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Modelling and Simulation of Three Phases to Seven Phases Transformer Connection

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Abstract—The main aim in this paper to build a three to seven phase AC multiphase transformers to converted into DC power through modelling and simulation. A new technique of pure seven-phase Sine-wave of fixed current/voltage and frequency is obtained now we have also used for R-L load and motor testing purposes. Here complete modelling has been simulated by using MATLAB Software. Multi-winding transformer block was taken from the sim-power system block library and turn ratios set in the dialog box then simulated. The whole modelling/design and simulation of the proposed work is presented in this paper. Seven phase transmission line system can be developed for the generation of bulk power transfer. As per need of the induction motor under a loaded condition is used for the viability of transformation system. In seven phase's, each phases shifted from the order by 51.42° (360°/7) and got the Sine-wave current/voltage. The novel scheme connection was expanded by using the modelling and simulation approach to prove the viability of the implementation and this type of transformer is required in aerospace engineering, railway engineering and automobile engineering applications.

Keywords— Multiphase system, Multiphase transmission line, Three-to-Seven phases, Multi-winding transformer

I. INTRODUCTION

The electric power from one circuit to another without changing a frequency and their mutual induction between two circuits linked by a common magnetic fluxes then this phenomenon is known as transformer [1]. It is an important element in the development of high-voltage electric power transmission line. It can be classified into various types viz. step up, step down and matching transformer [2]. Multiphase i.e. More than three phase systems are recently seen of their inherent advantage compared to the three phase counterparts. It has applicability of explored to electric power generation in multiphase systems [3-5] transmission [4-6] and utilization [7-8]. The research on seven-phase transmission line system was initiated due to the increasing a rising cost of right way for a transmission corridors, environmental program, and various stringent licensing laws [9]. Six-phase transmission lines can provide the same power capacity with a lower line voltage and smaller towers as compared to a standard double circuit three-phase line [4]. The dimension of the six-phase smaller towers may also lead to the reduction of magnetic fields and electromagnetic interference [9-10]. Generally no load test, blocked rotor and load tests are performed on a motor to determine its parameters [11-13].

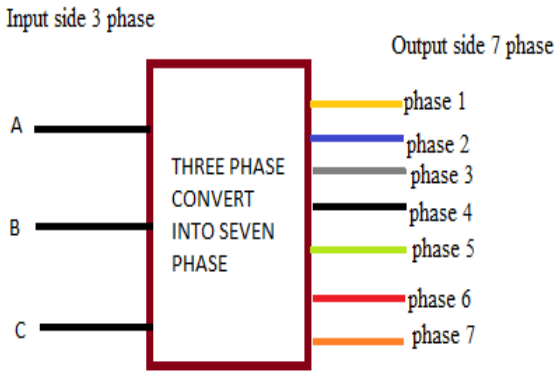


Fig. 1 Block diagram representation of the proposed system

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We know that multi-phase motors are invariably supplied by ac/dc/ac converters. The multiphase electric drive is limited for the modelling and controls the supply systems [14]. Our main objective is to develop static transformation system to change the phase number from three to seven (where n>3). Now we are generating a novel phase transformation system which convert three phase to a seven-phase supply [15]. In multiphase system six phases and twelve phases is found to produce fewer ripples with a high frequency in an AC-DC rectifier system. Thus six and twelve phase transformers are designed to feed a number of pulses rectifier system and technology has matured [13]. Now, twenty four phase and thirty six phase transformer systems have proposed for supplying a number of pulse rectifier systems [12-16]. These designs are also available for an odd number of phases, such as five, nine and eleven etc. In this paper we have proposed a special transformer connection scheme to get a seven-phase output supply from three-phase. The expected applications of the power transformer are the electric power transmission system and power electronic converters and the multiphase electric drive system. The block represented of the proposed system is shown in figure 1.The fixed voltage and fixed frequency available grid supply can be transformed to the fixed frequency seven-phase output supply. The output may be made variable by inserting the autotransformer at the primary side. The input and output supply can be arranged in the following manner [20] as below.

Input Star, Output Star.
Input Star, Output heptagon.
Input Delta, Output Star.
Input Delta, Output heptagon.

The input has being three-phase system the windings are connected in a usually fashion. The (seven phase) heptagon output connection may be derived following a similar approach. The output/secondary side connection is discussed in the following subsections.

