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TRANSFORMATION TERMS abc TO qdn FOR 9-PHASE SYSTEM WITH 3x9 MATRIX

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ABSTRACT

Order of the transformation matrix from abc coordinates to qdn for 9-phase induction motor was introduced in a square matrix form with order of 9x9. The size of this large matrix order can complicate the process of changing from 9-phase induction motor model of the form abc into qdn becomes less simple. Reducing matrix order obtains the efficiency of computation cost. In this paper we propose the unit vector relationships both abc and qdn coordinate transformation matrix obtained qdn term to order 3x9 in order to reducing significant parameter. Through the simulation can be shown that the response of the same input and the reference rotary speed different angles on the order of 3x9 coordinate transformation can produce a different response v_{qdn} *voltage and output voltage* v_{abc} *is the same for each reference frame.*

Keywords: Nine-phase system, abc coordinates, qdn coordinates, the 3x9 transformation matrix

INTRODUCTION

All orders of the transformation matrix from abc coordinates to qdn that have been introduced have square matrix form and the order was used to adjust the number of phases. Three-phase abc coordinate transformation introduced by Park contains the order 3x3 (Paul C. Krause, 1987), (Bimal K. Bose, 2002). Transformation of other variations has been developed with the same matrix size but different in the matrix elements (R. Krishnan, 2001), (Ned Mohan, 2003). Order of 5x5 matrix transformation has been introduced as a tool to analyze the dynamic model 5-phase induction motor (H. Xu, et al., 2002). The model dynamic of 5-phase induction motor is used as an observer in speed sensorless motor control (L. Parsa & H. A. Toliyat, 2007), (Libo Zheng et al.,2008). Order of 6x6-matrix transformation for the 6-phase has been introduced and applied as a tool to analyze the 6-phase motor and the results obtained is used as an observer in the speed control (A. R. Munoz & T. A. Lipo, 2000), (Renato O. C. Lyra, & T. A. Lipo, 2002). Order 9x9 transformation matrix has also been introduced to anticipate the development of equipment drives the increasingly considered to yield large power and small dimensions (E. Levi, et al.,2007). The transformation matrix for 9-phase system has an order of 9x9. All forms of transformation are obtained by using methods typical form abc then β α function which is placed in a vector space then projected to form projection of qdn (R. Krishnan, 2001), (Ned Mohan, 2003), (E. Levi, et al.,). The transformation contains a constant that is $2 / p$ or $\sqrt{2/p}$ of which p states the number of phases, while the order is according to the number of phases.

Although the method of projection to form αβ has a certainty in determining the form of inverse transformation because of the transformation matrix of a square, the cost to be paid is expensive in the process of finding the inverse, and the simplification for the nine-phase induction motor model of the form abc into qdn can be difficult. Order of the transformation matrix from abc coordinates to qdn on 9-phase induction motor was introduced in the form of a square matrix with order of 9x9. The size of this large order matrix can be difficult. Therefore, other methods are offered to overcome these difficulties. In this method, the function of 9-phase symmetry is placed in the abc coordinate system of nine mutually perpendicular. Each of these functions forms a vector. The sum of each vector produces a rotating vector space to the origin. Then, vector space occupies d-axis and negative derivation at q occupies in the coordinate axes qdn. Unit vector in each coordinate axis at qdn can be determined. Furthermore, the relationship of unit vector is gained between both abc and qdn 3x9 matrix. The reference axis of rotation is n because it generates space vector equal to zero axis that is perpendicular to the vector space. Unit vector in abc coordinates and qdn can be determined. Furthermore, the relationship of the two unit vectors is determined to obtain the transformation matrix 3x9 of which 9 refers the number of phases. Variations in the reference angular velocity are applied to prove the results obtained. We claim this transformation matrix 3x9 in order to increase efficiency on computation.

The purpose of the coordinate transformation is to simplify the forms and system analysis. The purpose of this simplification can be achieved when the order of the transformation matrix to form three rows that can describe the amount of the qdn axes coordinate and the number of columns 9 that describes the number of abc axes coordinates of nine phase. Thus, the form of 9-phase transformation matrices obtained becomes simple.

abc TO qdn COORDINATES

The f(t) function that can express the voltage, current, and the flux has a number of 9-phase symmetry. If the function f(t) expresses a negative voltage sequence then:

$$v_{a1} = V_m \cos \omega t \qquad (1)$$

$$v_{b1} = V_m \cos(\omega t - 2\pi/9) \qquad (2)$$

$$v_{c1} = V_m \cos(\omega t - 4\pi/9) \qquad (3)$$

$$v_{a2} = V_m \cos(\omega t - 2\pi/3) \qquad (4)$$

$$v_{b2} = V_m \cos(\omega t - 8\pi/9) \qquad (5)$$

$$v_{c2} = V_m \cos(\omega t + 8\pi/9) \qquad (6)$$

$$v_{a3} = V_m \cos(\omega t + 2\pi/3) \qquad (7)$$

$$v_{b3} = V_m \cos(\omega t + 4\pi/9) \qquad (8)$$

$$v_{c3} = V_m \cos(\omega t + 2\pi/9) \qquad (9)$$

Voltages are grouped according to the order of the last subscription so that the ninth voltage is grouped into three groups according voltage abc direction unit vector **u**. The first group is the voltage v_{a1}, v_{b1}, v_{c1}, the second group v_{a2}, v_{b2}, v_{c2}, and the third v_{a3}, v_{b3}, *and* v_{c3}. Each group is placed on nine (9) abc coordinate axes, each axis is mutually perpendicular to each other. To simplify the visualization, then each group is placed on three-dimensional coordinate system separately as Figure 1a, 1b, and 1c. Equation forming a rotating voltage vector to the origin is as follows:

$$\mathbf{v}_{abc} = v_{a1}\mathbf{u_1} + v_{b1}\mathbf{u_2} + v_{c1}\mathbf{u_3} + v_{a2}\mathbf{u_4} + v_{b2}\mathbf{u_5} + v_{c2}\mathbf{u_6} + v_{a3}\mathbf{u_7} + v_{b3}\mathbf{u_8} + v_{c3}\mathbf{u_9} \qquad (10)$$

