International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 3602–3610

# New Five-Level Active-Neutral-Point- Clamped-Converter with Cost Reduction for Medium Voltage Applications

P. Mahamood khan[1], M. Madhavi[2], Sk. Mabu Subhani[3], A. Sai Anusha[4]

*[1]Assistant professor, Dept. of EEE, VVIT College, Nambur, Guntur (Dt), AP, India,*
*pathanmehemudkhan@vvit.net*
*[2]PG Scholar, Dept. of EEE, VVIT College, Nambur, Guntur (Dt), AP, India,*
*modukuru.madhavi@gmail.com*
*[3]Assistant professor, Dept. of EEE, VVIT College, Nambur, Guntur (Dt), AP, India,*
*mabusubhani.2b5@gmail.com*
*[4]Assistant professor, Dept. of EEE, VVIT College, Nambur, Guntur (Dt), AP, India,*
*saianushaalla@vvit.net*

***ABSTRACT***

*Multilevel converters are a notable answer for different power applications, including sustainable power source transformation. 5- level active-neutral- point- clamped- converter (5L-ANPCC) is among the most favourable position topologies one of 5- level multilevel inverters. A novel 6-switch 5L-ANPCC (6S-5L-ANPCC) multilevel inverter is suggested, which can accomplish little cost since some high-speed recovery diodes are attempting to supplant the diode and dynamic switches. The wattless power operation is proposed by special modulation strategy. In this paper simulation is carried out in MATLAB/Simulink, the suggested model 6S-5L-ANPCC is best fit for application where power factor unity is applicable such as solar cell.*

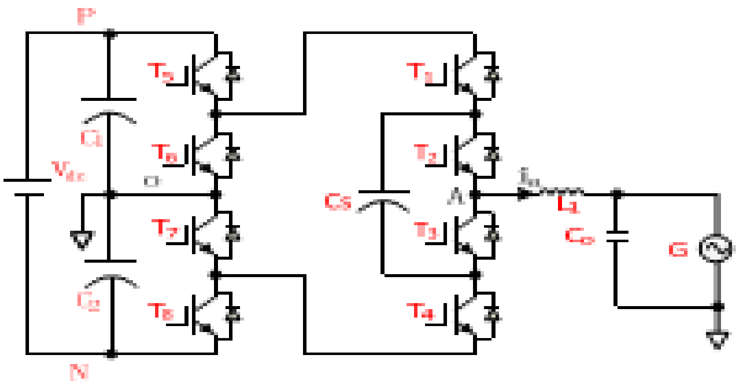
***Index Terms –*** *Flying-capacitor (FC), Neutral Point Clamped (NPC), Cascaded H-Bridge (CHB), 5-Level Active-Neutral-Point-Clamped- Converter (5L-ANPCC)*

## I. INTRODUCTION

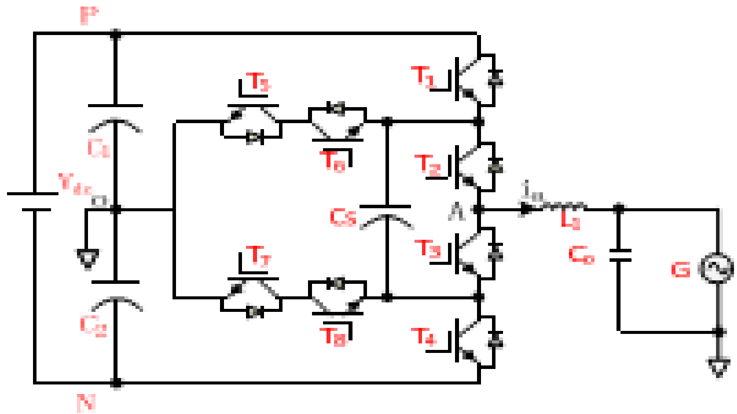
Multilevel inverters or converters are widely used in industrial medium voltages to minimize the switching losses, switch voltage stress, and electromagnetic interference. Multilevel inverters have many advantages such as higher efficiency; size of filter is small when compared to 2-level VSI (Voltage source inverter).

