ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Fault Operation and Control of 3-Level NPC Inverters

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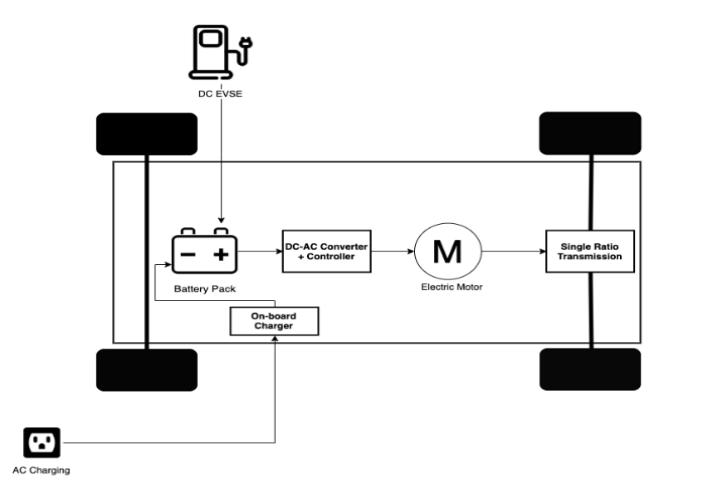
Outline

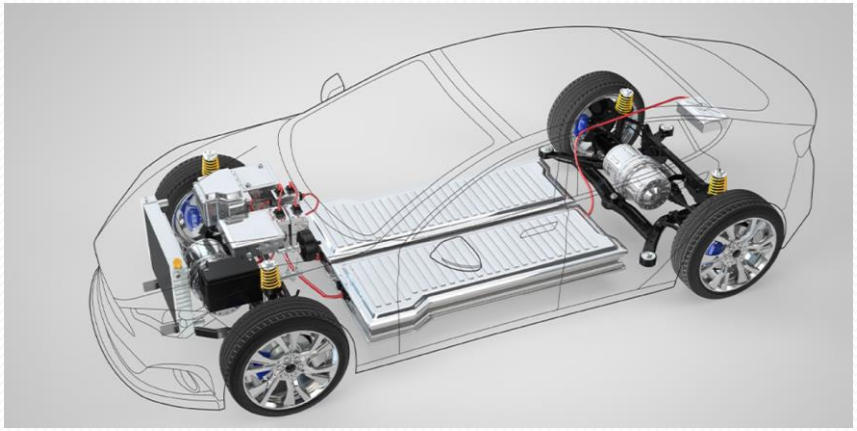
- Electrical Machine Drives
- Inverters
- Aim of the Study
- Inverter Control Techniques
- 3- Level NPC Inverters & Drive Methods
- Possible Fault States
- Operation Vector Under Fault States
- Conclusion

Electrical Machine Drives

- AC Machine Applications,
- Electrical Vehicles
- Renewable Energy Systems

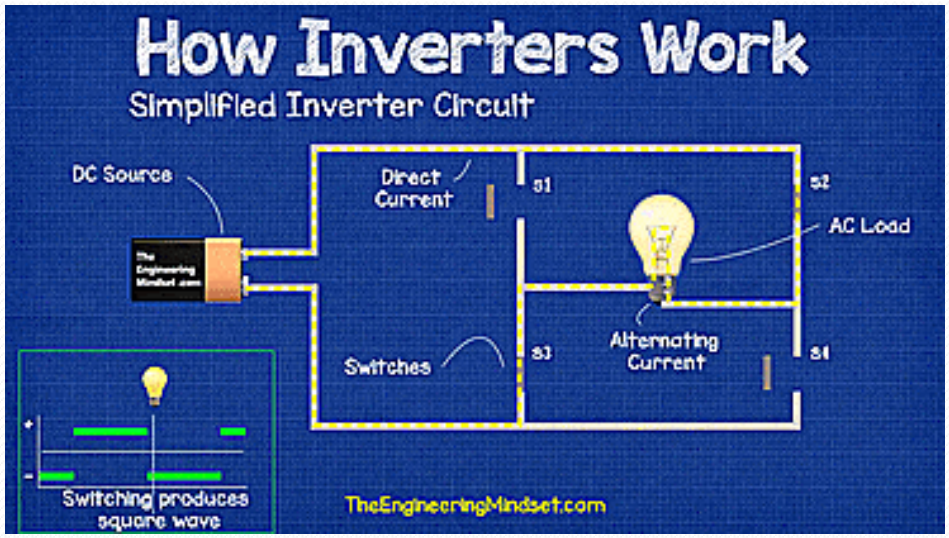
- Control of an AC Machine for desired Speed, Torque
- **DC/AC Converters (Inverters)**





