Determination of an Asymmetrical Nine Phase Induction Machine Stator and Rotor Inductances Using Winding Function Approach

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***Abstract*—It is an established fact that the simplest means of parameter extraction of an induction machine (e.g resistances and inductances) can be determined from no load (also known as synchronous) test and locked rotor (short circuit) test. To find the resistance of an electric machine for single or multiple phase induction machine pose no problem, because it is a straight forward approach. However, in multiphase induction machine, with phase number greater than three, such approaches are not utterly sufficient to determine the inductances of the machine. An efficient and easily applicable, analytical approach for calculating the inductance of an asymmetrical multiple phase induction machine based on machine geometric information is presented. An algorithm translated to a Matlab script is developed to numerically evaluate the inductances of any multiphase induction machine using turn function and winding function approach is thoroughly established. Important conclusions regarding the processes to obtain the inductance are presented.**

***Index Terms*—Winding Function, Turn function, Inductance, Multiphase induction machine**

I. Introduction

MULTI-phase induction machine as reported in most papers constitute two variants classified by their structural winding arrangements (i.e symmetrical or asymmetrical) round the stator slots and consequently, number of neutral points: The single neutral point multiphase induction machine wound to be usually symmetrical round the stator slots are in phases (5,7,9...) reported in [1]. The multiple neutral induction machines , structurally wound for symmetrical or asymmetrical windings is reported in [2], [3]. The later have been regarded as electric machine with a numbers of three (3), five(5), seven (7), phase set, connected in groups of (i.e 2,3,4...) with joint or dis-joint neutral and their respective windings uniformly distributed in the stator slot compartment of electric machines [4], [5]. The multiphase electric machine type are becoming a popular choice for electromechanical energy conversion, in the following sectors namely: wind energy conversion systems [6], [7], more electric aircraft [8], [9], hybrid electric vehicle [10], [11], to mention but a few. For example, a prototype design of the electric machine at the laboratory to test for it viability involves rewinding a conventional three phase induction machine for the same copper volume per weight to a new electrical machine with more than three phases which retain the electrical, mechanical and metallurgical material properties from the three phase electric machine. By rewinding a three phase induction machine, to obtain extra more phases through structural re-modification of the windings for the same copper weight volume, does not necessarily translate to increase power ratings, rather there are reported benefits derived from having electric machines re-configured for higher phases > 3 namely: power segmentation which improved reliability [12], higher efficiency and reduce torque ripple when compare on a scale with conventional three phase induction machine and improve voltage waveform [13], fault tolerant capabilities [14], arbitrary power sharing between set of windings [15].

Multiple-phase induction machine winding topology are replicate of the multiple single or three phase induction machine. As a result of this extra windings, coupling between the phases and other winding set in the stator compartment increase. In other to ensure an efficient dynamic and steady state simulation studies of the multiple phase induction machine, it is important to effectively find the inductances between phases and with other windings of another phase or sets in the multiphase induction machine. This is the motivation of this paper.

Finding the inductance of a three phase induction machine

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using a number of different approaches have been well reported in [16], with each work describing in full detail procedures on how these parameters can be determined. Multiphase induction machine are recently been used in the reviewed works above. So, it is essential to derive a precise method of computing the multi-stator inductances, to ensure accurate prediction of the machine performances when compared on a scale with a three phase induction machine. A number of works have reported parameter extraction of multiphase induction machine through specific machine equivalent circuits obtained from simplify model equations [17].

Parameter identification for distributed windings of multiphase induction machine have attracted great interest as it was explored in the works of [19], [20]. Two of their proposed test reported by the same authors are: Stand still time domain techniques combine with recursive least square algorithms and frequency domain techniques. Their approach to distributed windings machine parameter determination was to inject current into the non-torque producing plane $(x_i - y_i)$ subspace of multiphase induction machine model whose other subspaces are $\alpha - \beta$, $0_+, 0_-$. This approach to parameter determination of injecting the non-torque producing subspace is at variance with the method proposed by [21], [22] which inject current into the zero sequence subspace $0_+, 0_-$ which is feasible due to the access to the neutral point. The advantages of the approach by Yepes *et al* is that it does not requires access to neutral point connection when injecting current to the $(x_i - y_i)$ to determine the machine parameter, and their approach is suitable for machine with multiple isolated neutral points. In spite of the review works on how to determine the inductance of an induction machine, traditional no load and load test have been reported not to be sufficient to obtain the magnetising inductance of the induction machine and other parameter of the induction machine.