In multilevel topologies generally there are 3-traditional topologies exists, they are flying-capacitor (FC) multilevel inverter, neutral point clamped (NPC) multilevel inverter, and cascaded H-bridge (CHB) multilevel inverter. The trouble for controlling in a NPC multilevel inverter is the capacitor voltage across dc-bus. The NPC multilevel inverter develops the different voltage levels with respect to the neutral voltage by endorse diodes. The main drawback in NPC multilevel inverter is when voltage level is increased then switching devices number must be increased. To control the voltage across the capacitors, the FC topology requires some repetitive exchanging states. The control methodology gets convoluted furthermore; if the voltage level is increased then more number of capacitors is magnify. A combination of single dc voltage source with H- bridge cells gives the CHB multilevel inverter. Additionally, to possess new output levels, new cells are necessary. This will prompt difficulty for this kind of topology because extra DC sources are needed then cost will be high.

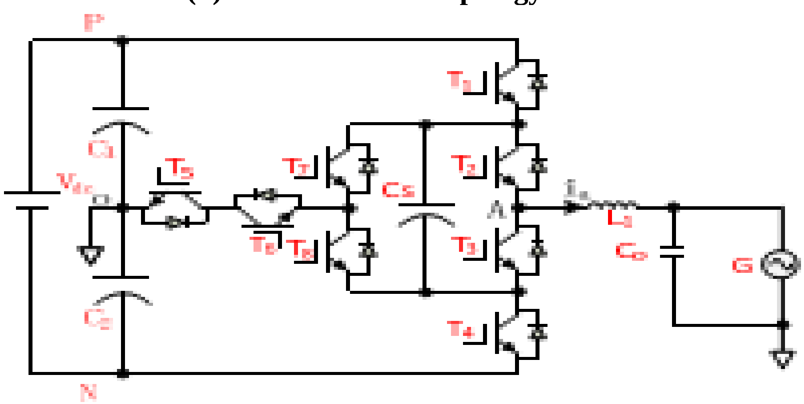
Three different types five-level Active-neutral-point-clamped-converter (ANPCC) is shown in figure.1. The ANPCC consolidates the highlights of FC and NPC multilevel inverters. The ANPCC topologies are accepting to ever increasing extent considerations these days in view of higher efficiency and more level outputs. A novel 6-switch 5L-ANPCC (6S-5L-ANPCC) multilevel inverter is proposed in this paper. The topology which is proposing receives just 6 dynamic semiconductor switches, extraordinarily lessening the size of circuit. This paper is sorted out as 5 different sections: II Section portrays working standards of proposed topology; III Section talks about the adjustment procedure of 6S-5L-ANPCC; IV Section appears the simulation and V Section shows the conclusion.




**(i) 1st ANPCC topology**




**(ii) 2nd ANPCC topology**




**(iii) 3rd ANPCC topology**

**Figure.1. 5-level ANPCC (5L-ANPCC) topology**

## II. Portrays working standards of proposed 6-Switch 5L-ANPCC (6S-5L-ANPCC)

### A. Introduction of 6-Switch 5L-ANPCC (6S-5L-ANPCC)

The 5 level-ANPCC are best suited for power source transformation which can improve the efficiency and output waveforms. Furthermore, in light of half bridge, no leakage current exists in 5L-ANPCC. Hence, this is reasonable for the transformer less solar cell system. Configuration of 6- Switch 5L-ANPCC is shown in Figure 2. It consists of six switches (T1 to T6) and two diodes (DF1 to DF2) and one capacitor (Cs).

