AN ADVANCED THREE PHASE VSI WITH 150^0 CONDUCTION MODE USING PIC16F72

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***ABSTRACT :** This paper presents a new modification and implementation for the most common, simple and well-known three-phase six insulated gate bipolar transistors (IGBTs) switch voltage source inverter (VSI). Via this strategy, each one of the six IGBTs conducts for 150^o instead of the known 180^o or 120^o conduction modes and this 150^0 conduction was get through using a PIC16F72 Microcontroller, resulting in a wye connected load, the output phase voltage becomes a seven-level, 12 steps waveform. In these 150^0 conduction-modes, controlling strategy is controlling very simply through the PIC16F72 Microcontroller and IGBTs. Hardware of three phase voltage source inverter in 150^0 conduction mode output voltages results was got same as a simulation results. So the using the new controlling strategy, this result a 50% reduction of the total harmonic distortion is obtained and simplicity of hardware compare to 180^0 and 120^0 conduction modes. Simulation and experimental results show the contribution of the proposed strategy. Simulation is done Mat-Lab and proutius simulator.*

KEYWORDS: Three phase voltage source inverter, Conduction Modes, PIC16F72 Microcontroller, IGBTs

I. INTRODUCTION

Inverters are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. For an inverter selection, various power topologies are there like VSI and CSI.[1] Also they are distinguishing like single phase, three phase, multilevel etc. Three phase inverter with different conduction mode (180^0 mode, 120^0 mode and 150^0 mode) is discussed. From this discussion comparison topics are achieved. Base on it, 150^0 conduction mode is selected for further work.[2]

New modification for the most common, simple and well-known three-phase six-switch voltage source inverter (VSI). In this modification, each one of the six transistors conducts for 150^0 instead of the known 180^0 or 120^0 conduction modes.[1] For a wye-connected load, the output phase voltage becomes a seven-level, 12 steps waveform. This result in a 50% reduction of the total harmonic distortion (THD), 75% reduction of voltage distortion factor (DF), and the lowest harmonic order (LOH) becomes 11 rather than 5. Comprehensive study for the three conduction modes is proposed, and a comparisons with other types of voltage source inverters, like the neutral point clamped (NPC) and the multilevel inverters (MLI) were also carried out. Simulation and experimental results show the contribution of the proposed strategy.[1] In a three phase VSI have a 150^0 Conduction Mode is more advanced as compare to 180^0 and 120^0.

The harmonic contents generated by power electronic devices have significant and detrimental effect on circuit output.[1] So, THD should be minimum for reliable operation of any circuit. THD is an important figure of merit for representing the characteristic of any circuit.[2] The comparative results of total harmonic distortion generated at the output for conduction period of switches in 120º conduction, 150º conduction and 180º conduction are present at the last with some another comparative issues.[2]

In IGBT based Inverter, we need to control the pulse of switching signal given to IGBTs of Hex-Bridge Module. This job can be done by PIC16F72 Microcontroller. Easily developed PWM pulses calculation of the PWM period and inbuilt analog-to-digital (A/D) converter module can have up to eight analog inputs for a device.

As shown in Fig. 1 connection diagram, DC supply for inverter is given by bridge module 35MT60 whose ac supply is taken through auto transformer (Variac) and required filter component. The auto transformer is used to apply variable ac voltage to rectifier unit for obtaining variable DC supply. This variable DC supply is used for open loop observation of three phase inverter. Three FGA25N120ANTD IGBTs is the main part of hex bridge. Three resistors of 1k1 connected in star is used as a load of three phase inverter.

