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A Review of the Methods for Improving the Efficiency of Drive Motors to Meet IE4 Efficiency Standards

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Abstract

High efficiency standards are slowly being introduced with IE3 efficiency levels shortly becoming compulsory in many countries; IE4 efficiency levels being developed for future implementation. In this paper a review is carried out of the IE 60034-30 standard which covers standard line-start induction motors. Some design techniques that can be used to increase efficiency in order to meet the IE4 standards are discussed. This standard is now being replaced by the IE60034-30-1 standard which extends to other line start motors and also IE 60034-30-2 is being introduced to cover variable speed drives in order to address developing technology. The conclusion is that IE4 standards are obtainable but careful design is needed to reach this. Examples from the literature are given.

Key words: Efficiency, Motors, Standards

I. INTRODUCTION

Increasing the efficiency of electric motors will result in a substantial energy saving on a world-wide basis. To do this the International Electrotechnical Commission (IEC) have developed standards in order to unify performance requirements in the form of the International Energy (IE) Efficiency Classifications. These were reviewed in [1] and this post-conference paper expands the review of these standards and adds some further detailing. These efficiency classifications currently run from IE1 up to IE4 [2], [3]. There is even talk of IE5 [4]. IE3 is already mandatory in the USA and will become mandatory in the EU and China for 7.5kW - 375kW machines in some applications from 1st January 2015 and for lower power up to 0.75kW from 1st January 2017. IE4 is still not scheduled but consideration now will allow for future planning and manufacturers are striving to make their machines more efficient. This paper will review- motors in the range 0.75 to 375 kW (fixed speed). The current standard is IEC 60034-30 [5] but the new standard under development is IEC 60034-30-1 (published March 2014) [6] and IEC 60034-30-2 (to be published shortly) which proposes widening from 120 W to 500 kW. We can categorize the machines efficiency classifications into:

- IE1 (standard efficiency)
- IE2 (high efficiency)
- IE3 (premium efficiency)
- IE4 (super premium efficiency)
- IE5 (ultra-premium efficiency - still little documentation)

We will address the issues concerned with induction motor losses which obviously affect the efficiency. While the IE4 standard is not yet in legislation, the definition is being used by manufacturers in readiness for implementation. Thus is it unlikely to change in its definition.

A. Life Cycle Costs

The U.S. Department of Energy [7] reported in 1980 that motors above 125 W use about 60 % of all electricity generated in the USA and that medium power motors (0.75 kW to 90 kW) use about 60 % of electricity supplied to all motors.

A 1 % increase in motor electrical energy efficiency would save 20 billion kW-hrs per year or $1.4 billion in electricity (at 7 cents per kW-hr) and 3.5 million barrels of oil in the U.S. These savings would be multiplied by about a factor of four on a worldwide basis. In addition with about 50 % increase in energy usage since 1980 [8] and an increase of 184 % in the value of the US dollar then this saving can be extrapolated to about $ 24 billion world-wide.

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At industrial drive level, [9] carries out five case studies which notes that most of the replacement high-efficiency motors repay the investment in new machinery in a matter of several months; only one example exceeds one year.

Automotive drive motors are a new technology and the two most popular motors for this application are the brushless interior permanent magnet motor and the induction motor. Induction motors are lower cost while they are less efficient. In [10] a comparison is made between equivalent induction and brushless permanent magnet 50 kW machines. Full life cycle costings, including thermal performance analysis, efficiency charts and driving cycles, were carried out. The total costs are very comparable, with the induction motor saving a substantial amount on manufacture while costing more to run over an estimated lifespan of the vehicle.

B. Efficiency Standards, Abbreviations and Time-Line Adoptions

There are several global standards agencies and different abbreviations are used. These can be noted:

- MEPS – Minimum performance standards - to legislate for increased energy efficiency many countries are adopting minimum efficiencies for many applications.
- NEMA – National Electrical Manufacturers Association in USA – NEMA Premium maps to IE3 and Super Premium to IE4
- EPAct 92– The US Energy Policy Act of 1992 which predates IEC and represents the first major energy law.
- EPAct 2005 – established NEMA premium efficiency (IE3)

Since three major regions are adopting IEC standards, then this has led to many other countries adopting the standards too. The timeline for MEPS in the USA, EU-27, and China are shown in Fig. 1 [4]. Global MEPS adoption is given in [11].