Inverters

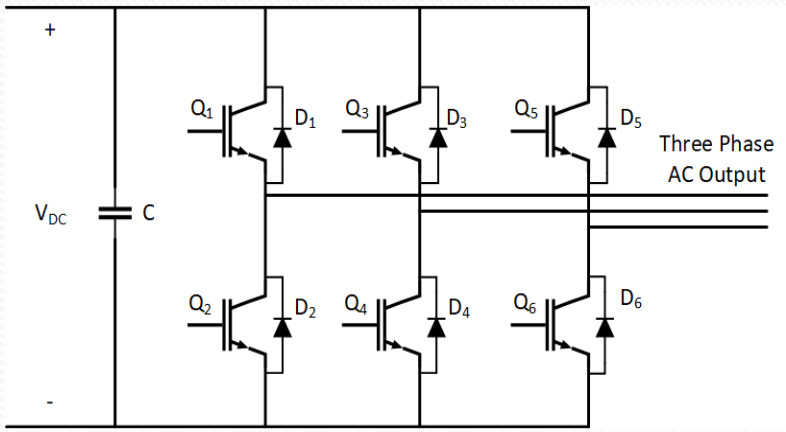
- DC voltage to AC voltage
- Opening and closing the switches with different times
- Square wave output voltage



Inverters

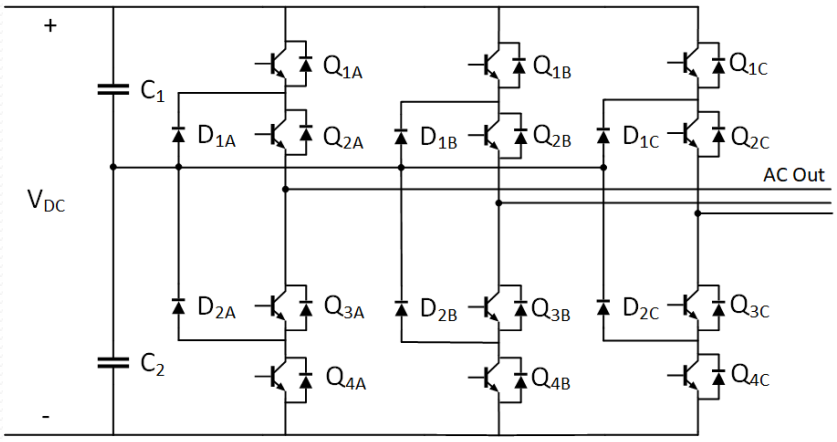
2-level Inverters

- [Vdc/2, -Vdc/2] voltage levels
- 6 switches
- Voltage stress of switch: Vdc



3-Level NPC Inverters

- [Vdc/2, 0, -Vdc/2] voltage levels
- 12 switches, 6 diodes
- Voltage stress of switch: Vdc/2