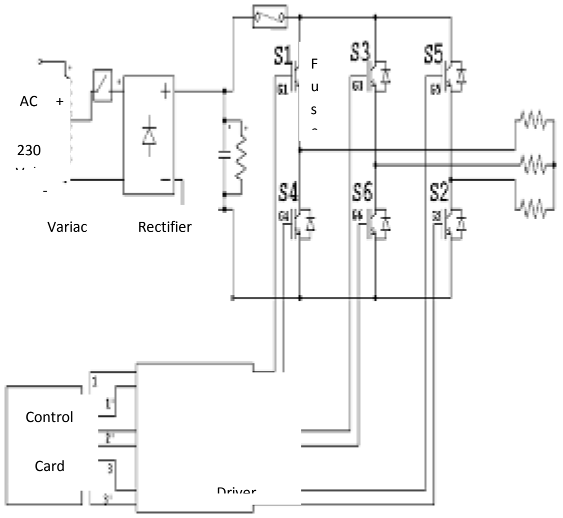

Figure 1. Wiring Diagram of 150^0 VSI

II. PIC16F72 MICROCONTROLLER

In IGBT based Inverter, we need to control the pulse of switching signal given to IGBT of Hex-Bridge Module. This job can be done by PIC 16F72 Microcontroller.

PWM Period

The PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following formula:

PWM Period = [(PR2) + 1] X 4 X TOSC X (TMR2 Prescaler Value) (1)

PWM frequency is defined as 1/ [PWM period]. When TMR2 is equal to PR2, the Following three events occur on the next increment cycle as shown in Fig. 2 and Fig. 3.

- TMR2 is cleared.
- The CCP1 pin is set (exception: if PWM duty cycle = 0%, the CCP1 pin will not be set). The PWM duty cycle is latched from CCPR1L into CCPR1H.

Setup for PWM Operation

The following steps should be taken when configuring the CCP module for PWM operation:

- Set the PWM period by writing to the PR2 register.
- Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON<5:4> bits.
- Make the CCP1 pin an output by clearing the TRISC<2> bit.
- Set the TMR2 prescaler value and enable Timer2 by writing to T2CON.
- Configure the CCP1 module for PWM operation.

ADC Module

The analog-to-digital (A/D) converter module can have up to eight analog inputs for a device. The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. This A/D conversion, of the analog input signal, results in a corresponding 10-bit digital number. The analog reference voltages (positive and negative supply) are software selectable to either the device's supply voltages (AVdd, AVss) or the voltage level on the AN3/VREF+ and AN2/VREF- pins. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode.

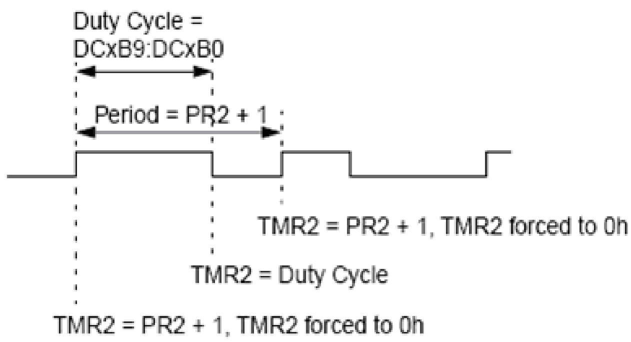

Figure 2. PWM Output Using PIC Controller

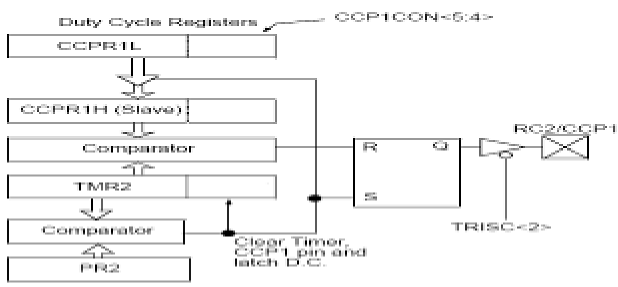

Figure 3. Simplified PWM Generator Block

The A/D module has four registers. These registers are:

_ A/D Result High Register (ADRESH)

_ A/D Result Low Register (ADRESL)
_ A/D Control Register0 (ADCON0)
_ A/D Control Register1 (ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The port pins can be configured as analog inputs (AN3 and AN2 can also be the voltage references) or as digital I/O.

III. DRIVER IC CHECK

The 6N137 is optically coupled gates that combine a GaAsP light emitting diode and an integrated high gain photo detector. An enable input allows the detector to be strobed. The output of the detector IC is an open collector Schottky clamped transistor. This unique design provides maximum ac and dc circuit isolation while achieving TTL compatibility. The optocoupler ac and dc operational parameters are guaranteed from -40°C to +85°C allowing trouble free system performance. The 6N137 is suitable for high speed logic interfacing, input/output buffering, as line receivers in environments that conventional line receivers cannot tolerate and are recommended for use in extremely high ground or induced noise environments.