ISSN: 2233-7857 IJFGCN

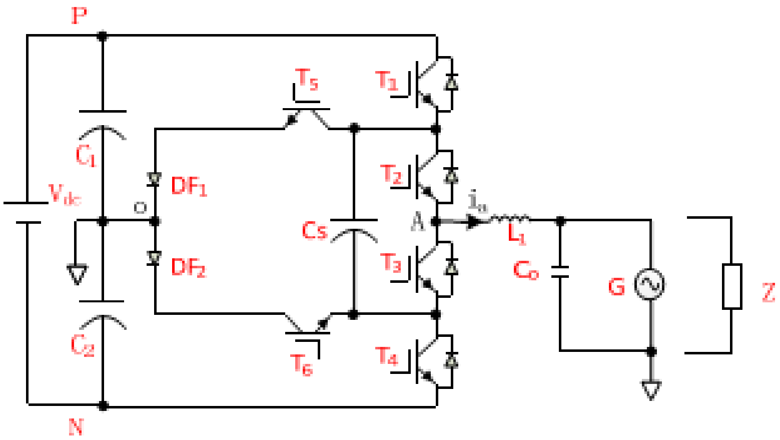



**Figure.2. Configuration of 6- Switch 5L-ANPCC**

From Figure 2, a DC source is connected in parallel to a series combination of 2 capacitors C1 and C2. In NFC and FC multilevel inverters which require 4 capacitors which are connected in series, the proposed scheme reduces the complication of capacitor voltage balancing. Furthermore, as opposed to customary 5L-ANPCC topology as shown in Figure 1, where it requires 8 switches and further type 5-level inverters need more switches, proposed 6S-5L-ANPCC has 2 diodes and 6 switches. 2 switches are reduced when compared to traditional method then wattless current also reduces. The wattless power operation is proposed by distinct modulation strategy in the accompanying segment which will be discussed.

### B. 6-Switch 5L-ANPCC (6S-5L-ANPCC) operation

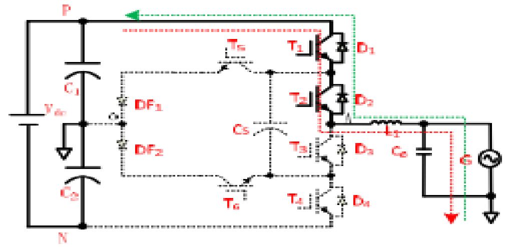
6S-5L-ANPCC contains 8 switching states which develop 5- level output voltage in view of voltage across capacitor as shown in table 1. Here +Vdc/2, +Vdc/4, 0, -Vdc/4 and –Vdc/2 are obtained which is 5 level output voltages. Figure 3 shows the individual 8 switching states from mode 1 to mode 8 and their current direction (wattless power in green colour and active power in red).

From Table 1, it is seen that certain output voltage levels are repetitive in nature for a portion of switching states; to produce +Vdc/2 excess switching states needed in mode 2 & mode 3; Also, (4,5) and (6, 7) are excess states to create 0 and - Vdc/2, individually. In spite of the fact that the repetitive states (2, 3) and (6, 7) create a similar voltage level at their output, their impact on the flying-capacitor voltage is inverse to one another because of the adjustment toward flying-capacitor current. This prompts the chance of controlling the flying-capacitor to a steady voltage of +Vdc/4.

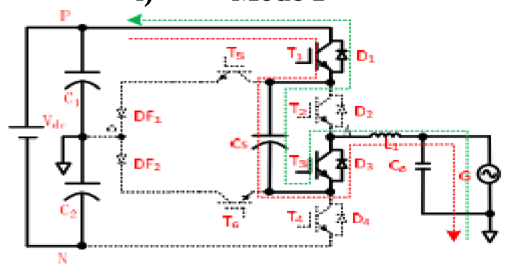
From Figure 3, it is clearly seen that amidst 8 switching states from that 4 modes (3, 4, 5, 6) permit one-way current flow way because of the existences of discrete diode. Along these lines, proper choice of exchanging states beneath wattless power activity is significant, which additionally builds the multifaceted nature of modulation. Thus, the suggested 6S-5LANPCC is reasonable for real power supplication (for example PV Grid-connected system). The accompanying segment will enclose the particular modulation scheme for suggested topology.

| Switching state | Switch number | | | | | | Output voltage VAo | Flying capacitor CS | |
|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | | *ia>0* | *ia<0* |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | +Vdc/2 | -- | -- |
| 2 | 1 | 0 | 1 | 0 | 0 | 1 | +Vdc/4 | Charge | Discharge |
| 3 | 0 | 1 | 0 | 0 | 0 | 1 | +Vdc/4 | Discharge | Charge |
| 4 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | -- | -- |
| 5 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | -- | -- |
| 6 | 0 | 0 | 1 | 0 | 1 | 0 | -Vdc/4 | Discharge | Charge |
| 7 | 0 | 1 | 0 | 1 | 1 | 0 | -Vdc/4 | Charge | Discharge |
| 8 | 0 | 0 | 1 | 1 | 1 | 0 | -Vdc/2 | -- | -- |