Substitution of the group voltage in the equation 10 can create equation 11.

$$\begin{aligned}\mathbf{v}_{abc} = {} & V_m \cos \omega t\,\mathbf{u_1} + V_m \cos(\omega t - 2\pi/9)\mathbf{u_2} + V_m \cos(\omega t - 4\pi/9)\mathbf{u_3} + \\ & V_m \cos(\omega t - 2\pi/3)\mathbf{u_4} + V_m \cos(\omega t - 8\pi/9)\mathbf{u_5} + V_m \cos(\omega t + 8\pi/9)\mathbf{u_6} + \\ & V_m \cos(\omega t + 2\pi/3)\mathbf{u_7} + V_m \cos(\omega t + 4\pi/9)\mathbf{u_8} + V_m \cos(\omega t + 2\pi/9)\mathbf{u_9}\end{aligned} \qquad (11)$$

Vector magnitude generated by the nine-phase voltage can be done by applying Pythagoras theorem, namely:

$$\left|\mathbf{v}_{abc}\right| = \sqrt{v_{a1}^2 + v_{b1}^2 + v_{c1}^2 + v_{a2}^2 + v_{b2}^2 + v_{c2}^2 + v_{a3}^2 + v_{b3}^2 + v_{c3}^2}$$

Vector magnitude obtained is:

$$\left|\mathbf{v}_{abc}\right| = \sqrt{\frac{9}{2}}V_m \qquad (12)$$

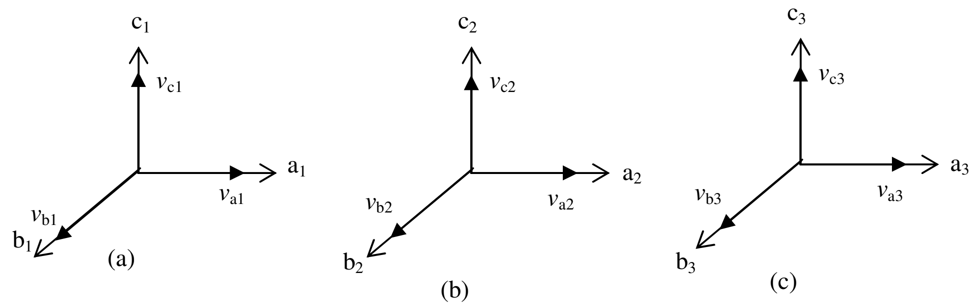

Figure 1. Vector diagram of the coordinate system of nine mutually perpendicular drawn separately

Unit vector is obtained by comparing vectors with greatness of the vectors such as in equation 13:

$$\mathbf{u}_{abc} = \frac{\mathbf{v}_{abc}}{\left|\mathbf{v}_{abc}\right|} \qquad (13)$$

Substitution the group voltage equation into equation 13 results equation 14.

$$\begin{aligned} &= \sqrt{\frac{2}{9}}(\cos\omega t\,\mathbf{u_1} + \cos(\omega t - 2\pi/9)\mathbf{u_2} + \cos(\omega t - 4\pi/9)\mathbf{u_3} + \\ &\cos(\omega t - 2\pi/3)\mathbf{u_4} + \cos(\omega t - 8\pi/9)\mathbf{u_5} + \cos(\omega t + 8\pi/9)\mathbf{u_6} + \qquad (14) \\ &\cos(\omega t + 2\pi/3)\mathbf{u_7} + \cos(\omega t + 4\pi/9)\mathbf{u_8} + \cos(\omega t + 2\pi/9)\mathbf{u_9}) \end{aligned}$$

Rotation $\mathbf{v}_{abc}$ vector is according to the time functions and form vector space. As a starting point to facilitate analysis, the space vector $\mathbf{v}_{abc}$ is placed in the qdn coordinate system that is, at first, assumed to occupy the q-axis as shown in Figure 2.

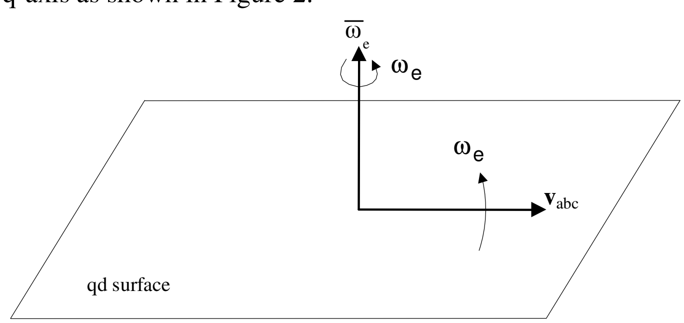

Figure 2. $\mathbf{v}_{abc}$ vector rotates in the plane

The space vectors can be derived into the new vector space $-d\mathbf{v}_{abc}/dt$ that is placed on the axis d. The minus sign is taken as the consideration that the product multiplication is $\mathbf{u_d}$ x $\mathbf{u_q}$ = $\mathbf{n}$ (negative sequence). $\mathbf{v}_{abc}$ vector rotates in the space of qd with center at the origin that is the reference rotation vector space and can be expressed in terms of equivalent $\mathbf{n.v}_{abc} = 0$ with $\mathbf{n} = \mathbf{u_1} + \mathbf{u_2} + \mathbf{u_3} + \mathbf{u_4} + \mathbf{u_5} + \mathbf{u_6} + \mathbf{u_7} + \mathbf{u_8} + \mathbf{u_9}$. Thus, the vector n is perpendicular to the space of qd; therefore, it would coincide with ω as shown in Figure 3.

