Session 4a
Ozpineci

UT-BATTELLE

Cascaded Multilevel Inverters for Aggregation of Fuel Cells

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OAK RIDGE NATIONAL LABORATORY
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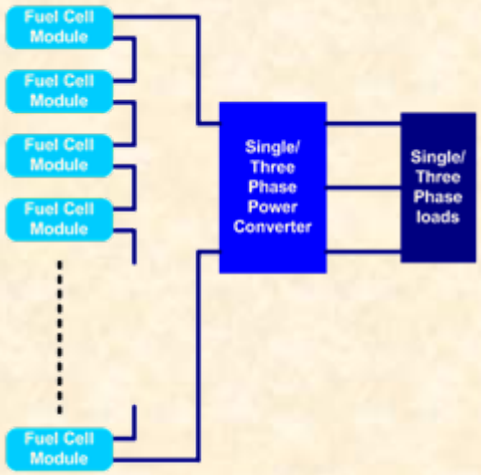
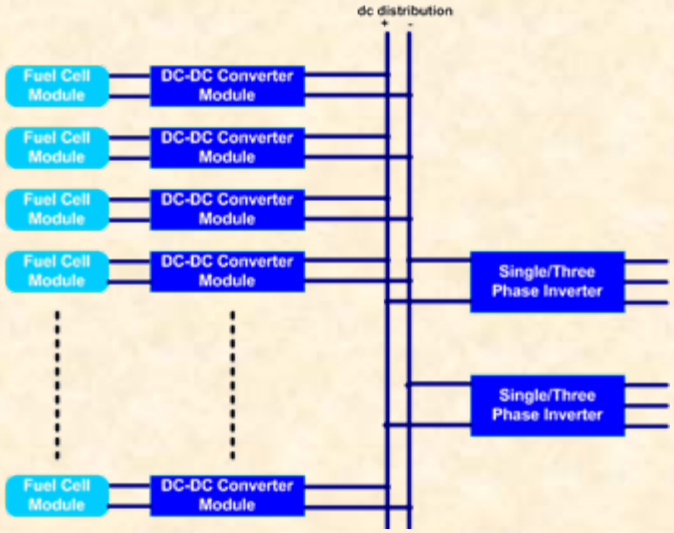
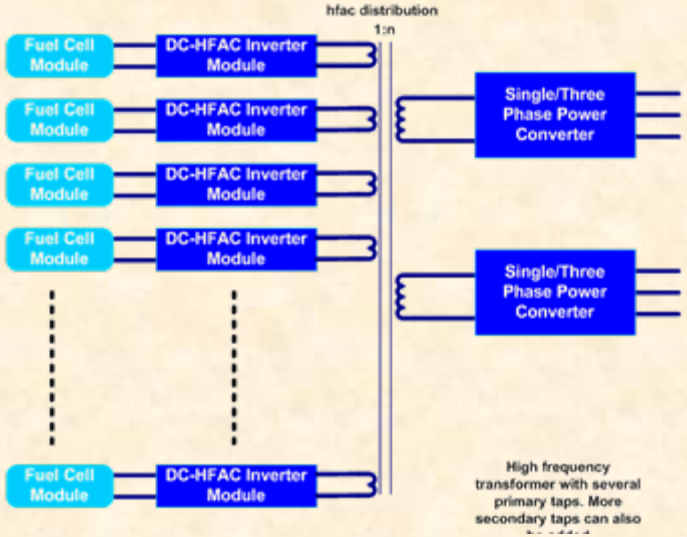
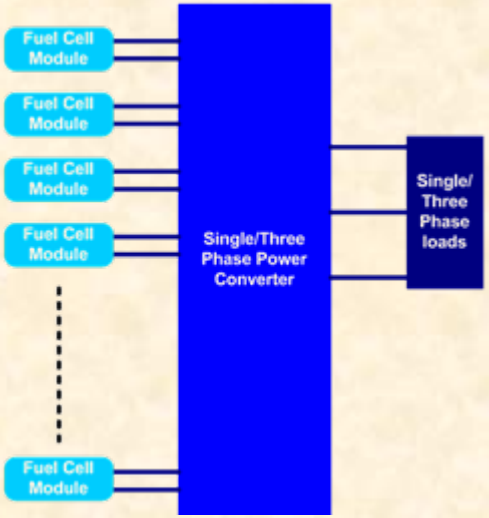
Several Possible Configurations