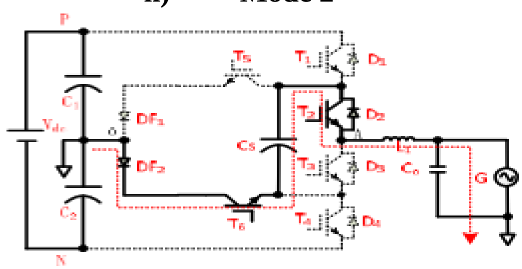
**Table -1: 6S-5L-ANPCC output voltage VAo with different Switching staes**



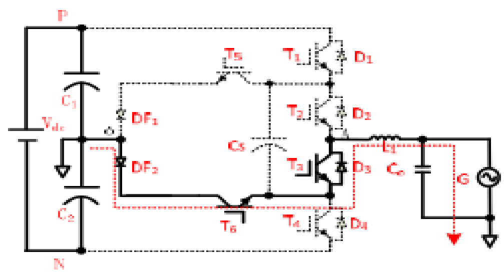
**i) Mode 1**



**ii) Mode 2**

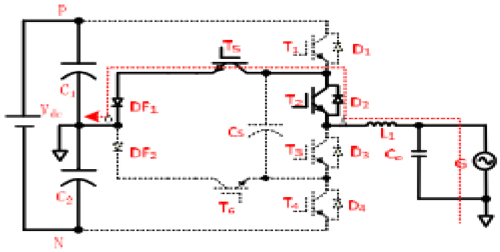


**iii) Mode 3**

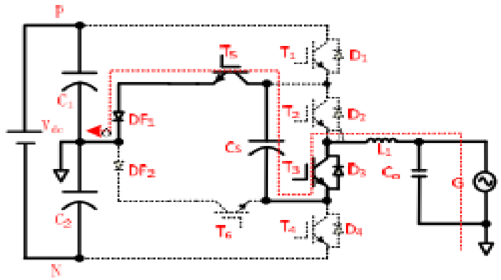


**iv) Mode 4**

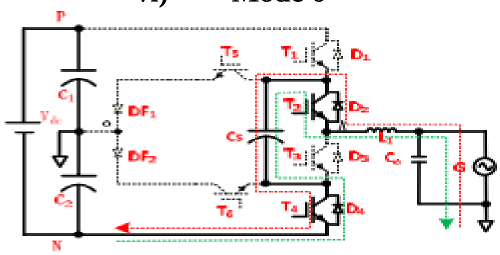
ISSN: 2233-7857 IJFGCN



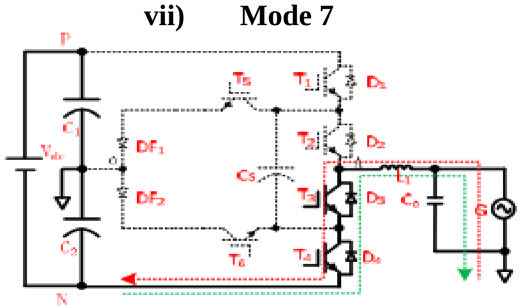

**v) Mode 5**




**vi) Mode 6**




**vii) Mode 7**




**viii) Mode 8**

**Figure.3. Current direction for 6S-5L-ANPCC in 8- Switching modes**

## III. Section talks about the adjustment procedure of 6S-5L-ANPCC

It is clear from Figure 3, 4 switching modes permit one-way current path because of the reception of quick recovery diode. Along these lines, the modulation technique for 6S5L-ANPCC is not the same as conventional ANPC topology.

Choice of output voltage at zero level: here in both modes (4& 5) has zero level output have a place with one-way current direction expresses: in mode 4 the current can just spill out of left to right (+ve) while mode 5 permits just -ve current. So decision of output voltage at zero level depends on the course of current direction at output.

