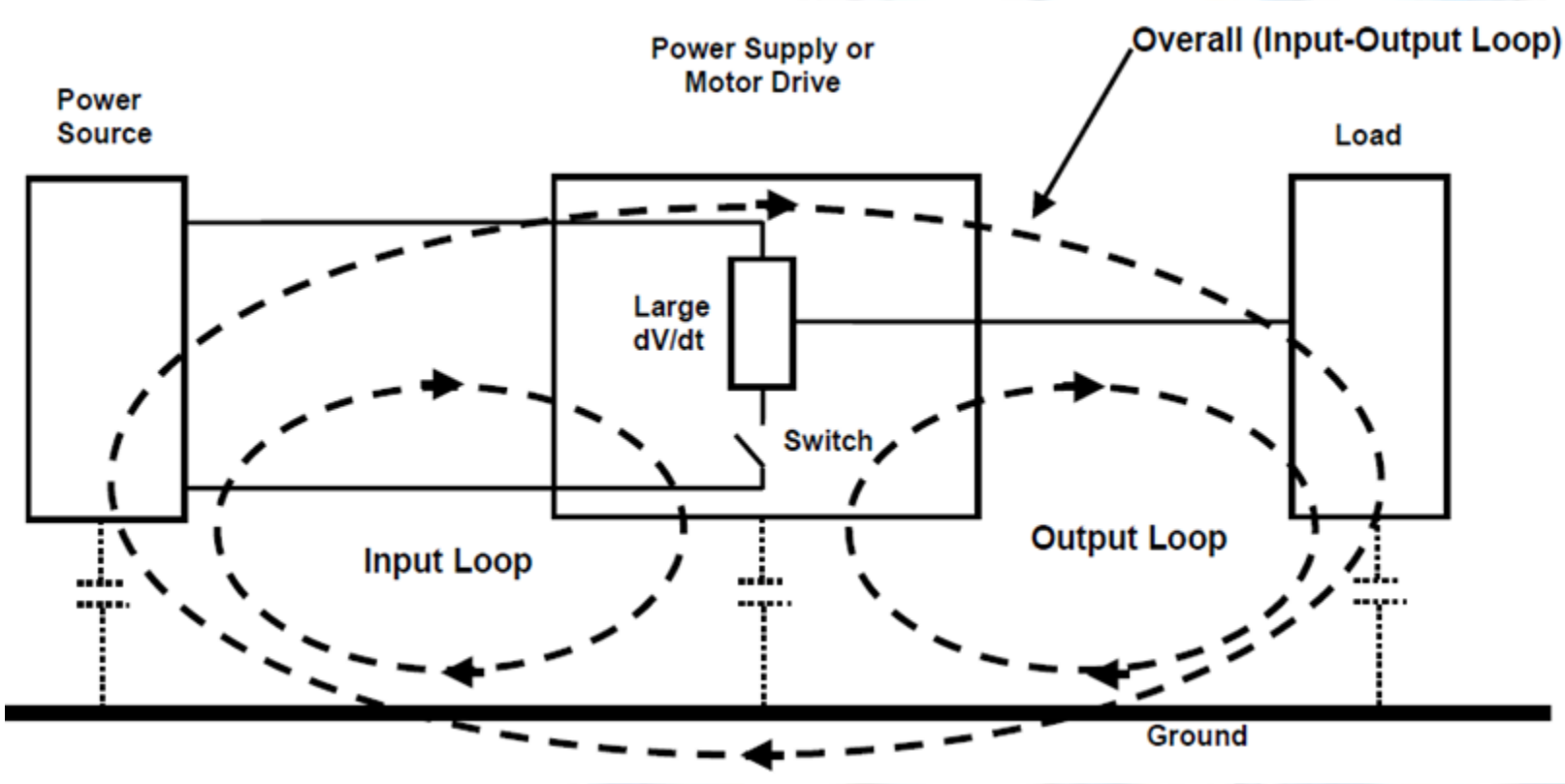


Switching frequency 10KHZ to 100KHZ

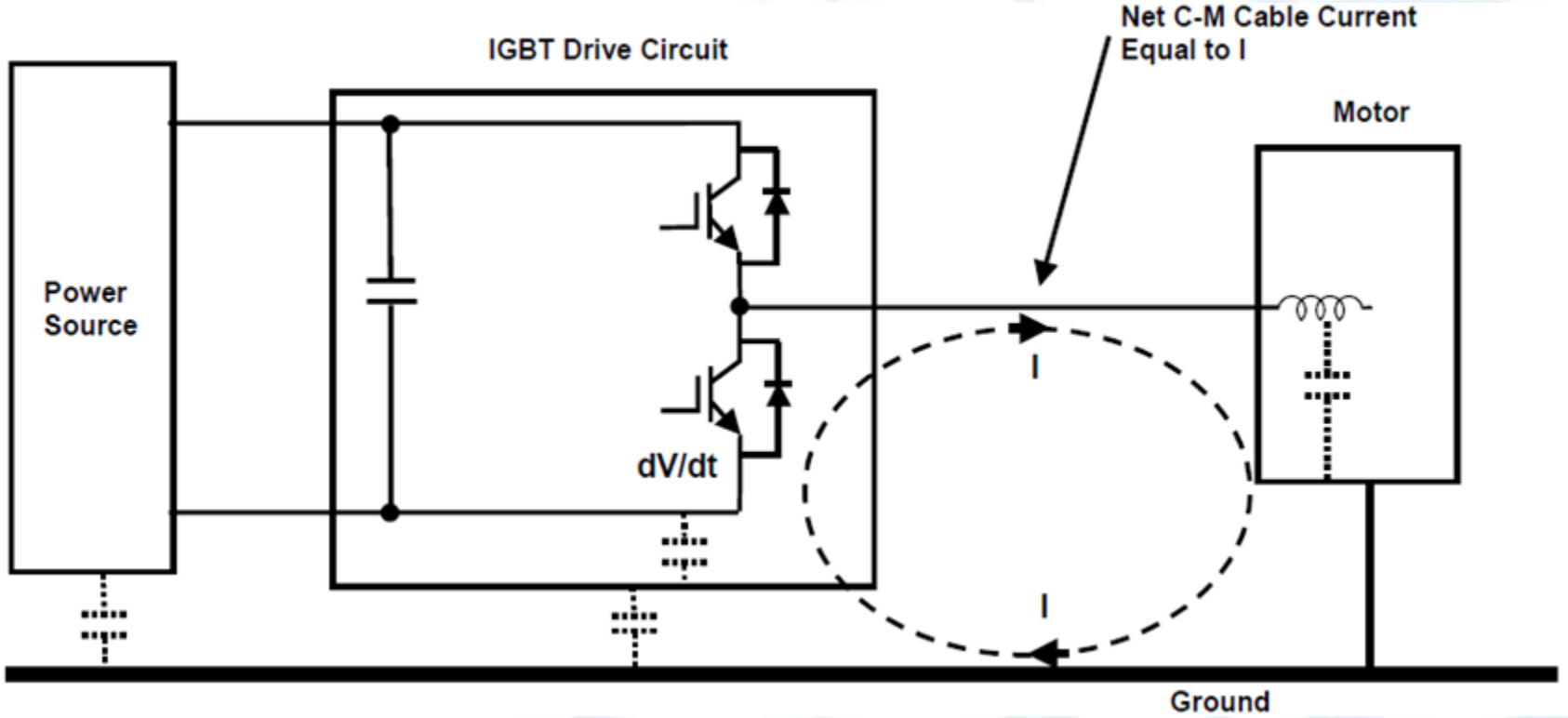
Switching power supply



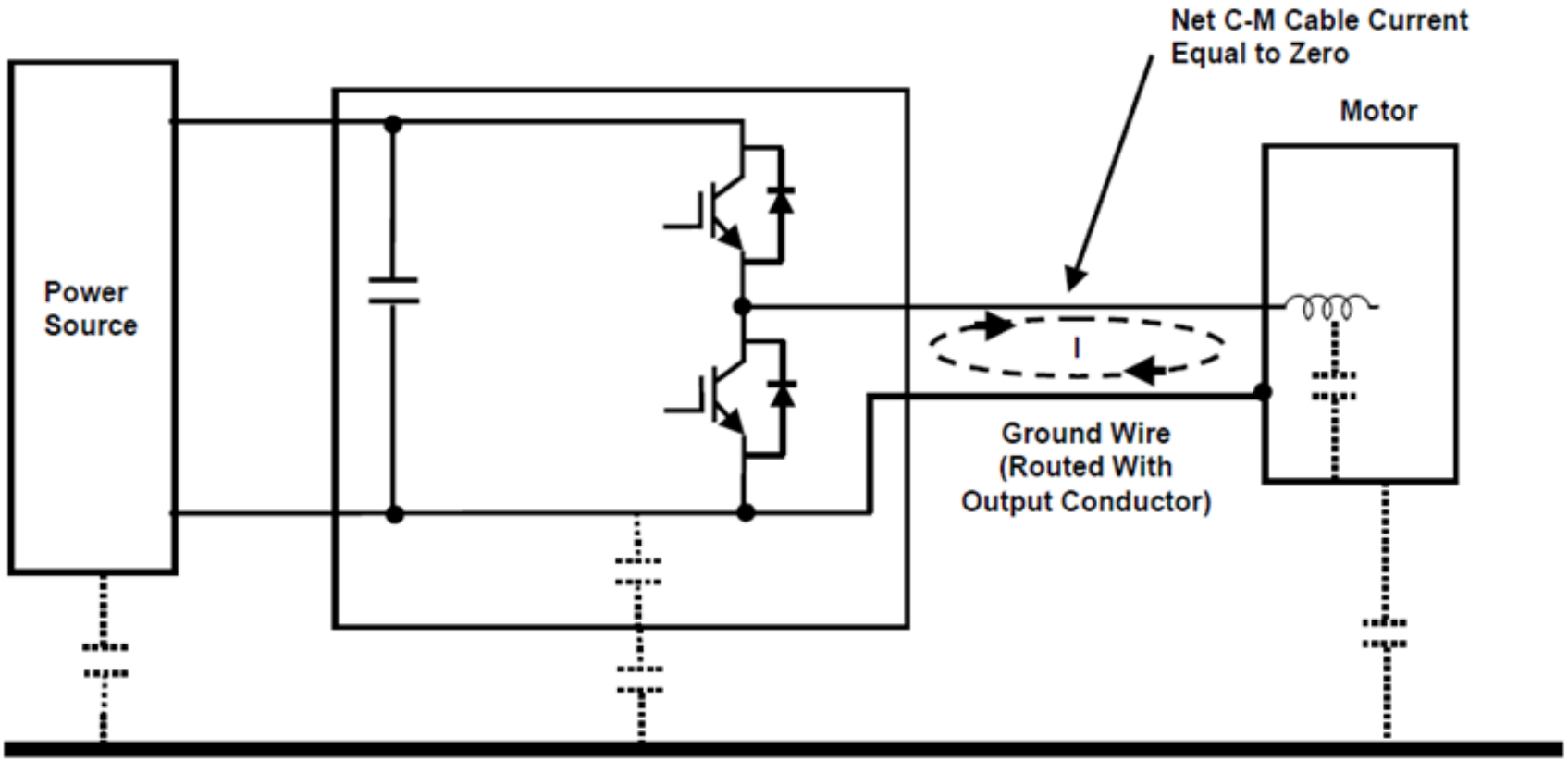
C-M Current Loops



Basic IGBT Motor Drive