Clearly, determining the inductance of this more phases machine is quite challenging. Identification of asymmetrical induction machine parameters using winding function (WF) approach have not been covered in literature to the best of my knowledge. Therefore, it is of interest to determine the inductance of the multiphase induction machine using winding function approach to obtain an achievable dynamic performance in the same sense as three phase machines. Modern known approach to determining the inductance of induction machine is via finite element approach [24]. However, the approach is often time consuming and cannot substitute the place of WF approach if the objective of the development is to determine the machine inductance value via analytical means for quick simulation study in addition machine performances.

Analytically, calculated inductance of an asymmetrical multiphase induction machine using WF approach have not been studied in literature to the best of author's knowledge. The inductance of the multiphase induction machine obtained through winding function approach can be combined with values of machine parameters obtained from no load and locked rotor test to study the machine dynamic behaviour. Therefore, the purpose of this paper is to establish on a

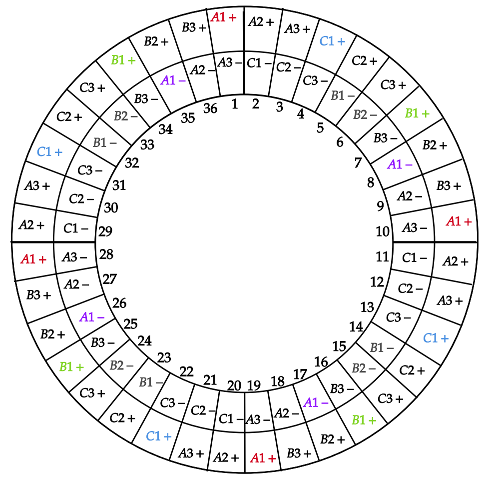

Fig. 1. Tri-Three Phase Clock diagram for the winding distributions in slots.

strict mathematical basis, an efficient and simple analytical and numerical approach in conjunction with the turn and winding function, expressed analytically, to find the inductance of an asymmetrical multiple phase induction machine, results of which can be deployed for quick simulation studies to study the multiple phase transient and steady state studies. An algorithm developed, is translated into Matlab script to calculate these inductances which is presented in section III . The following are the contributions of this paper:

a) The winding function approach gives a better way to determine machine self and mutual inductance between phase windings and other sets of windings housed in the same stator frame for quick simulation studies. The inductance are obtained in a single step without expensive and elaborate experimental layout to determine machine inductance.

b) Determination of the inductance of the multiphase induction machine for electromagnetic studies comes with great simplicity as long as the information regarding the machine geometry is known and its associate winding pattern.

c) The analytical approach to determine machine inductance can be quickly configured into a matlab programe script to calculate the inductance in readiness for simulation studies.

Fig.1 shows a clock diagram of a chorded asymmetrical nine phase induction machine with winding distributions in slots. This paper is organized as follows: Section II describes the background of winding function. Nine phase Induction machine inductance determination for asymmetrical induction machine are shown in Section III and application of winding function approach to the derived model inductance. Section IV discusses the results and finally, Section V concludes the paper.

II. TURN AND WINDING FUNCTION BACKGROUND

The turn and winding function theory is based on spatial distribution of windings in the stator slots of an induction machine [25]. An example of the distribution of the windings in a 36 slot stator is shown in Fig.1. The turn and winding function of the stator and the rotor loop are defined using piecewise linear function. which describe the values of the turn function (TF) and winding function (WF) round the stator and rotor periphery. Given the information regarding the machine geometry, e.g , number of pairs of poles, machine core length, stator bore diameter air gap length, and information regarding the permeability of the core material of the machine, it is realistic to evaluate the inductance of the induction machine in a single step. The distribution of each phase windings, is model by a turn function, that define the turns at any specific angle θ in the stator periphery. The first procedure is to calculate the TF for each phase from the clock diagram winding plan or winding layout given by Fig.1. In developing the turn function, the current direction in the slot for each winding spread or distribution, together with the number of turns of each coil side for the specific windings are considered. The WF is next obtained by subtracting the mean value (i.e removing the dc component) of the turn function from the turn function. Next, the plot of the TF and WF can be drawn by varying the circumferential angle round the stator slots. The determination of the machine inductances (i.e self and mutual), air-gap flux densities and the MMF harmonics are made easier using the turn and winding function. One benefit of the WF approach is that the method assumes no symmetry in the arrangement of motor windings in the entire slots. The winding function expression is given by [25]:

$$N_i(\phi,\theta) = n_i(\phi,\theta) - \langle n_i(\phi,\theta)\rangle \tag{1}$$

where, $n_i(\phi,\theta)$ is the turn function of coil and $\langle n_i(\phi,\theta)\rangle$ is the average of the turn function of coil

The mutual inductance between any two circuit in an electric machine can be express as [25]:

$$L_{ij}(\theta) = \frac{\mu_0 r l}{g(\phi,\theta)} \int_0^{2\pi} N_i(\phi,\theta) N_j(\phi,\theta) d\phi \tag{2}$$

Where, $N_i(\theta_r,\phi)$ and $N_j(\theta_r,\phi)$ are the winding function of circuit i and j which is a function of spatial distribution of the MMF due to a unit current flowing in the winding, $g(\phi,\theta)$ is the gap function, r is the average radius of the air-gap, l is the axial length of the stator. For a squirrel cage rotor, this value of gap function is constant, because of the assumption of the uniformity of the air gap. θ, is the angular rotor position with respect to some arbitrary position. ϕ is a particular point along the air-gap.

III. SELF AND MUTUAL INDUCTANCE BETWEEN WINDINGS OF MULTIPLE SETS

A. STATOR-STATOR INDUCTANCE

The inductances between phases of a winding sets is express in (3). The mutual inductance between winding sets of different stator windings of the tri-three phase inductance machine can be express in matrix form using (4).

$$L_{ii} = \begin{bmatrix} L_{asiasi} & L_{asibsi} & L_{asicsi} \\ L_{bsiasi} & L_{bsibsi} & L_{bsicsi} \\ L_{csiasi} & L_{csibsi} & L_{csicsi} \end{bmatrix}, \forall\ i\ =\ 1,2,3 \tag{3}$$

$$M_{ij} = \begin{bmatrix} L_{asiasj} & L_{asibsj} & L_{asicsj} \\ L_{bsiasj} & L_{bsibsj} & L_{bsicsj} \\ L_{csiasj} & L_{csibsj} & L_{csicsj} \end{bmatrix} \tag{4}$$

The off diagonal mutual inductance matrices are obtained using (4) by towing the line of execution of these expressions for each sub windings matrices: Matrices M_{12}, and M_{13} is obtained by $\forall\ i\ =\ 1\ , j = 2,3$. The same applies to matrices M_{21}, M_{23} obtained by $\forall\ i\ =\ 2\ , j = 1,3$ and consequently for matrices M_{31}, M_{23} obtained by $\forall\ i\ =\ 3\ , j = 1,2$. The mutual inductance between the three set of stator and that of rotor windings are obtained in similar fashion as with (5). Matrice L_r enclosed the rotor self inductance and the mutual inductance with other rotor bars.

$$L_{sri} = \begin{bmatrix} L_{asir1} & L_{asir2} & \cdots & L_{asirn} \\ L_{bsir1} & L_{bsir2} & \cdots & L_{bsirn} \\ L_{csir1} & L_{csir2} & \cdots & L_{csir2} \end{bmatrix} \forall,\ i = 1,2,3 \tag{5}$$

The entry elements of the inductance matrices for (3) and (4) are obtained using (6). A matrix can be developed from the (6) for self and mutual inductance matrices between the winding sets.

$$L_{ij} = L_{ji} = L_{ms} \cos\left(|i-j|\frac{2\pi}{m} + b\xi\right) \forall,\ b\ = 0,1,2 \tag{6}$$

where i, j represent the index for the rows and columns of the inductance matrices of (3) and (4). $m = 3$, applies to all the three phase sets of windings making up for the nine phase induction machine. ξ is the shift angle between the sets, and here $(\xi = \pi/9)^\circ$ for asymmetrical winding with isolated neutral. L_{ms} is the peak value of the magnetising inductance.