II. IEC 60034-30, IEC 60034-30-1 AND -2

The current standard covers fixed-speed, 3-phase cage induction motors with a grid supply of 50 or 60 Hz and with 2, 4 or 6 poles (IEC 60034-30 1st Edition 2008-10). There are now plans to split this into two for both variable and fixed speeds and include 8 pole machines and not just cage rotor machines:

- IEC 60034-30-1 – Efficiency classes of line operated AC motors – published March 2014: 3-phase ac induction (cage and wound); single phase ac induction; line start permanent magnet; and sinusoidal reluctance.
- IEC 60034-30-2 – variable speed: permanent-magnet synchronous; and wound rotor synchronous.

For the 60034-30 standard, the supply frequency is the main difference between US and EU MEPS with the US being 60 Hz and EU 50 Hz. This is carried through into the new 60034-30-1 standard. However, since 60034-30-2 considers variable speed motors then this is not relevant and full efficiency charts need to be considered.

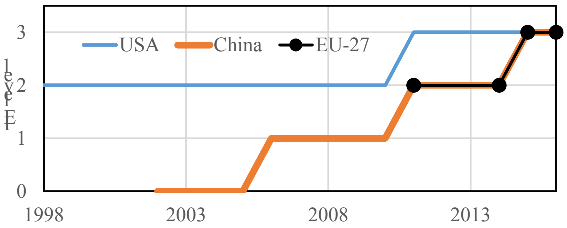

Fig. 1. IE efficiency timeline.

TABLE I
Efficiency Rating Classification Possibilities for Different Line-Start Machines in the IE 60034-30 Standard (IE1 is Possible for All Motors)

Motor Type			**IE2**	**IE3**	**IE4**
3-phase squirrel cage induction motor	Random and form winding IP2x (open motors)		Yes	Difficult	No
	IP4x and above (enclosed)	Random winding	Yes	Yes	**Difficult**
		Form winding	Yes	Difficult	No
3-phase wound rotor induction motor			Yes	Yes	No
1-phase squirrel cage	1 capacitor		Difficult	No	No
	2 switchable capacitors		Yes	Difficult	No
Line start permanent magnet motor			Yes	Yes	**Yes**
Line start wound rotor motor			Yes	Yes	**Difficult**

To be thorough, NOT covered by IEC 60034-30 [2] are: variable speed non-sinusoidal voltage (DC, switched reluctance, brushless DC: These have to be tested in a complete system); very high speed or very low speed; motors that cannot be covered in IE1 to IE4 classifications (motors with completely integrated brake and sliding rotor motors only excluded when the brake cannot be disassembled or separately fed); motors with extended temperature range < -20°C and > 60°C (smoke extraction motors above 400°C, cold storage warehouse motors, oven supply motors); motors completely integrated into a machine; and motors with integrated frequency converters (piggy-back converters and on-coil electronics).

The types of motor covered and the projected possibility of meeting the IE efficiency standards are shown in Table I for the fixed supply frequency standard. The variation of efficiency with size is given in Fig. 2 for a 4 pole motor. Obviously with technology and material improvements then this table is subject to change.

The variation of efficiency for different pole number and size is illustrated in Fig. 3. It should be noted that the 4 pole motor is the most efficient machine. There are several reasons for this. The 4 pole motor is the most common machine so has undergone most design development. However, in terms of design, as the pole number increases then the speed reduces. The torque is a function of current so for a given torque the current, and hence copper losses, tend to be almost constant;

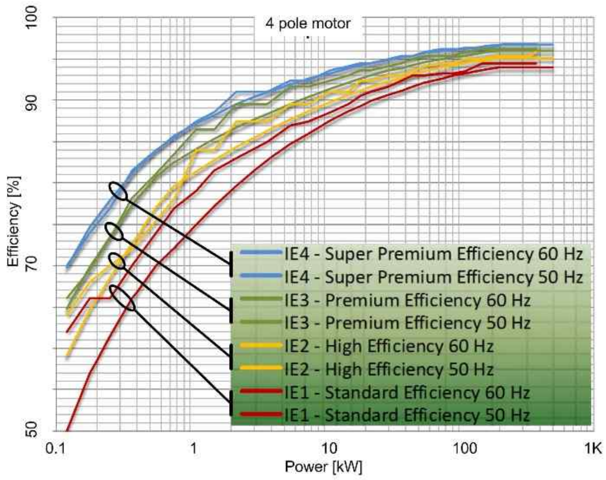

Fig. 2. Efficiency variation for 4 pole machine.