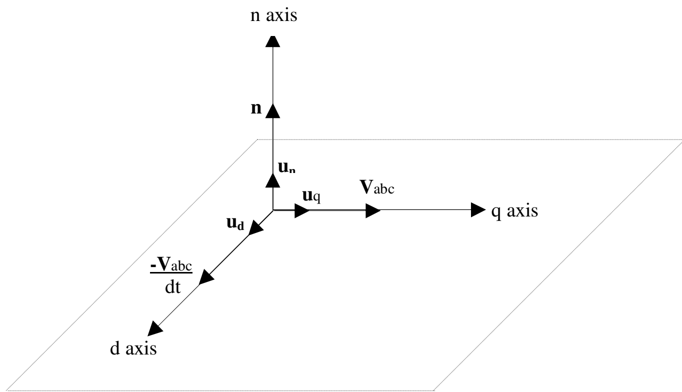

Figure 3. The unit vector in the coordinate qdn

Unit vector in qdn coordinates obtained from the third $\mathbf{v}_{abc}, -d\mathbf{v}_{abc}/dt$, and **n** vectors is shown in Figure 3. In qdn coordinates, unit vectors $\mathbf{u}_{ds}$, $\mathbf{u}_{qs}$ and $\mathbf{u}_{ns}$ are also depicted (Figure 3). Unit vector $\mathbf{u_q}$ can be expressed by the following equation 15:

$$\mathbf{u}_q = \frac{\mathbf{v}_{abc}}{|\mathbf{v}_{abc}|} = \frac{\mathbf{v}_{abc}}{\sqrt{\frac{9}{2}}V_m} \tag{15}$$

Substitution from equation 11 into equation 15 creates equation 16.

$$\begin{aligned}\mathbf{u_q} = \sqrt{\frac{2}{9}}(&\cos\omega t\,\mathbf{u_1} + \cos(\omega t - 2\pi/9)\mathbf{u_2} + \cos(\omega t - 4\pi/9)\mathbf{u_3} + \\ &\cos(\omega t - 2\pi/3)\mathbf{u_4} + \cos(\omega t - 8\pi/9)\mathbf{u_5} + \cos(\omega t + 8\pi/9)\mathbf{u_6} + \\ &\cos(\omega t + 2\pi/3)\mathbf{u_7} + \cos(\omega t + 4\pi/9)\mathbf{u_8} + \cos(\omega t + 2\pi/9)\mathbf{u_9})\end{aligned} \tag{16}$$

Unit vector $\mathbf{u_d}$ can be expressed in the following equation 17:

$$\mathbf{u}_d = \frac{-d\mathbf{v}_{abc}/dt}{|-d\mathbf{v}_{abc}/dt|} = \frac{-d\mathbf{v}_{abc}/dt}{\sqrt{\frac{9}{2}}\omega V_m} \tag{17}$$

Substitution derived from equation 11 into equation 17 results equation 18.

$$\begin{aligned}= \sqrt{\frac{2}{9}}(&\sin\omega t\,\mathbf{u_1} + \sin(\omega t - 2\pi/9)\mathbf{u_2} + \sin(\omega t - 4\pi/9)\mathbf{u_3} + \\ &\sin(\omega t - 2\pi/3)\mathbf{u_4} + \sin(\omega t - 8\pi/9)\mathbf{u_5} + \sin(\omega t + 8\pi/9)\mathbf{u_6} + \\ &\sin(\omega t + 2\pi/3)\mathbf{u_7} + \sin(\omega t + 4\pi/9)\mathbf{u_8} + \sin(\omega t + 2\pi/9)\mathbf{u_9})\end{aligned} \tag{18}$$

Unit vector **n** can be expressed in the following equation 19:

$$\mathbf{u}_n = \frac{\mathbf{n}}{|\mathbf{n}|} = \sqrt{\frac{1}{9}}(\mathbf{u}_1 + \mathbf{u}_2 + \mathbf{u}_3 + \mathbf{u}_4 + \mathbf{u}_5 + \mathbf{u}_6 + \mathbf{u}_7 + \mathbf{u}_8 + \mathbf{u}_9) \tag{19}$$

The relationship between the unit vectors in qdn coordinates and abc coordinates is obtained by comparing the two unit vectors, then:

$$\begin{bmatrix} \mathbf{u}_q \\ \mathbf{u}_d \\ \mathbf{u}_n \end{bmatrix} = \sqrt{\frac{2}{9}} \begin{bmatrix} \cos\theta & \sin\theta & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/9) & \sin(\theta - 2\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 4\pi/9) & \sin(\theta - 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 8\pi/9) & \sin(\theta - 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 8\pi/9) & \sin(\theta + 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 4\pi/9) & \sin(\theta + 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/9) & \sin(\theta + 2\pi/9) & \frac{1}{\sqrt{2}} \end{bmatrix}^{T} \begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \mathbf{u}_3 \\ \mathbf{u}_4 \\ \mathbf{u}_5 \\ \mathbf{u}_6 \\ \mathbf{u}_7 \\ \mathbf{u}_8 \\ \mathbf{u}_9 \end{bmatrix} \quad (20)$$