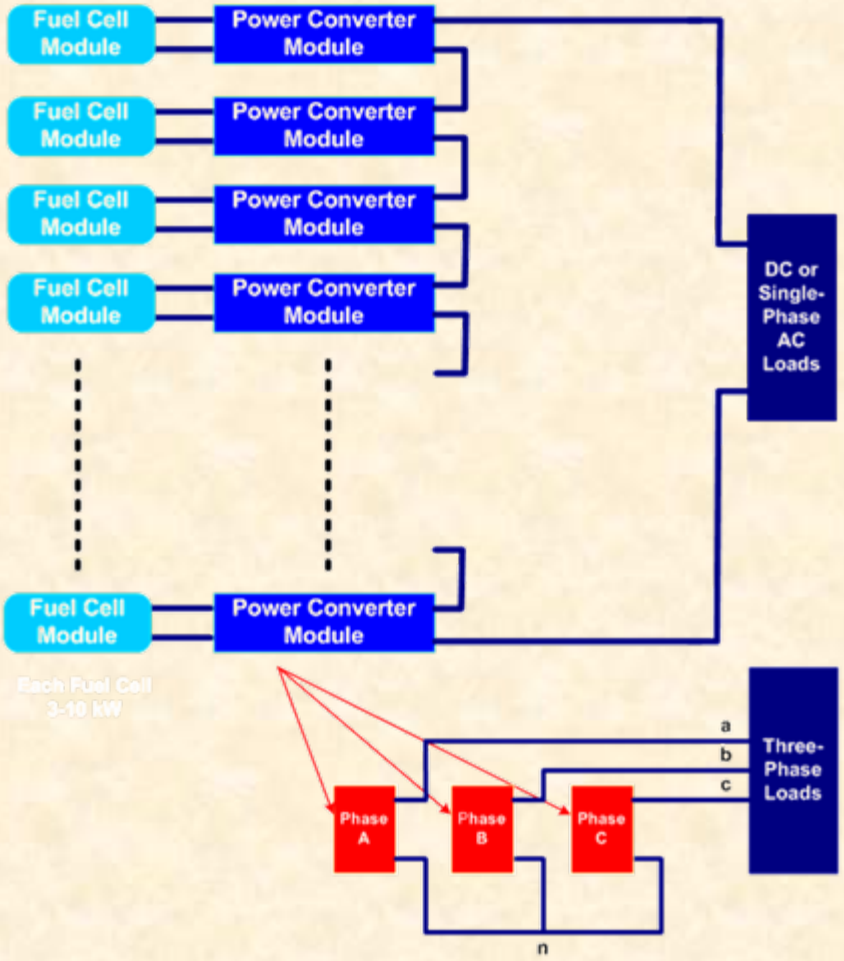








Cascade Multilevel Inverters (CMLI)



- **Each power converter module typically consists of a dc/dc voltage regulator and an H-bridge inverter**
- **Single-phase, multi-phase, three phase wye or delta connections are possible**
- **Can be used in many power applications**

