EE 580 – Electric Machines and Drives System

Simulation of Single Unipolar Carrier Signal Based Space Vector (SV) PWM for Induction Motor Drive.

Submitted by,
Vigneshwaran.R,
Power Engineering,
M.Tech, 2nd year,
224102114.

Submitted to,
Dr. Ravindranath Adda,
Dept. of EEE
IIT Guwahati

Objective:

- To run an induction motor in carrier-based space vector modulated PWM technique.
- To use Unipolar carrier signal to operate an three level inverter to drive an induction motor.

Three-Phase Three-Level Neutral Point Clamped (NPC) Converter:

Three level converter gives more voltage level resulting in reduced harmonics in the output voltage waveform.

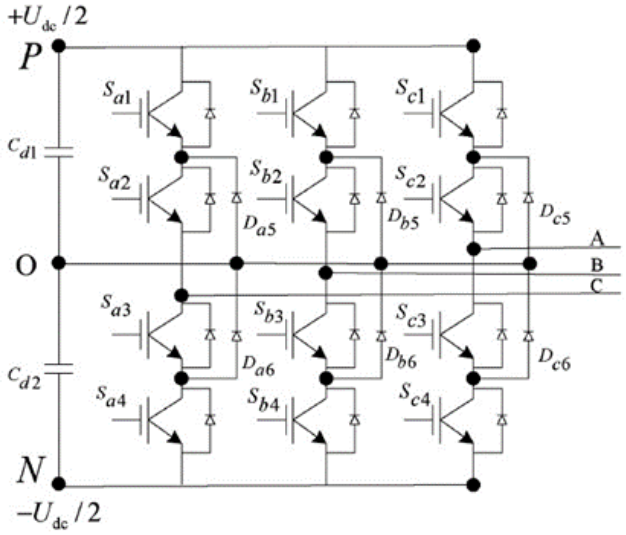

Figure 1- Three level NPC

It also leads to reduced voltage stress across the power diodes, which results in lower switching loss contributes to overall higher efficiency compared to two level converters. NPC topology helps in voltage balancing and reduces the risk of overvoltage conditions.

Space Vector Modulation:

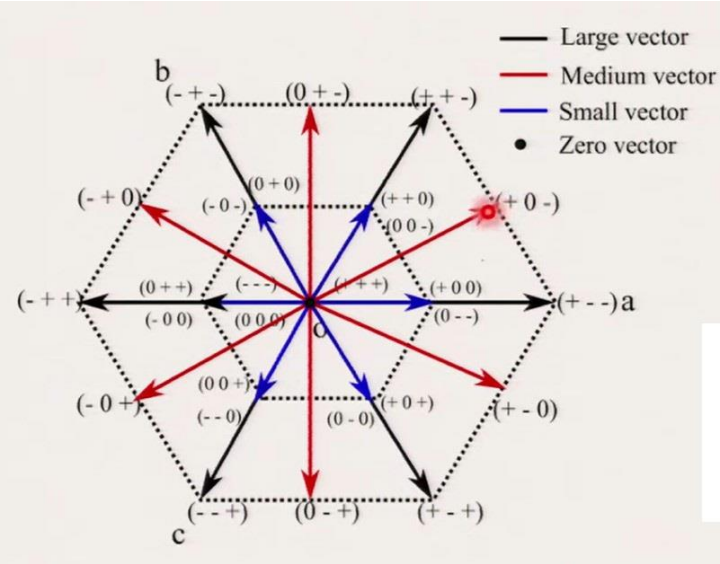

Figure 2 - Space Vector diagram

- Each leg has three states (+, 0 and -). So, for three legs total 27 states (3*3*3).
- It gives 27 vectors.
- 6 Large vectors (1 Multiplicity) = 2/3*V_d

- 6 Medium vectors (1 Multiplicity) = $(1/\sqrt{3})*V_d$
- 6 Small vectors (2 Multiplicity) = $(1/3)* V_d$
- Zero vector (3 Multiplicity) = 0.
- To generate a reference vector, nearby vectors are activated to a particular number of time and sequence. And both zero vectors are activated for equal amount of time for best harmonic performance.
- The small vectors are also termed as pivot vectors.