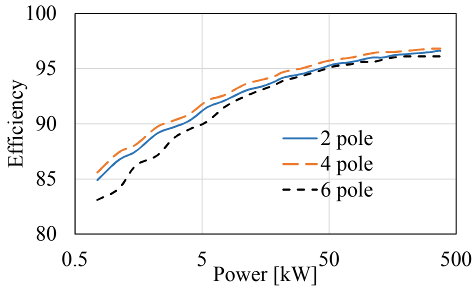

Fig. 3. Efficiency at 50 Hz for different pole numbers for IE4 (fixed frequency supply).

but the power decreases with pole number with fixed torque so that moving from 4 poles to 6 poles will reduce the efficiency. However, moving from 4 poles to 2 poles increases the end winding length of the stator winding substantially as the coils have to span approximately 180 mechanical degrees rather than 90 mechanical degrees. Therefore this produced more stator copper losses and thus the efficiency decreases.

The use of the standards with possible applications, and the various machines that will be covered in the new standard IEC 60034-30-2 are reviewed in [12].

A. Mathematical Model in the Rotor Reference Frame

Response is the same as that of the low-pass filter, as shown in Fig. 8.

III. EFFICIENCY TESTING STANDARDS WITH IEC 60034-2-1 AND 60034-2-3

When assessing the efficiency of a machine a standard set of tests is required to allow direct comparison and codification. Standard IEC 60034-2-1 “Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)” was published in 2007 [13]. This was supplemented in 2010 by IEC 60034-2-2 for test methods for large machines [14]. In order to take into account variable speed drive motors then IEC 60034-2-3 “Rotating electrical machines - Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC induction motors” was published in 2013 [15]. IEC 60034-2-1 is expected to be revised and published in 2014 and the main change is a flowchart that has been introduced to clarify the precise order of individual tests (these help break down the losses). This flowchart was illustrated in [1].

Efficiency testing of different variable speed drive motors obviously presents a dilemma since control plays such an important part in the efficient use of variable speed motors. This is illustrated by the work in [16]-[19]. Middelberg discussed the caveats to attaining high efficiency systems though implementation of the IE3 classification in [20] due to other losses in the complete mechanical and electrical system, and this will be further complicated in a variable speed system. A design philosophy for designing motors to attain IE4 is put forward in [21] and this considers the fluxing of the machine.

IV. INDUCTION MOTOR LOSS CHARACTERISTICS AND INFLUENCES

In this section the losses in an induction motor are addressed. In terms of designing an induction motor [22] and [23] give a good treatise on standard design methods. [24] illustrates the focus on the use of the equivalent circuit when designing the induction motor. The losses were discussed in [24] and the loss variation is illustrated in Fig. 4 across a range of sizes [25]: the windage and friction is a mechanical problem but this does affect the thermal design; the core losses increase slightly with size; stray load losses increase considerably with power; rotor losses increase slightly with power; and stator losses decrease considerably with power due to a reduction in p.u. magnetizing current, improvement in cooling and p.f. Stray load losses present an interesting case because these are essentially losses that cannot be accounted for. Glew, in 1998 [26], presented a challenge to academia to investigate this. Obviously anomalies can occur with the test procedure. For instance, the core loss resistance is often obtained from no-load tests. This is highly none linear and a function of the flux levels and distribution in the machine. When the machine is loaded the flux distribution will change significantly so the use of a constant core loss resistance is somewhat arbitrary. In addition, the personal opinion of the author, inter-bar currents are seldom included in the analysis and this is a loss source that needs investigating. This is underpinned by [27].

In order to improve the efficiency of an induction motor then each of these components needs to be addressed. The friction and windage can be improved by use of better and lower friction bearings. If no fins are fitted to the end-rings then this can reduce windage losses although it can affect the air circulation in the end-region and hence affect the thermal performance. The core loss has been steadily reducing due to

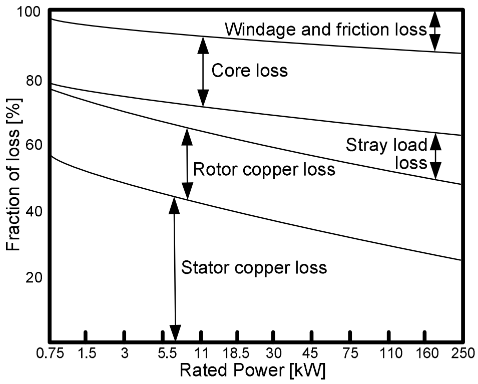

Fig. 4. Components of induction motor loss [11].