Features

- 5 kV/ms Minimum Common Mode Rejection (CMR) at VCM = 50 V for HCPL-X601/X631, HCNW2601 and 10 kV/ms Minimum CMR at VCM = 1000 V.
- High Speed: 10 MBd Typical
- LSTTL/TTL Compatible
- Low Input Current Capability: 5 mA
- Guaranteed ac and dc Performance over Temperature: -40°C to +85°C
- Available in 8-Pin DIP, SOIC-8, Widebody Packages
- Strobable Output (Single Channel Products Only)
- MIL-STD-1772 Version Available (HCPL-56XX/66XX)

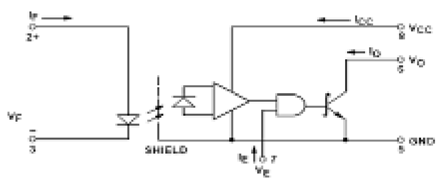

Figure 4. Internal Structure of Gate Driver IC

IV. EXPERIMENTAL RESULTS

Control Circuit Testing

The required 150 degree PWM gate pulses are generated by PIC16F72.This IC gives six PWM pulses. Using ADC channel of controller frequency of pulse will be varying to 50Hz to 1kHz.On 50 Hz switching frequency satisfactory results are achieved.

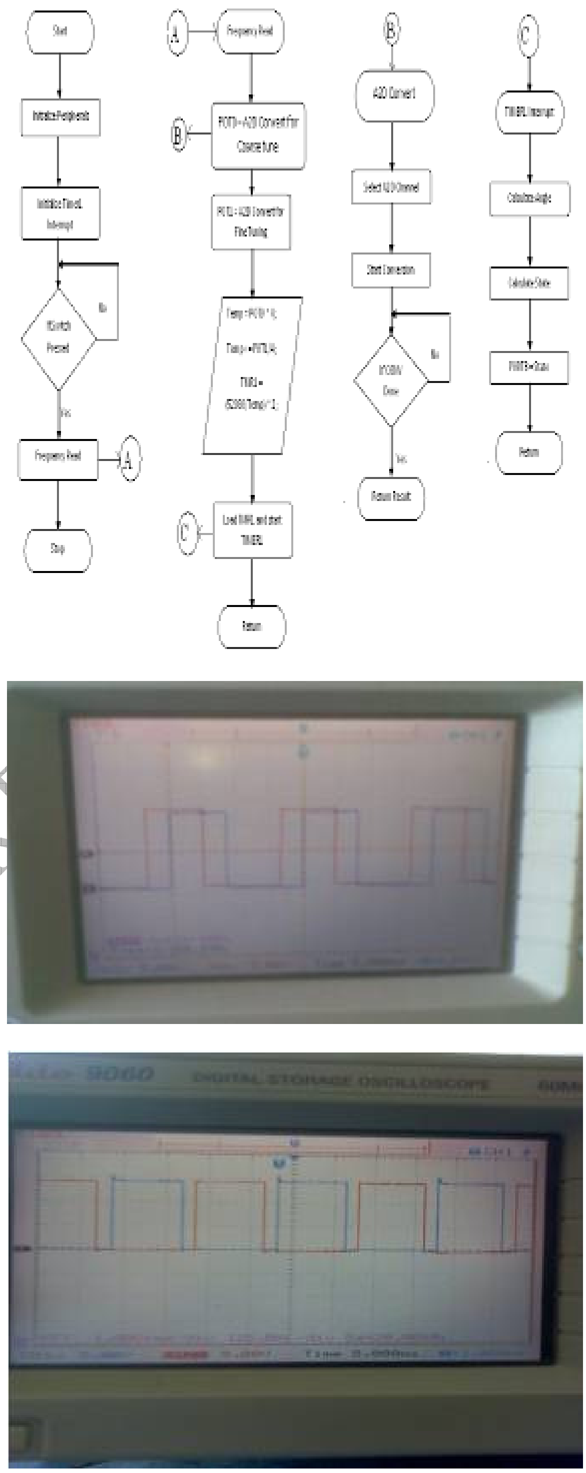

Figure 5. Control Circuit (a) Flow Chart of 150 degree Phase Shifted PWM using PIC16F72 (b) Gate Pulses with 60 degree Phase Shift (c) Complimentary gate pulse of G1 and G4