Pivot vectors and Switching regions:

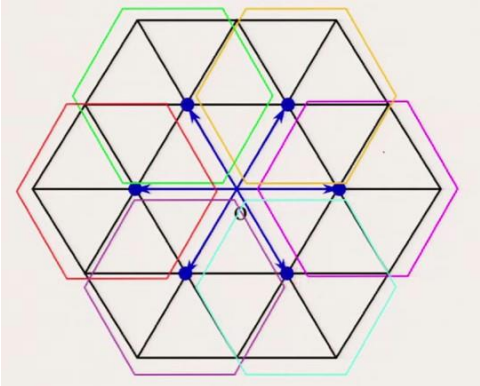

Figure 3 - Three level space vector diagram visualized as two level space vector diagram

Using this three level SV diagram can be visualized as two-level SV diagram. Each pivot vectors have a boundary. In two level inverters, starting and ending vectors are zero vectors. But in three level inverters, starting and ending vectors are pivot vectors (small vectors).

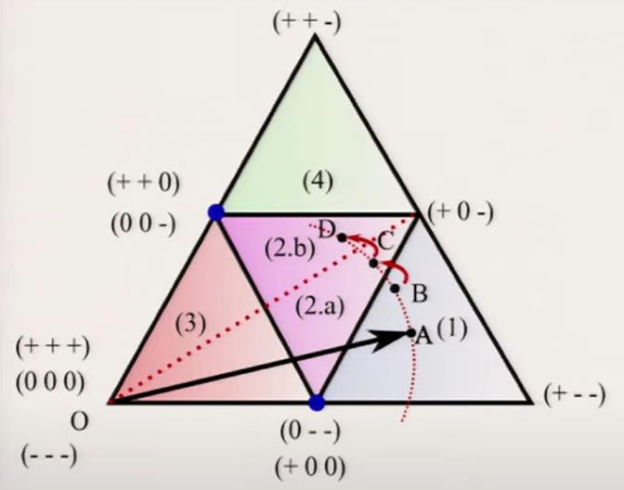

Figure 4 - Switching region determination

Which pivot vectors to choose determined by the boundary region. And a additional switching is done to change this pivot vectors. Timings to switch each vector is determined by the volt sec balance. This selection of region and timing calculation is a tedious process.

Carrier based Space Vector modulation:

Switching sequence of Space Vector PWM and sine PWM is almost similar. But, the only difference is zero switching state in sin PWM is uneven and in SV PWM, zero switching state is even.

The zero vector “000” can be more than “111” vector and vice versa. Whereas, in SV PWM both vector are switched for same period of time.

If the zero switching states in sine PWM is made even then it is similar to SV PWM. This can be achieved by injecting a common mode voltage to the reference signal.

$$V_{Common} = \frac{(V_{max} + V_{min})}{2}$$

Equ-1

This common mode voltage is achieved by the MATLAB/SIMULINK logic. This common mode voltage is given as offset to three voltages.

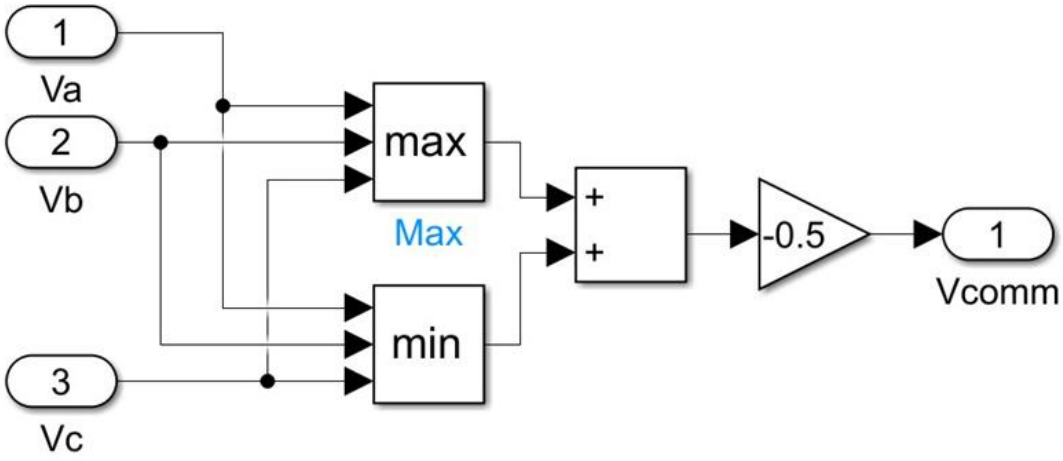

Figure 5 - Simulink logic to create offset

Carrier based Space Vector modulation after adding offset.