Because the unit vector matrix multiplied $\mathbf{u}_{qdn}$ with matrix transpose itself produces the identity matrix, the inverse matrix of $\mathbf{u}_{qdn}$ unit vectors will be obtained from $\mathbf{u}_{abc}$ namely:

$$\begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \mathbf{u}_3 \\ \mathbf{u}_4 \\ \mathbf{u}_5 \\ \mathbf{u}_6 \\ \mathbf{u}_7 \\ \mathbf{u}_8 \\ \mathbf{u}_9 \end{bmatrix} = \sqrt{\frac{2}{9}} \begin{bmatrix} \cos\theta & \sin\theta & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/9) & \sin(\theta - 2\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 4\pi/9) & \sin(\theta - 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 8\pi/9) & \sin(\theta - 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 8\pi/9) & \sin(\theta + 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 4\pi/9) & \sin(\theta + 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/9) & \sin(\theta + 2\pi/9) & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} \mathbf{u}_q \\ \mathbf{u}_d \\ \mathbf{u}_n \end{bmatrix} \quad (21)$$

$\mathbf{v}_{abc}$ vector thatis expressed in qdn coordinates can be seen from:

$$\mathbf{v}_{abc} = \begin{bmatrix} v_{a1} \\ v_{a2} \\ v_{a3} \\ v_{b1} \\ v_{b2} \\ v_{b3} \\ v_{c1} \\ v_{c2} \\ v_{c3} \end{bmatrix}^{T} \begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \mathbf{u}_3 \\ \mathbf{u}_4 \\ \mathbf{u}_5 \\ \mathbf{u}_6 \\ \mathbf{u}_7 \\ \mathbf{u}_8 \\ \mathbf{u}_9 \end{bmatrix} \text{ so,}$$

$$\begin{aligned} \mathbf{v}_{abc} = \sqrt{\frac{2}{9}}\,[&v_{a1}cos\,\theta + v_{a2}cos\,(\theta - 2\pi/9) + v_{a3}cos\,(\theta - 4\pi/9) + \\ &v_{b1}cos\,(\theta - 2\pi/3) + v_{b2}cos\,(\theta - 8\pi/9) + v_{b3}cos\,(\theta + 8\pi/9) + \\ &v_{c1}cos\,(\theta + 2\pi/3) + v_{c2}cos\,(\theta + 4\pi/9) + v_{c3}cos\,(\theta + 2\pi/9)]\,\mathbf{u}_q \\ + \sqrt{\frac{2}{9}}\,[&v_{a1}sin\,\theta + v_{a2}sin\,(\theta - 2\pi/9) + v_{a3}sin\,(\theta - 4\pi/9) + \\ &v_{b1}sin\,(\theta - 2\pi/3) + v_{b2}sin\,(\theta - 8\pi/9) + v_{b3}sin\,(\theta + 8\pi/9) + \\ &v_{c1}sin\,(\theta + 2\pi/3) + v_{c2}sin\,(\theta + 4\pi/9) + v_{c3}sin\,(\theta + 2\pi/9)]\,\mathbf{u}_d \\ + \sqrt{\frac{1}{9}}\,[&v_{a1} + v_{a2} + v_{a3} + v_{b1} + v_{b2} + v_{g3} + v_{c1} + v_{c2} + v_{c3}]\,\mathbf{u}_n \end{aligned} \qquad (22)$$

When the voltage vector in qdn coordinates is called $\mathbf{v}_{abc}$, it is clear that:

$$\mathbf{v}_{abc} = \mathbf{v}_{qdn} \qquad (23)$$

and

$$\mathbf{v}_{qdn} = [v_q \quad v_d \quad v_n] \begin{bmatrix} \mathbf{u}_q \\ \mathbf{u}_d \\ \mathbf{u}_n \end{bmatrix} \qquad (24)$$

Therefore, it can be written that:

$$\begin{aligned} v_q = \sqrt{\frac{2}{9}}\,[&v_{a1}cos\,\theta + v_{a2}cos\,(\theta - 2\pi/9) + v_{a3}cos\,(\theta - 4\pi/9) + \\ &v_{b1}cos\,(\theta - 2\pi/3) + v_{b2}cos\,(\theta - 8\pi/9) + v_{b3}cos\,(\theta + 8\pi/9) + \\ &v_{c1}cos\,(\theta + 2\pi/3) + v_{c2}cos\,(\theta + 4\pi/9) + v_{c3}cos\,(\theta + 2\pi/9)] \end{aligned} \qquad (25)$$

$$\begin{aligned} v_d = \sqrt{\frac{2}{9}}\,[&v_{a1}sin\,\theta + v_{a2}sin\,(\theta - 2\pi/9) + v_{a3}sin\,(\theta - 4\pi/9) + \\ &v_{b1}sin\,(\theta - 2\pi/3) + v_{b3}sin\,(\theta - 8\pi/9) + v_{b3}sin\,(\theta + 8\pi/9) + \\ &v_{c1}sin\,(\theta + 2\pi/3) + v_{c2}sin\,(\theta + 4\pi/9) + v_{c3}sin\,(\theta + 2\pi/9)] \end{aligned} \qquad (26)$$

$$v_n = \sqrt{\frac{1}{9}}\left[v_{a1} + v_{a2} + v_{a3} + v_{b1} + v_{b2} + v_{b3} + v_{c1} + v_{c2} + v_{c3}\right] \quad (27)$$

