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Coil Winding Of Induction Machine

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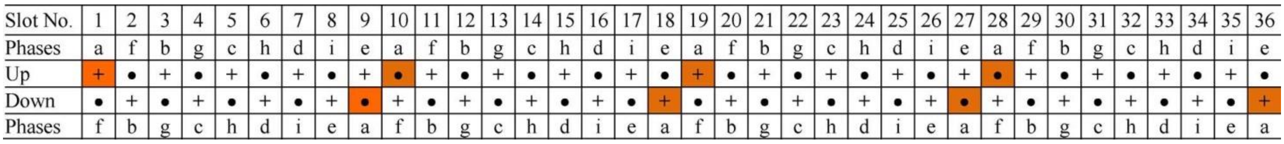
Abstract: A general winding design rule for the pole- phase modulation (PPM) induction machine is proposed, and three different structures, analogous as conventional winding machine, toroidal winding machine, and double- rotor toroidal winding machine, are compared. The results corroborate advantages of the conventional winding machine over the others in operation to the PPM. A steady model for the conventional winding- predicated PPM induction machine, including inductance matrices, voltages, flux liaison, mechanical dynamics, and choker equation, are deduced by employing the winding distributed function. A prototype validates the feasibility of the designed pole- changing winding and the erected model, which is suitable for operation in different poles, singly; also, it illustrates effective operation in the pole- changing process, where both operating modes attend. Double vector control algorithms are developed to control the PPM induction machine for different poles, singly, with their different parameters and the given rotor flux liaison. also, only four current sensors are demanded, indeed however there are nine winding currents; the choker share function ensures a constant choker during pole changing. The simulated and experimental results corroborate the proposed winding design, model, and control system of the PPM induction machine drive

Keywords: Induction machines, magnetic analysis, pole changing, pole-phase modulation, vector control.

I. INTRODUCTION

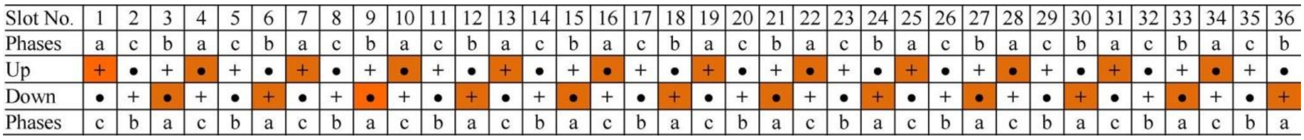
INDUCTION MACHINES (IMs) are extensively used in wind power conventional and cold-blooded electric vehicles and other artificial areas. In integrated starter/ creator and/ or propulsion operations, the extended speed/ necklace capabilities of machines are desirable, because high starting necklace allows briskly acceleration, while high speed allows advanced cruising haste. For this purpose, the conventional machines have to be large, which results in large volume and weight, high cost, and low effectiveness. Pole changing is an eligible scheme to ameliorate the speed/ necklace capabilities of machines. In the history, the windings arede-energized previous to pole changing and the stator winding needs to be reconfigurable using contactors, which will produce a spastic necklace; the electronic pole changing has been studied to overcome this problem The pole- phase modulation(PPM) fashion of IMs that can change the poles and phases(two degrees of freedom) contemporaneously, presents further inflexibility to achieve the electronic pole changing when compared to pole change(one degree of freedom) only. The PPM fashion typically employs multiphase machines, similar as the change of 3- phase/ 12- pole mode to 9- phase/ 4- pole mode. When compared to the conventional three- phase machines, the multiphase machines offer fresh degrees of freedom, which could be used for fault-tolerant operation. Under the fault conditions, the remaining healthy phases in a multiphase machine can be used to compensate for the faults and continue the drive operation. Multiphase motor drives will be more dependable than conventional three- phase motor drives. Also there are numerous control styles related to multiphase machines, analogous as predictive current control, fuzzy logical control, space vector modulation, vector control etc.