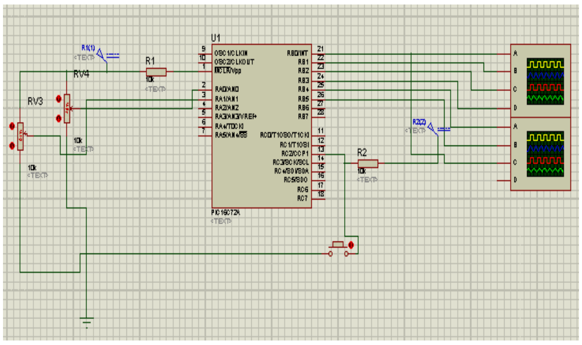

Figure 6. Controller Circuit for Inverter 150^0 conduction mode

Simulation of control circuit is done in Proteus Simulator. HI-TECH C Compiler is used for PIC MCUs also. It is a free-standing, optimizing ANSI C compiler. In addition, a number of graph objects can be placed on the schematic to enable conventional time, frequency and swept variable simulation to be performed. Schematic diagram of control card shown in Fig.5.20

Driver Circuit Testing

Driver circuit and isolated power supply for each gate pulse are shown in Fig. 7-8 show the generated gate pulse with 60 degree phase shifted. Driver circuit input and output waveform are shown in Fig. 9.

The output pulse of dead band circuit is given to the driver circuit having IC 6N137.There is a need for electrical isolation between the logic level control signal and driver circuit. This isolation is provided by optocoupler inside the driver IC. Different driver ICs for top and bottom IGBT are supplied with isolated power supply. The output of driver circuit is given to gate of IGBT through 10 ohm gate current limiting resistor, Test results shows the input and output of driver IC. We can observe the delay time and propagation time from the results. The test results prove that the delay time and propagation time of driver IC are same as given in its datasheet. The total response time given in datasheet is maximum 20 nsec. The result also gives 20 nsec response times which is less than maximum, Fig. 9 show the response time of Gate driver IC.

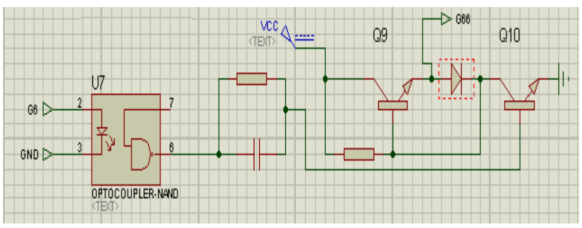

Figure 7. Driver Circuit for Inverter 150^0 conduction mode

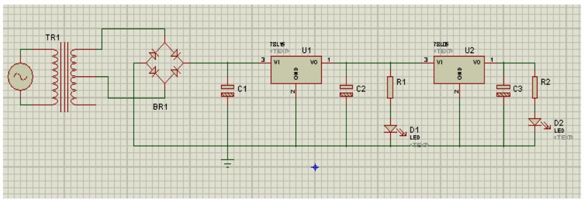

Figure 8. Isolated Power Supply for Driver circuit

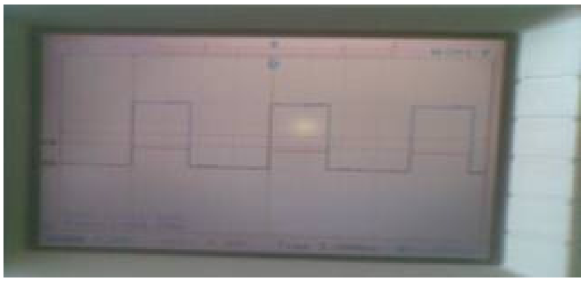

Figure 9. Driver circuit input and output waveform (Scale: x-axis: 5msec/div, y-axis: (ch-1:5V/div), (ch-2: 5V/div))

Line Voltage Output

Here twelve switching patterns are presented per cycle; with each pattern duration is 30^0. Three switches are conducting in one interval- as in 180^0 mode, while only two switch conduct in the next one as in 120^0 mode. Fig. 10 show simulated output voltage waveforms for wye-connected load.