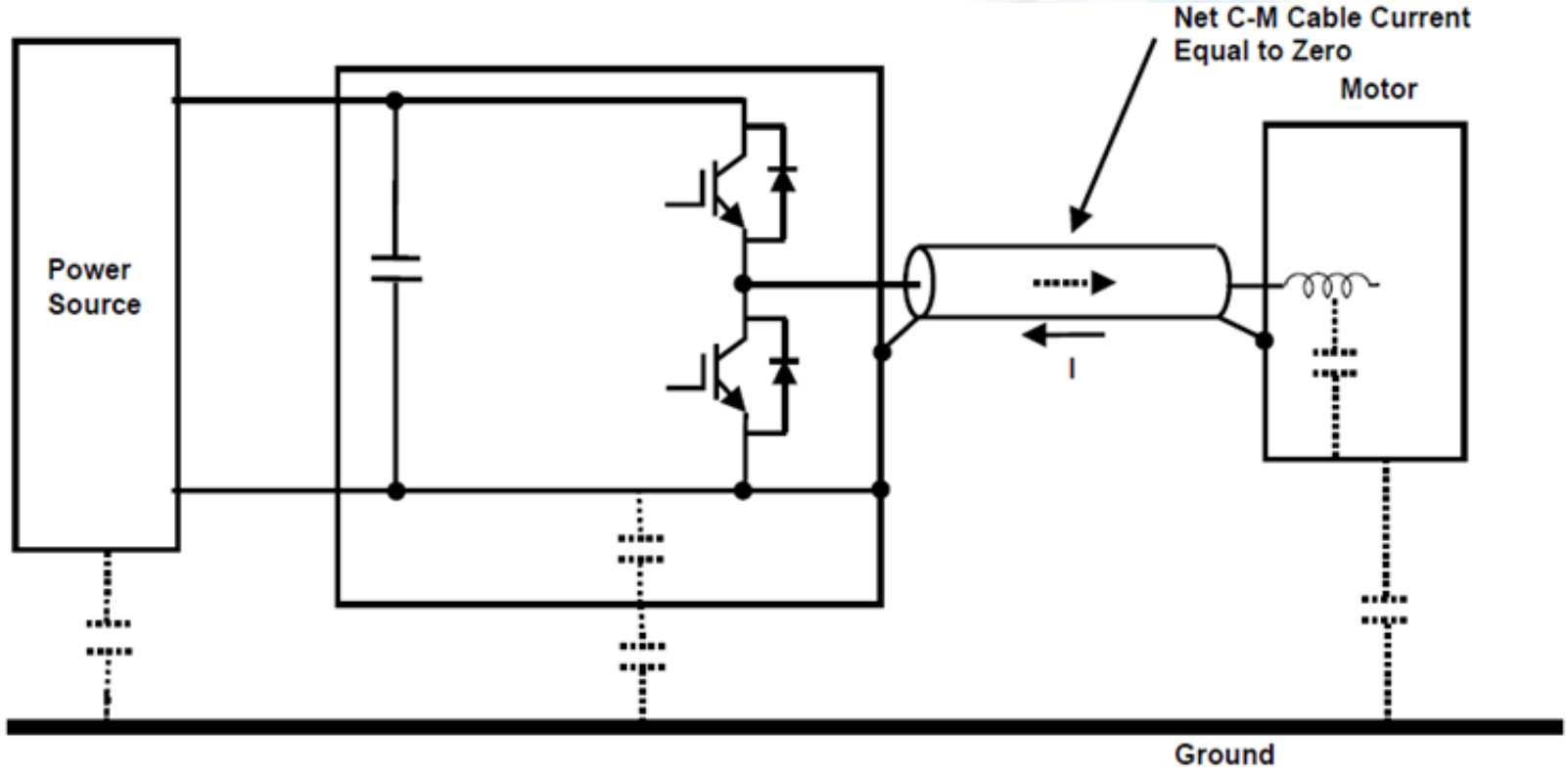


Ground Wire From Motor Housing to VFD



This is the Ideal Solution But May Be Difficult to Implement
Either the Motor Housing Must be Floating (as shown), or the Switch Common Must be Connected to Ground