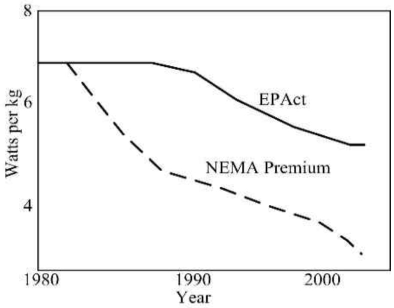

Fig. 5. Reduction in iron loss in magnetic steel.

use of improved steels [28]. The stray load loss can be reduced by operation at a lower slip – an indirect result of lower rotor resistance. Cast copper rotors can reduce the resistance and directly rotor losses. The stator losses will also go down with reduced rotor resistance. A further recent development is to remove rotor copper losses completely during steady state by using line-start PM motors [29], [30]. In the next section each of these loss components is addressed.

A. Mechanical Losses [28]

Reduced motor losses allow use of a smaller cooling fan with less friction and windage. Bearing sizes can be reduced for greater efficiency, but shaft loading would be limited, especially with belt-driven loads. For maintenance reasons, some users prefer the use of the same size bearing on both ends of the motor. Addition of a larger bearing on the opposite drive end (making it the same as the drive end) increases friction and reduces motor efficiency. The opposite-drive-end bearing is lightly loaded and does not require this large bearing for typical loads.

B. Reduction in Iron Losses

Iron loss reduction was addressed in [28]. Care has to be taken when modifying and redesigning a machine because reducing the size can increase flux levels and losses. Actual losses in the steel have gone from about 10 W/kg of steel to less than 4 W/kg. This issues with iron loss in modern variable speed drives is that there is often an extended field weakening range (particularly in automotive drives) and the steel data provided may be insufficient to calculate the iron loss accurately at high frequency.

C. Casting Copper Rotors

The use of cast copper rotors to reduce the rotor copper losses is addressed later. However, [31] gives a chart which provides data concerning the effects of additives on the conductivity of copper. When casting a copper rotor, alloys were used to reduce the melting point and workability because Al melts are 676°C while Cu at 1250°C [32][33]. Magnetic steel will possibly melt at about 1350°C depending on the additives so that accurate temperature control of the copper is vital. However, casting techniques have now been developed so that adding alloying elements is now not required and the casting is done at high temperature. This leads to a much lowed die life. Further discussion of cast copper rotors is in [34][35].

D. Equivalent Circuit – Reduction of Full Load Slip with Copper Rotor

The rotor circuit has an efficiency that is (1-*slip*). Typically the *slip* for small motors is up to 5 % and for large motors it is much less than 1 %. Replacing the cast aluminium rotor at 5 % with a rotor with cast copper may reduce the full load slip to 2 to 3 % (since copper is approximately double the conductivity of aluminium) but the copper may have alloys which will reduce conductivity. Therefore even in an ideal case the efficiency may only improve by 3 % even for a small motor and additional stator copper loss improvement and reduced stray load losses. The conclusion when moving from an aluminium to a cast copper cage rotor is that while a straight swop of material will garner an improvement in performance, the full load slip will be lower so that the flux may be higher, since the machine demagnetizes as the slip increases. Therefore the machine should be redesigned since fluxing levels will change to maximize the effect of using copper.

E. Inter-bar Current Loss

Stray load loss has been studied for many years and it is essentially loss under load that cannot be accounted for using normal testing methods. One source could be inter-bar current, particularly in skewed cast rotors. Cast copper gives low inter-bar resistance. Measuring the inter-bar resistance can also be difficult. A method was discussed in [36] although this is destructive. Since the cage end-rings need to be removed.

Variation of rotor impedance parameters with inter-bar resistance is shown in Fig. 7 from [37] and it illustrates that the effective rotor resistance increases with skew and is higher than would normally be calculated with no inter-bar current. Fig. 8 shows the skew terms in the equivalent circuit [37]. Tests were done on two rotors – one unskewed and one skewed – which were manufactured in the same way and same batch so that the interbar resistance should be very similar. It was not possible to vary the interbar resistance because it is a function of manufacture. The same stator was used in the two tests.