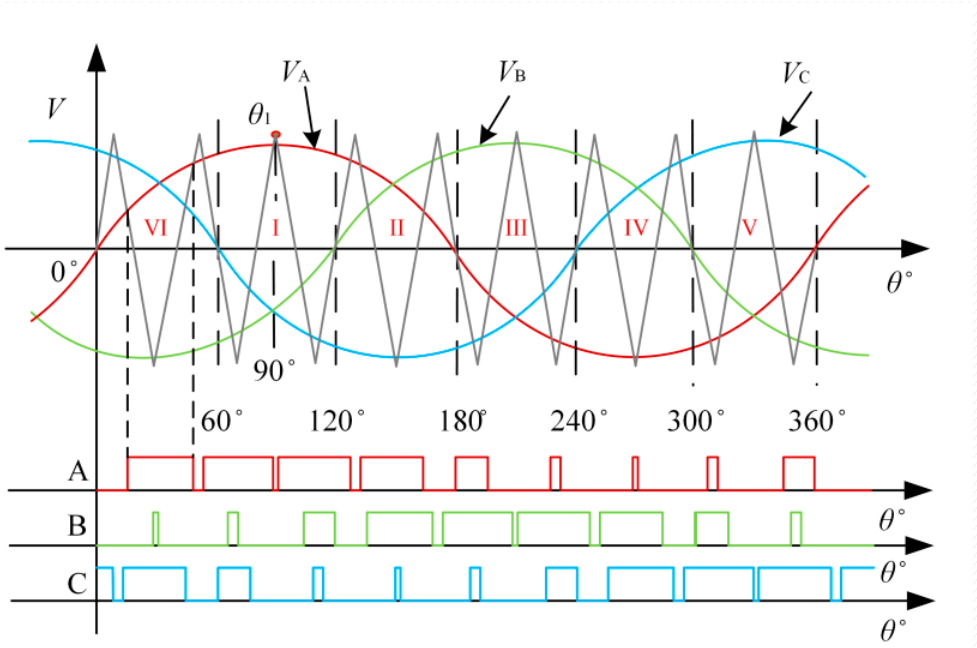
Aim of the Study

- 800V 15 kW AC Motor Drives with 3-Level NPC Inverter
- Control Methods Abilities of the Inverter
- Observing Fault Situation Behavior of Inverter
- Fault Tolerant Operations of 3-level NPC Inverters

Inverter Control Techniques

- **Sinusoidal PWM**

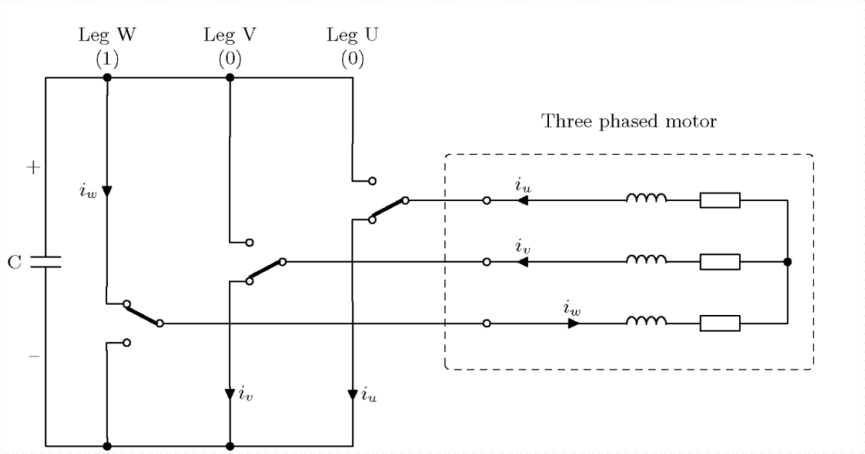
- 2 carrier triangular signals
- 3 reference signal with 120° phase shift
- Modulation index, m_i
- $V_{out} = \frac{m_i V_{dc}}{2}$