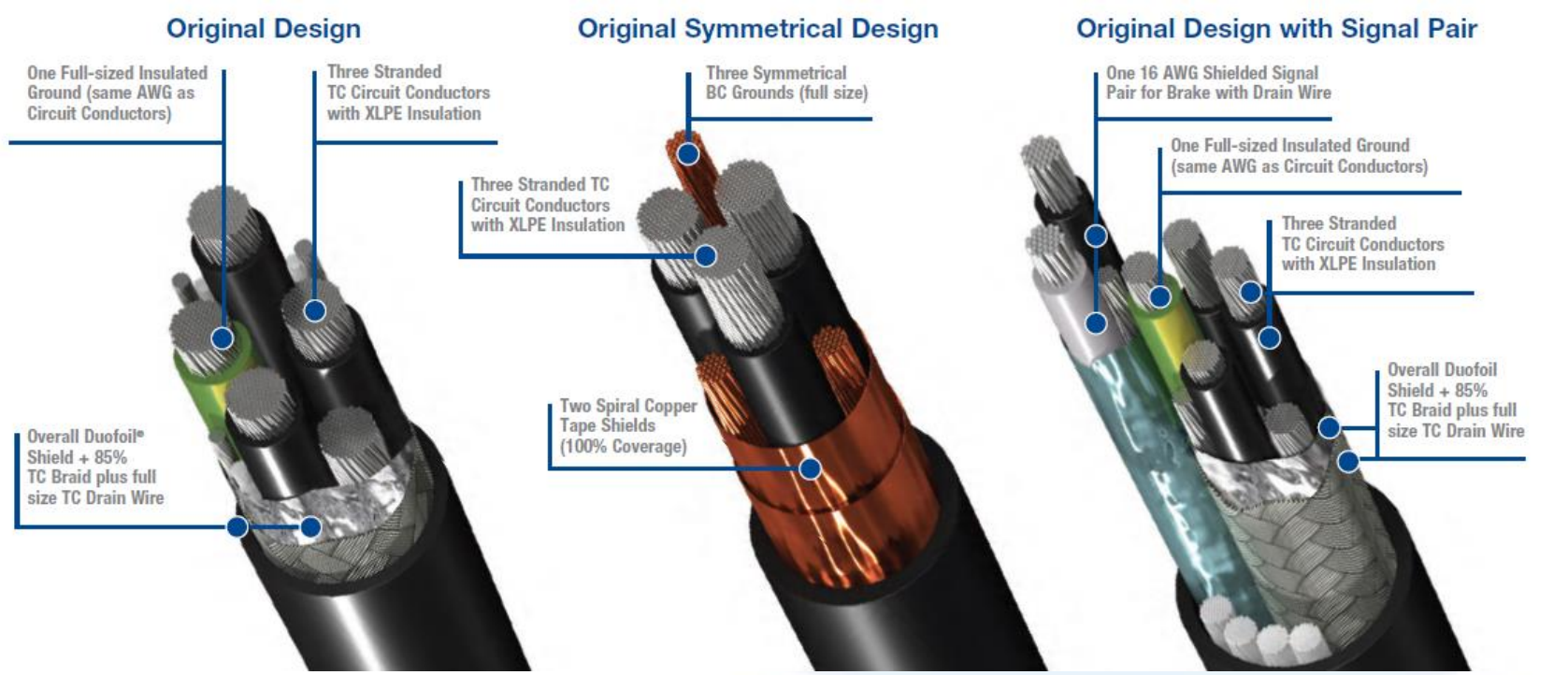
Shielded Cable Solution



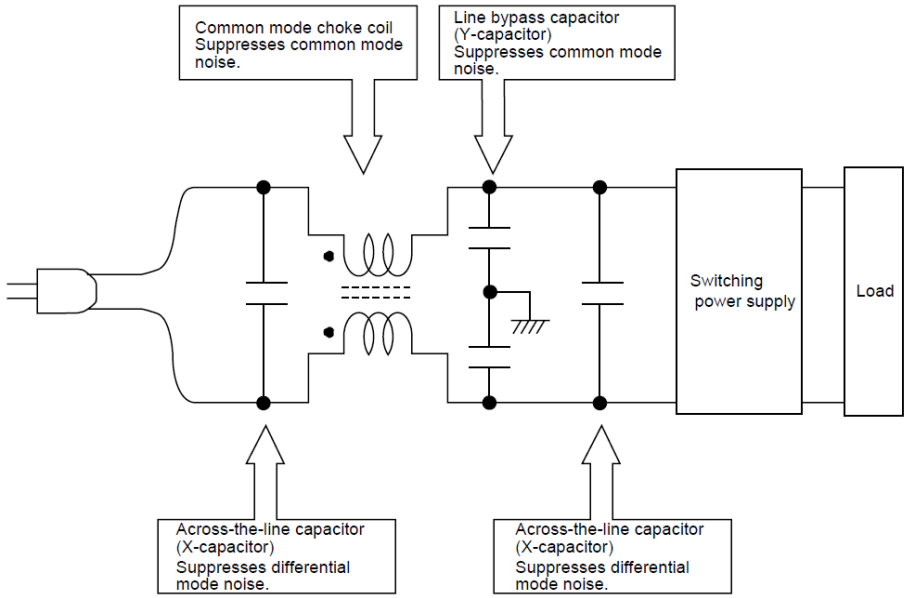
Similar to the Ground Wire Described Previously, But More Effective For Radiated Emission
Shield Must Be Connected to Motor Housing on One End and to the Switch Common on the Other End
Shield May Be Terminated With a Capacitor on One End as a Compromise

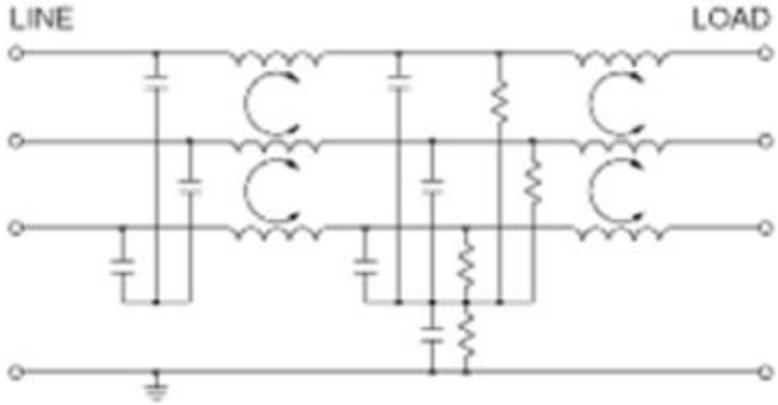
VFD Cables

PWM type power cable is intended to minimize the common mode voltage by providing a better high frequency return path to the VFD power source.