B. ROTOR-ROTOR INDUCTANCE

The rotor inductances for a squirrel cage rotor are developed in this section. The turn function and winding function are describe by the piecewise linear function described in (7) . The inductances of a non-skewed rotor are derived using the piecewise function, together with (2) to obtain the inductances given by (10)-(11).

$$n_i(\theta) = \begin{cases} 0 & 0 \le \theta \le \theta_i \\ 1 & \theta_i \le \theta \le \theta_i + \alpha_r \\ 0 & \theta_i + \alpha_r \le \theta \le 2\pi \end{cases} \tag{7}$$

$$N_i(\theta) = \begin{cases} \frac{-\alpha_r}{2\pi} & 0 < \theta < \theta_i \\ 1 - \frac{\alpha_r}{2\pi} & \theta_i < \theta < \theta_{i+1} \\ \frac{-\alpha_r}{2\pi} & \theta_{i+1} < \theta < 2\pi \end{cases} \tag{8}$$

The rotor inductance matrix is given by (9), The element of the rotor inductances is define

$$L_r = \begin{bmatrix} L_{kk}+L_0 & L_{ki}-L_b & L_{ki} & \cdots & L_{ki}-L_b \\ L_{ki}-L_b & L_{kk}+L_0 & L_{ki}-L_b & \cdots & L_{ki} \\ L_{31}^{r} & L_{ki}-L_b & L_{kk}+L_0 & \cdots & L_{ki} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ L_{ki}-L_b & L_{ki} & \ldots & \cdots & L_{kk}+L_0 \end{bmatrix}$$
$$\text{where } L_0 = 2\left(L_b+L_e\right) \tag{9}$$

Where the L_b and L_e are inductances of the rotor bar and end ring. The rotor self inductance matrix is given by:

$$L_{kk} = \frac{\mu_0 r l \alpha_r}{g}\left(1-\frac{\alpha_r}{2\pi}\right) \tag{10}$$

The rotor mutual inductance with other rotor bar is:

$$L_{ki} = -\frac{\mu_0 r l}{g}\left(\frac{\alpha_r^2}{2\pi}\right) \tag{11}$$

C. STATOR-ROTOR MUTUAL INDUCTANCE

The entry elements of the inductance matrices for (5) are populated using (12). The matrices for (5), denote the stator-rotor inductance matrices resulting from the mutual inductances between the stator and rotor for each winding sets, taking into account the shift angle between the winding sets.

$$L_{srj}(\theta_r) = L_m \cos\left(P'\left(\theta_{r\delta}+\frac{\alpha_r}{2}+b\xi\right)\mp k\frac{2\pi}{m}\right) \quad \forall,\ j=1,2,3 \tag{12}$$

$$L_m = \frac{16}{\pi}\frac{\sin\left(P'\frac{\alpha_r}{2}\right)}{\left(2P'\right)^2 N_{si}}L_{msi} \tag{13}$$

$$L_{msi} = \frac{\mu_0 \pi l r}{g}\left(\frac{N_{si}}{2P'}\right)^2 \tag{14}$$

Where P' is the number of pairs of poles, N_{si} is the total number of turns per phase of each sets, θ_r is the rotor angle, ξ is the shift angle between the three set of three phase windings, L_m is the peak value of the mutual inductance between the stator and the rotor, and $m = 3$. Matrices elements of the matrices L_{sr1}, L_{sr2},L_{sr3} dependent on rotor angle θ_r, are formed using (12). The first three rows of L_{sr1}, is formed using (12). For $b = 0$, and the first three row run for the loop $k = 0, 1, 2$. The procedure is repeated again for $b = 1, 2$, and run for the loop $k = 0, 1, 2$ to populate matrices L_{sr2} and L_{sr3} shown in (11). where, $\alpha_r = \frac{2\pi}{n}$, $\theta_{r\delta} = \theta_r + (i-1)\alpha_r$. The i in this expression is the index rotor bar number, running from $i = 1, 2, 3....n$ rotor bars.