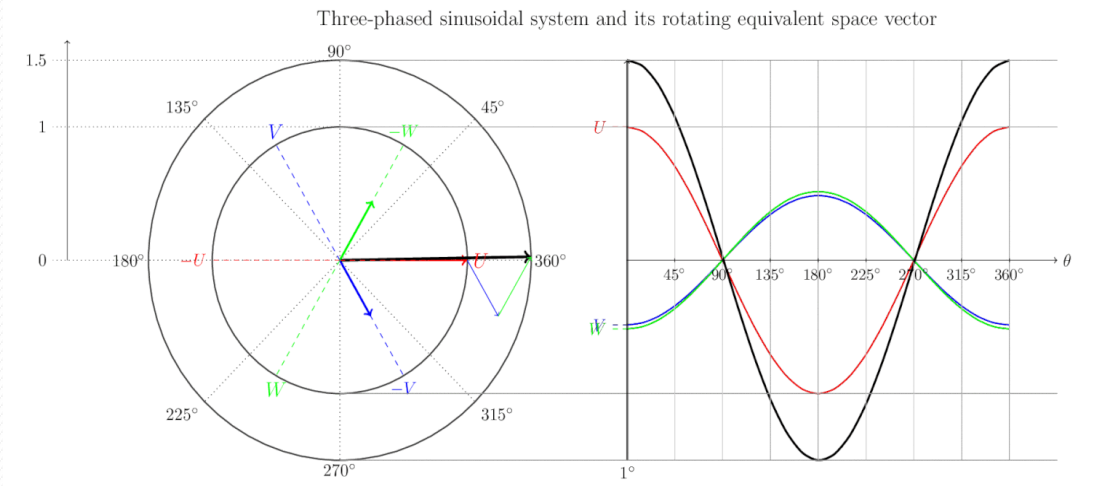


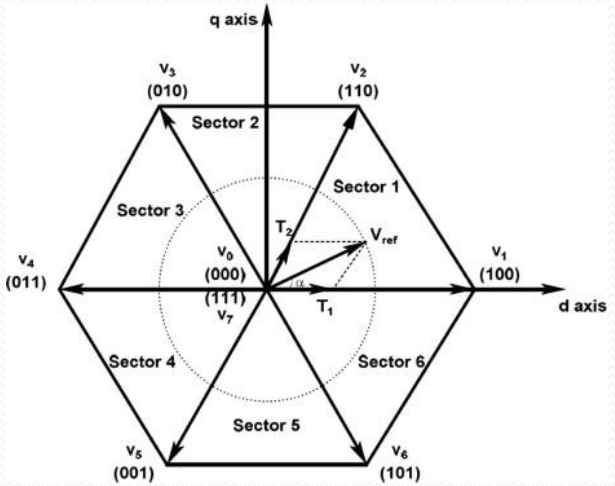
Inverter Control Techniques

- **Space Vector PWM (SVPWM)**

- Rotating frame to Stationary frame
- Equivalent vector defined sum of three vector.
- Clark & Park Transformations



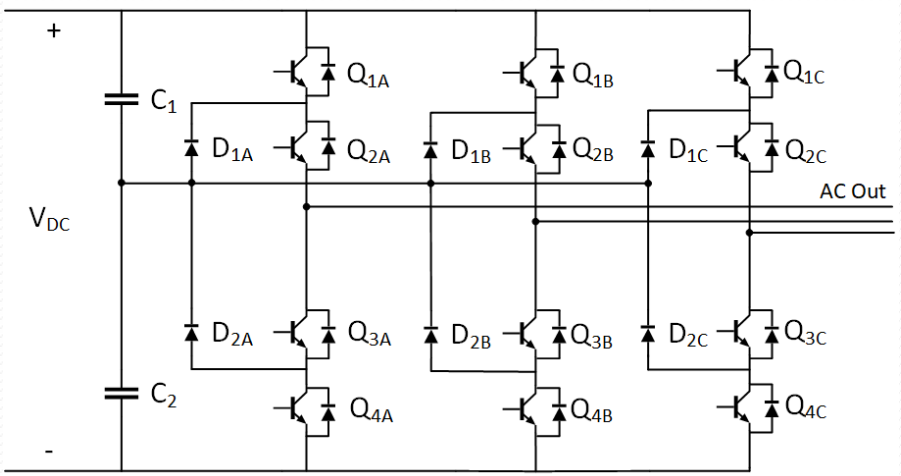




3- Level NPC Inverters & Drive Methods

- 12 switches & 6 diodes to obtain P, O, N states.