II. WINDING ARRANGEMENT OF SEVEN PHASE STAR OUTPUT

In this iron core are separated in designated with one primary and three secondary coils, six terminal of primary side are connected in an adoptable manner resulting in star and or delta connection and the 18 terminals of secondary's are connected in a different fashion in a star/heptagon output. The new connection scheme of secondary winding to obtain an input star, output star and the corresponding phasor diagram shown is Figure 3. Similarly for input delta, output star connection and phasor diagram is also shown in the figure 5. The construction of the output (star) phase with requisite phase angles of 360/7=51.42° between each phase is obtained using appropriate turn ratio and the governing phasor equation given in (3). Selecting the turn ratio is the key in creating the phase displacement in the output phases.

The turn ratio between different phases is given in the table 1. The input phases are made and is given with letter is "x", "y" and "z" and output are designed with letter is "a", "b", "c", "d", "e", "f" and "g". The mathematically derivation for this connection is the basic addition of real and imaginary part of vectors. Given example, to the solution (1) gives the turn ratio of the phase "b", (Vb taken as unity).

$$Vx [\cos(2\pi/7) + j \sin(2\pi/7)] - Vz [\cos(1.66\pi/7) - j \sin(1.66\pi/7)] = 1 \quad (1)$$

Equating real and imaginary parts and solving Vx and Vz We get,

$$|Vx| = \sin(2\pi/7)/\sin(\pi/3) = 0.1721$$

$$|Vz| = -\sin(2\pi/7)/\sin(\pi/3) = 0.9028 \quad (2)$$

Thus equation (3) is the result voltage of the two different coils; one output phase is generated from only one coil namely "a3a4" in contrast to another phase utilizes by two coils.

$Va = VmaxSin(\omega t)$ $Vx = VmaxSin(\omega t)$
$Vb = VmaxSin(\omega t+2\pi/7)$ $Vy = VmanSin(\omega t+2\pi/3)$
$Vc = VmaxSin(\omega t+4\pi/7)$ $Vz = VmaxSin(\omega t-2\pi/3)$
$Vd = VmaxSin(\omega t+6\pi/7)$
$Ve = VmaxSin(\omega t-6\pi/7)$
$Vf = VmaxSin(\omega t-4\pi/7)$
$Vg = VmaxSin(\omega t-2\pi/7)$

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$$\begin{vmatrix} Va \\ Vb \\ Vc \\ Vd \\ Ve \\ Vf \\ Vg \end{vmatrix} = 1/\sin(\pi/3) \begin{vmatrix} \sin(\pi/3) & 0 & 0 \\ \sin(8.571) & 0 & -\sin(51.42) \\ 0 & \sin(42.85) & -\sin(54.54) \\ -\sin(34.2) & \sin(25.71) & 0 \\ -\sin(34.2) & 0 & \sin(25.71) \\ 0 & -\sin(54.54) & \sin(42.85) \\ \sin(8.571) & -\sin(51.42) & 0 \end{vmatrix} \quad (3)$$