The line-to-neutral voltage, show in (2) Van, is expressed in Fourier series, as:

$$V_{an\_150^0} = \sum_{n=1,3,5..}^{\infty} \frac{V_d}{6n\times\pi}\left[\begin{array}{l} 4+Cos\dfrac{n\pi}{6}+Cos\dfrac{n\pi}{3}-Cos\dfrac{2n\pi}{3}-2Cos\dfrac{5n\pi}{6} \\ -Cos\dfrac{7n\pi}{6}-Cos\dfrac{4n\pi}{3}+Cos\dfrac{5n\pi}{3}+2Cos\dfrac{11n\pi}{6} \end{array}\right] Sin\left(\omega t+\frac{\pi}{3}\right)$$

(2)

Each switch is continuously conducting for 150^0. The getting signals are shifted from each other by 60^0 to get three-phase balanced voltages. A 30^0 dead-time period is provided between two series switches conducting.THD of the output voltage is affected by the power factor and the conductive angle usually. Power factor of load cannot be determined by the designers, and conductive is a facility for designer. So the suitable conductive angle is selected considering high RMS and low THD of the output voltage.[10] The new conduction mode (150^0) for Three Phase Voltage Source Inverter has the results of experimental can be expressed as follows.

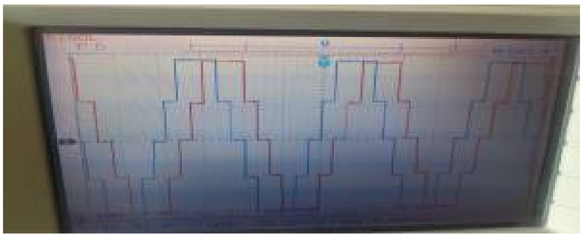

Figure 10. Line Voltage with 120 degree shifted waveform(Scale: x-axis: 5msec/div, y-axis: (ch-1:5V/div), (ch-2: 5V/div))(Scale: x-axis: 5msec/div, y-axis: (ch-1:50V/div), (ch-2: 50V/div))

Phase Voltage Output

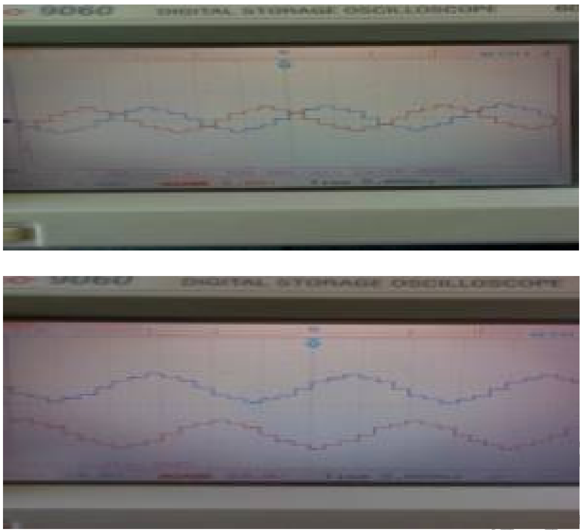

Figure 11. Phase Voltage with 120 degree shifted waveform(Scale: x-axis: 5msec/div, y-axis: (ch-1:5V/div), (ch-2: 5V/div))(Scale: x-axis: 5msec/div, y-axis: (ch-1:50V/div), (ch-2: 50V/div))

As shown in connection diagram, DC supply for inverter is given by bridge module 35MT60 whose ac supply is taken through auto transformer (Variac) and required filter component. The auto transformer is used to apply variable ac voltage to rectifier unit for obtaining variable DC supply. This variable DC supply is used for open loop observation of three phase inverter. Three FGA25N120ANTD IGBTs is the main part of hex bridge. Three resistors of 1.1kΩ connected in star is used as a load of three phase inverter.

So the when 1.1kΩ star connected load used for three phase voltage source inverter applied a 150^0 conduction mode pulse than the phase voltage was made as show in Fig. 11 (a) and (b), Three phase voltage source inverter in 150^0 conduction mode with a star-connected load, the output phase voltage becomes a seven-level, 12 steps waveform, compared to the known only four or three levels in 180^o and 120^0 conduction modes, respectively.