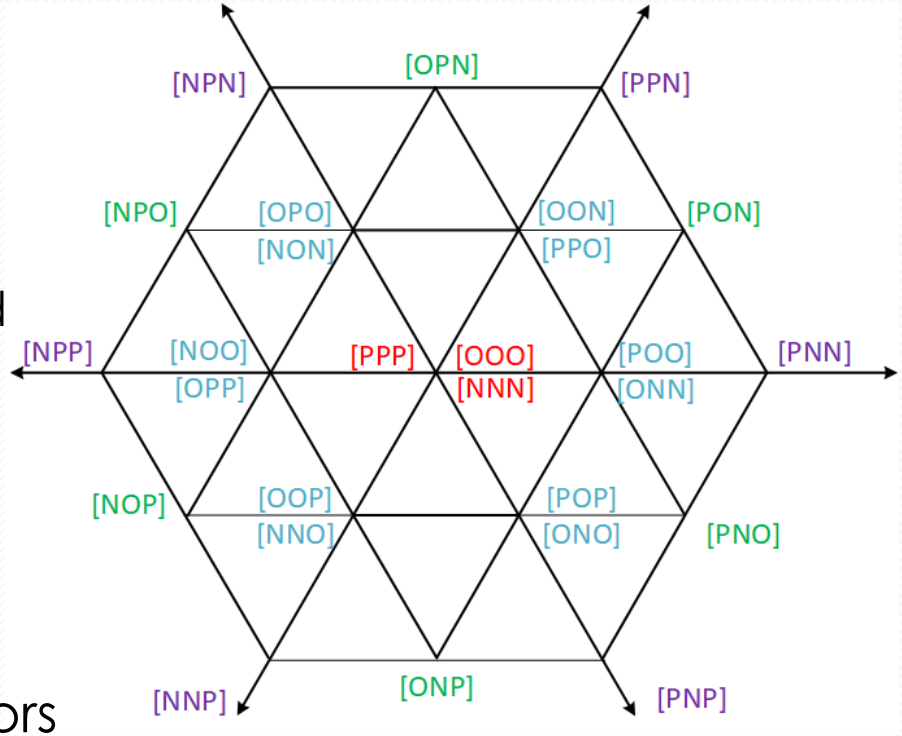
State	Vout	Q1	Q2	Q3	Q4
P	+Vdc/2	ON	ON	OFF	OFF
o	o	OFF	ON	ON	OFF
N	-Vdc/2	OFF	OFF	ON	ON



3-Level NPC Inverter Circuit

Control Techniques

- **Space Vector PWM (SVPWM) for 3-Level NPC Inverter**
- Totally 27 pace vectors
- Required output vector is obtained by using four vectors.
- Reference vectors can also be manipulated with small vectors.
- [PPP], [OOO], [NNN]: zero vectors



Space Vector Diagram of 3-Level NPC Inverter

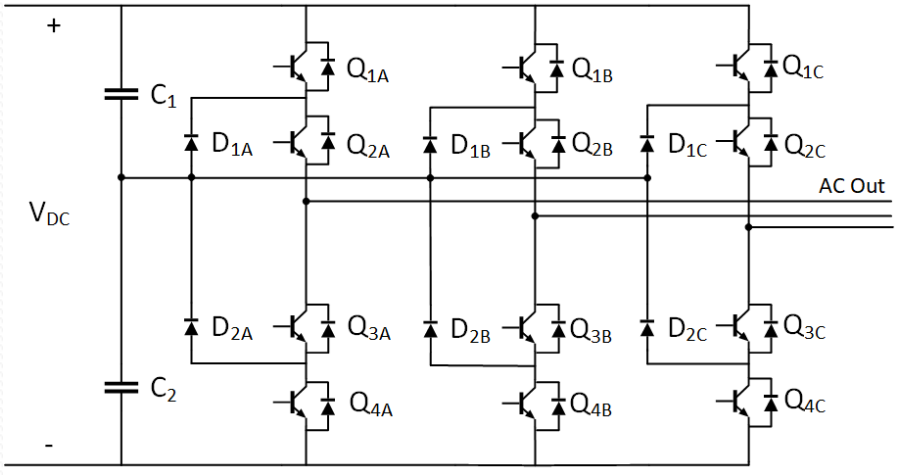
Possible Fault Scenarios

Short Circuit

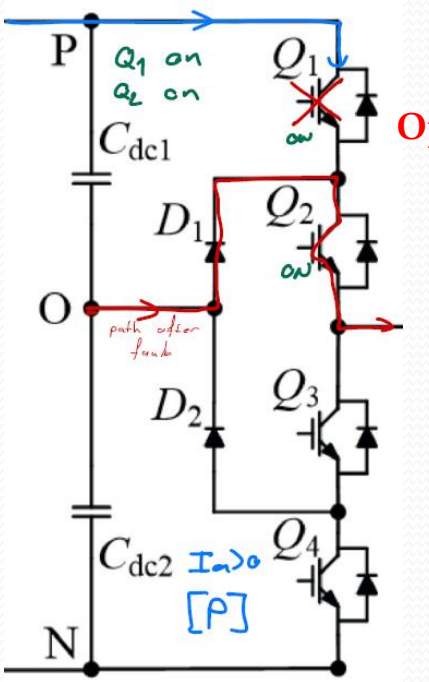
- Overcurrent condition
- Current distortion observed significantly.