Out of 2 sets of repetitive exchanging states where yield +Vdc /2 level, here mode 3 (+Vdc/2) and mode 6 (-Vdc/2) permit one-way current-flow way. These 2 states must be utilized while output current and voltage are corresponging way. In this manner, when considering power factor condition, we can just utilize mode 2 (+Vdc/2) and mode 5 (-Vdc/2) to accomplish +Vdc/2 output level for different voltages and directions of current flow.

Thus, for low power factor which prompts vast locale of output voltage & current inverse way, a huge FC voltage wave will be created. For this situation, an enormous benefit of FC is chosen to lessen the voltage swell.

From the examination above, it is inferred that the multifaceted nature of adjustment is expanded when converter is working beneath wattless power position. Hence, just wattless power operation is talked about. Figure 4 shows the operation for 6S-5L-ANPCC when pf is 0.866.

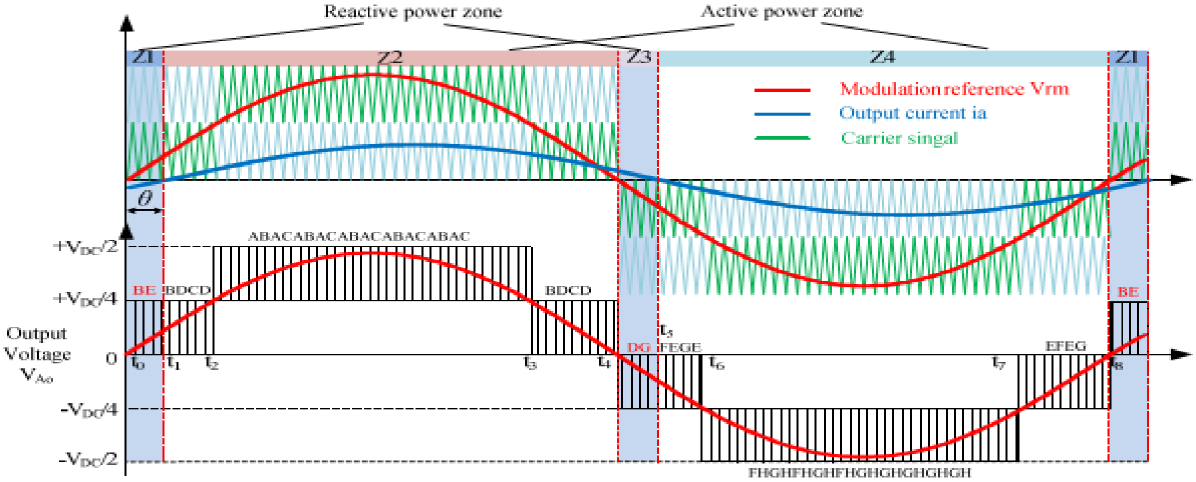



**Figure.4. 6S-5L-ANPCC when power factor is 0.866 using PWM modulation**

From Figure 4, it very well may be seen that during an entire network cycle, there are 4 zones as indicated by just like the output voltage & current are identical way: Z2 & Z4 are real power while Z1 & Z3 are wattless power zones.

As referenced previously, the determination of 2 excess switching states produce zero level output depends on the heading the current at output. While from t1 → t5, the current is +ve& mode 4 is picked. Correspondingly, from t0 → t1 and t5→t8, mode 5 is chosen due to -ve current at output.

Zone Z1 (t0→t1): inverter is yielding 0 and +Vdc/4. In this district, just mode 2 can be utilized to create +Vdc/4 at output since current & voltage are inverse way. For zero level output state, mode 5 is chosen due to -ve current at output. In this way, (2, 5) states blend is acquired.

Zone Z2 (t1→ t2 & t3→ t4): the output voltage is exchanged among 0 and +Vdc/4. Since it is in the real power zone, 2 repetitive +Vdc/4 states feasible utilized. This offers a chance to direct the voltage over FC. At the point while real flying-capacitor voltage is lesser than source flying-capacitor voltage, exchanging state 2 is picked; while more prominent than source flying-capacitor voltage, mode 3 is chosen to release FC. When zero output level, mode 4 is picked. Thus, the exchanging state arrangement of (2, 4, 3, 4) is accomplished.