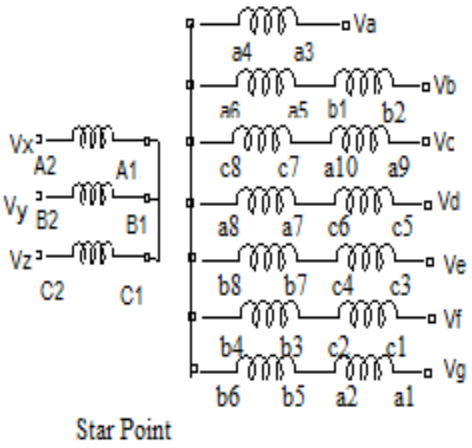
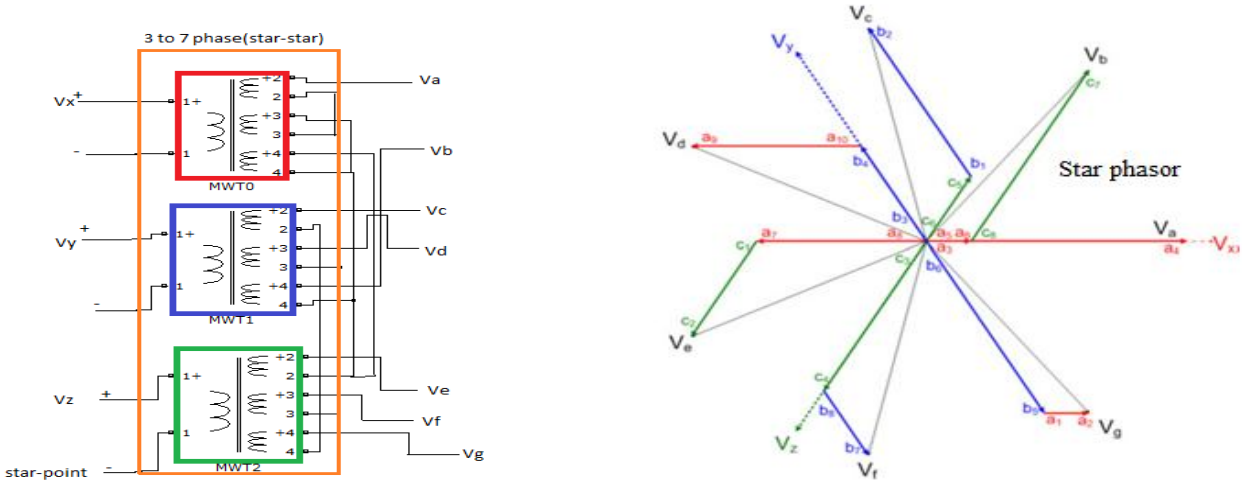


Fig. 2 Proposed transformer winding star-star connection



(*MWT=Multi-winding transformer)

Fig. 3 (A) A new schematic diagram of a three phase to seven phases "star-star" power transformer with secondary windings and (B) Phasor diagram of the transformer connection (star-star) [9].

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III. WINDING ARRANGEMENT OF SEVEN PHASE DELTA OUTPUT

In this case winding arrangement three separate cores designed with individual carrying primary and two secondary coils. In this designed the phase difference will be 51.42. Six terminals of primaries are connected in an appropriate manner resulting in delta-heptagon. Modelling and Simulation, Eighteen terminals of secondaries is connected in star-heptagon output. The turn ratios are different in an individual phase. The input phases are designed given with letters “x”, “y”, and “z” and the output are designated with letters are “A”, “B”, “C”, “D”, “E”, “F” and “G”. The (delta-star) three phases to seven phase winding connection designed model are shown in figure 4. In this value of Va = Vx Three-phase voltages may be defined as.

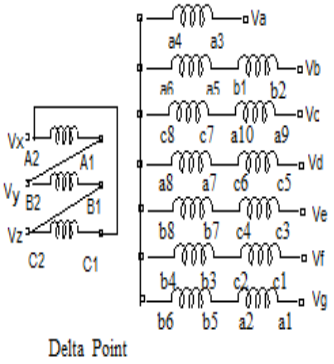
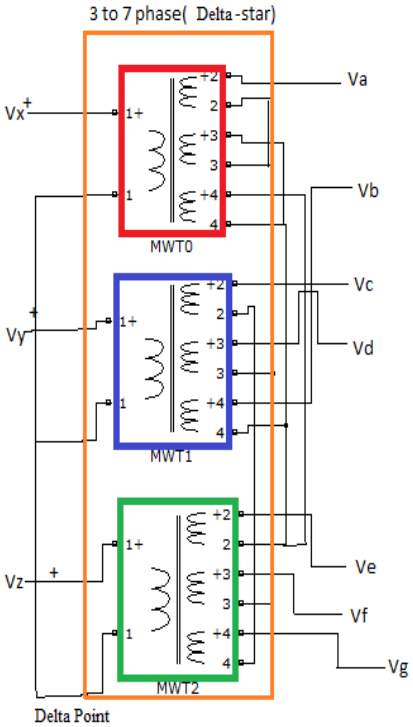
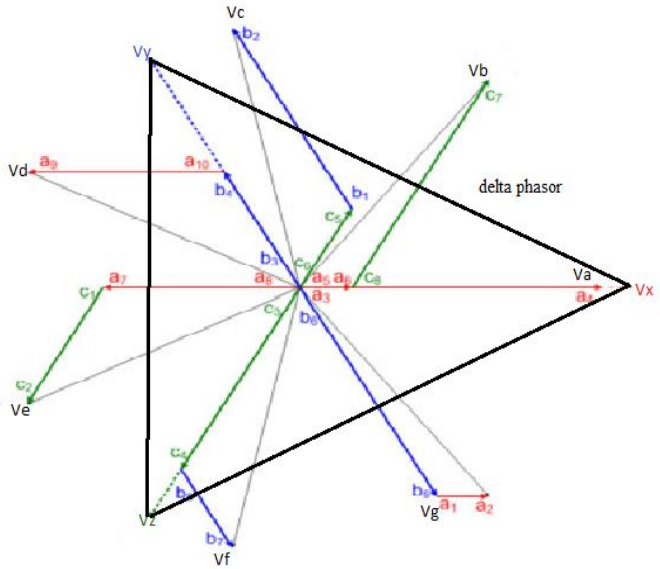