Writing the inductance matrix in compact form:

$$L = \begin{bmatrix} [L_{11}] & [M_{12}] & [M_{13}] & [L_{sr1}] \\ [M_{21}] & [L_{22}] & [M_{23}] & [L_{sr2}] \\ [M_{31}] & [M_{32}] & [L_{33}] & [L_{sr3}] \\ [L_{sr1}]^T & [L_{sr2}]^T & [L_{sr3}]^T & [L_r] \end{bmatrix} \tag{15}$$

where, the matrices L_{11},L_{22},L_{33},M_{12},M_{13},M_{21},M_{23},M_{31},M_{32} are a 3×3 matrices. L_{sr1-3} are a $3\times n$ matrices. L_r is a $n\times n$ matrices. The matrices for $L_{11} = L_{22} = L_{33}$ is given by equation (3).

$$L_{ii} = \begin{bmatrix} L_{ls1}+L_{ms1} & L_{ms1}\cos\left(\frac{2\pi}{3}\right) & L_{ms1}\cos\left(\frac{4\pi}{3}\right) \\ L_{ms1}\cos\left(\frac{4\pi}{3}\right) & L_{ls1}+L_{ms1} & L_{ms1}\cos\left(\frac{2\pi}{3}\right) \\ L_{ms1}\cos\left(\frac{2\pi}{3}\right) & L_{ms1}\cos\left(\frac{4\pi}{3}\right) & L_{ls1}+L_{ms1} \end{bmatrix} \tag{16}$$

The matrices M_{ij} is mutual inductance between one winding sets and another winding set given by:

$$M_{ij} = L_{ms1}\begin{bmatrix} \cos(k\xi) & \cos\left(\frac{2\pi}{3}\pm k\xi\right) & \cos\left(\frac{4\pi}{3}\pm k\xi\right) \\ \cos\left(\frac{4\pi}{3}\pm k\xi\right) & \cos(k\xi) & \cos\left(\frac{2\pi}{3}\pm k\xi\right) \\ \cos\left(\frac{2\pi}{3}\pm k\xi\right) & \cos\left(\frac{4\pi}{3}\pm k\xi\right) & \cos(k\xi) \end{bmatrix}$$
$$ij = ji,\ \forall\ i,j\ = 1,2 \text{ and } i,j\ = 2,3 \text{ where, } k = 1$$
$$ij = ji,\ \forall\ i,j = 1,3 \text{ where}, k = 2 \tag{17}$$

where ξ is the disposition angle between the three winding sets. The stator to rotor inductance matrices is obtained using (12)-(14). Based on Fig.1, a script code is written to generate the turn function and winding function of the chorded nine phase machine. The plot of this turn function and winding function as a function of the spatial angle is shown in result section.

D. NUMERICAL EVALUATION OF MACHINE INDUCTANCE

In practice, it is always necessary to make a decision as to weather one wishes to expend energy as to determine the inductance of the machine from experimental work or a time consuming process involve in finite element method. All this procedure, take much time and effort to find the inductance of multiple phase induction machine. In most of this applications, no attempt is made to present a thorough discussion or procedure for finding the inductances of multiple phase machine. The procedure to obtain the inductances will be clearly outline in the develop algorithm describe in this section. Using the clock diagram shown in Fig.1, The inductances for the nine phase induction machine is evaluated, using a combination of the turn function and winding function waveform derived from the piecewise linear function of the three sets of the three phase windings round the stator slots. Taking into account the usual three phase angular shift (i.e $\pm120°$) between phases of a sets and geometric shift angle ($\xi = \pm\frac{\pi}{9}°$) between one set of three phase winding and another sets of three phase winding, while, developing the piecewise linear function.