(t2→t3): the voltage at output is changed from +Vdc/4 to +Vdc/2 level. Mode 1 is necessary to produce +Vdc/2 voltage at output. Additionally, in real power zone, suitable choice of repetitive exchanging states (2, 3) is essential. Thusly, succession of (2, 1, 3, 1) ensures FC voltage adjusting & converter output.

Zone Z3 (t4→t5): current is -ve, appropriately mode 4 is expected to 0-level. Mode 7 is chosen to create -Vdc/4 voltage at output. In this area, exchanging states arrangement (4, 7) is procured.

Zone Z4 (t5 → t8): like Z2 zone, mode 4 & mode 8 exist chosen for 0 and -Vdc/2 yield levels. While yielding -Vdc/4 voltage levels, excess exchanging states (6, 7) are utilized on the other hand to keep flying-capacitor adjusted. Thus, during t5→t6 and t7→t8, exchanging state arrangement (6, 5, 7, 5) is accomplished; from t6→t7, exchanging state arrangement (6, 8, 7, 8) is received.

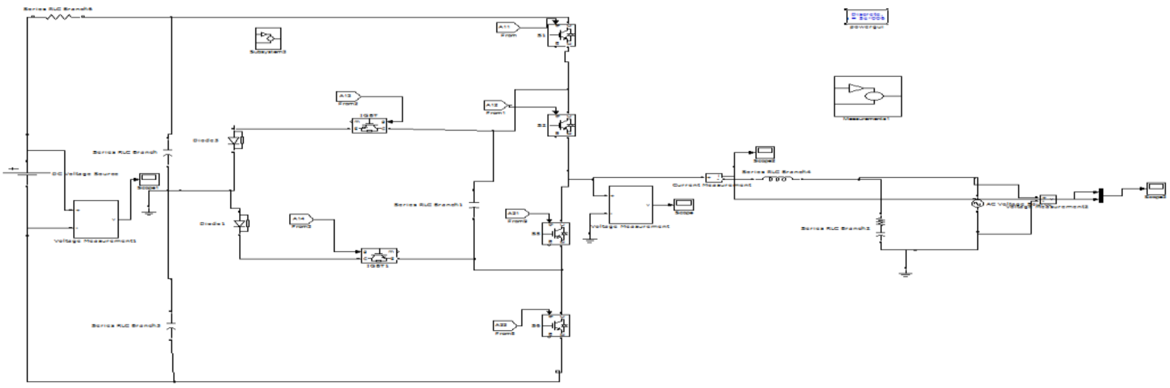
## IV. Simulation Results

So as to affirm the adequacy of regulation system particularly beneath wattles power situation, simulation results confirmation onetime completed utilizing MATLAB. The suggested system has been simulated with 2 cases: UPF condition and wattless power case. A 500W load is connected at output of inverter when simulation is carried out. Table 2 shows the system parameters for the proposed system.

| | | | |
|---|---|---|---|
| **Input voltage** | 400V | **Grid voltage** | 110V |
| **DC capacitor** | 2000µF | **Grid Frequency** | 50Hz |
| **Flying capacitor** | 310 µF | **Output current** | 4.6A |
| **Output filter inductor** | 1.6mH | **Switching Frequency** | 15kHz |