Fig. 4 Proposed transformer winding delta-star connection





(*MWT = Multi-winding transformer)

Fig. 5 (A) A new schematic diagram of a three phase to seven phases “delta-star” power transformer with secondary windings and

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(B) Phasor diagram of the proposed transformer connection (delta-star).

TABLE: 1
SECONDARY TURNS (N2) TO THE PRIMARY (A1A2) TURNS (N1)

Name of windings	Turn ratio	Name of windings	Turn ratio	Name of windings	Turn ratio
a1a2	0.1721	b1b2	0.7900	c1c2	0.5010
a3a4	1.0000	b3b4	0.5010	c3c4	0.7900
a5a6	0.1721	b5b6	0.9029	c5c6	0.340
a7a8	0.6506	b7b8	0.3400	c7c8	0.9029
a9a10	0.6506				

$Vj = Vmax \sin(\omega t + n\pi/3)$
J = x, y, z, and n=0, 2, 4, respectively, (4)
$Vk = Vmax \sin(\omega t + n\pi/7)$,
k=1,2,3,4,5,6,7,8,9,10,11 and n=0,2,4,6,8,10,12,14,16,18,20 respectively (5)
Using equation (3), An seven-phase output can be created from a three phase input supply.
A transformer has a two-port network, the opposite connection is possible if seven-phase supply is given at the input, the output can be three phase. It is very important if the power generated is seven phases it has to be converted to three phase which has to be connected to the grid.
A general expression for "n" phase system was drive as.
$Vr = [(-1)a\ Vx \sin(\theta) + (-1)b\ Vy \sin(f) + (-1)c\ Vz \sin(\gamma)]$ Where r=phase no 1,2,3……n, (6)

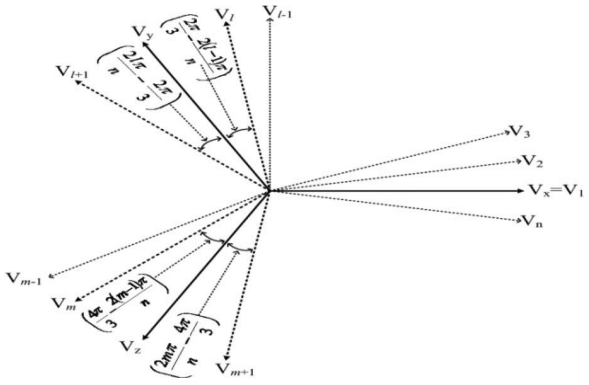


Fig. 6 General phasor diagram of three phase system from "n" phase system [9].

From the above figure 6 we can derive an expression for a general case,
Let us assume $Vx = V_1$; and n= number of phases in the system.
Vx, Vy, V_1, V_2, V_3,…., Vm…., are the phases. Then
$Vy=1/\sin(2\pi/n)[\sin(21p/n-2\pi/3)V_1+\sin(2\pi/3-2(l-1)\pi/n)V_{l+1}]$
Where 1 = 4 and $(21\pi/n) > (2\pi/3) > (2(1-1)\pi/n)$ and n=11
$Vy=1/\sin(2\pi/7)[\sin(2x4\pi/7-2\pi/3)V_4+\sin(2\pi/3-2(1)\pi/7)V_{4+1}]$
$Vy=1/\sin(51.42)(\sin(85.71)+\sin(68.571)V_5$, and it lies between 120>120>99.18