Open Circuit

- Chance to operate with limited conditions
- Effect of fault of middle switches is larger

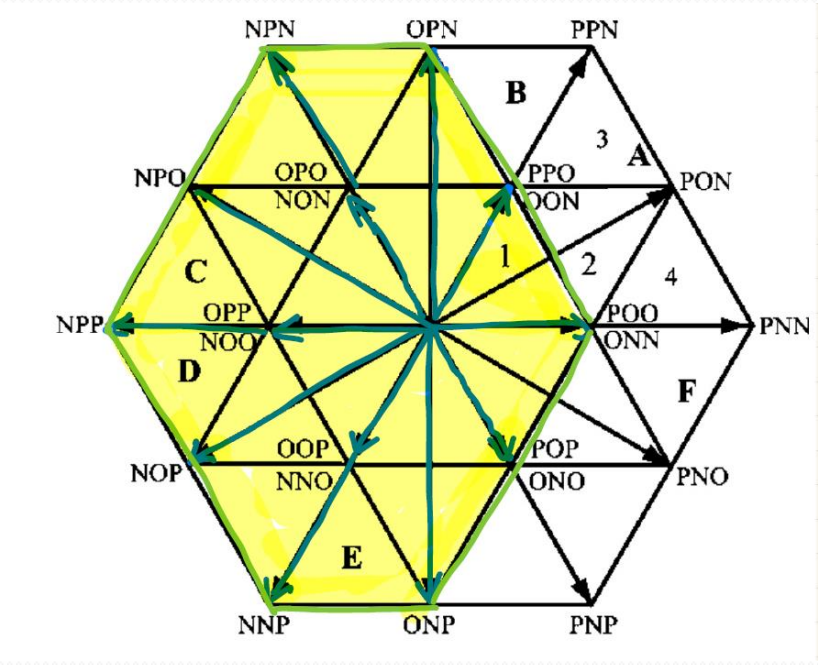


Space Vectors Under Fault States



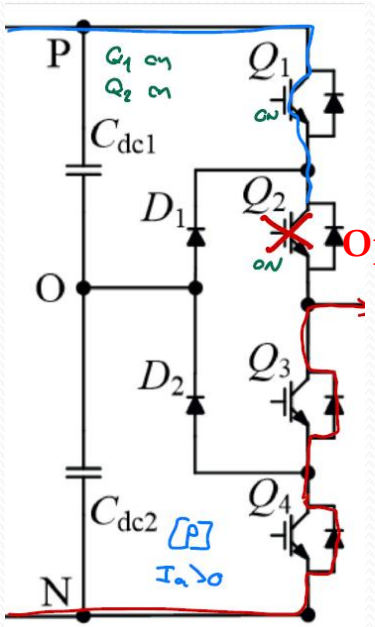
Q1
Open Circuit

Current flow of phase-a
when Ia>0 and at P-state

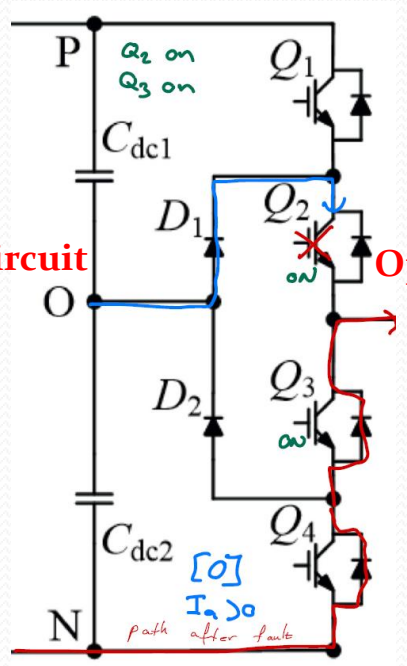