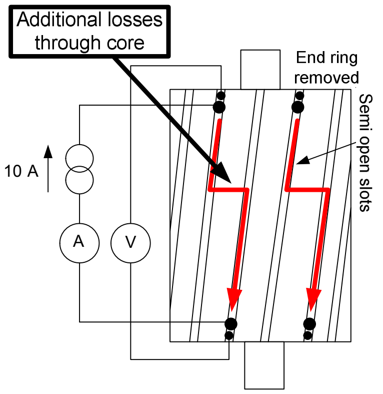

Fig. 6. Measurement of inter-bar resistance.

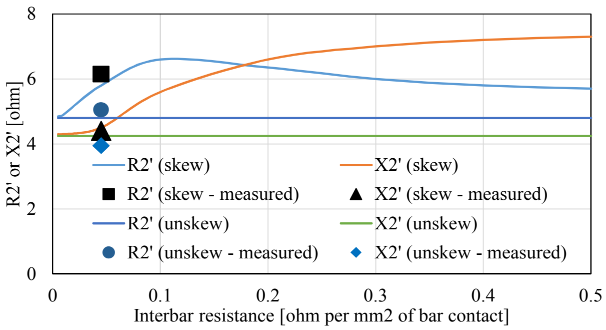

Fig. 7. Effect of inter-bar resistance on rotor equivalent circuit parameters.

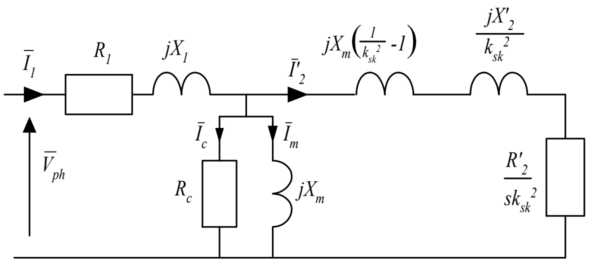

Fig. 8. Skew terms in equivalent circuit.

F. Thermal Design

This is an important aspect to the operation of an induction motor and the thermal operation of the machine is closely linked to the losses. Thermal design can improve motor performance and extend its maximum operating limits. The change in performance was illustrated in [38] and transient thermal simulations are given in Fig. 9. These are a simulations where a 2 pole motor is running light before it was braked down to zero speed then allowed to return to synchronous speed. The return to no load speed is at higher temperature and lower torque. The change in performance is due to increasing copper resistance with increasing temperature which obviously leads to increased losses and reduced efficiency.

G. Manufacturing Costs – Move to Cast Copper Cage

These were studied in [39] for a 7.5 kW machine. The cost breakdown is illustrated in the paper. Using the base of the aluminum rotor motor with 91.6 % efficiency and a cost of \$ 335, it was found that moving to a higher efficiency gives an increased cost of \$365 but an increase in efficiency of 93.8 %. The increase in cost is due to the use of copper rather than aluminum for the cage. If the efficiency is kept constant at 91.6 % then the machine can be made smaller so that the cost reduces to \$345. The increase due to the copper cage is offset by cost reductions in stator and rotor lamination material and required stator copper. By using a cast copper cage the size can be reduced for a similar efficiency which will reduce cost. If the size is maintained then the efficiency can be improved. This illustrates that cost and loss reduction demands often oppose each other in terms of design requirements.

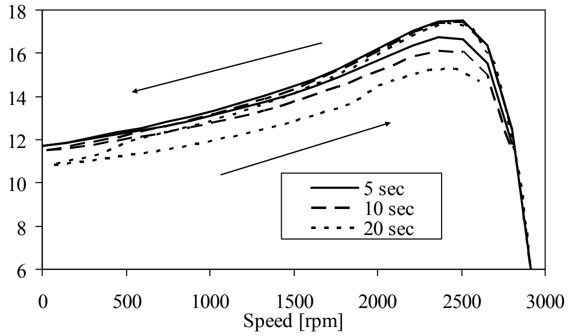

Fig. 9. Transient simulations of 2 pole induction motor as it is stalled when cool and returned to full speed over timed periods.

TABLE II
DIFFERENT MOTORS USED

Motor No.	Efficiency issue of improvement	Pole No.	Power [kW]	Motor Type
1	Inter-bar losses	2	2.2	Cast aluminium rotor IM
2	Thermal design	2	2.2	Cast aluminium rotor IM
3	Aluminium to copper rotor change (Favi)	2	1.5	Cast aluminium and copper IM
4	Line start PM motor	2	0.37	Cast aluminium cage and ferrite magnet rotor
5	Synchronous reluctance motor	4	11 to 315 kW	Ducted reluctance rotor from ABB

V. MOTOR EXAMPLES

The paper examines several motor examples. It draws on previous work from several different studies so that there are a variety of machines studied but most of them are small 2 pole induction motors. Table II lists the different machines to illustrate their similarity and enable comparison.