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$Vz=1/\sin(2\pi/n)\,[\sin(2m\pi/n-2\pi/3)\,Vm+\sin(2\pi/3-2(m-1)\pi/n)\,V_{m+1}]$

Where $(2m\pi/n)>(2\pi/3)>(2(m-1)\pi/n)$ and $m>1$

N=7

M=8

$Vz=1/\sin(51.42)\,[\sin(2x8\pi/7-2\pi/3)\,V_8+\sin(2\pi/3-2(7)\pi/7)\,V_9]$

$Vz=1/\sin(51.42)\,[\sin(291.42)\,V_8+\sin(-240.00)\,V_9]$, and it lies between $298.81>120>230.09$

IV. SIMULATION

The new designed/modelling is the first using "Sim power system" block set of the MATLAB/Simulink sofware. Multiwinding transformer block is chosen from the sim-power system block library and the turn ratios are set in the dialog box and the simulation is run. The resulting input and output votage and current waveform are given in Figure 8 for star-star and Figure 10 for delta-star. The output will be unbalance if input is unbalanced and also if the input is balance then output is also balance. The three phase output from a seven phase input supply can also be obtain in similar fasion.

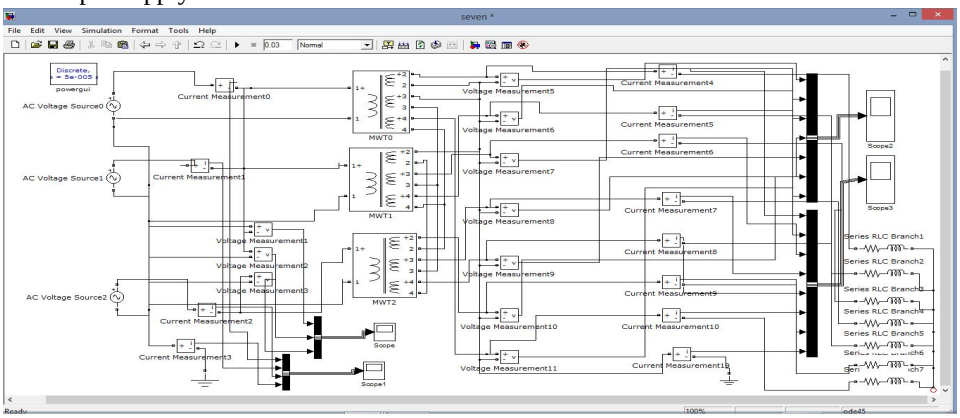


Fig. 7 MATLAB/SIMULINK model of Three-to-Seven phases Star Transformation

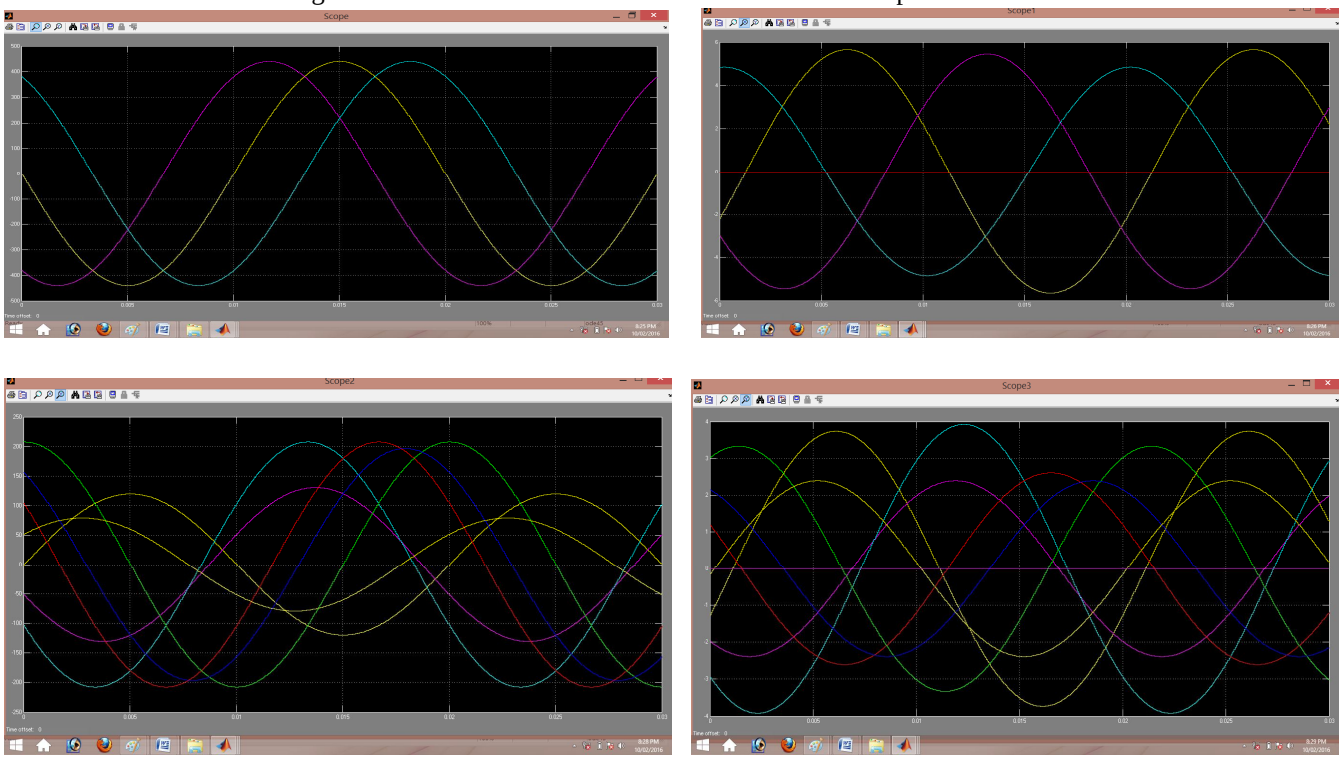


Fig. 8 (A) Input voltage and current waveforms of Star-Star and (B) Output voltage and current waveforms of Star-Star

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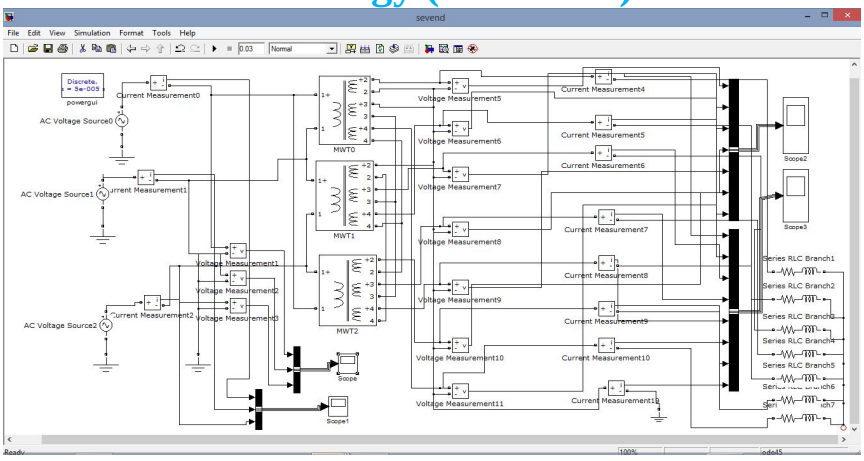