**Table-2: System parameters**

**R-LOAD (Unity power factor condition)**



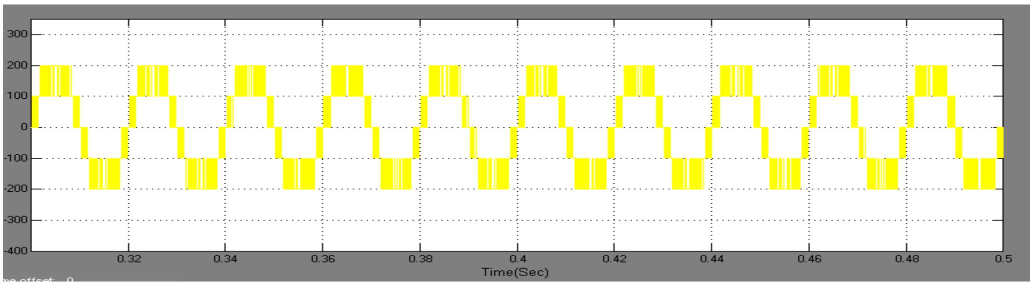



Figure.5. Waveform of inverter output voltage

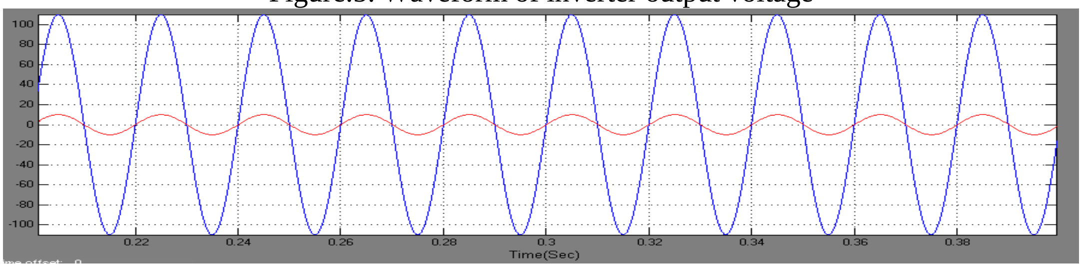
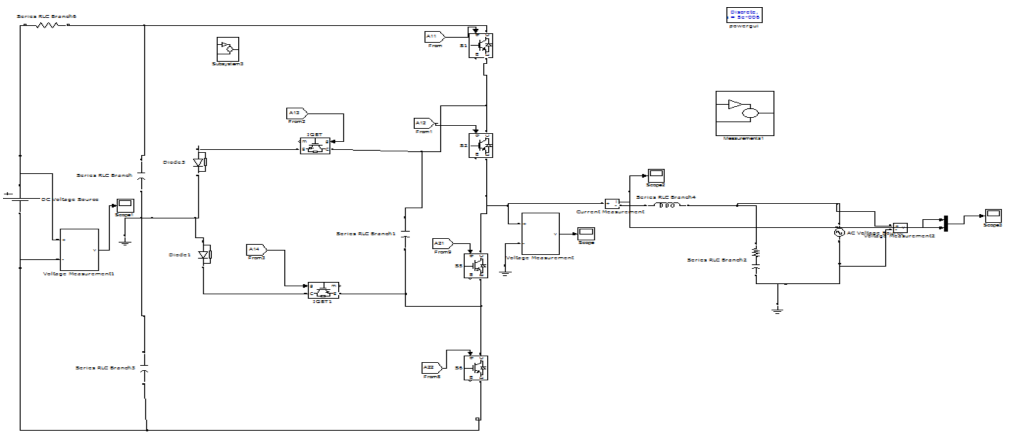