A. 2-pole 1.5 kW Machine

This machine was manufactured by Favi, France [24] and the aluminum cage was replaced by a cast copper cage with the

Fig. 10. 2-pole 1.5 kW cage machine.

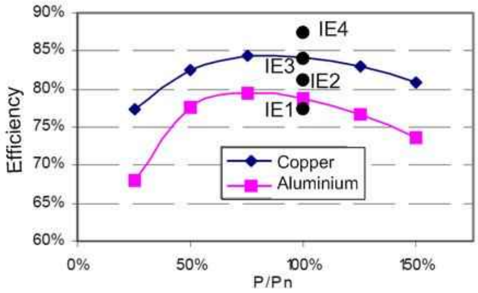

Fig. 11. Efficiency curves for 2 pole 1.5 kW machine in [3].

same dimensions. A half-cross section representation is shown in Fig. 10. The reported loss components in [24] and these show a large decrease in rotor copper loss and also a reduction in stator copper loss. The cast copper rotor increases the motor from IE1 to marginal IE3. There is an obvious reduction in copper loss but this will also be a reduction in iron loss and stray load loss since it is operating at lower slip.

B. *Larger Induction Motors*

Larger motors need to have high resistance for starting and low resistance when running. This is particularly true for high efficiency motors where the efficiency decreases with rotor resistance at full load but the starting torque increases with rotor resistance. Therefore a high efficiency cast copper cage machine may have starting issues if it is line start. Shaping of the rotor bars can be carried out [33]. Major manufacturers such as Siemens are using cast rotor cages although others such as ABB are still using cast aluminium rotors in high efficiency motors and are able to reach IE4 efficiency in the range from 75 to 375 kW with carefully design.

C. *Line Start PM Motor*

Line start permanent magnet motor may be the only way to realize IE4 operation in some instances and these will be covered in the revised standards. These have a PM rotor for steady-state operation and a cage to enable self-synchronization. They are often small and single phase but they can be 3-phase. At full load there is negligible rotor Cu loss since it is synchronous. Fig. 12 shows an example from [40]. This is for a 2 pole machine and an aluminium rotor was replaced with a line start rotor with 4 magnets and a cage. The efficiency rating went from IE1 to IE4. For the cage rotor machine – 2826 rpm, p.f. = 0.79, efficiency = 62 %, which will just reach IE1 efficiency; for the line start PM machine – 3000 rpm, p.f. = 0.82, efficiency = 84 %, which easily meets IE4. This illustrates why the line start permanent magnet motor is becoming more popular in small applications, particularly in domestic appliances such as washing machines, where improved efficiency is being pursued in many countries. The magnets can be ferrite rather than rare earth which is somewhat more economical.

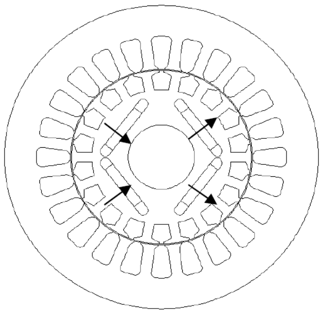

Fig. 12. 2-pole line start PM – rotor has both interior permanent magnets and a cage.

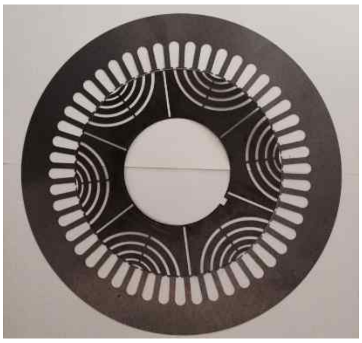

Fig. 13. 6-pole synchronous reluctance machine lamination.

D. *Variable Speed Machine – Variable Reluctance Machines*

If we go to variable speed operation then brushless permanent magnet machines can be used. These are expensive and there is a lot of literature on them. The revised standards will include these. If we want high efficiency magnetless machines then a new commercial machine is the synchronous reluctance machine that ABB are now producing. While the ABB machines are 4 pole, Fig. 13 illustrates a 6 pole type of ducted rotor but the design is similar. They claim to be reaching IE4 in the range of 11 to 315 kW. The rotor and stator in Fig. 13 are actually from a brushless doubly-fed reluctance machine [41]. This is development from the synchronous reluctance motor but has two sets of 3-phase windings with different pole number. It is still in early development but it is aimed at variable speed operation so will be covered by standard IEC 60034-30-2 when it is published.