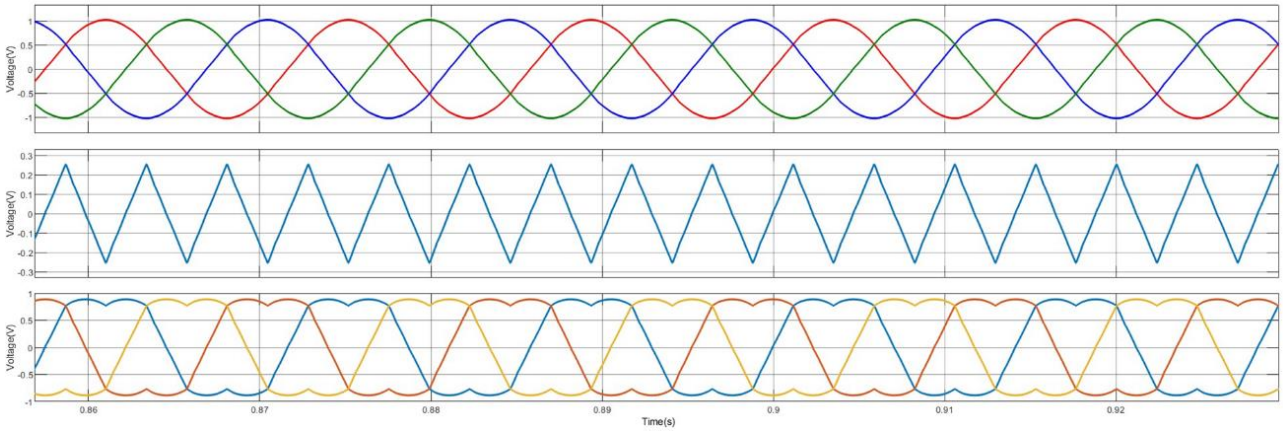

Figure 6 - Reference signal after adding offset

It can be noted, with addition of common mode voltage amplitude of the reference signal is reduced of 15% but still gives same voltage magnitude as sin PWM. So, we can increase it upto 15% more modulation. Effectively, SV-PWM modulation is 1.15 times more than sin PWM.

To operate the three-level inverter by this reference signal, two carrier signal is required. One for the positive side and other for the negative side. Development of high frequency carrier signal and

level shifting it requires an additional circuit. So, the reference signal to modified such that only one carrier signal is required.

After modifying reference signal for single carrier wave.