Properties

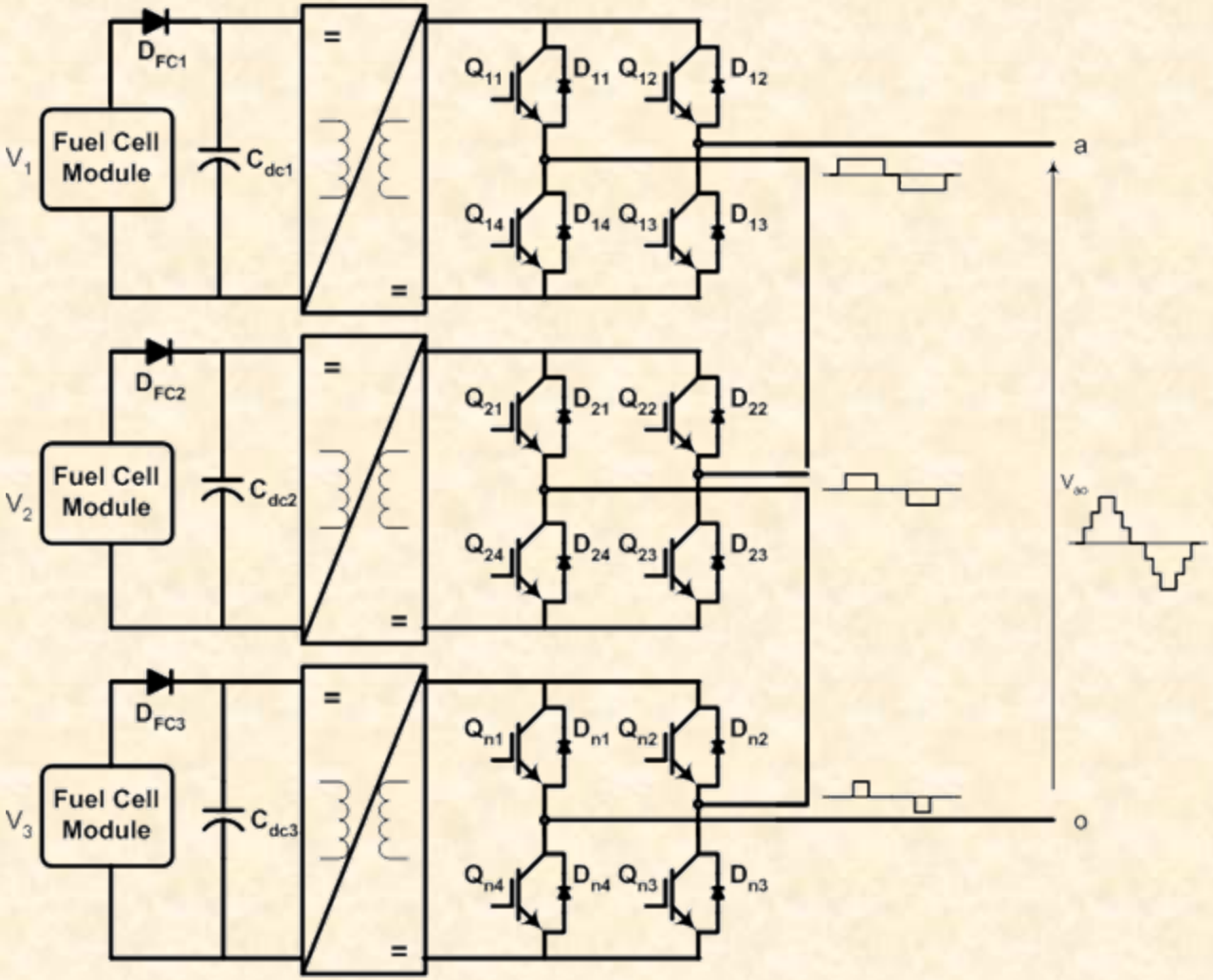
Advantages

- **Modular**
  - Reduced manufacturing and maintenance costs
- **Scalable**
  - Reduced design cost
- **Fault tolerant operation**
  - Increased availability
  - Redundant levels
  - Possible reconfiguration
- **Energy storage**
- **Low harmonic distortion**
  - Reduced filters