The inductances between phases are evaluated using (2). A Matlab script is developed to plot the turn function and winding function of the respective inductances between phases of a winding set, following the background of turn function and winding function given section II. In addition, inductances between a phase from one set and another phase of other sets are also obtained. A 'trapz' function is included in the Matlab script to obtain the area under the curve of the respective winding function.The numerical evaluations of the area is done utilizing the full range of the rotor angle θ_r for one cycle in discrete steps. Finally, the inductance values as describe in this section are numerically evaluated to obtained the inductances from the graph, given the machine geometric parameters. The

TABLE I
ALGORITHM

Algorithm for Nine Phase Inductance Matrix Calculation

Define all machine geometric parameters
Choose a reference magnetic axis
Obtain the geometric angle between windings
Define the Turn Function(TF) and Winding Function(WF) expressions
for $i = 1, 2....36$ slots, **do** Turn function (TF) of each phase windings
solve for the mean value of the TF $\langle n_i(\phi, \theta)\rangle$
Evaluate the winding numerically :$N_i(\phi, \theta) = n_i(\phi, \theta) - \langle n_i(\phi, \theta)\rangle$
Obtain plots for the TF and WF based on machine geometry
for $k = 1, 2....9$, **do** inductance for each phase
Numerically evaluate the WF using **'Trapz'** function in Matlab
Return all results of phase inductances in matrix form
end
end

results from this exercise gives the inductances of the nine phase induction with multiple set of windings. Which can used for quick simulation studies for multiple stator winding set, to study the transient and dynamic studies characteristics of the nine phase induction machine.

Table I, shows the algorithm developed to obtain the inductance of the asymmetrical nine phase induction machine. The numerical results after execution are returned. The highlighted matrices in (15) and their respective elements is numerically obtained using the algorithm describe in table I and shown in (15). The matrices L_r is straight forward to obtain, and will not be reproduce here.

IV. Results

The Nine phase asymmetrical induction machine used for the analysis in this paper is a $P_{rated} = 4kW$, four pole, 36 slots induction machine, with $V = 380\,\mathrm{V}$, $f = 50\,\mathrm{Hz}$, stator resistance $R_s = 1.3\,\Omega$, rotor bar resistance $R_b = 77\,\mu\Omega$, rotor end Ring Resistance $R_e = 5\,\mu\Omega$, rotor bar Inductance $L_b = 100\,\mathrm{nH}$, rotor end ring Inductance $L_e = 20\,\mathrm{nH}$, Turns per phase $N_s = 17\,\mathrm{T}$, rotor axial length $l = 140\,\mathrm{mm}$, stator bore average radius $r = 50\,\mathrm{mm}$, Total number of stator slots $Q_s = 36$, number of rotor Bars $Q_r = 28$, air-gap length $g = 0.5\,\mathrm{mm}$, [26] . The machine initially a three phase and it winding configuration was is re-calculated for three set of three phase winding $a_ib_ic_i$ for $i = 1, 2, 3$ segmented in the stator compartment of the stator. Based on these specifications a clock winding diagram showing the winding placement in the stator slots is shown in Fig.1.

The plot of Fig.2, show the winding functions for selected Phases of the nine phase induction machine studied in this paper. The philosophy behind this selection approach is to show a reduction in the phase harmonics spectrum when the MMF's of phases $as1, as2, as3$ are added together in comparison to the harmonic spectrum when only phase $as1$ is considered alone. This spectra of waveform from the two graphs support the earlier premises that an asymmetrical induction machine has lesser ripple in comparison to symmetrical type of winding.

Suffice to say is Fig.3, the winding function of a single phase as_1 and its respective spectrum waveform MMF, in comparison to the total winding function of all the first phases of each sets, and their respective spectrum shows some higher order harmonics eliminated. Although, during the design of the windings, the q value (i.e slot/pole/phase) of the nine phase machine is shared between the three sets i.e, $q_i = \frac{q}{3}$. This choice of q_i result in a concentrated type of winding, which is not the best practice, because of the high number of harmonics this type of winding yield, and this is evident in the spectra waveform in Fig.3(c). A percentage of the harmonics can be removed by adding all the MMF of the same phase sets together to have a more better MMF waveform. The reduction of the harmonics due to this choice is illustrated in the spectra waveform shown in Fig3(d). The variation of the inductance with respective rotor angle is shown in Fig.4 and Fig.5. A comparison of the stator-rotor inductance for rotor bar number 1 and rotor bar 14 is shown is Fig.4. The stator–rotor mutual inductance and their derivative is shown in Fig.5(a)-(d).