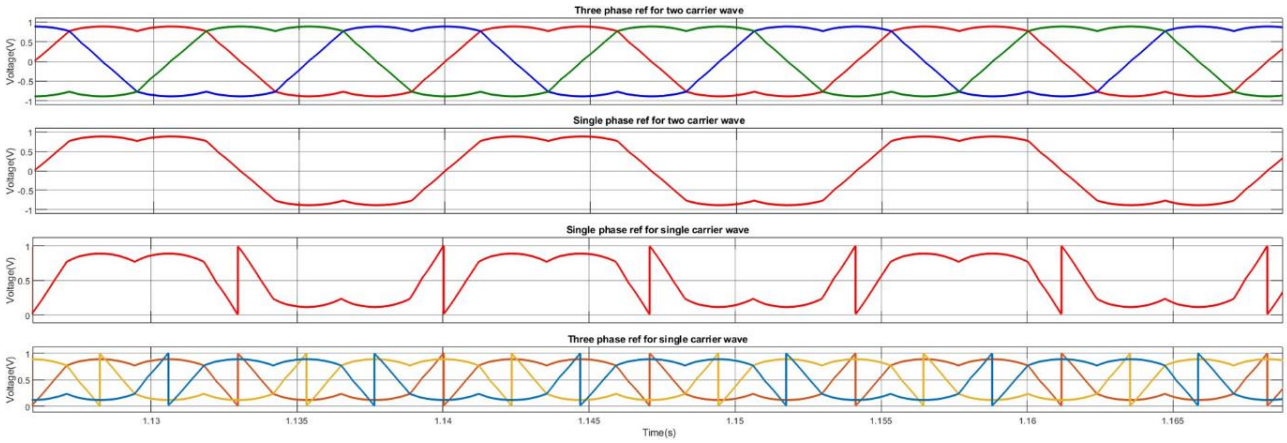

Figure 7 - After modifying ref signal for single carrier signal

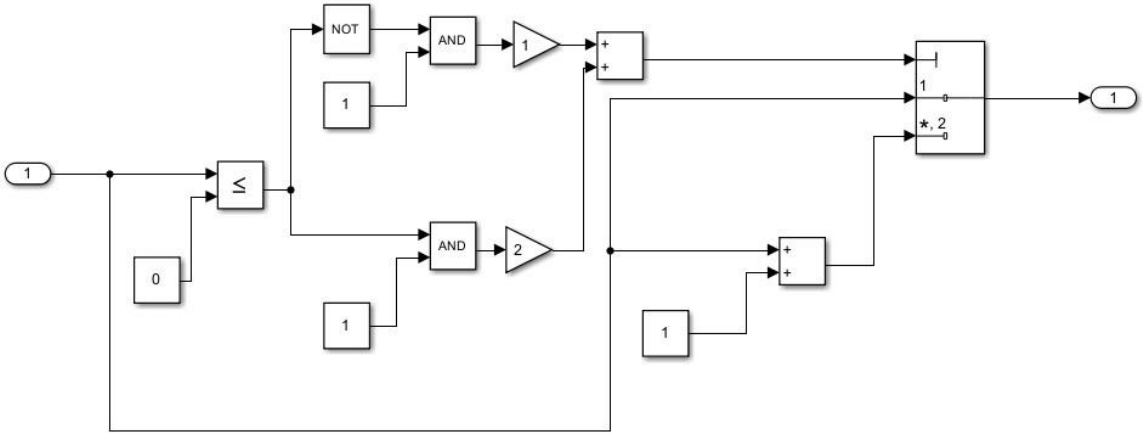

Figure 8 - Simulink logic to modify ref signal for single carrier signal

But now since the zero-switching vector won't have same switching time we again have to add another common mode offset to the reference wave. So, now we again have to add the equation again from eq.1.

After adding second offset for single carrier wave equal zero switching vector.