Fig. 9 MATLAB/SIMULINK model of Three-to-Seven phase Delta Transformation

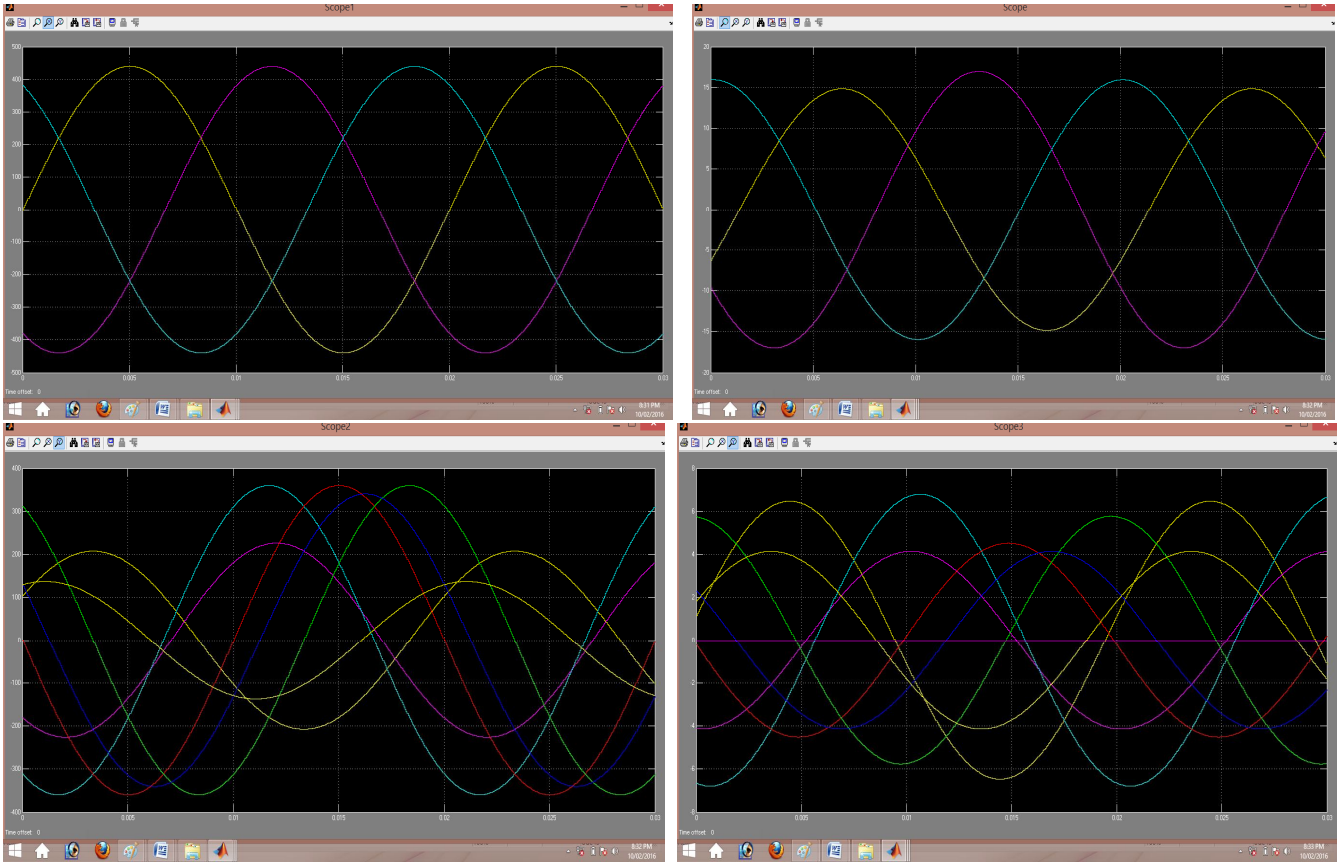


Fig. 10 (A) Input voltage and current waveforms of delta-star and (B) Output voltage and current waveforms of delta-star

V. RESULTS AND DISCUSSION

Here simulation and experimental are setup and their results is obtained by using the designed three to seven phase transformation system. The novel designed transformation system ratio are 1:1 (input: output), then the output voltage is similar to the input voltage. Now transformation ratio can be altered to suit the step up or step down requirements. In this simulation we have No-load and load tests are performed on the three to seven phase transformers and their load test are performed by connecting eleven phase RL load. The value of load is given by R=50Ω and L=5mH. Thus the simulation Diagram of (star-star) and (Delta-Delta) new connection of a three phase primary side and a seven phase secondary side are shown in figure 7 and figure 9 respectively. When three different single phase auto transformers are used to supply input phases of the transformer connections. The output voltage can also be adjusted by simply varying the taps of the autotransformer. The output voltage is balance then input voltage is also balance. Any

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unbalancing in the input is directly reflected in the output phases. Under no-load conditions, 440 V is applied at the primary side. The input side voltage and current wave forms, under no-load and loaded steady-state conditions, the input voltage and currents under loaded conditions are 220V and 4 A are recorded and shown in Figure 8. Corresponding no-load and loaded condition voltage and current wave forms for the secondary side (seven phase) and the loaded current in the secondary side is nearly 7 A and the voltage is 360 V are presented in the figure 10.

