EFFECT OF EDDY CURRENT ON THE MAGNETIC INDUCTANCE OF SYNCHRONOUS MACHINE

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Abstract

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The project deals with both experimental and simulation analysis of the synchronous machine. The effect of Eddy currents on the impedance is verified experimentally. A core set-up is designed and analysed for the influence of Eddy current in the system. The set-up is altered to reduce the effect of Eddy current and to validate the effect of it on the magnetic inductance.
INTRODUCTION:

The synchronous machine is one of the most essential and important types of electric machines. Most generating machines at power stations are of the synchronous type which is otherwise called synchronous generators or alternator. The basic principle of a generator is, periodically varying flux in a coil induces an electromotive force in it. The field windings, which carry an excitation current, act as the prime source of the flux. They are designed in a way to produce North-South magnetic pole pairs for producing a periodically varying magnetic flux. The three-phase induction coils are connected in Series/Parallel and in Star/Delta connection. The kind of coil connection is based on the desired supply voltage and rated current.

The described arrangement is called the Armature winding, wherein the armature coils carry the currents, which produce a magnetic rotating field. The latter interacts with the magnetic field of the field winding by generating an electromagnetic torque. The resulting electromagnetic torque naturally tends to align the two magnetic fields in order to minimize the electromagnetic energy in the system. The design of the machine is usually made in a way that the field windings are placed in the rotor and the armature windings are slotted in the stator. The stator is made of a high permeability; high electric resistivity laminated magnetic material (silicon steel). The rotor is often made of massive steel or cast iron. In salient pole generators, the rotor saliencies, as well as the stator saliencies, can be laminated.

According to the Faraday’s Law of Induction, when a time-varying flux links coil N times, a voltage is induced in it, that is directly proportional to the rate of change of flux with respect to the time.

\[ E = -\frac{N\Delta\phi}{\Delta t} \]  

(1)

According to the Lenz’s minus sign convention in the Faraday’s law, the induced voltage in the coil is such to oppose the cause that produced the flux variation. Thus, if a conductive closed path is available to the induced electromotive force; an induced current is generated, which reacts against the inducing flux. A time-varying flux always induces loops of current in metallic parts of electrical machines. These loops are called Eddy currents and are responsible for two main phenomena: the magnetic reaction to the flux and the loss production. The first one prevents a time-varying flux to fully penetrate a magnetic path, making the apparent reluctance of the magnetic circuit higher than in the stationary case. The second one wastes electric energy in heat by Joule’s effect. All electrical machines encounter Eddy current and are impossible to eliminate them completely. However, where their effects are undesired, they can be mitigated by the rational geometric design of the magnetic path and by the choice of not well conducting magnetic materials.

Eddy currents find anyway many practical applications, such as Electromagnetic damping of the Coil of Galvanometer. The heat generated due to Eddy currents is used, to produce induction furnaces, to prepare alloy of metals. Also due to the ability to generate a drag force (Opposing force), it finds applications in braking trains.
**PROBLEM STATEMENT:**

In traditional control strategies of synchronous machines, the field winding is flown by DC current. This is why the excitation current classically does not contribute to the generation of Eddy currents, neither in the rotor nor in the stator iron. However, some important applications involving fast field current control in recent years have required the application of fast switching power electronics to the field winding. It is therefore important to understand in what measure time-varying excitation current can produce eddy currents in the massive rotor of a salient pole synchronous machine. On the other hand, it is necessary to understand if the induced eddy currents could be a hindrance for the establishment of the desired time-varying magnetic flux. To this end, consider a four-pole synchronous machine as shown in figure 1a. The 4 poles in the machine act as the path for the flux induced in the machine. The flux starts in the North Pole, crosses twice the air gap and completes a closed path through the South Pole of the machine. Since there are 4 distinct magnetic flux paths, the flux gets divided by half at the North Pole and sums up at the South Pole (identical). The flux lines always form a closed path and this can be justified using the equation:

\[ \nabla \cdot B = 0 \quad (2) \]

A more simplified model is depicted in Figure 1b since the flux path is identical and is magnetically decoupled, a full flux path is considered for the research and analysis. Single pole path model is simple and more convenient, also the number of pole paths do not add knowledge to the study. In the present project, the effects of the eddy currents described above (magnetic reaction and losses) are studied by the influence that they have on the impedance of the field winding. At first, a real synchronous generator is used to acquire experimental data. In particular, an alternated voltage at variable frequency has been applied to the terminals of the field winding in order to measure the resulting excitation current. From the collected data it has been possible to calculate the winding resistance and inductance vs the frequency. The experimental test has given some insight into the variation of active and reactive power absorbed by the field winding [1].

A second phase of the project has been devoted to conceiving an electromagnetic set-up for future and more accurate tests on the effects of eddy currents. Said set-up has been first analytically designed and then tested by FEMM (Finite element method magnetics) software, in order to confirm the relationship between winding inductance, resistance and frequency.
PROBLEM APPROACH:

According to the considerations exposed in the paragraph “Problem statement”, one pole pair magnetic structure can be conveniently represented as shown in Figure 2. A core structure of Height $2h$, width $2b$ and length $2a$ are considered to derive the expression for the inductance and to study the effect of frequency changes in the system. The core is wound with two coils of $N$ turns, connected in series to each other and has an air gap length $d$. The core material is surrounded by a yoke structure, which is considered to be finely laminated with a poorly conductive magnetic material.