**Figure.6. Waveform of output current and grid voltage**

**RL-LOAD**



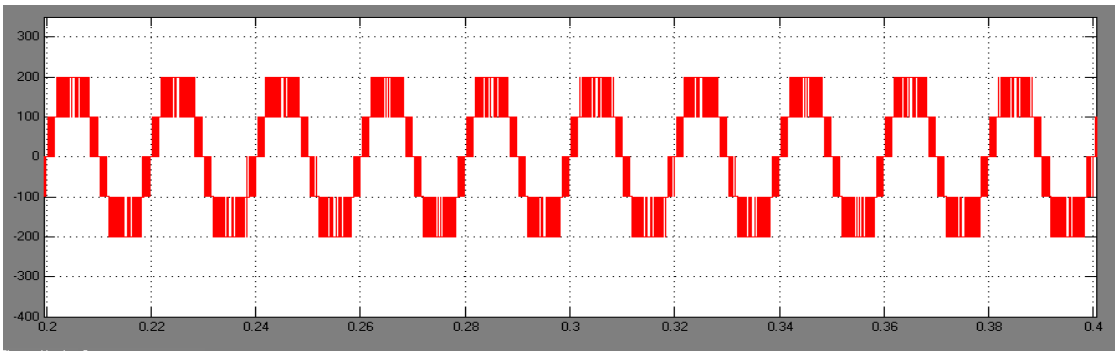



**Figure.7. Waveform of inverter output voltage**

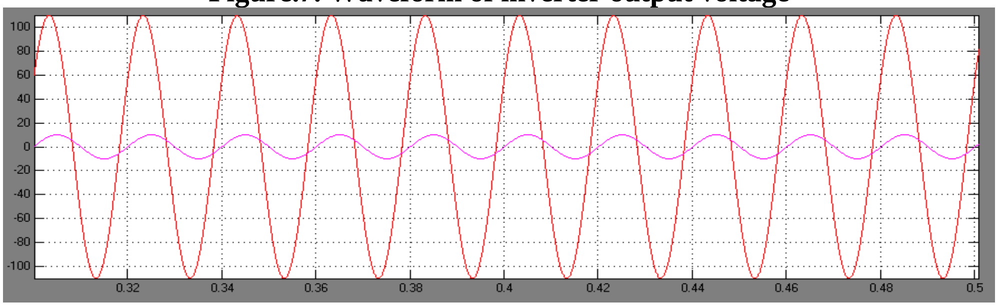



**Figure.8. Waveform of output current and grid voltage**

## V. Conclusion

An epic 6-switch 5-level flying-capacitor form ANPCC has been suggested. Contrasted with conventional 5-level ANPC inverters, it decreases 2 dynamic switches. The operating standards & exchanging states are introduced. The particular balance procedure of 6S-5L-ANPCC beneath wattless power condition onetime examined. Concern identified with the adjusting of FC voltage also, wattless power activity is talked about. The proposed system onetime simulated with 2 cases: UPF situation and wattless power case to illustrate the adequacy of suggested topology.

## REFERENCE

1. H. Wang, Y.-F. Liu, and P. C. Sen (2015)A neutral point clamped multilevel topology flow graph and space NPC multilevel topology. *Energy Conversion Congress and Exposition (ECCE), 2015 IEEE*: 3615-3621.
2. Soeiro.T.B, Carballo. R, Moia. J, Garcia. G. O, Heldwein. M. L (2013)Three-phase five-level active-neutral-point-clamped converters for medium voltage applications. *Power Electronics Conference*(COBEP), Brazilian: 85-91
3. K.Wang, Y.Li and Z. Zheng (2011) A neutral-point potential balancing algorithm for five-

level ANPC converters.*Proc. ICEMS*: 1-5.

4. L.A. Spepa, P.M. Brbosa, P.K. Steimer, and J. W. Kolar (2008) Five-Level virtual -flux direct power control for the active neutral-point clamped multilevel inverter. *Proc. IEEE PESC*: 1668-1674.
5. J. Rodriguez, S. Bernet, B. Wu, J. O. Pontt, and S. Kouro (2007) Multilevel voltage-source-converter topologies for industrial medium-voltage drives.*IEEE Trans. Ind. Electron., vol. 54, no. 6*: 2930-2945
6. Kouro. S, Malinowski. M, Gopakumar. K, Pou. J, Franquelo. L (2010) Recent Advances and Industrial Applications of Multilevel Converters. *IEEE Trans. Ind. Electron., vol. 57, no. 8:* 2553-2580
7. P.Barbosa, P. Steimer, J. Steinke, J. meysenc (2005)Active Neutral-pointclamped Multilevel Converter. *Power Electronics Specialists Conference. PESC'05*: 2296-2301.
8. T. Brückner, S. Bernet, and H. Güldner (2005) The active NPC converter and its loss-balancing control. *IEEE Trans. Ind. Electron., vol. 52, no. 3*: 855-868
9. J. Rodriguez, J. S. Lai, and F. Z. Peng (2002) Multilevel inverters: A survey of topologies, controls, and applications. *IEEE Trans. Ind. Electron. Vol. 49, no. 4*: 724-738
10. A. Nabae, I. Takahashi, and H. Akagi (1981) A new neutral-point clamped PWM inverter.*IEEE Trans. Ind. Applicant., vol. IA-17*: 518-523
11. P Hammond (1997) A New Approach to Enhance Power Quality for Medium Voltage AC Drives. *IEEE Trans. on Industry Applications, 33(1)*: 202-208.

ISSN: 2233-7857 IJFGCN