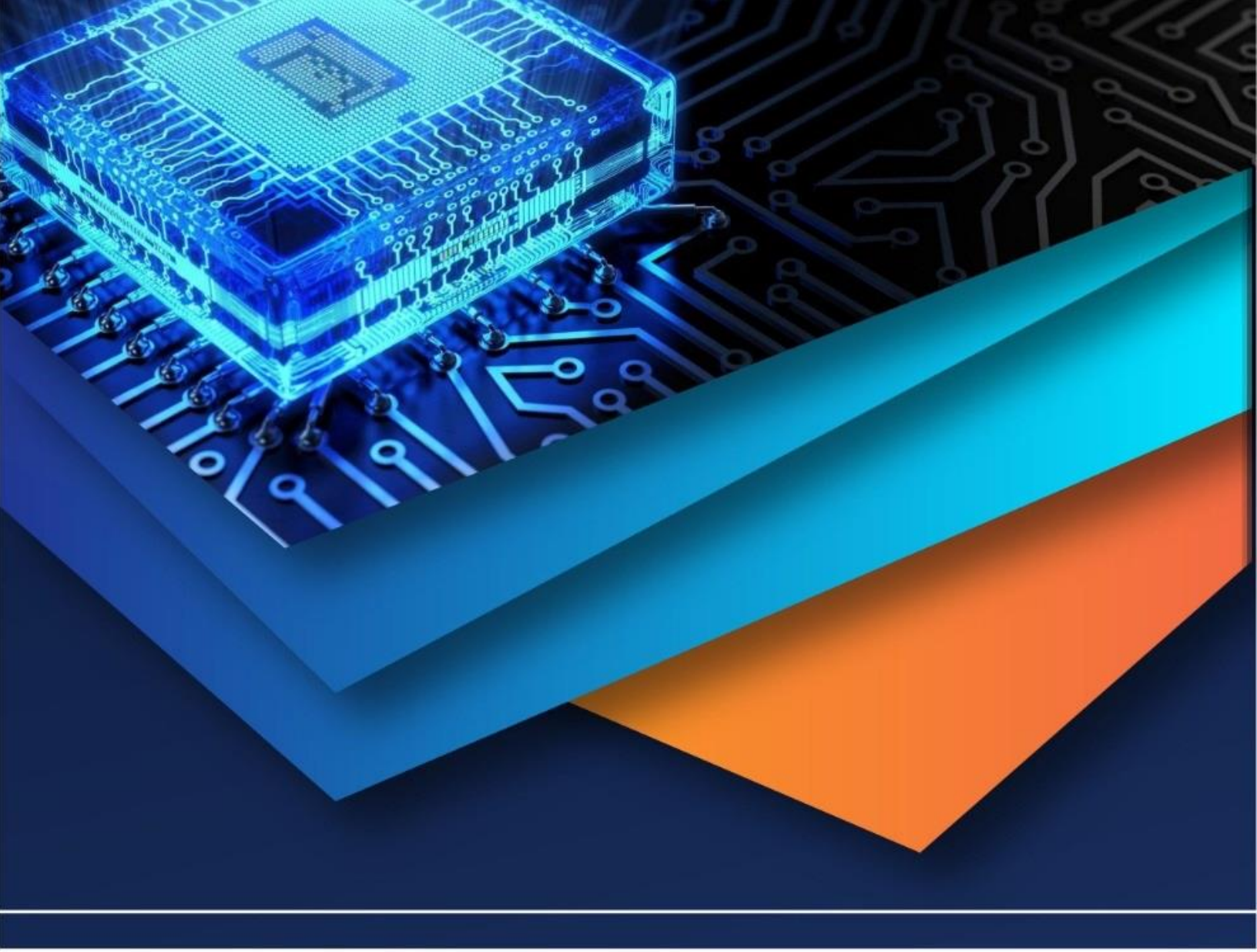
VI. CONCLUSION

Here in this paper a different complex transformer winding connection scheme was developed to transform three phase grid power to a seven-phase output supply. In this method main data of transformer, phase shifting and winding connections of the transformer. The seven-phase induction motor under a loaded condition is used to prove the viability of the transformation system. The 3/7 AC multiphase transformer has been simulated by using MATLAB simulation software, which has been proved to be powerful tools to simulates such a typical connection transformers.

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