In matrix form, equations 25, 26 and 27 can be written:

$$\begin{bmatrix} v_q \\ v_d \\ v_n \end{bmatrix} = \sqrt{\frac{2}{9}} \begin{bmatrix} \cos\theta & \sin\theta & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/9) & \sin(\theta - 2\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 4\pi/9) & \sin(\theta - 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta - 8\pi/9) & \sin(\theta - 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 8\pi/9) & \sin(\theta + 8\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 4\pi/9) & \sin(\theta + 4\pi/9) & \frac{1}{\sqrt{2}} \\ \cos(\theta + 2\pi/9) & \sin(\theta + 2\pi/9) & \frac{1}{\sqrt{2}} \end{bmatrix}^{T} \begin{bmatrix} v_{a1} \\ v_{a2} \\ v_{a3} \\ v_{b1} \\ v_{b2} \\ v_{b3} \\ v_{c1} \\ v_{c2} \\ v_{c3} \end{bmatrix} \quad (28)$$

In its compact form equations, the voltage relationship between the two coordinates qdn with abc in equation 28 can be expressed as:

$$\begin{bmatrix} v_q \\ v_d \\ v_n \end{bmatrix} = T(\theta)\left[v_{a1} \quad v_{a2} \quad v_{a3} \quad v_{b1} \quad v_{b2} \quad v_{b3} \quad v_{c1} \quad v_{c2} \quad v_{c3}\right]^{T} \quad (29)$$

RESULTS AND DISCUSSION

To test the results of the analysis, simulations are performed with the chart as in Figure 4. Nine-phase voltage acts as input of the transformation of abc to qdn term. The output of the transformation becomes the input for the inverse transformation from qdn to abc. As a reference, the rotation is ω which can be replaced when needed.

Nine-phase voltage symmetry has maximum voltage 100/3 volts at 50 Hz. Each phase is separated by an angle of 40^o to the phase of each other. To determine the response of output, some changes are made as the reference of angular velocity ω in the three conditions ω of which they are equal to synchronous speed ω_e, equal to the rotor speed ω_r and equal to zero (stationary). Input voltage to the treatment is shown in Figure 5; when ω uses synchronous rotation ω_e=50 rad/sec can generate a voltage response v_{qdn} like Figure 6. In Figure 6, there are three outputs voltage i.e. v_q, v_d and v_n forming dc signal, and the value of v_q and v_n is equal to zero, while v_d equals to $\sqrt{9/2}$ of the peak input voltage. This v_{qdn} voltage when used as an input inverse transformation response is obtained as shown in Figure 7, which gives responses to the output matching the input. When input voltage is fixed as Figure 4 and the value of the reference is changeable, rotation becomes equal to ω_r = 48 rad/sec and the v_{qdn} voltage response and v_{abc} voltage are obtained respectively such as in Figure 8 and Figure 9. Both voltage responses v_d and v_q dispute an angle of 90^o with the v_q that is a negative function of sinusoidal and lags. Although v_{qdn} as input inverse transformation matrix is a different form, the response output voltage is equal to input voltage.

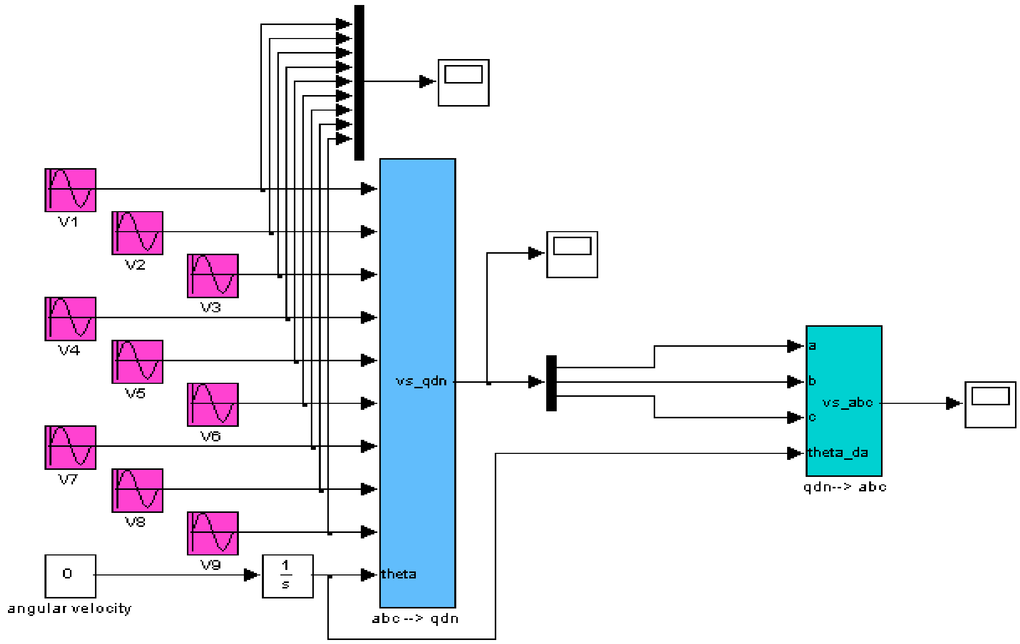

Figure 4 Chart simulation using matlab simulink

When reference is replaced with a round of ω = 0 or stationary and the input the voltage equals to Figure 4, resulting different responses of the voltage v_{qdn} of which its reference ω_r is different. There are changes in the function of v_q which is positive but it still lags 90^o sinusoid as shown in Figure 10. v_{abc} output voltage respon remains the same like before such as shown in Figure 11.