VI. MOTOR DESIGN

When required to meet IE4 standards then modern design methods should be used. A flowchart is shown in Fig. 14.

When initially designing then usually simple design "rules of thumb" are used which dictate the flux density, current density and thermal limits. These are many and varied but some points to note are:

- Attention to each loss component
- Good quality low loss steel
- Low friction bearings
- Good cooling
- Do not reduce the size to an impractical size
- Careful magnetic design

Simply replacing the aluminium cage with a copper cage (i.e., using the same rotor and stator laminations, axial core length and windings but casting the rotor with a copper cage rather than aluminium) will not necessarily improve it and may not optimize the design. In Fig. 14 shows that electromagnetic, thermal and mechanical software can be used. Modern design software now often allows linkage between the different packages, or packages may carry out two or three of these analyses in the same simulation. An iterative process can be used in many cases since the temperature variations are closely linked to the electromagnetic performance and vice versa.

A. Use of Design Software

For electrical machine design the software tends to fall into two categories – analytical and numerical (finite element analysis – FEA - for electromagnetics and computational fluid dynamics – CFD - for thermal)

Analytical tools can be used to gain understanding of the problem and to size the motor. Software for electromagnetic and thermal design are SPEED and Motor-CAD. These tend to be fast and allow "What-if" analysis using easy-to-use user interfaces and parameterized geometries. Scripting can also be used to automate the design process and carry out optimization. The accuracy can be improved with combined iterative electromagnetic/thermal analysis since losses depend on temperature and temperature depend on losses.

Numerical analysis gives a check to the initial analytical designs and fine tunes the design and allows special geometry features (FEA/CFD). Here, adjustments are made to the analytical models to improve accuracy (calibration). A lot of the analytical and numerical packages can be linked to achieve best design.

B. Complex Loss Types and FEA

As discussed above, packages can be linked. An example of complex loss assessment is shown in Fig. 15. More complex loss mechanisms benefit from FEA analysis and here an analytical thermal design package (Motor-CAD from Motor Design Ltd.) is linked to a finite element analysis package in order to get surface magnet eddy current loss and also proximity losses in stator windings. Automated links from the lumped circuit thermal solver to the FEA code can speed up with this analysis often if a loss calculation is going to take several days to set up and calculate then it may be tempting to make estimates based on previous experience rather than by calculation (less accurate) but validation is needed for finer detail.

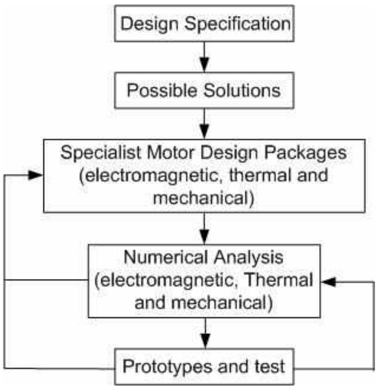

Fig. 14. Design Process Flowchart.

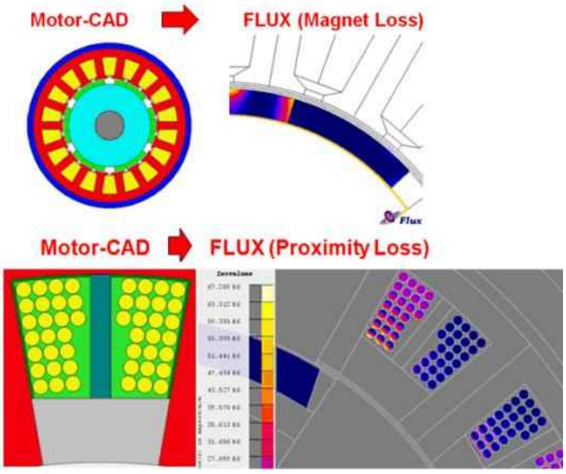

Fig. 15. Linked thermal and FEA for calculation of magnet surface losses and winding proximity losses.

