5.3 Pulse Generation Methods for Multilevel Inverters with Reduced Switch

To control the inverter switches and generate the desired voltage levels, an efficient **pulse generation method** is required. These methods vary depending on the inverter topology but generally include modulation techniques that optimize switching performance. Here are the most commonly used pulse generation methods:

1. **Pulse Width Modulation (PWM)**

PWM is widely used in multilevel inverters to control the switching devices and synthesize the output voltage.

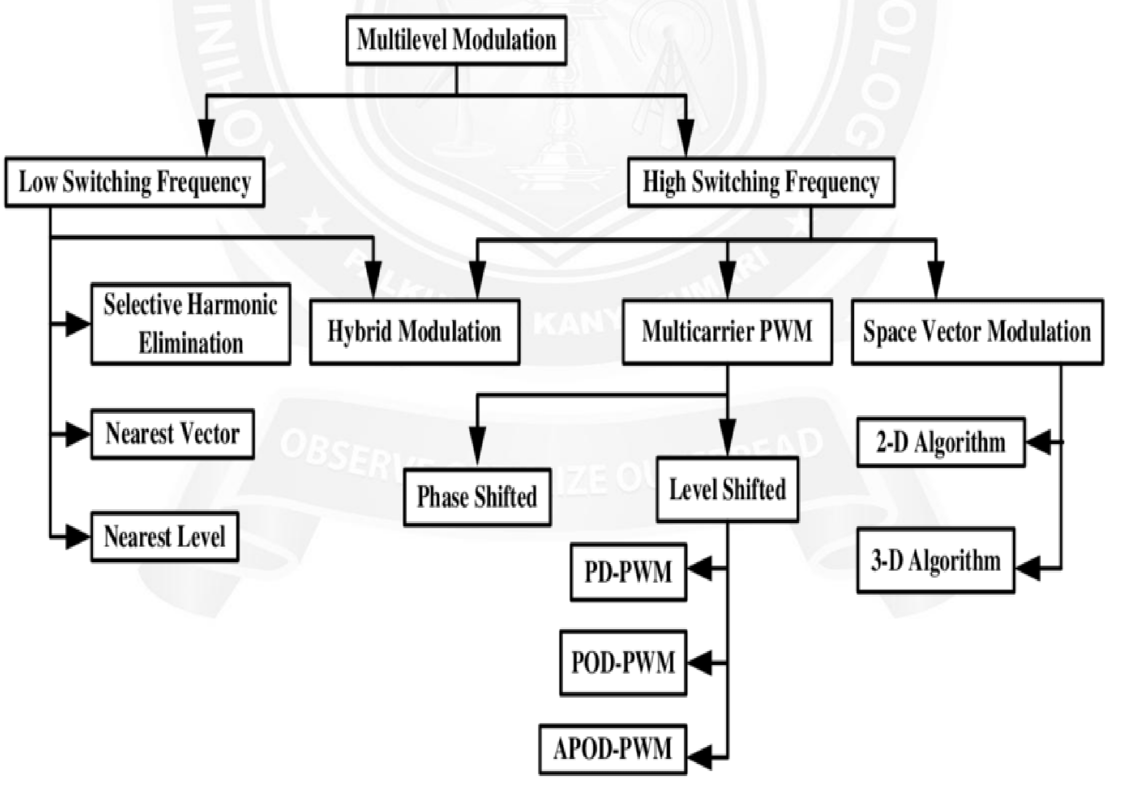

Figure 5.3.1 Multilevel inverters Modulation Methods

[Source: "Multilevel Converters for Industrial Applications" Page: 214]

- **Sinusoidal PWM (SPWM)**:
  - In SPWM, a sinusoidal reference signal is compared to a triangular carrier wave. The intersection points between the carrier and the reference signal determine the switching instances.
  - For MLIs, the reference sinusoidal wave is typically split into multiple phases, each controlling a specific set of switches in the inverter. By generating different PWM signals for each switch, the inverter can achieve multiple voltage levels.
  - **Reduced Switch Count**: By using **optimum modulation schemes**, the number of switches can be minimized for each level, with fewer harmonics and better voltage control.
- **Modified PWM**:
  - In some designs, modified PWM techniques can be used to reduce the switching losses and reduce the switch count by generating smoother transitions between levels.
  - This is achieved by altering the carrier signal or using multi-phase modulation techniques.

2. **Space Vector Pulse Width Modulation (SVPWM)**

SVPWM is another advanced modulation technique used for multilevel inverters, which minimizes harmonics and switching losses.

- **Principle**: In SVPWM, the voltage space vector is divided into sectors, and the reference voltage vector is synthesized by switching between various available voltage vectors in the sector.
- **Application to MLI**: For multilevel inverters, the concept of space vector modulation is extended, with multiple voltage vectors corresponding to different levels of the inverter. The voltage vectors are selected based on the desired output voltage.
- **Reduced Switch Count**: SVPWM allows for an optimized selection of voltage vectors, reducing the number of switches in the inverter without sacrificing performance.

3. **Carrier-Based PWM Techniques (Phase Shifted, Level Shifted)**

Carrier-based PWM techniques use triangular or sawtooth carrier signals, with the phase and/or level shifting applied to reduce harmonics and balance switching.

- **Phase-Shifted PWM (PS-PWM)**:
    - In this method, each carrier signal (used to control the switches) is shifted in phase relative to the others. This creates a smoother output voltage waveform and is particularly effective for **cascade H-bridge** multilevel inverters.
    - For reduced switch count, phase-shifting allows for better utilization of each switch and a reduction in the overall number of switching operations.

- **Level-Shifted PWM (LS-PWM)**:
  - In this method, each carrier signal is aligned with the reference signal, creating distinct voltage levels. This method can be used to generate multiple levels of output with reduced switching complexity.
  - A careful arrangement of the carriers and the phase-shift strategy ensures a reduced number of switches while achieving higher voltage levels.

4. **Selective Harmonic Elimination (SHE) PWM**

SHE PWM is an optimization technique aimed at eliminating specific harmonic components in the output waveform, usually in the lower order harmonics.

- **Principle**: The idea is to select switching angles that minimize specific harmonics, leading to a cleaner output voltage waveform. By choosing appropriate switching angles, higher voltage levels can be generated without increasing the switch count.
- **Application to MLI**: In a multilevel inverter, **selective harmonic elimination** can be used to suppress lower-order harmonics (such as the 5th, 7th, and 11th harmonics) and improve the waveform quality, reducing the required number of switches.

Conclusion:

The working principle of **multilevel inverters with reduced switch count** revolves around designing systems that can generate high-quality voltage waveforms with fewer components by optimizing switching strategies. Using **diodes, capacitors, H-bridge cells, and asymmetric voltage sources**, these inverters achieve multiple voltage levels without a significant increase in the number of switches.

Effective **pulse generation methods** such as **SPWM, SVPWM, Phase-Shifted PWM, and Selective Harmonic Elimination** are key to controlling the inverter switches, achieving the desired output voltage, and minimizing switching losses. Each method offers distinct advantages depending on the specific application, but the ultimate goal is to reduce the complexity of the system while maintaining performance.