These styles can be appertained to the pole- changing control of IMs due to their multiphase behavior; for illustration, the multiple- planes can be introduced in the PPM control of IMs. A layout of the stator winding is vital for the PPM. The toroidal winding was first proposed for this purpose in With the toroidal winding, the coil pitch can be change through control coil current, as a result of the fact that three degrees of freedom(coil pitch), For the traditional winding structure, the coil pitch is fixed. therefore, it's more flexible to achieve PPM using the toroidal winding than the traditional winding. still, the toroidal winding will beget a low operation of bull and high bull lossAuthors previously presented the winding design system, machine modeling, and control system for the traditional winding- predicated PPM in the papers still, a brief prolusion and simple simulation were not in- depth enough to wholly express its principle; also there were no experimental results supported at that time. This paper will fill up this gap through extending them in a detailed and systemic way as follows Section II proposes a winding design system for traditional winding predicated PPM, where the poles and phases can be changed simultaneously, and three sample machines are designed; JMAG- predicated FEM analysis is employed in Section III to corroborate the proposed design system for a PPM IM operating in pole and phase changing; three PPM IMs are compared in Section IV, where one is with the proposed conventional winding structure, the others with the toroidal winding structure; Section V builds the conventional winding- predicated PPM model for the purpose of control and flash analysis; the double vector controls are proposed in Section VI to ensure the designed motor of achieving the smooth pole- changing transition; simulation results are shown in Section VII to corroborate the erected PPM IM model and the control styles are suitable of fluently operating in PPM modes, which are realizable for analysis control of machine ,Section VIII provides the designed prototype of the PPM IM, experimental setup, and experimental results to validate the proposed traditional winding based PPM IM drive.



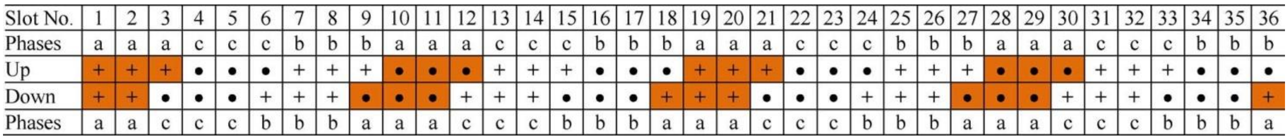
Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Phases	a	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e
Up	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•
Down	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+
Phases	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e	a	f	b	g	c	h	d	i	e	a

Table: 1 WINDING CURRENTS FOR THE 9-PHASE/4-POLE MODE



Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Phases	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b
Up	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•
Down	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+	•	+
Phases	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a	c	b	a

Table: 2 WINDING CURRENTS FOR THE 3-PHASE/12-POLE MODE



Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Phases	a	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b
Up	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•
Down	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+	+	+	•	•	•	+
Phases	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b	a	a	a	c	c	c	b	b	b	a

Table: 3 WINDING CURRENTS FOR THE 3-PHASE/12-POLE MODE

II. WINDING DESIGN FOR PPM

A. Design Rule

Both sides of each coil in a conventional winding are placed in the inner places of the stator core. The coil pitch is equal and constant for all coils, which can not be changed during winding reconnection for pole changing. Denoting as the number of pole dyads and as the number of phases for a coetaneous speed, and and for another set of pole dyads and phases in the same stator places, they have

$$Q=2P_{1q1m1} = 2p_{2q2m2}$$

Where Q is the number of stator places; is pole dyads; is the number of phases; is the number of places per pole per phase. The pole rate is defined by

$K = 2_{p2 = q1m1}$

Where p1 < p2 and an integer.

The design rule of pole- changing windings for the PPM IM is epitomized as follows
1) elect the number of stator places;
2) elect pole rate;
3) Select phase rate j in
J = m` , j = 1 . 2;
4) Calculate rate using;
5) Select coil pitch and connect the coils into windings.
There are two important points

B. Prototype Design

1) The coil should have a pitch equal to, or slightly lower than, a full pitch for lower number of poles. In other words, the coil pitch should be designed according to low pole- number mode, which can be full pitch or fractional pitch winding.

For illustration, the winding with 2 modes, videlicet, 9 phases with 4 poles and 3 phases with 12 poles, should be designed on the base of 9- phase/ 4- pole mode, with a full pitch or fractional pitch.

2) To drop the leg- number of the power motor, should be named, which leads to the minimal leg- number for the power motor. Prototype Design To estimate the proposed design rule, a 36- niche double- subcaste winding machine is designed. The machine could be operated in 9- phase/ 4- pole mode, 3- phase/ 12- pole mode, and 3- phase/ 4- pole mode, independently.

The PPM will be performed by con- trolling each winding current, and the pole changing is achieved when the motor is operating on line, without the need for any mechanical contactor. For 9- phase/ 4- pole mode and 3- phase/ 12- pole mode, there's, and the number of motor legs is 9. For 9- phase 4- pole and 3- phase 4- pole mode, there is , and the number of motor legs is 9. When the coil is designed with fractional pitch for the lower number of poles, defining coil pitch, the winding distribu- tion and their current directions are those shown in Tables I – III, where the signs and denote the current flowing into and out of the runner, independently.