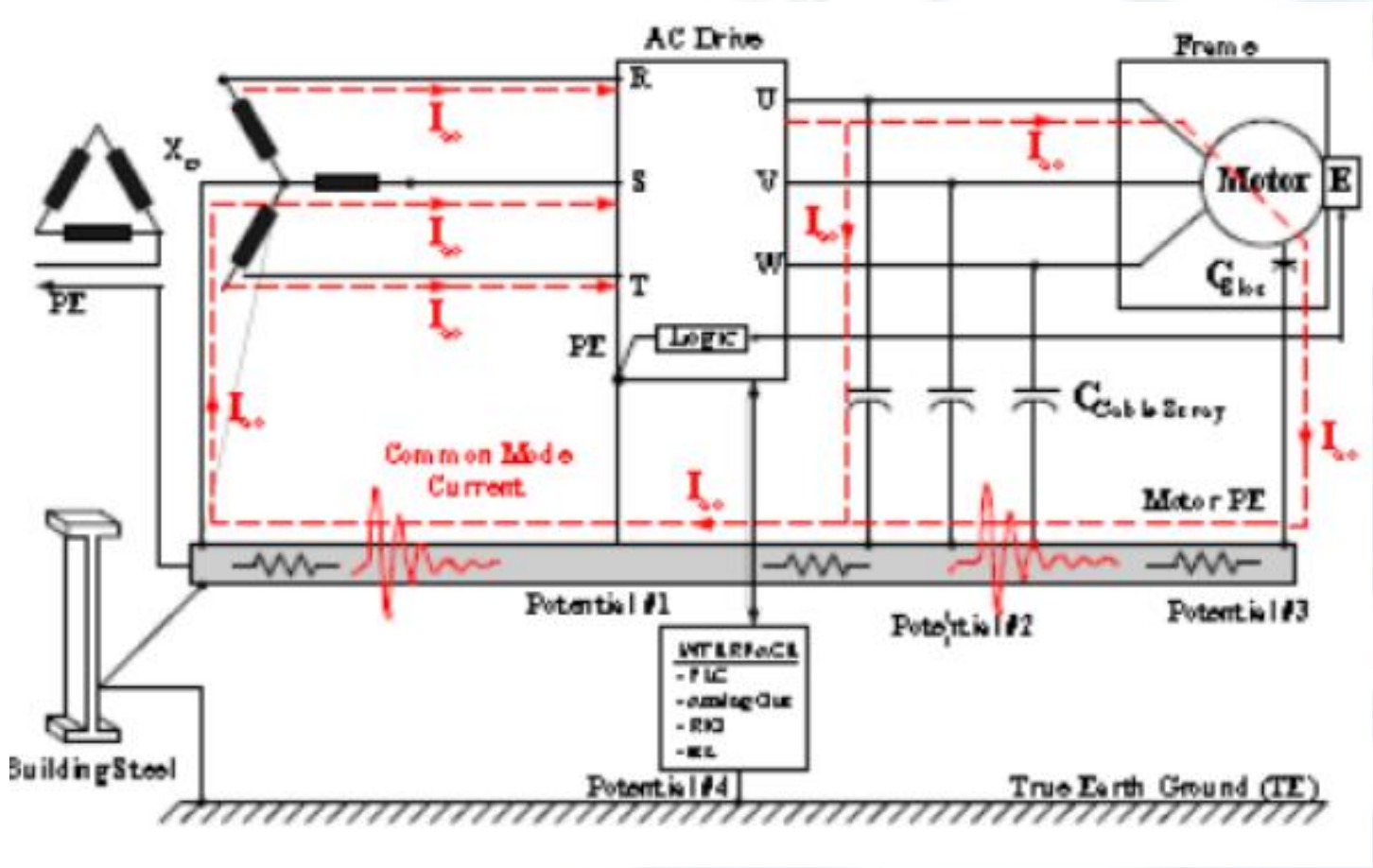
Power Conditioner



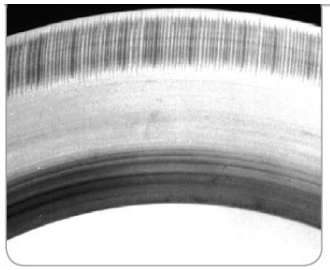


Common Mode Choke

Bearing Damage



Insulated Bearing



Fluting on the outer ring raceway of a bearing

Fluting on the inner ring raceway of a bearing

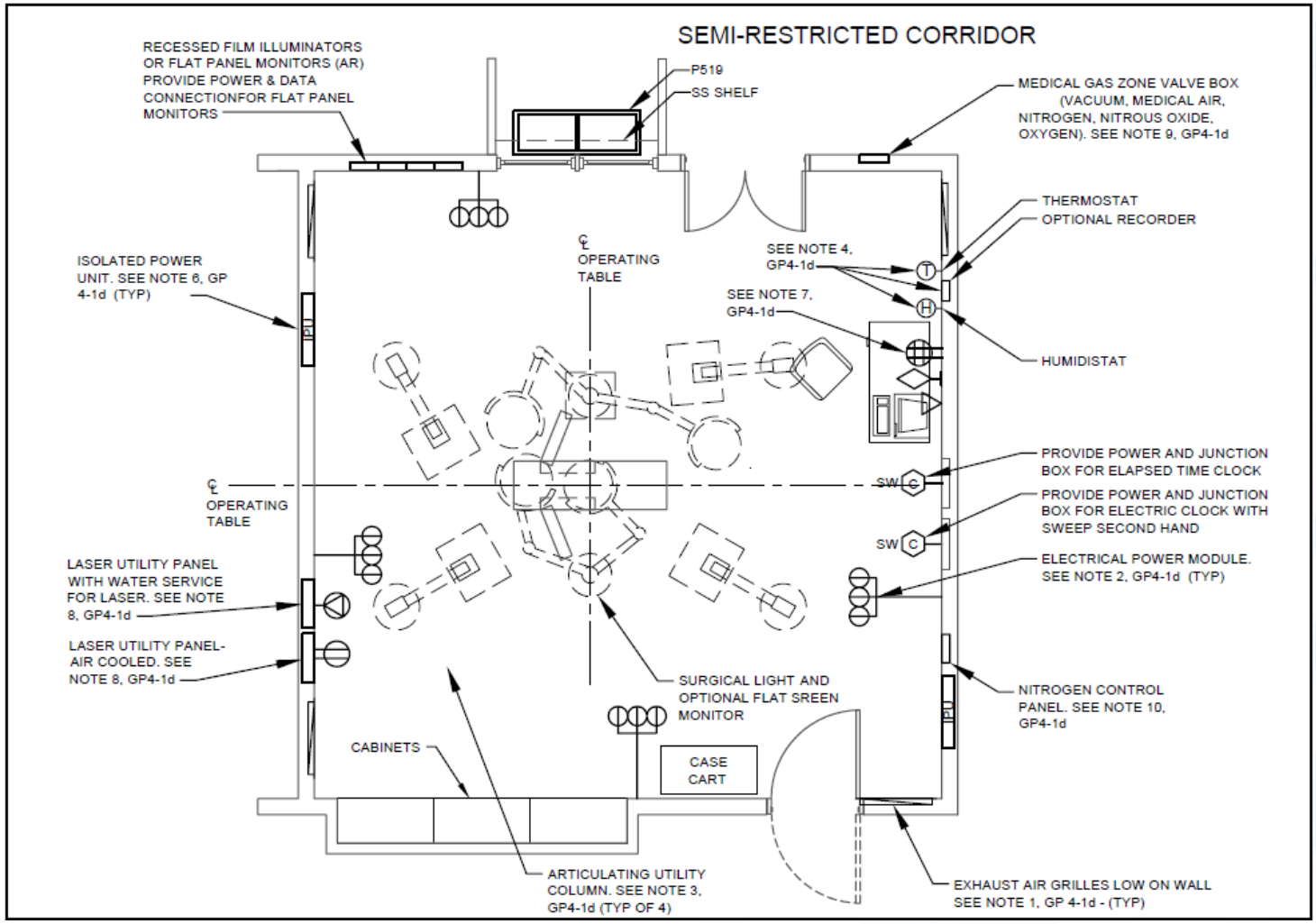
Blackened grease

-Insulated bearings (ceramics)