There is much less literature on thermal design compared to electromagnetic design. There are several different cooling options and these are included in the design package Motor-CAD. It is important to consider these:

- TENV: Totally enclosed non-ventilated; natural convection from housing
- TEFC: Totally enclosed fan cooled; forced convection from housing
- Through Ventilation
- Totally Enclosed with Internal Circulating Air; internal air circulating path; water jacket as heat exchanger
- Open end-shield cooling
- Water Jackets, axial or circumferential
- Submersible cooling
- Wet Rotor and Wet Stator cooling
- Spray Cooling, e.g., oil spray cooing of end windings
- Direct conductor cooling, e.g., Slot ducts with oil

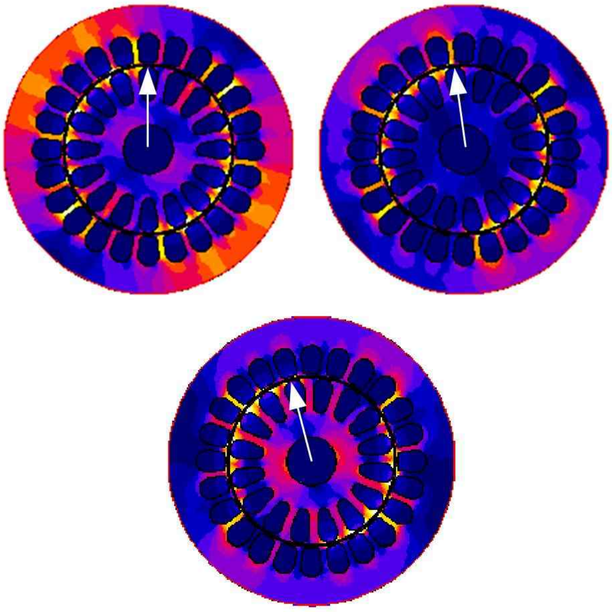

Fig. 16. Multiple axial slices in FEA to represent skew; arrows indicates rotor displacement between slices which rotates from slice to slice.

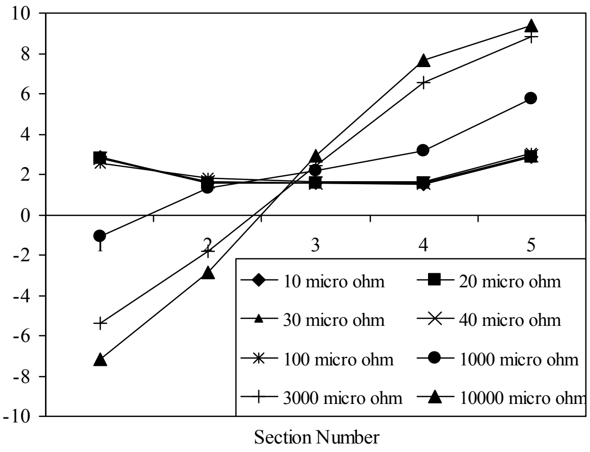

Fig. 17. Variation of torque on axial slices as inter-bar resistance varied.

C. Inter-Bar Current Modelling Using FEA

Some effects such as inter-bar resistance can be modelled in FEA too. In [42] FEA was used to calculate it using multiple axial slices with a connecting circuitry. This is illustrated in Fig. 16. It can be seen the rotor is rotated slightly to represent skew. This is for a 3 slice model but up to 9 were used in [42]. While the net torque on the rotor is positive, further analysis on each slice illustrates that some may have negative torque rather than positive. Fig. 17 shows this for a machine that has about 10 Nm of torque and is modelled with five slices. As the inter-bar resistance is varied the change in torque from one end of the machine becomes larger. Effects such as this will influence the efficiency and there is still room for further research work here.

VII. CONCLUSIONS

IE classifications have been introduced and with time the efficiency is improving. The next level of efficiency to be legislated for by many countries with be IE3, with IE4 being considered for future implementation. Several different design characteristics for an induction motor are highlighted as needing investigation and careful design in order to push the efficiency up to IE4. Other motor types are being used in addition to the induction motor as an alternate option. While the IE4 classification is not yet in legislation it is being used by many manufacturers to benchmark the efficiency of their machines in preparation of its introduction. With the inclusion of variable speed motors in IEC 60034-30-2 then the efficiency has to be considered with variation of both speed and torque. Therefore efficiency charts are being developed in several design packages. These are very relevant to automotive drive motors which have a very wide maximum power range. Part 2 of the standard is slated for publication in 2015 and it is expected that there will be many more studies conducted on high efficiency variable speed drives since it will be a tougher task to meet these standards.

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