![Figure 2: A simplified model of a synchronous machine pole-pair showing the core, yoke and windings along with its dimensions](image)

According to Maxwell Law,

$$\nabla \times H = J$$

(3)

According to the Ampere Law,

$$\oint \sum H \cdot dl = \sum N l$$

(4)

Integrating along $2h$ in figure 2,

$$\int_{-h}^{h} H \cdot dl = H \cdot 2h$$

(5)

Integrating over $h$ and air gap $d$ in figure 2,

$$\int_{h}^{h+d} H_0 \cdot dl = H_0 \cdot 2d$$

(6)

From equation 5 and 6,

$$2H_0d + 2Hh = 2Nl$$

(7)

Flux $\varphi$ is a Magnetic Flux Density $B$,

$$\varphi = \varphi_0 \Rightarrow B = B_0$$

(8)

We know that,

$$B = \mu H; \quad B_0 = \mu_0 H_0$$

(9)

From equation 9 we get,

$$H \cdot \mu_0 = H_0$$

(10)
Substituting values of equation (7) in (9) we get Magnetic Flux Density,

\[ B_0 = \frac{\mu_0 \mu_r N l}{(h + d \mu_r)} \]  

(11)

By Gauss Law,

\[ \varphi = \int B \cdot dA \Rightarrow \varphi = B_0 \cdot 2a \cdot 2b \]  

(12)

Self-inductance \( \Psi \) is,

\[ \Psi = 2N \varphi \Rightarrow \Psi = \frac{8N^2 \mu_0 \mu_r ab l}{(h + d \mu_r)} \]  

(13)

Inductance \( L \),

\[ L = \frac{\Psi}{I} \Rightarrow L = \frac{\mu_0 \mu_r (2N)^2 (ab)}{2(h + d \mu_r)} \]  

(14)

Reluctance \( R \),

\[ R = \frac{l}{\mu A} \]  

(15)

The resultant Inductance is,

\[ L = \frac{(2N)^2}{2(R_0 + R)} \]  

(16)

**ELECTRICAL MACHINE - SYNCHRONOUS GENERATOR:**

To start the analysis, a four pole, three-phase synchronous generator’s field windings as shown in figure 3 and figure 4 is fed with a voltage generated by one single phase of another three-phase synchronous generator. In order to vary the voltage frequency, the speed of the generator is controlled using a parallel excited coaxial DC motor. The voltage and current of the excitation windings were recorded for frequency between 0-25 Hz. All coming plots are plotted for various frequencies from 0-25 Hz of the synchronous machine by controlling the speed of the DC motor coupled to the three-phase synchronous Generator. By taking the Fast Fourier Transform of the measured periodic non-sinusoidal data, we get a discrete plot of the different frequency components.
ANALYTICAL ESTIMATION OF THE FIELD WINDING INDUCTANCE FOR THE SYNCHRONOUS GENERATOR USED IN EXPERIMENTAL TEST:

Parameters of the machine in figure 4:

Pole Enclosure = 75%

d of Air gap = 2.4 mm

No of turns (N) = 460 turns

Axial Length = 0.2 m

The radius of Air gap = 0.2 m

No of Pole paths = 2

From Equation (16),

\[ L = \frac{(2N)^2}{2R_0 + R} = 2 \times \frac{(4\pi \times 10^{-7}) \left(0.75 \times \frac{N}{2}\right)(0.2)(0.2)(2+460)^2}{2+2.4+10^{-3}} = 20.88 \text{ H} \]

The Magnitude and the Phase of the targeted fundamental frequency for both applied voltage and resulting current are used for the calculation of the Series Resistance and Inductance. In the graph, the Fundamental frequency component of Voltage and Current are shown in Figure 5, Figure 6, Figure 7, and Figure 8, which are related to the field winding of the Synchronous generator at frequency 42.88 Hz.
CALCULATION OF IMPEDANCE:

The calculation of parallel resistance and inductance of the excitation winding includes the supplied voltage, excitation current $I$, and phase difference $\vartheta$ as shown in figure 5-8. From the phasor diagram in figure 9, the parallel resistance and parallel inductance formula is,

$$ Rp = \frac{\omega |\psi|}{|I|} = \frac{2\omega N \phi}{-|I| \sin \vartheta} = \frac{V}{-|I| \sin \vartheta} \quad (17); \quad Lp = \frac{|\psi|}{|I|} = \frac{2N \phi}{|I| \cos \vartheta} = \frac{V}{\omega |I| \cos \vartheta} \quad (18) $$

![Figure 9: Phasor diagram and relative schematic circuit for an inductor model with parallel resistance and inductance](image)

![Figure 10: Parallel Resistance vs f](image)

![Figure 11: Parallel Inductance vs f](image)

![Figure 12: Parallel Resistance Vs (f ^0.5)](image)

![Figure 13: Parallel Inductance vs (f ^0.5)](image)
One can observe in figure 9 that the Parallel Resistance increases steeply at the initial frequency, linearizes and almost saturates at higher frequencies. The Parallel Resistance curve for the root of the frequency in figure 12 suggests that $R_p$ is directly proportional to the $(f)^{0.5}$, which suggests the thickness of lamination is greater than the penetration depth according to equation 19. The Parallel inductance decreases with increase in frequency as shown in figure 11 and 2. At higher frequency, it seems to tend to a constant value. The DC inductance of the generator should be close to 18 H from figure 11. The calculation of the inductance of the machine gave 20.88 H, which means that the calculation and plots are coherent.