-Shaft grounding systems

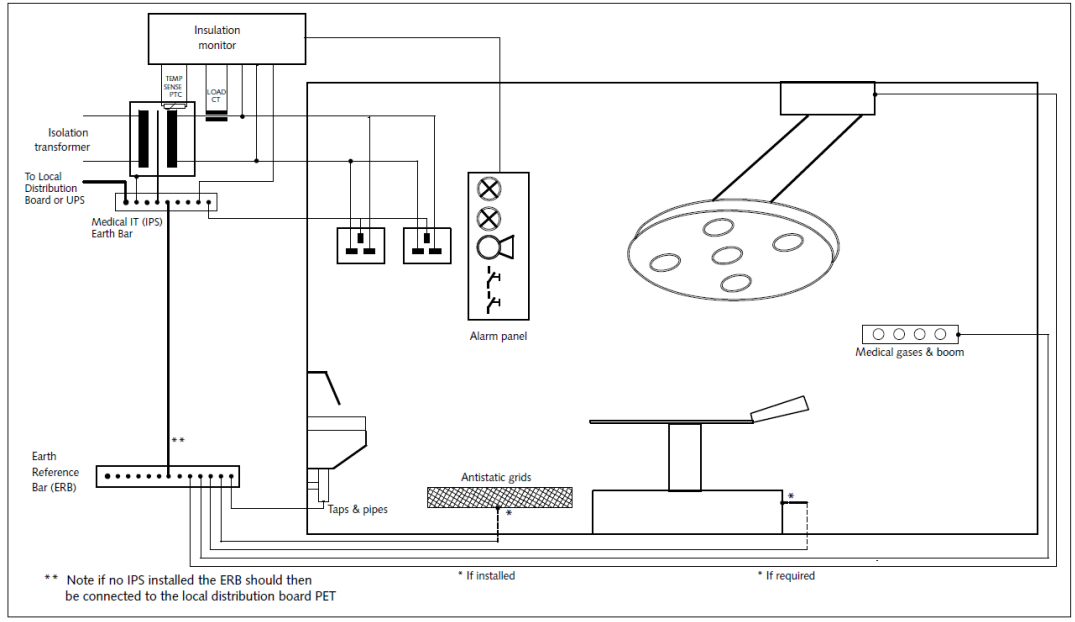
Healthcare Unit

General Operating Room



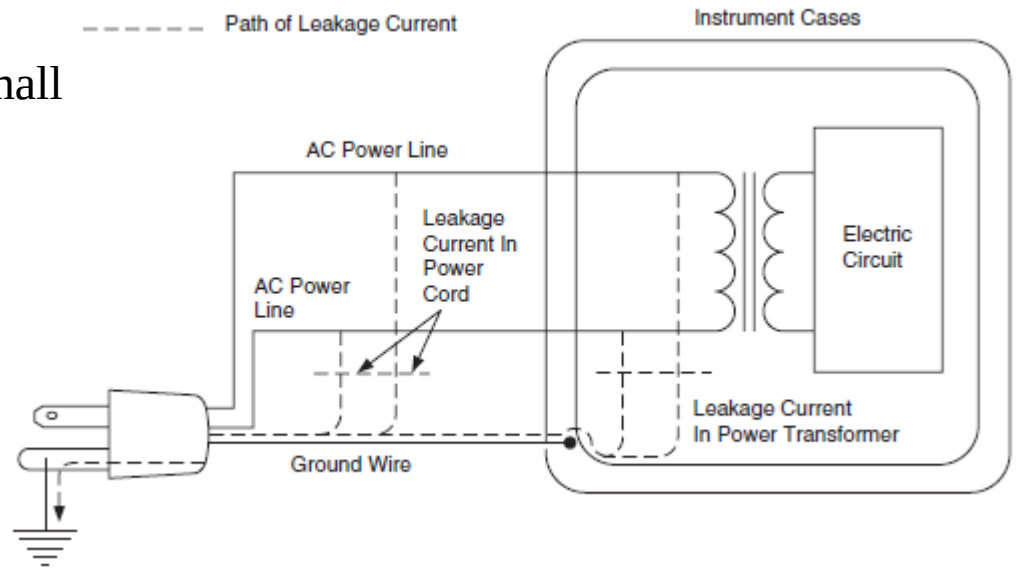
IT earthing -IMD

94 Figure 38 IPS theatre earthing arrangement

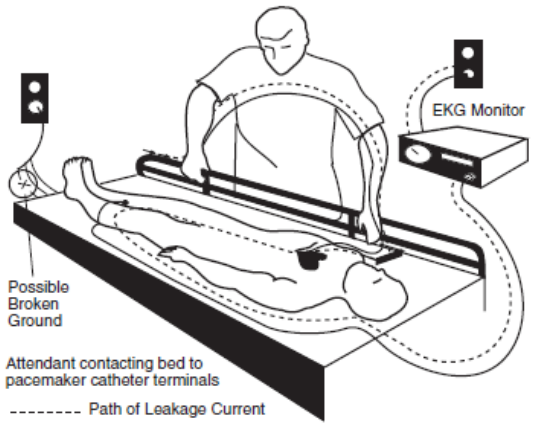


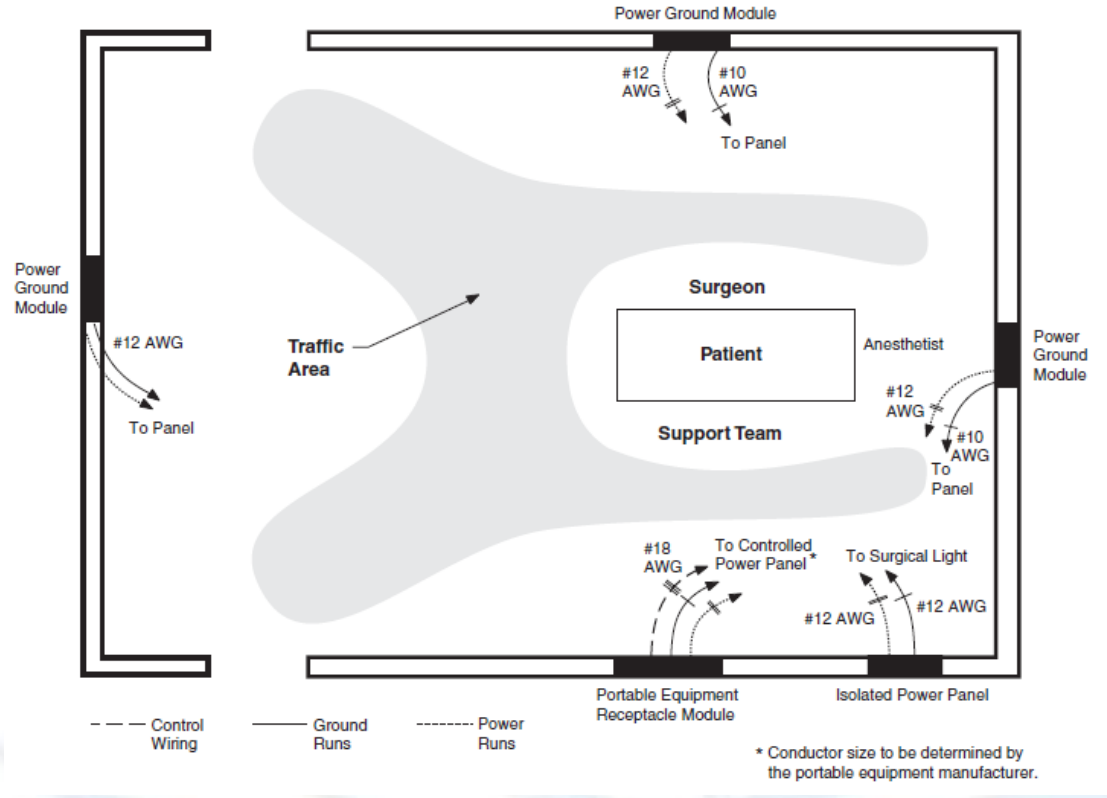
Ground Wire Sizing

The grounding conductor provides a path for leakage current which could be conducted to an electrical appliance case. The magnitude of this leakage current depends on the characteristics of the appliance and its insulation.
The leakage current could result in potential differences between pieces of equipment and could flow through vital organs of the patient, if a patient current path is established.
For example, during cardiac catheterization, small amounts,of current could cause ventricular fibrillation.