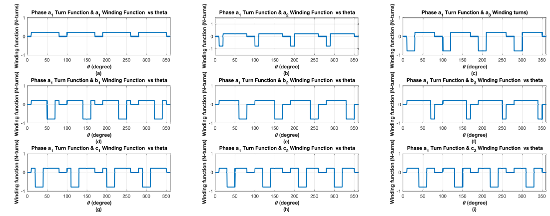

Fig. 2. Winding function of different Phases: (a) Phases (a_1, a_1) (b) Phases (a_1, a_2), (c) Phases (a_1, a_3), (d) Phases(a_1, b_1) (e) Phases (a_1, b_2) (f) Phases (a_1, b_3) (g) Phases (a_1, c_1) (h) Phases (a_1, c_2) (g) Phases (a_1, c_3)

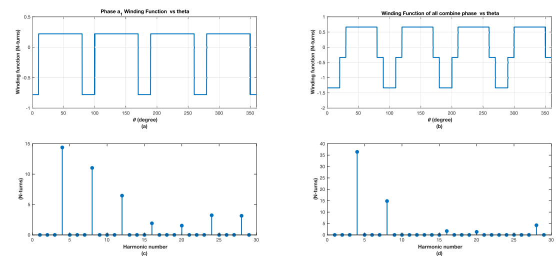

Fig. 3. Winding function and Harmonic Spectrum of winding set (a) Winding function of Phase a_1 of winding set 1. (b) Total winding Function of the combine Phases 'as'of all the winding sets. (c) Harmonic spectrum of Phase a_1 set 1 acting alone. (d) Harmonic spectrum of all the combine set acting altogether.

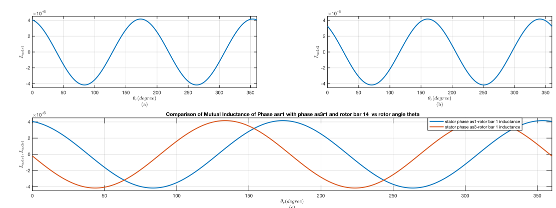

Fig. 4. stator-rotor mutual inductances : (a) Between phase $a1$ and rotor bar 1 (a) Between phase $a1$ and rotor bar 2 (c) Comparison between stator-rotor as_1 and a_{s3} with respect to rotor bar number 14.

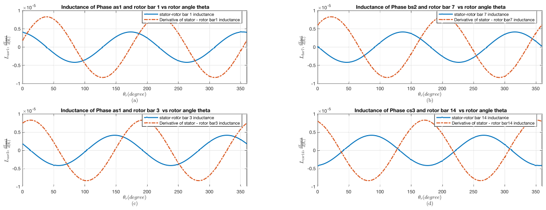

Fig. 5. stator-rotor mutual inductances of different phases and their derivatives: (a)Phase $as1$ with respect to rotor bar 1, (b)Phase $bs2$ with respect to rotor bar 7, (c)Phase $as1$ with respect to rotor bar 3, (a)Phase $cs1$ with respect to rotor bar 14..

V. Conclusion

With the aid of winding function approach, this paper have shown the connection between turn function and inductance of multiple phase induction machine. Inductance variation curves and harmonic spectrum curves has been shown to illustrate the justification for asymmetrical connection have lesser ripple harmonic content . The winding function is evidently a fast and satisfactory method to determine the inductance of the multiphase induction machine. Also, more importantly, sequence harmonics of multiple phases can be found using the approach. The method is also of practical relevance in the determination of multiple phase inductances. This paper present a winding function approach to determine in analytic form the inductance of an asymmetrical winding nine phase induction machine, with three isolated neutral points. An algorithm, coded into a Matlab script is use to obtain the inductance of the multiple set winding machine, in conjunction with the method of winding function approach. The approach allows for higher order harmonic value of the inductance value to be determine. The inductance value present an easy way to determine the inductance of the machine without elaborate laboratory experiment. The results from this exercise can be use to study both the transient and dynamic studies for multiple windings induction machine.

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