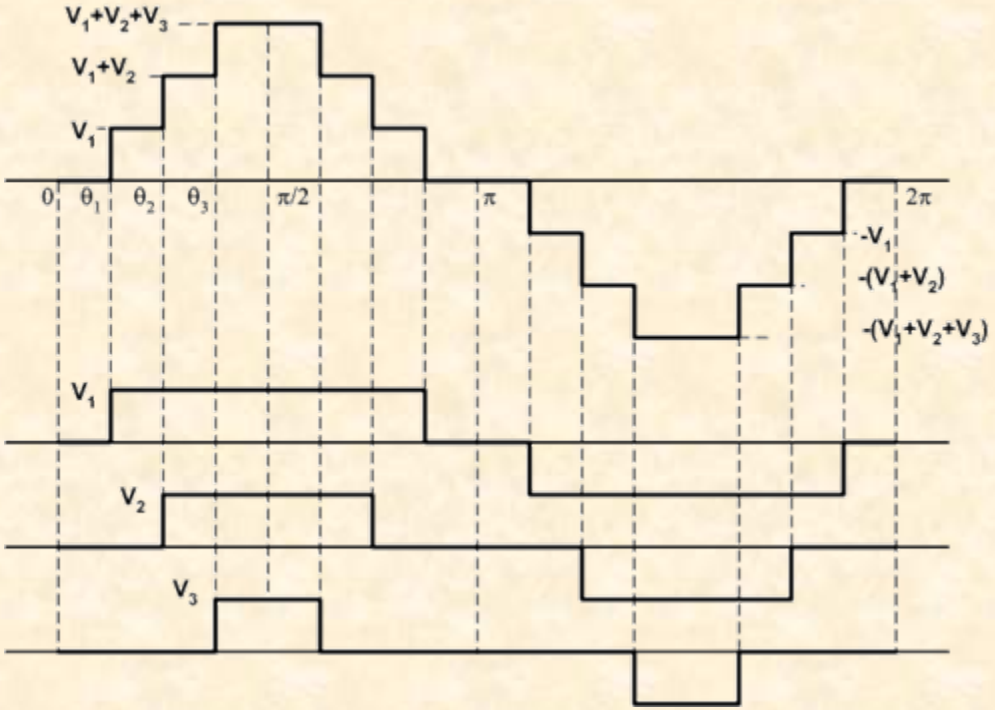
Disadvantages

- **Component count**
  - Extra switches and transformers
  - Higher component cost
  - Low voltage components
- **More complicated control**
- **Isolated dc sources**