III. PPM VERIFICATION

A. JMAG Based PPM model

The major dimensions of the intended prototype, which contains 33 rotor bars and 36 stator slots, are listed in Table IV. The magnetic field of the PPM machine is estimated using the finite element programme JMAG-studio to contrast two operation modes.

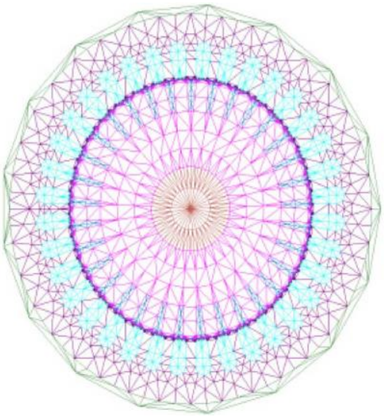


Fig. 1. Finite element mesh model in JMAG software

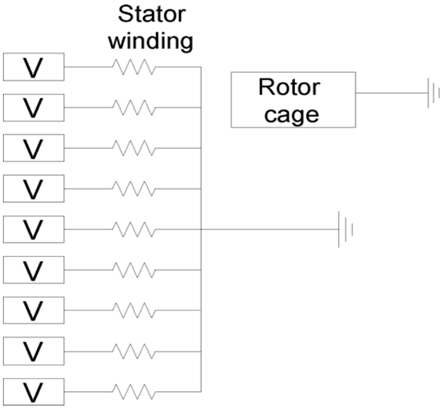


Fig. 2. Winding circuit in JMAG software.

Employing the technique of field-circuit coupling. The JMAG's winding circuit and finite element model are depicted in Figures 1 and 2, respectively. 20 157 nodes and 25 938 first-order elements, including air-gap elements, make up the 2-D finite element mesh. In comparison to other areas of the machine, the mesh in the gap is smaller.

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B. Calculated Result

For the 3- phase/ 4- pole mode, three coils of every phase have unstable back electromotive forces(EMF) because of theirnon-identical space distributions, which causes the circulating winding current in three coils, so it isn't practical in the PPM operation. Then we just use the 3- phase/ 12- pole mode and the phase/ 12- pole mode and(b) 9- phase/ 4- pole mode. 9- phase/ 4- pole mode for pole changing. The prototype presents the different responses in the flux field when its winding ter- minals are supplied with the 3- phase voltages and the 9- phase voltages, independently.

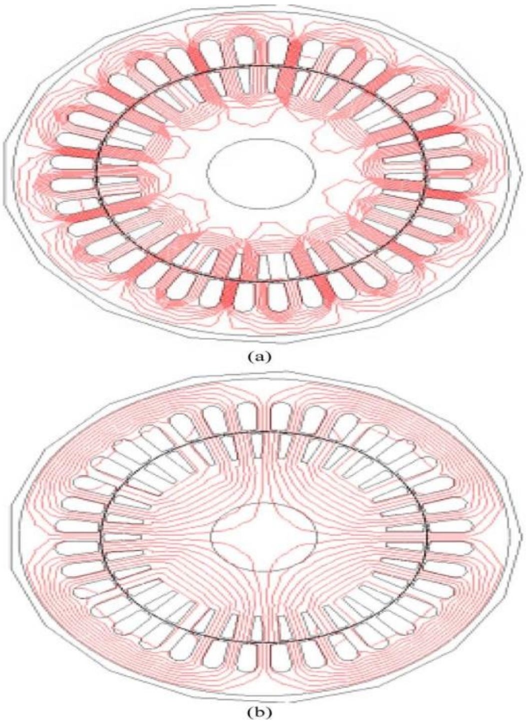

Fig. 3. Magnetic field of the machine for different poles:
(a) 3-phase/12-pole mode and
(b) 9-phase/4-pole mode.

The glamorous fields, in steady state, are shown inFig. 3. When the 3- phase voltage of 50 Hz is amped , in Fig. 2, the 12- pole glamorous field is generated, as shown in Fig. 3(a); and the 9- phase voltage of 50 Hz results in the 4- pole glamorous field, as shown in Fig. 3(b). 4 – 6 show the speed, necklace, and phase current during the no- cargo starting process. The pole number is changed when the different voltages are applied to the same machine. 7 shows the necklace comparison of the machine operating in 9- phase/ 4- pole and 3- phase/ 12- pole modes, independently. In the computation, there's the same magnitude of the applied voltage with the same frequence, and the speed slip is0.04. The 3- phase/ 12- pole mode provides advanced necklace with lower speed, when compared to the 9- phase/ 4- pole mode of lower necklace and advanced speed. During simulation, the 3- phase/ 12- pole mode has an effectiveness of80.2, and the 9- phase/ 4- pole mode with an effectiveness of89.