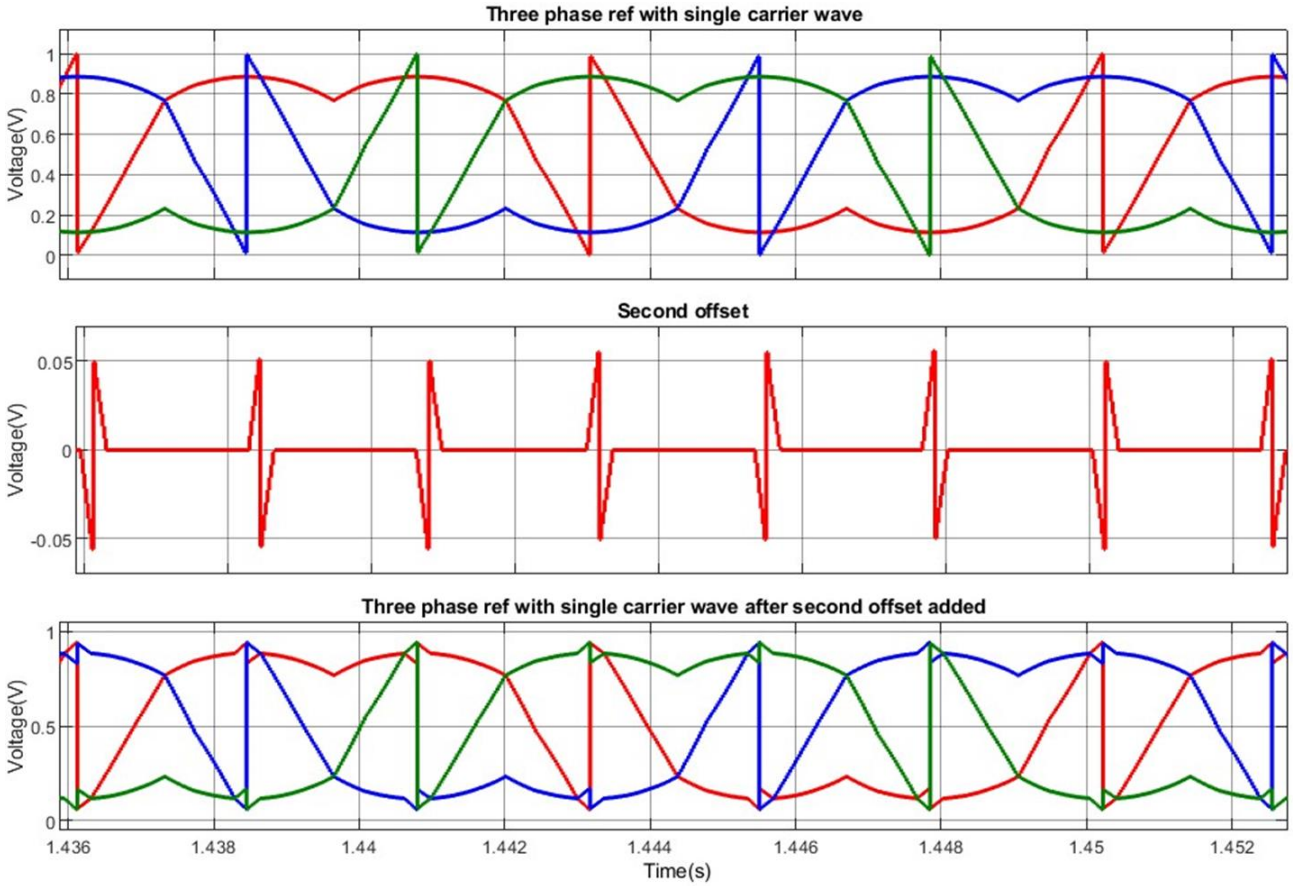

Figure 9 - Final wave form for unipolar carrier signal

By using this reference signal, three level NPC inverter is operated. Output voltage of the inverter is applied to the inputs of the induction motor to run the motor and the results are observed.

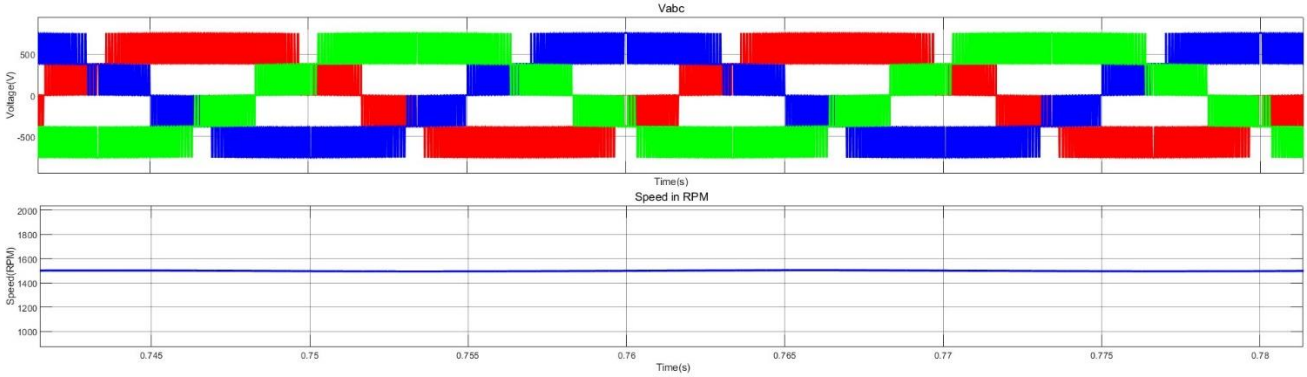

Figure 10 - Output voltage of inverter and motor speed

Conclusion:

By using the three-level inverter, the ripple in the induction motor is reduced. And by using the unipolar carrier signal strategy, hardware implementation of the control strategy can be made simpler.