Space Vector Diagram for Q1 fault

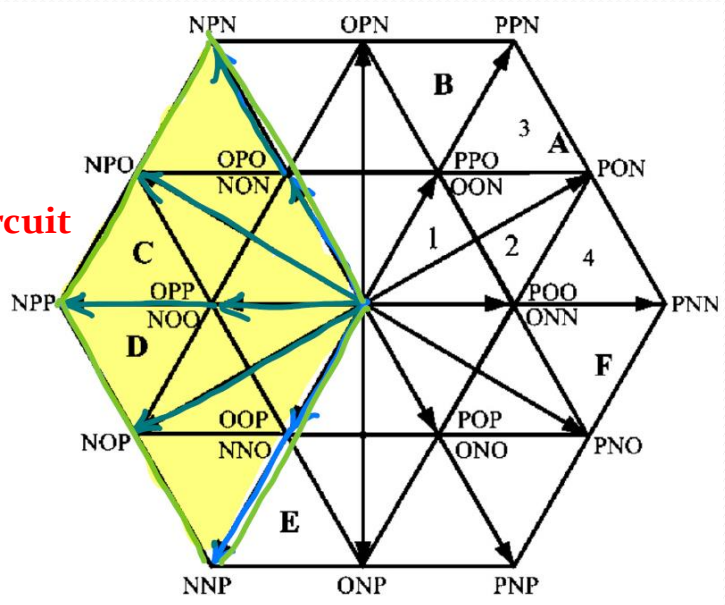
Space Vectors Under Fault States



Q2 Open Circuit



Q2 Open Circuit

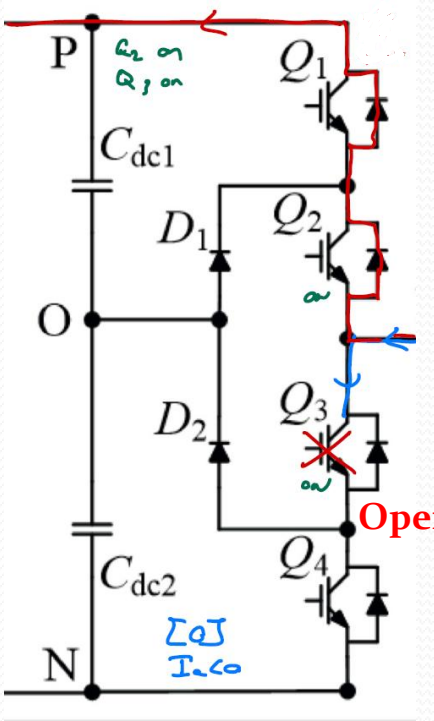


Current flow of phase-a when Ia>0 and at P-state

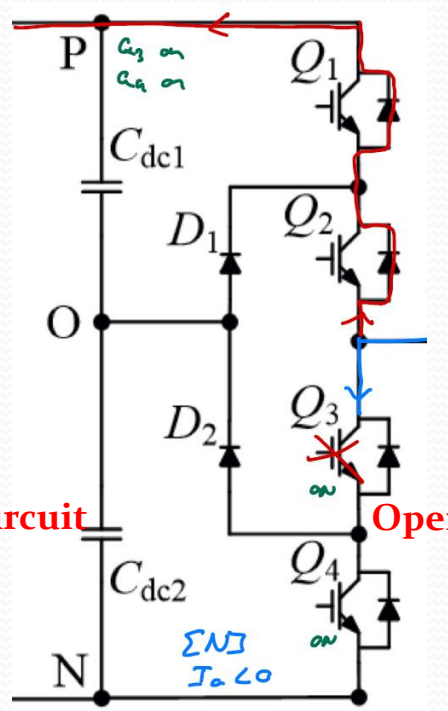
Current flow of phase-a when Ia>0 and at O-state