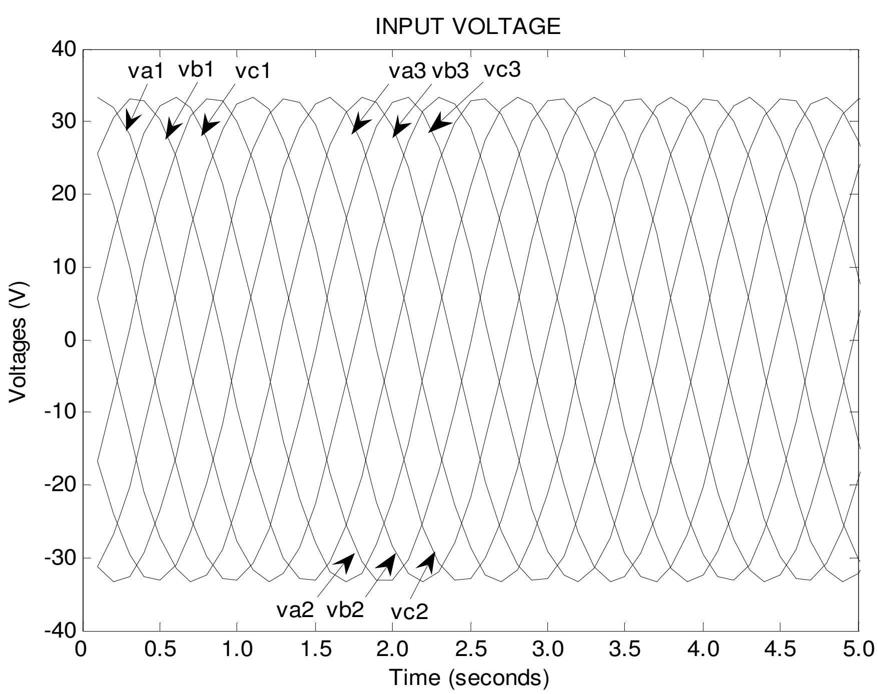

Figure 5. v_{abc} input voltage is transformed to the form v_{qdn} with $\omega = \omega_e$

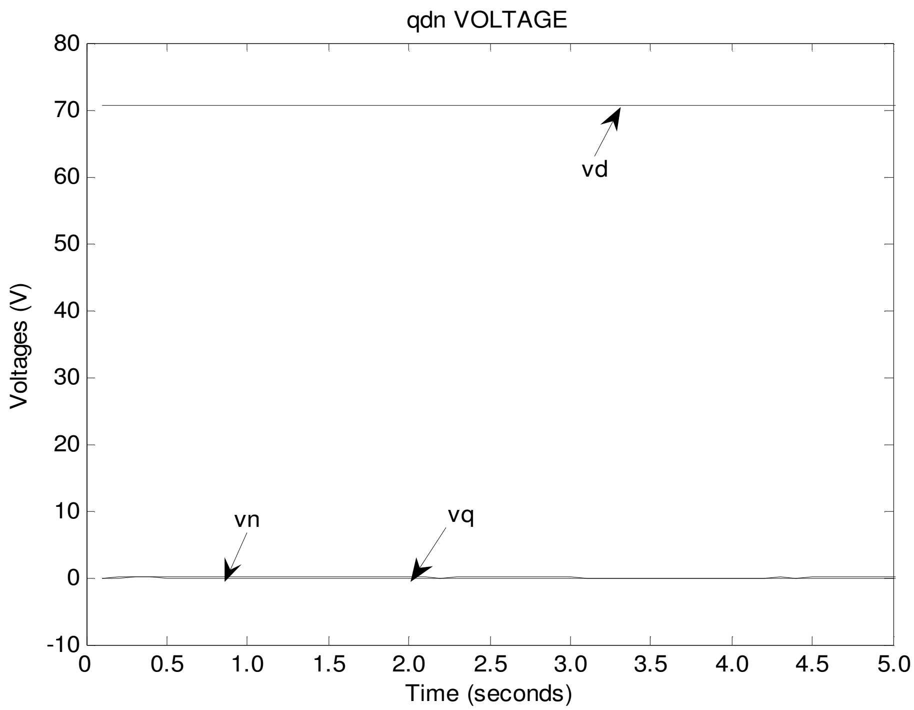

Figure 6. v_{qdn} output voltage of v_{abc} voltages transformation with $\omega = \omega_e$

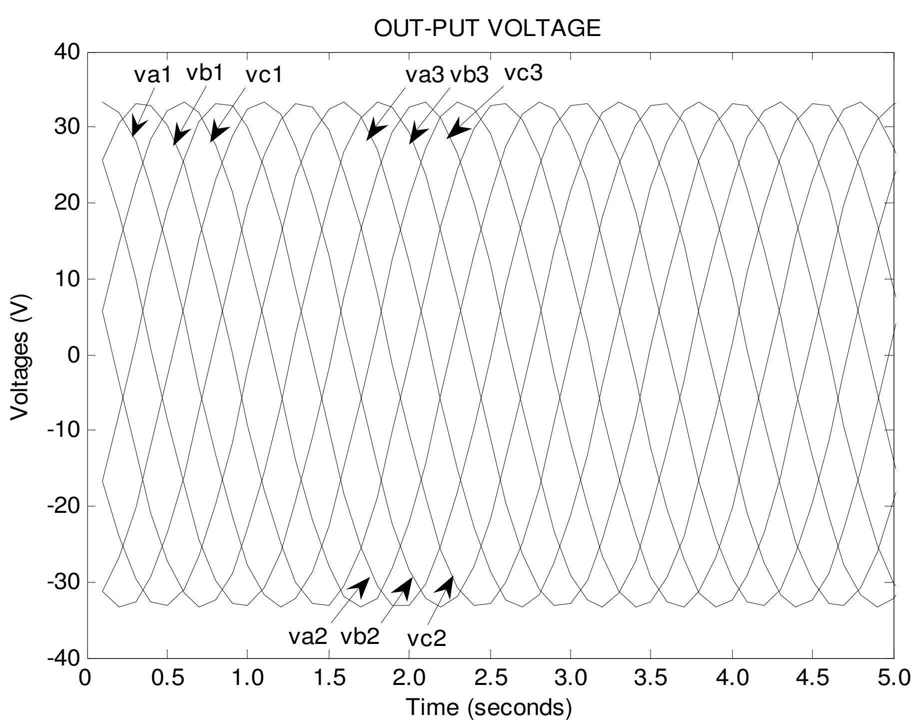

Figure 7. v_{abc} output voltage of v_{qdn} voltages transformation with $\omega = \omega_e$