Circuit Diagram

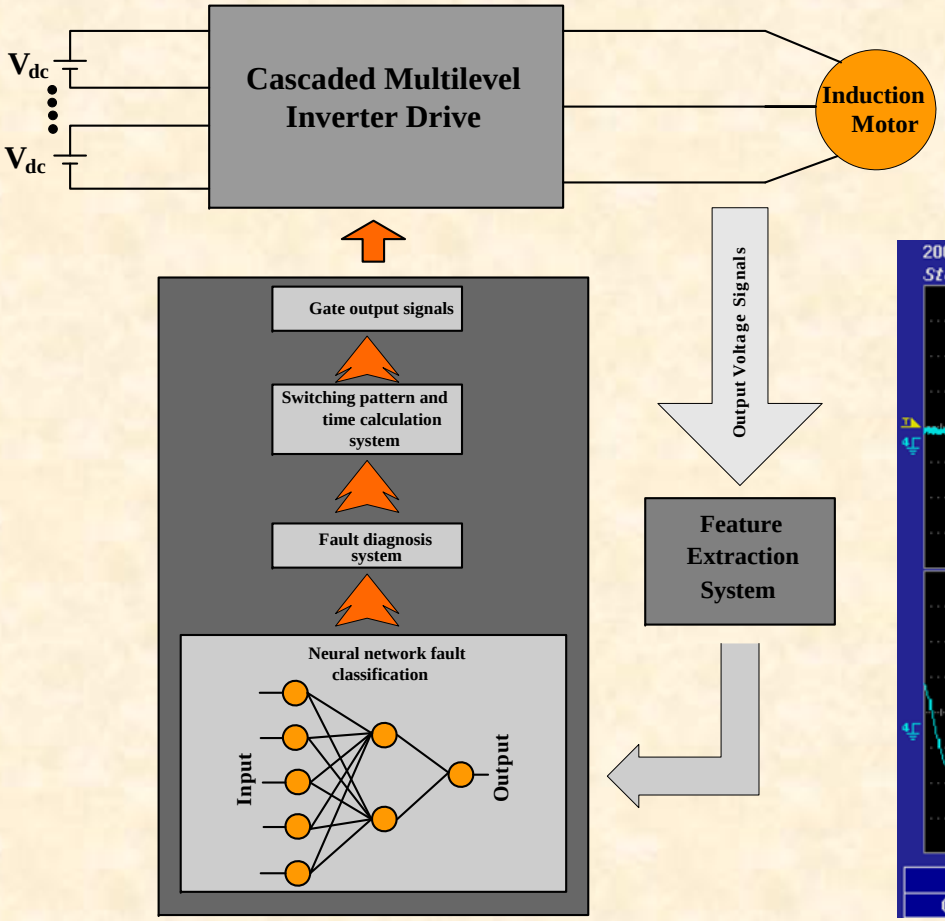


Waveform Generation

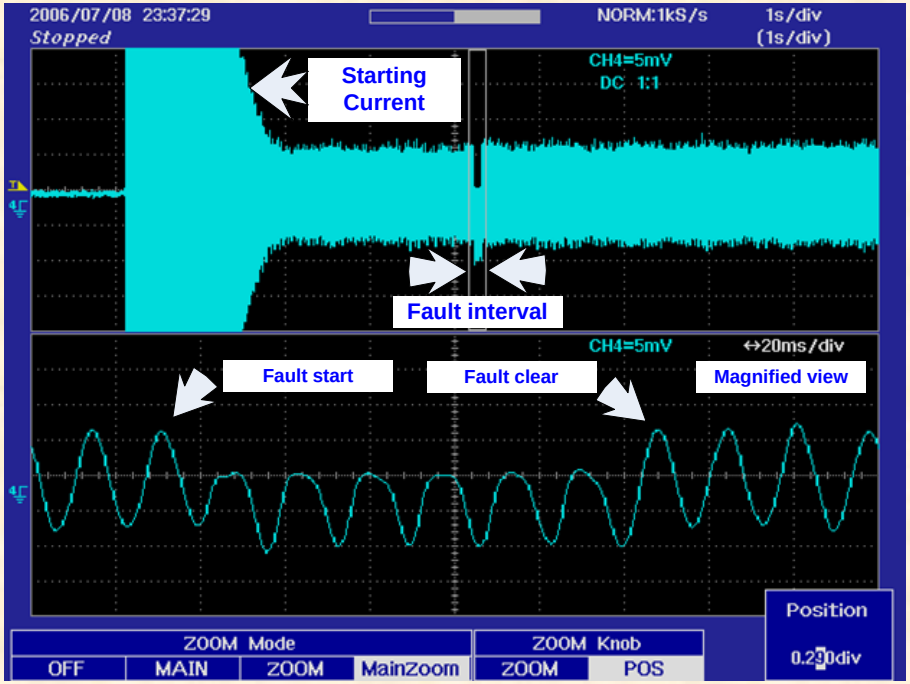


- **Synthesize desired ac voltage from several levels of dc voltages**
- **More levels produce a staircase waveform that approaches a sinusoid**
- **Harmonic distortion of output waveform decreases with more levels**
- **No voltage sharing problems with series connected devices**
- **Low dV/dt reduces switching losses and EMI**
- **Multilevel PWM is possible**