Space Vector Diagram for Q2 fault

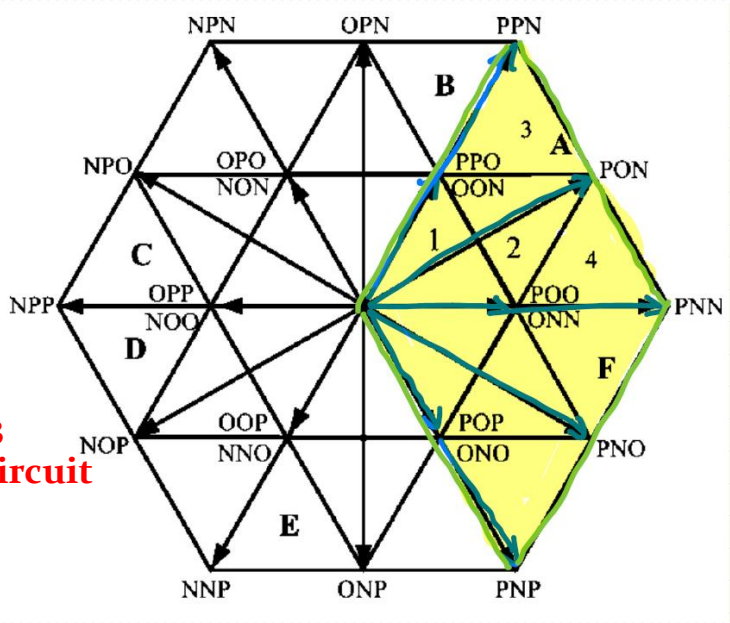
Space Vectors Under Fault States



Current flow of phase-a when Ia<0 and at O-state

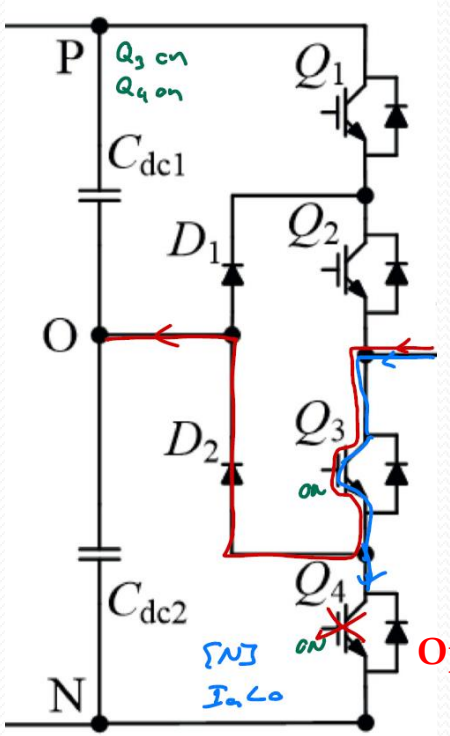


Current flow of phase-a when Ia<0 and at N-state

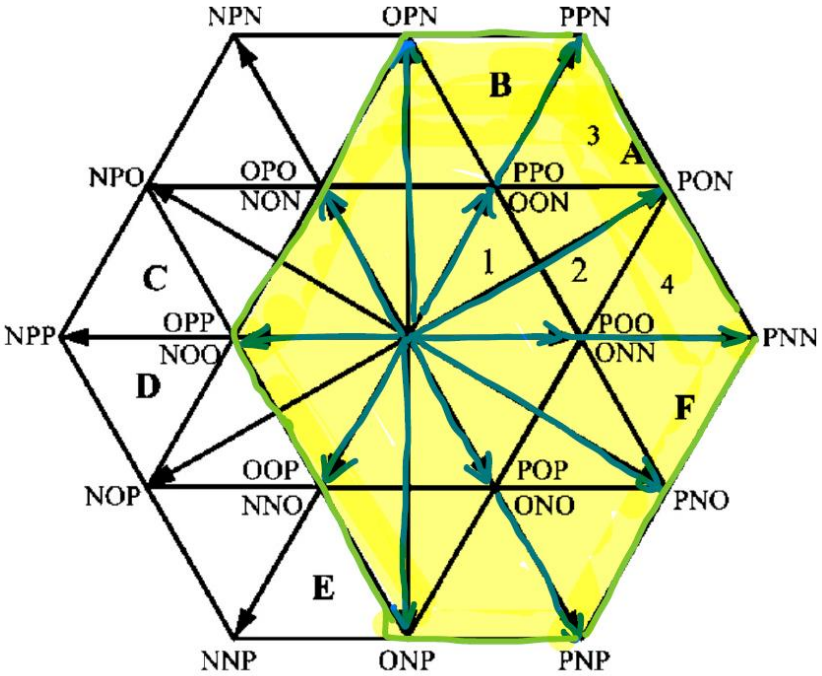


Space Vector Diagram for Q3 fault

Space Vectors Under Fault States



Q4
Open Circuit



Space Vector Diagram for Q4 fault

Conclusion

- 3-Level NPC Inverters are efficient inverter solutions for High Voltage AC Machines.
- Open circuit fault is tolerable
- Fault in 1st and 4th switches can be tolerable with limited conditions.

Thank you for your attention.