Comparison between Simulation and Hardware Result

Hardware results of generated gate pulses, driver circuit input-output waveform, line to line output voltage and phase voltage waveform are as same as simulated results. Fig. 12 to Fig. 15 are shows the Comparative Result for complimentary gate pulse, driver circuit input-output waveform, line to line output voltage waveform and phase voltage waveform.

When compared simulation and Hardware result for a gate pulse, driver circuit input-output waveform, line to line output voltage waveform and phase output voltage waveform all of same, and phase output voltage waveform was 7-levels and 12 steps they have near about sinusoidal waveforms so the total harmonics distortion was less or reduce a 50% in a three phase voltage source inverter through the 150^0 conduction mode as compare to the 180^0 and 120^0 conduction modes.

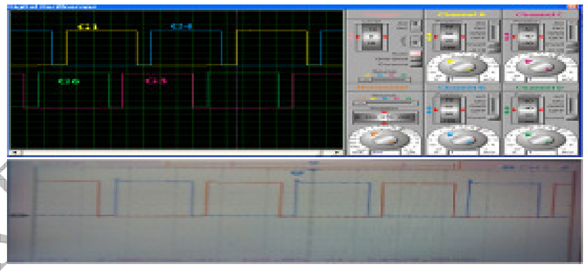

Figure 12. Comparative Result for Output Complimentary Gate pulse

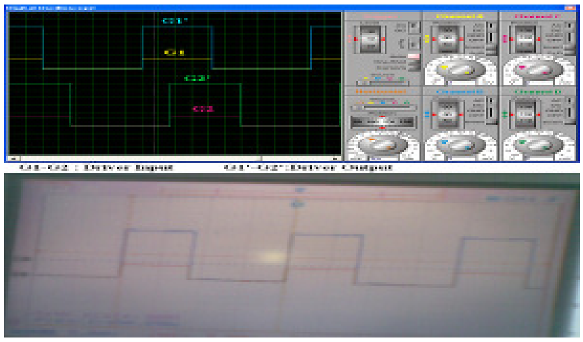

Figure 13. Comparative Result for Driver circuit input and output waveform

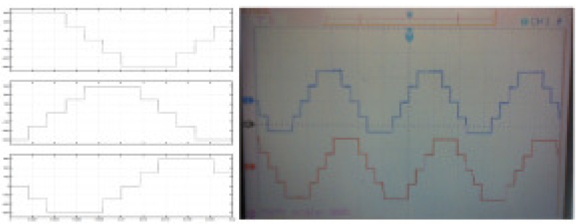

Figure 14. Comparative Result of Output Line voltage

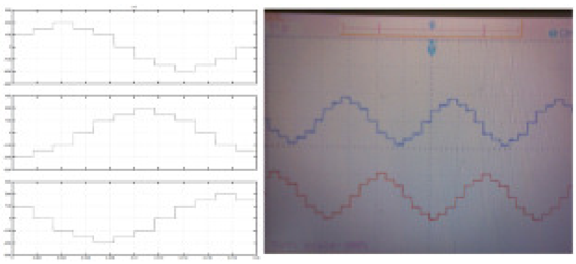

Figure 15. Comparative Result of Output Phase Voltage

V. CONCLUSION

Three phase voltage source inverter in 150^0 conduction mode using PIC16F72 Microcontroller controlling circuit with a star-connected load, the output phase voltage becomes a seven-level, 12 steps waveform, compared to the known only four or three levels in 180^o and 120^0 conduction modes, respectively. This result in a reduction of the total harmonic distortion, reduction of voltage distortion factor, and the lowest harmonic order becomes 11 rather than 5. Comprehensive study for the three conduction modes is proposed; the 150^0 inverter is advantageous and increases the RMS value of output voltages, total required VA ratings of the inverters reduced greatly over wide load conditions. By the comparative study and simulation of different conduction mode of three phase VSI , better performance is achieve in 150^0 mode without adding extra component. So, on the basis of simplicity, economy, easy to implement and less personates of total harmonics distortion at output side 150^0 is suitable topology.

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