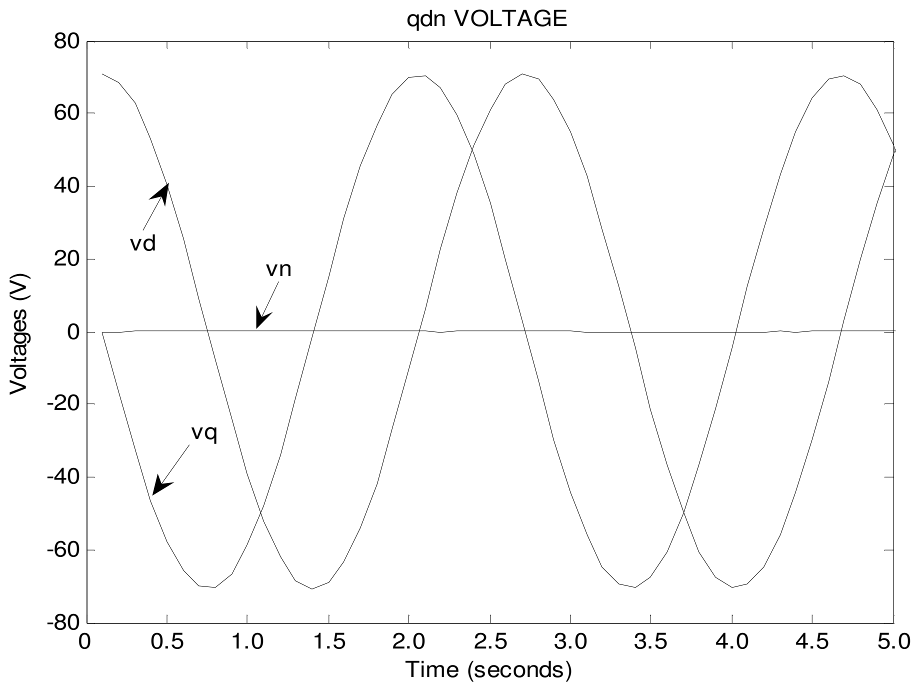

Figure 8. v_{qdn} output voltage of v_{abc} voltages transformation with $\omega = \omega_r$

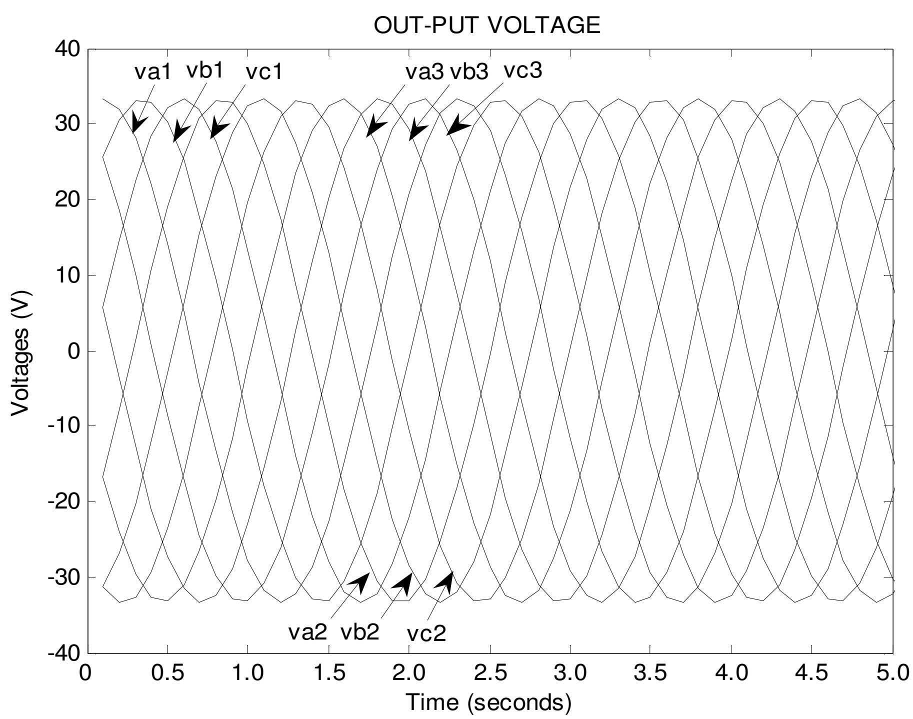

Figure 9. v_{abc} output voltage of v_{qdn} voltages transformation with $\omega = \omega_r$