IV. COMPARISON OF THREE PPM MACHINE

A. Three Structure of PPm Machine

Three structures of PPM machines, that are based totally at the traditional winding, toroidal winding, and dual-rotor toroidal winding [33], are considered, denoted on this paper as system-1, device-2, and gadget-3, respectively, with the same inner rotor. In system-3, there is an outer rotor, an internal rotor, and a stator with toroidal winding [33]. Fig. 8 provides some toroidal coils in a stator core [7]. The toroidal coil desires twice the coil turns compared to standard coils for the equal magnetomotive pressure (MMF). So the stator resistance according to phase is greater than that of the conventional winding machine. gadget-three has rotors whilst compared to device-2, and both the internal and outer rotors are cage structure. It confirmed this type of gadget's geometry and prototype. desk V shows the parameters of the three machines.

B. Comparison Of Three Machine

The same voltage is carried out to 3 machines, respectively, with the frequency of 50 Hz and the rate slip of zero.04 (1440 r/ min). both rotors of device-3 have the identical speed. Fig. 9 offers their constant magnetic fields at load. 3 machines show the magnetic fields of 4 poles. machine-1 and machine-2 have the identical magnetic subject distribution. For system-three, there are magnetic lines in each the inner and outer rotors, because of torques produced in both internal and outer rotors. Stator cur- rents, torques, and efficiencies are distinct in 3 machines, as shown in table VI, wherein the coil-head losses are disregarded.For machine-three, rotors utilize both facets of the toroidal winding, which reduces the non-energetic winding copper and copper loss, when as compared to machine-2. additionally, this shape makes machine-3 roughly equal to 2 machines (ma- chine-2) linked in collection. Assuming the voltage, torque, present day, flux (flux density), and energy of system-2 as 1 consistent with unit (pu) for the equal terminal voltage and frequency carried out to device-three, every equal machine of gadget-three will get0.five pu voltage, which reasons the flux (or flux density) to be around zero.5 pu, so the core loss is extensively decreased. With the equal slip frequency, the stator and rotor currents are around0.5 pu..

As a end result, every rotor will produce torque with around zero.25 pu and rotors will make a complete torque around 0.five pu. The decreased present day will cause a reduced copper loss (round 1/four). consequently, for the same voltage, supply frequency, and slip frequency, machine-3 produces the strength of around zero.5 pu when as compared to device-2, however the center loss is reduced to half of and the copper loss is decreased to 1-fourth, which ends up in higher efficiency than gadget-2. In desk VI, device-2 offers the very best copper loss, leading to the bottom performance. moreover, gadget-2 requires extra coils than gadget-1. system-3 has double rotors with one stator and makes use of each facets of the coils, in place of only one facet of the coils as in device-2. both rotors of system-3 produce torque and bring about high efficiency. Torque per unit current of the 3 machines are three.forty five N.m/A, three.31 N.m/A, and 3.sixty seven N.m/A, respectively. consequently, system-three presents higher toque ability compared to device-2.

V. WORKING MECHANISM OF COIL

The induction coil determines how effectively and effectively a workpiece is heated. Induction coils are the water-cooled copper conductors fabricated from copper tubing that is reality formed into the form of coil for the induction heating device. Induction heating coils do not themselves get warm as water flows thru them. art work coils range complexity from a clean helical coil (along facet some of turns of copper tube wound round a mandrel) to a coil this is precision machined from strong copper and brazed. Coils switch electricity from the power supply to the workpiece with the beneficial resource of producing an alternating electromagnetic field due to the alternating current flowing in them. The coil's alternating electromagnetic area (EMF) generates an triggered modern-day (eddy slicing-edge modern-day) inside the workpiece, which generates warm temperature due to I Squared R losses (center losses). The 5bf1289bdb38b4a57d54c435c7e4aa1c within the workpiece is proportional to the coil's EMF strength. This transfer of strength is called the transformer effect or eddy current effect.