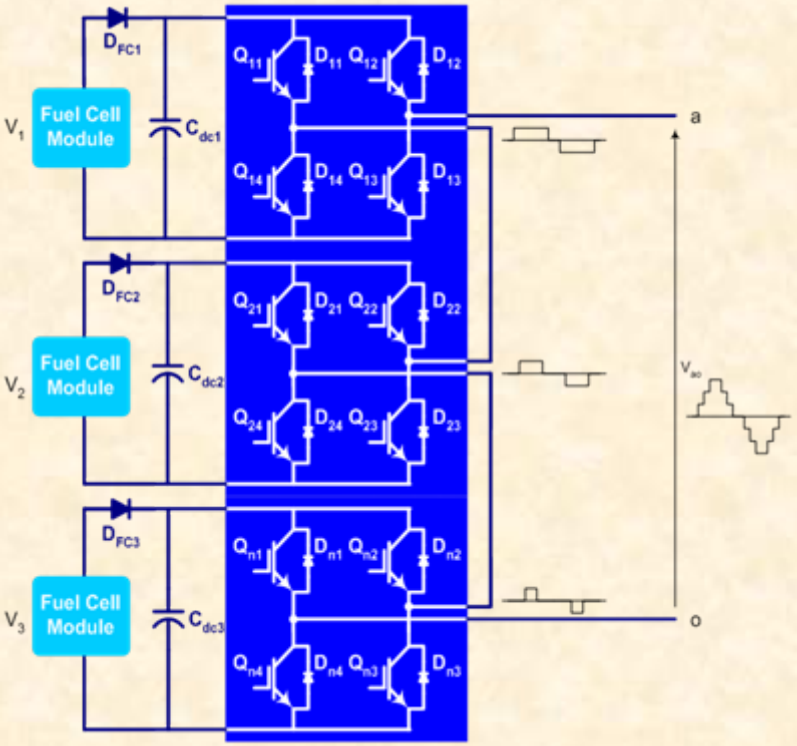
Fault Tolerant Operation



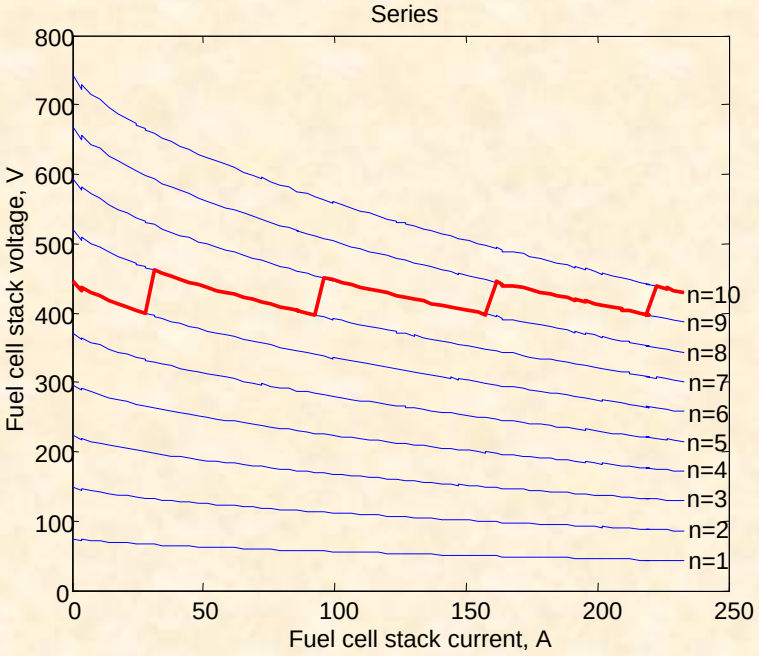
Open circuit fault



Alternative CMLI

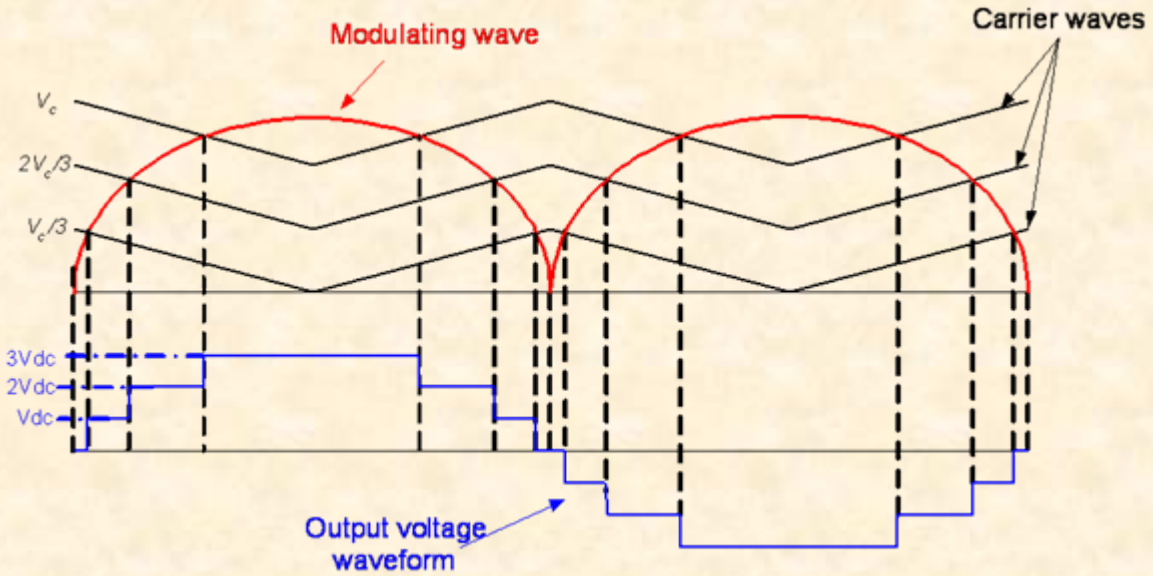


7-level cascaded multilevel inverter



Level reduction technique for a 10 dc source CMLI

Multilevel Modulation at Fundamental Frequency



V_{ao}^*: modulating wave