Ground Wire Sizing



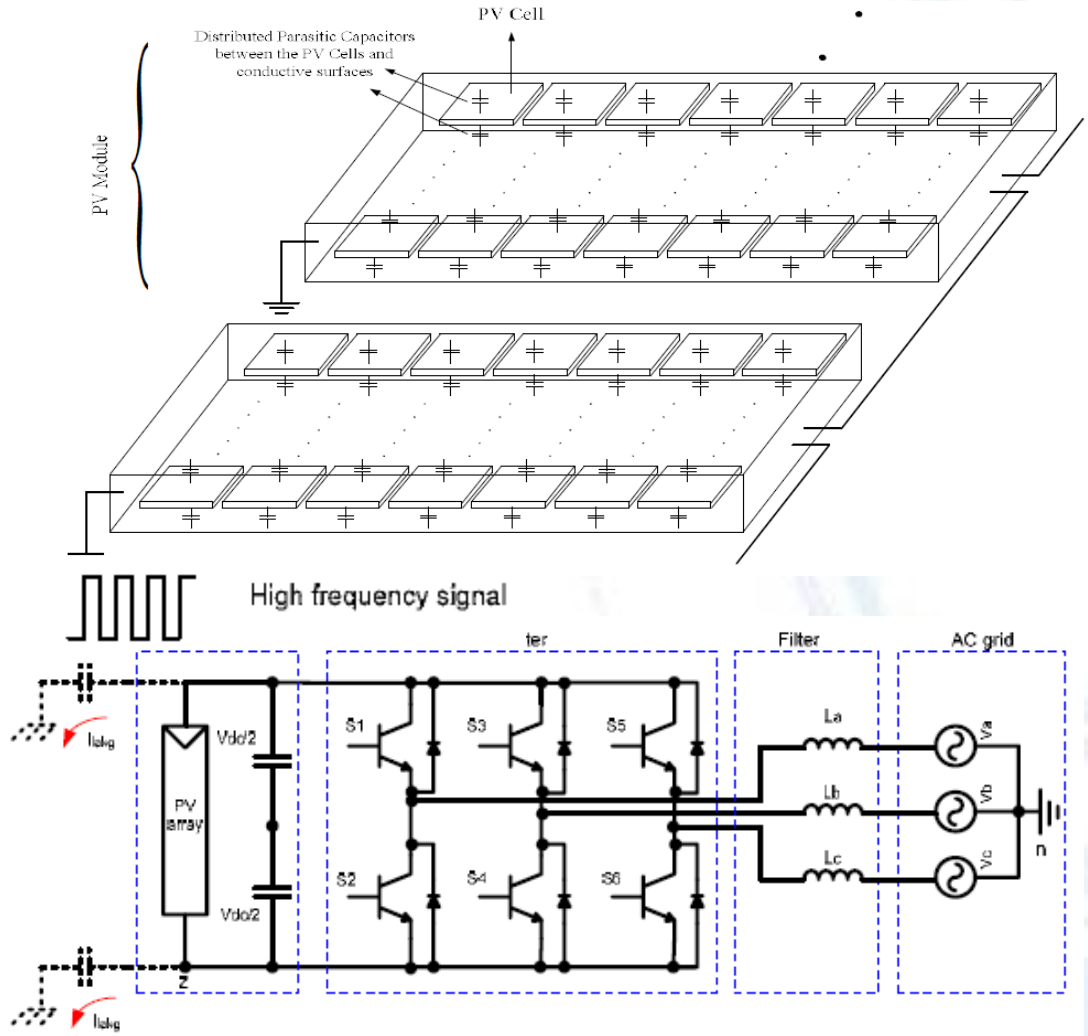


NEC-Code

Current codes and standards for new construction of critical care areas require that no more than 40 mV exist between the reference point and exposed conductor surfaces in the patient's vicinity.
Using the isolated system, an initial line to ground fault can be kept as low as 5 mA, if the system is operating in the "safe" condition. The power cord ground wire could easily accommodate a 5 mA fault and stay well within the requirements of NFPA No. 99 and the NEC

Photovoltaic Inverters

Stray Capacitance



Leakage Current

Stray capacitance, between earth and metallic frame, can reach 1µF for 1 kW of installed peak power (1µF/kWp) .
The PV modules become vulnerable to leakage currents especially for the case of Transformer less Inverter due to the lack of galvanic isolation.

This ground leakage current will :
- Lead to safety issues,
- Degrade the efficiency of thin-film modules ,
- Create EMI problems ,
- Disrupt protection coordination and introduce extra losses, and line current distortion.

EARTH CAPACITANCE OF PV UNGROUNDED SYSTEMS

Conditions	Capacitance
Glass-faced panels	50 - 150 nF/kW_{peak}
Thin-film panels	Up to 1 µF/kW_{peak} (damp environments or rainy days)

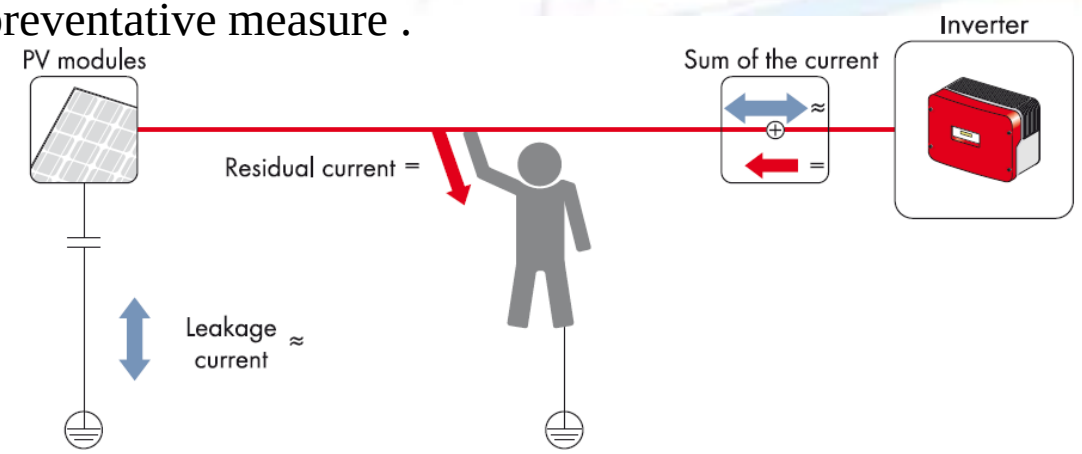
DIN-VDE 0126-1-1 standard

Some standards have been established in Germany by DIN (Deutsches Institut für Normung e. V.).

The DIN-VDE 0126-1-1 standard limits the rms value of leakage current in PV systems to 300 mA.

DIN-VDE 0126-1-1 Standard

Moreover, according to this standard, even a jump in the leakage current requires disconnection of the inverter.
Sudden surges of residual current of over 30 mA , the inverter disconnects automatically from the utility grid as a preventative measure .



Leakage current rise disconnection times specified in VDE 0126-1-1.

Leakage Current Increase (mA)	*Disconnection Time (sec.)*
30	*0.30*
60	*0.15*
100	*0.04*

Injected DC Current

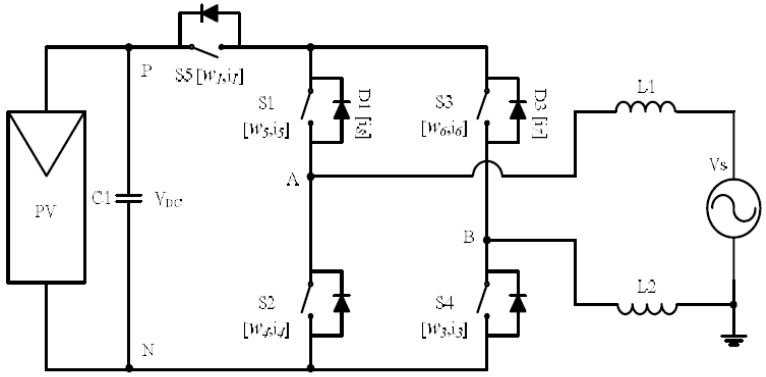
These inverters may inject DC currents to the utility grid.
-Decreases the power rating of the distribution transformer and decreases the system energy efficiency by causing additional losses both in the grid side and in the inverter side.
-Saturate the distribution transformer.
To avoid these drawbacks, the DC current injection is limited in several standards.

DC current injection limits specified in IEEE 1547, IEC 61727, VDE 0126-1-1, and EN 61000-3-2.