VI. PRODUCT AND ITS APLICATION

the electrical cars are electro-mechanical device that converts electrical electricity to mechanical power and they may be used in extensive form of commercial and home equipments to offer purpose electricity. The motors uses both Alternating modern or Direct contemporary and have several kinds of winding designs to get extraordinary running pace (rpm) and cargo situations or purpose strength ratings normally (HP or KW). maximum common vehicles are Induction winding coil layout because it gives many blessings. The automobiles are either operated on single phase kind or three- section relying on responsibility and according winding coils are designed. single phase motors perform at 250 volt and are on the whole used for low energy score as much as 1000 Watts, viz big variety of domestic and kitchen and other handheld home equipment consisting of the domestic pump units used in houses or buildings. The three -phase cars are excessive strength rated as much as 500 KW used commonly in commercial software. The most of device and machines use three section cars in range of 2 kiloW to 50 kiloW compressors, blowers, machines and equipments. a few submersible pumps utilized in irrigation also are 3 segment cars.

VII. MANUFACTURING PROCESS

The subsequent items are main system steps:

- Dismantling motor body and removal of rotor meeting
- Checking the electric circuit and electrical Stamping. In case of harm to enameled copper twine winding, the precise coil or entire is removed from the middle slots with the aid of unique scrapping equipment and cutters.

- the brand new coil is wound with specific identical gauge and insulation grade. The motor coil design is accompanied in terms of no of winding turns and lay within the middle slot. The completed stator/ rotors are checked for insulation integrity.
- The stampings are checked and repaired or replaced partially as per unique layout.
- The bearing damage is classed and repaired or changed. The rotor shaft if damaged may be changed.
- The motor is assembled with due care and unfastened rotation and alignment of rotor is checked. After mechanical checks, mugger check is completed to look the electrical integrity earlier than powering and checking the velocity in rpm. constrained power rating is checked with load before dispatch to customer

VIII. CONSTRUCTION

The induction motor specifically divided in to 2 components.

(1) Stator
(2) Rotor

In case of D. C. Motor basically it is divided into principal elements

(i) Yoke
(ii) Armature.

Yoke is outer & stationary part, similarly the outer portion of the induction motor is called stator. it is also desk bound part of the induction motor. The stator of the induction motor is cylindrical in form. The internal part of D. C. Motor i.e., armature is rotating in nature. similarly the rotating a part of the induction motor is referred to as rotor. The rotor lies inside the stator. it's far cylindrical in shape. Rotor is split into types.

(i) Squirrel cage Rotor
(ii) phase wound Rotor or Slip ring Rotor, determine shows the disassembled view of an induction motor with squirrel cage rotor.

(a) Stator
(b) Rotor
(c) bearing shields
(d) Fan
(e) air flow grill
(f) terminal container.

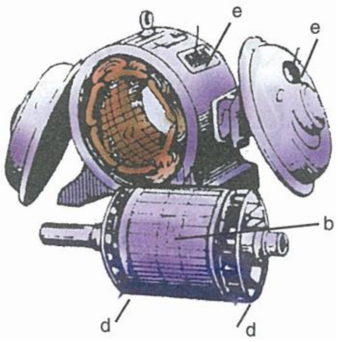

Fig:4:Motor

Further determine indicates the disassembled view of a slip ring motor
(a) stator
(b) rotor
(c) bearing shields
(d) Fan
(e) ventilation grill
(f) Terminal field
(g) Slip ring
(h) brushes & brush holder.

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IX. CONCLUSION

The paper proposed a preferred winding design rule for pole converting within the PPM IM. A prototype with a 36-slot stator and pole-changing windings turned into designed and analyzed. 3 sorts of machine systems, together with the traditional winding, toroidal winding, and twin-rotor toroidal winding, have been com- pared. each the system with the traditional winding and the device with the twin-rotor toroidal winding showed excessive effi- ciency. moreover, the system with the traditional winding presented a extra simple structure than the device with the dual-rotor toroidal winding. As a end result, this machine has a rea- sonable overall performance value ratio and is an attractive solution. Finite element-primarily based JMAG changed into used to affirm the proposed design rule and the feasibility of the designed machine with pole-changing windings. A uniform model of the conventional winding-primarily based PPM IM (together with inductance matrices, voltage, flux linkages, me- chanical dynamics, and torque equations) was constructed for its anal- ysis and manage, in particular throughout pole changing. Double vector manipulate algorithms had been developed to easily control this type of induction machine where the torque share characteristic became em- ployed to make certain a regular torque all through pole changing. A PPM IM that may perform in three-segment/12-pole mode and 9-section/four- pole mode become prototyped. The simulated and experimental re- sults efficaciously proven the proposed winding design rule, the constructed version, and the double vector manage primarily based PPM IM drive.

X. ACKNOWLEDGEMENT

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