V_c : carrier wave

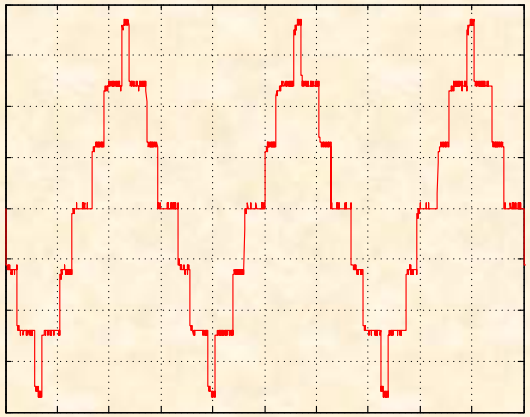
$2V_c/3 < V_{ao}^*$: 7-levels

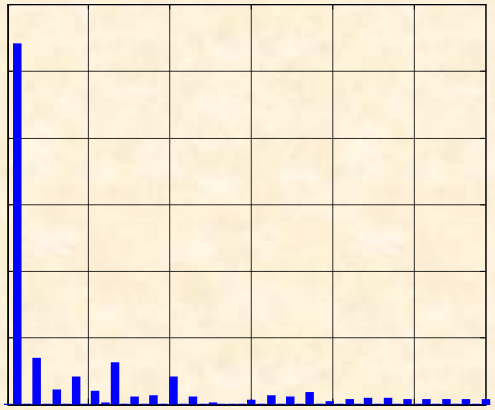
$V_c/3 < V_{ao}^* < 2V_c/3$: 5-levels

$0 < V_{ao}^* < V_c/3$: 3-levels

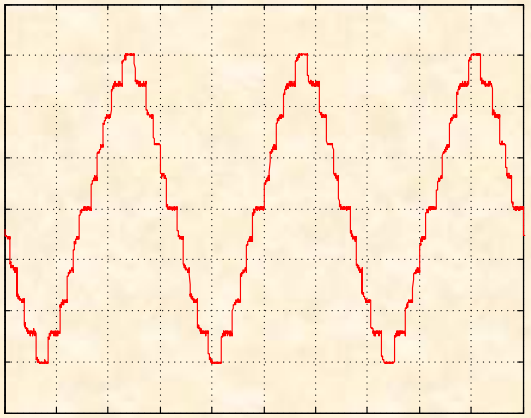
Output Voltage Waveforms

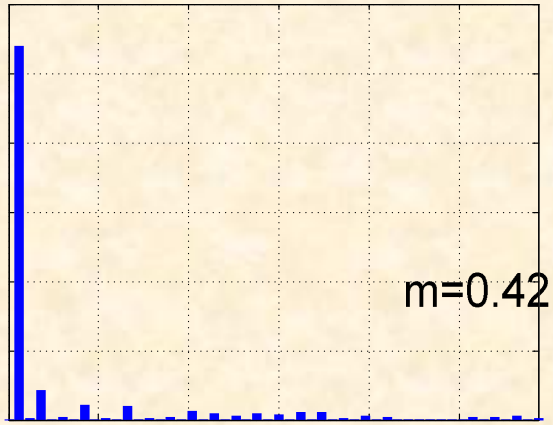
7-level output voltage waveform for low fuel cell load