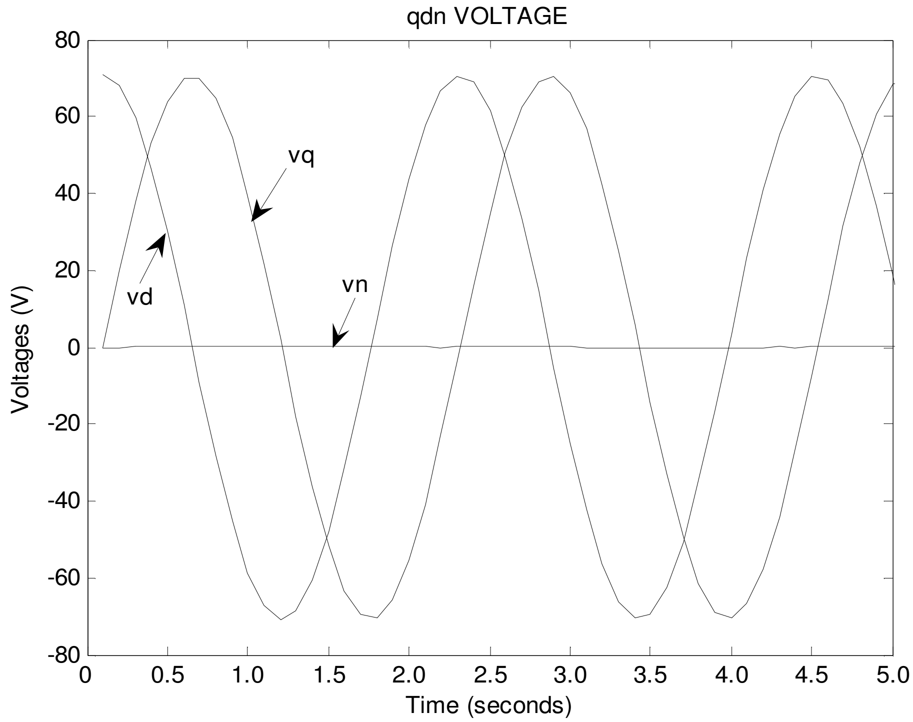

Figure 10. v_{qdn} output voltage of v_{abc} voltages transformation with $\omega = 0$

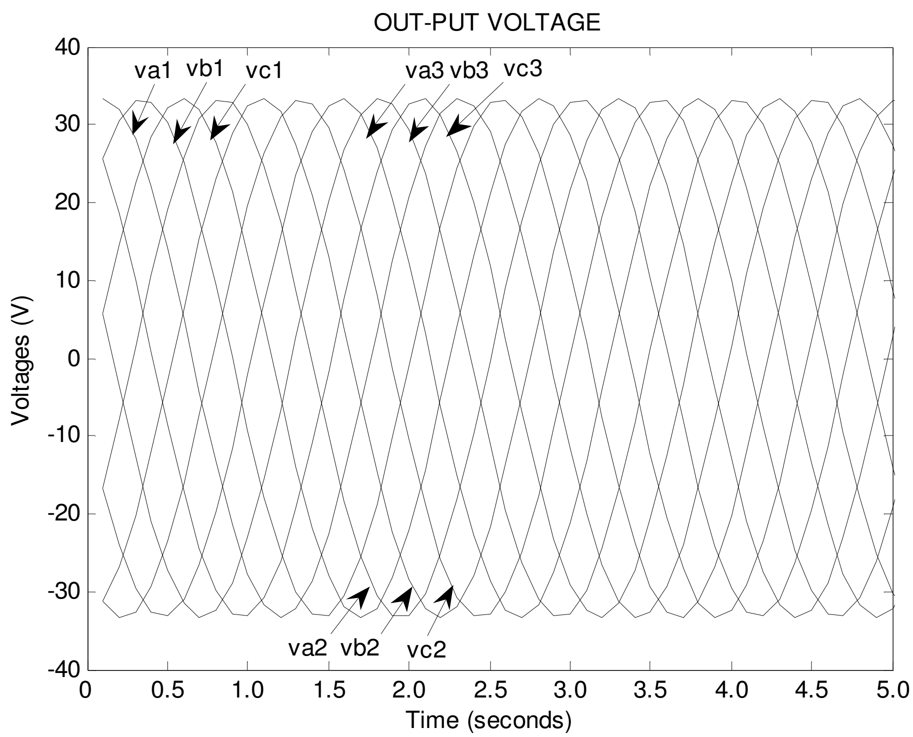

Figure 11 v_{abc} output voltage of v_{qdn} voltages transformation with $\omega = 0$

CONCLUSION

The transformation of 9-phase abc coordinates to the coordinates qdn and it's simulation have been done in three kinds of change of reference angular velocity. When the synchronous rotation $\omega = \omega_e$ is used as a reference, angular velocity can generate the output voltage (v_{qdn}) indicating that a dc signal with v_n and v_q is equal to zero while the voltage v_d is equal to $\sqrt{9/2}$ times the peak input the voltage. When the angular velocity reference equals to ω_r the output voltages (v_{qdn}) are obtained, of which v_d and v_q voltage responses are negative function of sinusoid dispute with the angle of 90^o and v_q is lagging. Meanwhile, if the reference angular velocity is $\omega = 0$ or stationary, the voltage responses obtained v_{qdn} are very different from the response v_{qdn} voltages reference ω_r. There is a change in the function of v_q that is a positive sinusoid but it is still lags 90^o. Although the voltage v_{qdn} is different forms, when it is transformed back to form v_{abc} through the inverse order of 9x3 matrix, it can create the same results with the form v_{abc} input the voltage. The results of the order 9x3 matrix inverse of the three changes in the reference angular velocity produce the output voltage which is the same as the input voltage.

It is concluded that the transformation of 9 phase abc system to qdn by 3x9 matrix with different angular velocity reference generates a response (v_{qdn}) which is different and the transformation qdn to 9 phase abc system by inversing 9x3 matrix with different angular velocity reference generates output (v_{abc}) 9-phase system.

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