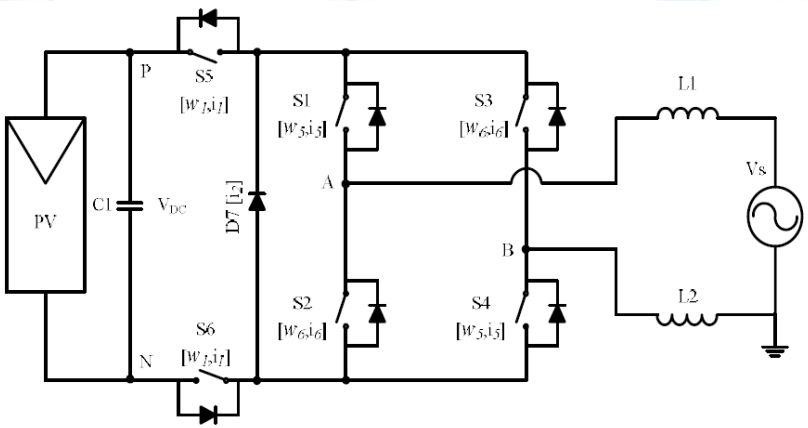
	IEEE 1547	***IEC 61727***	***VDE 0126-1-1***	***EN 61000-3-2***
DC Current Injection	*< 0.5% of rated output current*	*< 1% of rated output current*	*< 1 A*	*< 0.22 A*

H5-H6 Inverters

- Due to these restrictions on leakage current and due to the aforementioned drawbacks of leakage current, several GCTSIs are invented with low leakage current characteristic

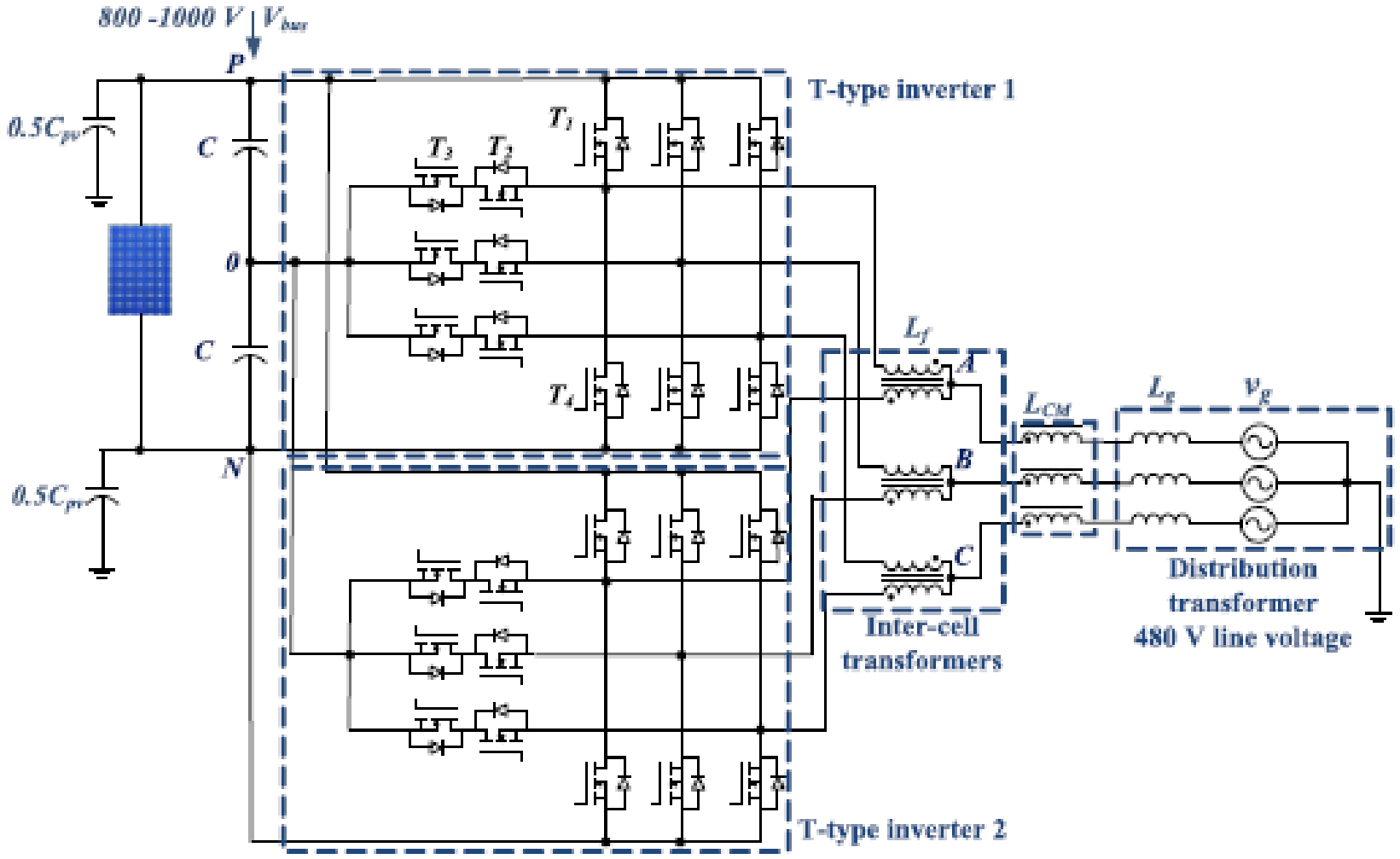


The H5 topology



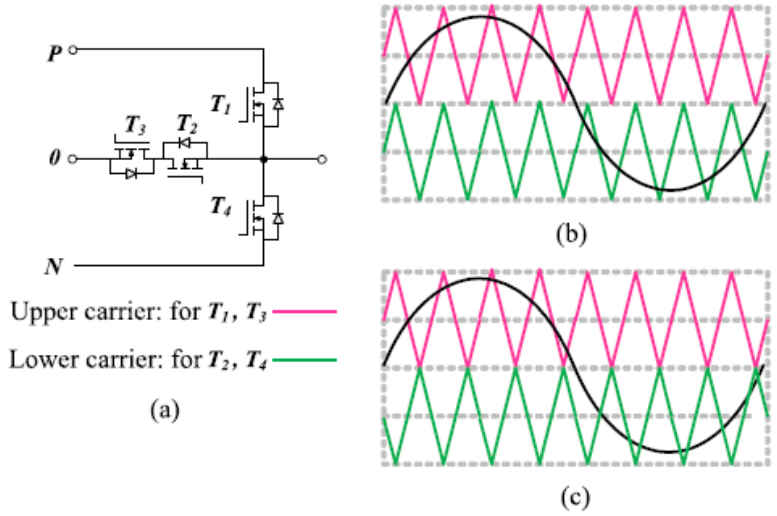
The H6 topology

T-Type Transformerless PV Inverter

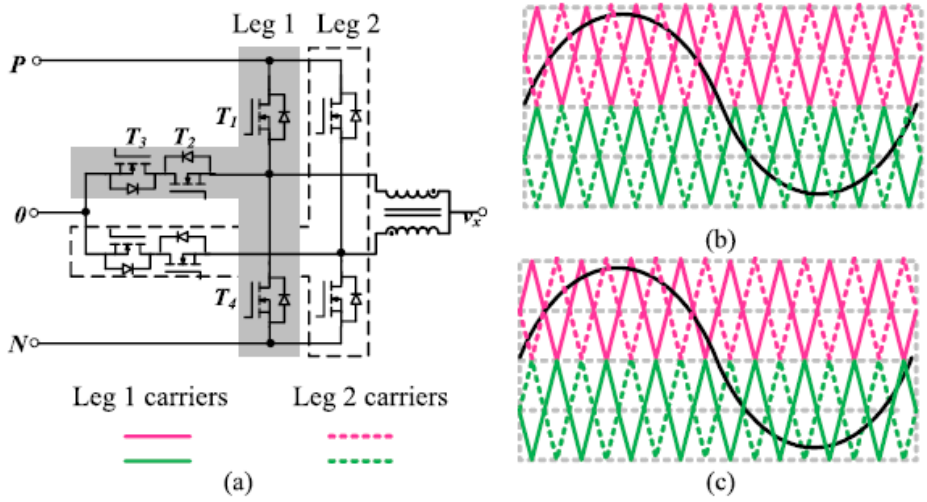


5-level T-type transformerless PV inverter.