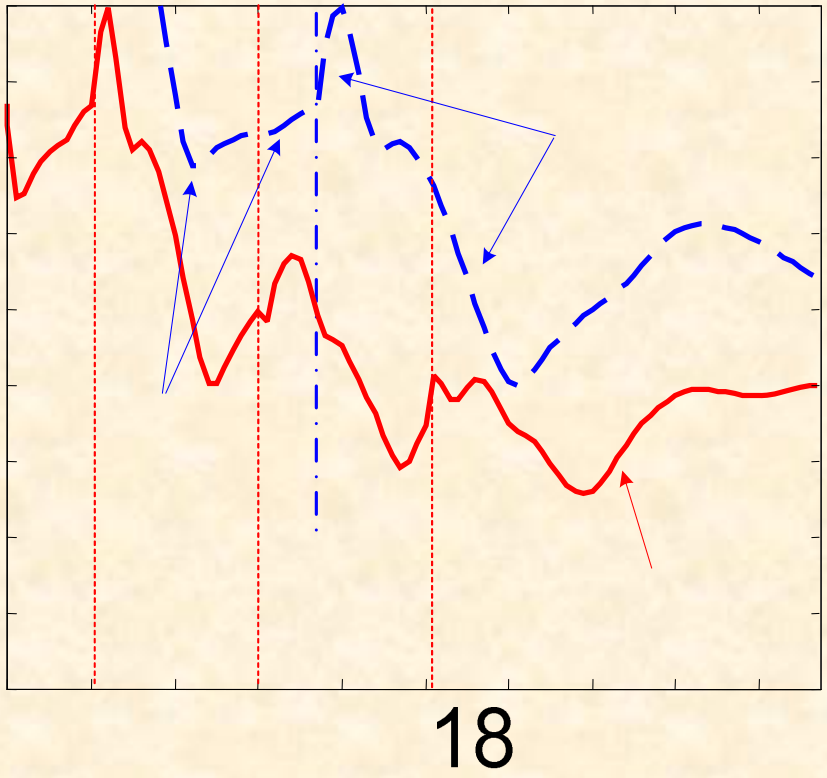
11-level output voltage waveform for high fuel cell load





Same peak fundamental voltage

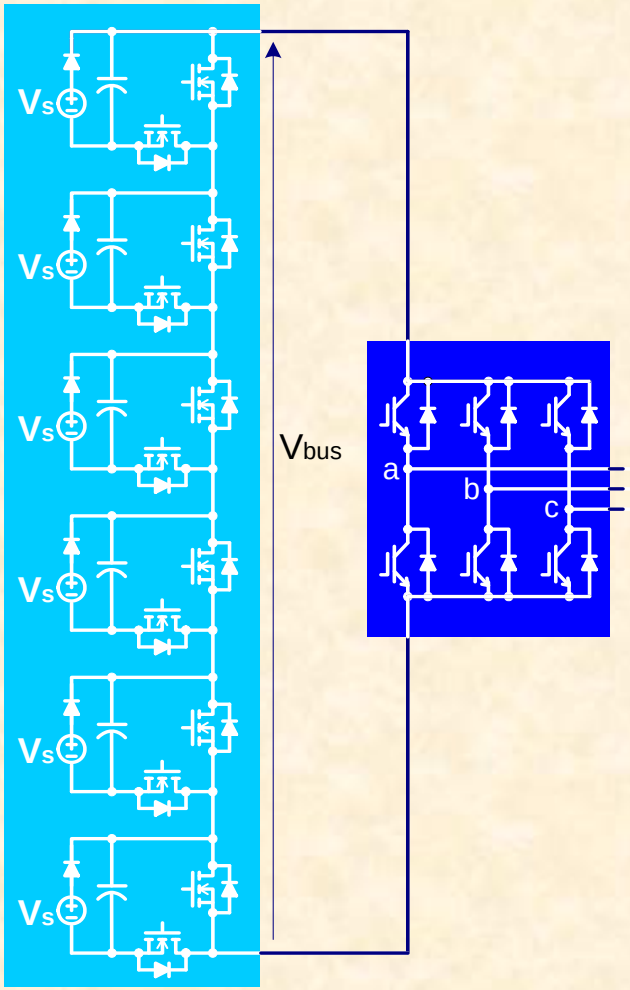
Total Harmonic Distortion



Total harmonic distortion of the output voltage with respect to the modulation index (up to 41st harmonic)

- **No filtering**
- **For lower total harmonic distortion**
  - **Multilevel PWM**
  - **Optimized switching angles**

Another Alternative CMLI



- **Vertical switch (S_{v1}) OFF**

  Horizontal switch (S_{v1}) ON

  ⇒Fuel cell supplies power

- **Vertical switch (S_{v1}) ON**

  Horizontal switch (S_{v1}) OFF

  ⇒Fuel cell inhibited

For More Information

http://www.ornl.gov/peemrc/
http://www.ntrc.gov/

http://www.ornl.gov/~webworks/cppr/y2001/rpt/121814.pdf

TRADE STUDY ON AGGREGATION OF MULTIPLE 10-KW SOLID OXIDE FUEL CELL POWER MODULES