Modulation method for 3 and 5 T Level Inverters

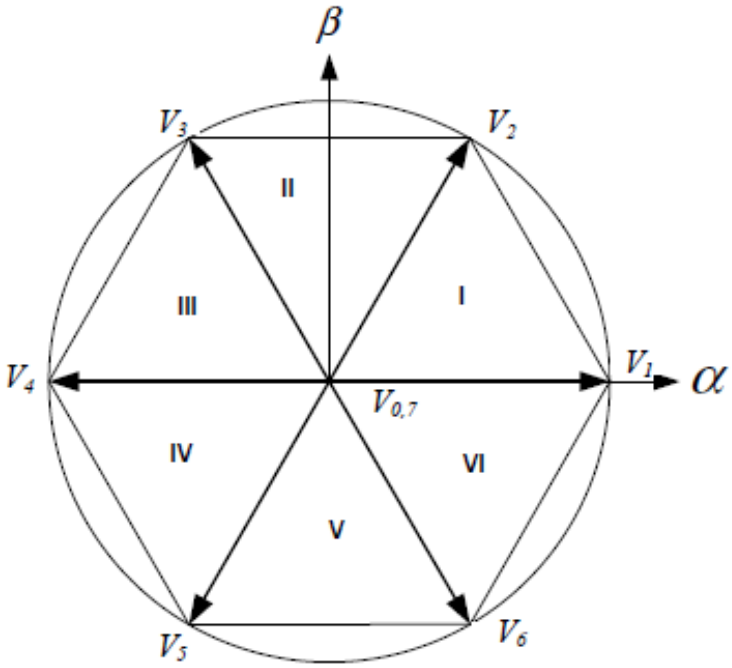


Modulation methods for $3LT^2$ inverters: (a) One T-type phase leg; (b) PD modulation; and (c) POD modulation.



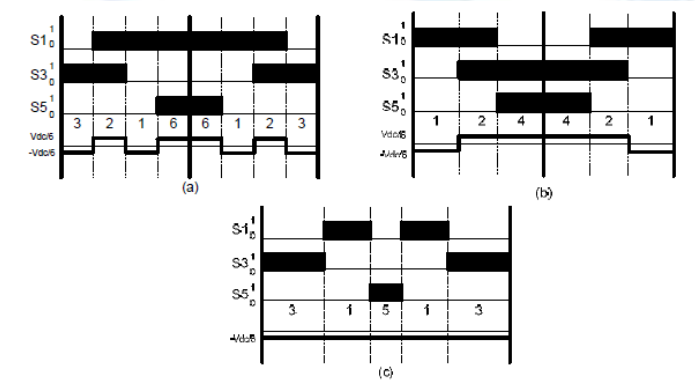
Modulation methods for the $5LT^2$ inverter: (a) Two T-type phase legs; (b) interleaved modulation based on PD; and (c) interleaved modulation based on POD.

SVPWM



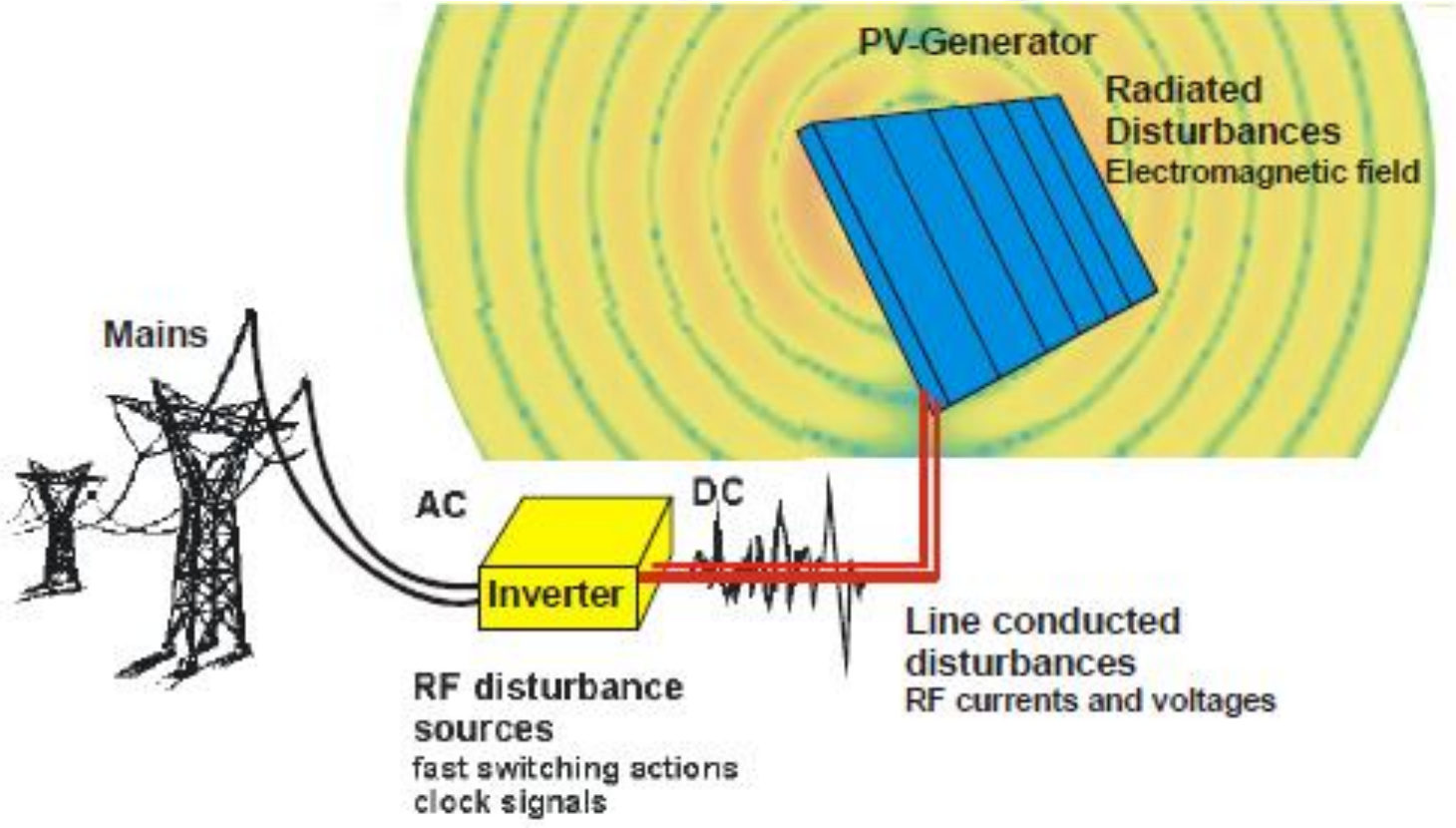
Active Vectors	Null Vectors
$(0,0,0)V_1$	$(0,0,0)V_0$
$(1,1,0)V_2$	$(1,1,1)V_7$
$(0,1,0)V_3$	
$(0,1,1)V_4$	
$(0,0,1)V_5$	
$(1,0,1)V_6$	

.General Space Vector Modulation for three-phase inverters.



Reduced Common Mode Voltage Space Vector Modulations, (a) AZSPWM1, (b) AZSPWM2, (c) RSPWM3

EMI Electromagnetic Interference



Frequency Range

Cables connecting PV panel with inverter are hundreds of meters, This current-carrying conductor can work as active unintended antennas in the radio frequency range. therefore, the most significant interference may be at the frequency range 30-300kHz – 300-3000MHz.

WAVELENGTH IN DIFFERENT FREQUENCY RANGE

Frequency	Wavelength [meters]	Antenna length [meters]
3-30 Hz	10^8-10^7	10^8-10^7
30-300 Hz	10^7-10^6	10^7-10^6
300-3000 Hz	10^6-10^5	10^6-10^5
3-30 kHz	10^5-10^4	10^5-10^4
30-300 kHz	10^4-10^3	10^4-10^3
300-3000 kHz	10^3-100	10^3-100
3-30 MHz	100-10	100-10
300-3000 MHz	10-1	10-1
300-3000 MHz	1-0.1	1-0.1
3-30 GHz	0.1-0.01	0.1-0.01
30-300 GHz	0.01-0.001	0.01-0.001

EMI

Interferences influencing shortwave broadcast and beacons look particularly dangerous because they are used to communicate with merchant ships and aircraft.

if PV generation systems are close to airports or placed on the building roofs the noise can be dangerous.

Guidelines to minimize interference :
- Install the right EMC filters (reduce leakage current)

- Use twisted Shielded pairs, connected at both sides to ground, to connect the PV inverter to the PV panel.

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THANK YOU

MERCI