The curves of active and reactive power absorbed by the field winding are function of Voltage, Current and the phase difference ($\phi$) between those. The active and reactive power is, in this case, those absorbed by a choke, an inductor like a coil with iron core. Thus the active power represents the losses in the iron core whereas the reactive power is related to the maximal instantaneous magnetic energy stored in the system. Both Active and Reactive power in figure 14 and 15 is a function of frequency. The Power versus Frequency curves can be related to the Penetration depth, Skin effect, Steinmetz's Theory and the Current density in the core material. The penetration depth $\delta$, frequency $f$, permeability $\mu$ and conductivity $\sigma$ are related by:

**Penetration depth in conductor:**

$$\delta = \left(\frac{1}{\nu f \mu \sigma}\right)^{1/2} \quad (19)$$

**Steinmetz's theory:**

$$P(\text{eddy}) = \frac{(Bf)^2}{\rho} \quad (20)$$

Skin effect is the attitude or tendency of an alternating current to concentrate at the surface of a conductor. At low frequency, the current density is uniformly distributed throughout the conductor. As the frequency increases, the current density shifts towards the conductor surface and concentrates thereby at its periphery. The same kind of behavior can be observed for the induced eddy currents. According to Steinmetz’s theory, the power loss related to eddy current is proportional to the frequency squared, the thickness of material squared and to the magnetic flux density $B$ squared. It is also inversely proportional to the resistivity of the core material, as it is shown in equation (20). Steinmetz's theory holds well where the penetration depth is much bigger than the...
biggest cross-sectional dimension. From the equation (19), it has been seen that the penetration depth is inversely proportional to the frequency of the excitation current, the magnetic permeability and the electrical conductivity of the core material. In other words, the penetration depth decreases with an increase in frequency.

From the Power Curve in figure 14 and figure 15, it is observed that at a frequency from 0 - 5 Hz the conductor is fully penetrated because the power increases more than linearly with the frequency. The iron core is massive which means that the penetration depth is way bigger than the biggest cross-sectional dimension. It is then observed that the linear proportionality is a transition region between the squared and the square root dependence of the power. At higher frequencies, it is observed that the thickness of lamination is much greater than the penetration depth. Thus the Power is proportional to the square root of Frequency.

**FEM SET-UP DESIGN:**

After the results of the experimental Test, the next step is to Design an experimental set-up made of a Core Material around a Yoke structure in order to study the Eddy Currents and their contribution to the Power Loss, the reduction of main flux due to eddy current reaction. The designed setup will be supplied by a synchronous generator with the following characteristics:

**RATING OF THE MOTOR AND MAIN DIMENSIONS OF THE SETUP:**

\[
\begin{align*}
\text{Voltage} & = 220 \text{ V} ; \text{Current} = 5.3 \text{ A} ; \cos \theta = 0.8 \\
Q &= \sqrt[3]{V I \cos \theta} = 1.211 \text{ kVA} \quad (21) \\
Iq &= \frac{Q}{\sqrt{3}V} = 3.18 \text{ A} \quad (22) \\
X &= \frac{V}{\sqrt{3}Iq} = 40 \Omega \quad (23) \\
L &= \frac{X}{w} = 127 \text{ mH} \quad (24)
\end{align*}
\]

- \(a = 0.025 \text{ m}\) - half pole width [m]
- \(b = 0.025 \text{ m}\) - half pole length [m]
- \(d = 0.06 \text{ m}\) - winding width [m]
- \(e = 0.06 \text{ m}\) - winding width [m]
- \(f = 0.07\) - winding height [m]
- \(FF = 0.6\) - fill factor
- \(plw = 0.005 \text{ m}\) - winding holder thickness
- \(h = 0.1 \text{ m}\) - core half height [m]
- \(L = 0.127 \text{ H}\) - wanted inductance [H]
- \(\mu_0 = 4\pi \times 10^{-7} \text{ H/m}\) - permeability of vacuum
- \(\mu_r = 300 \text{ (Core)}\) - relative permeability
- \(dRdl = 0.001028 \Omega \text{m}\) - specific resistance

It is essential to calculate the target value of the inductance of the set-up that can be fed without overheating the supplying three-phase synchronous generator and without producing an excessive voltage drop in it. The reactance related to reactive power that the generator can produce in normal conditions is therefore considered. The total impedance of the machine was calculated as 40 Ohms and the inductance at \(f = 50 \text{ Hz}\) as 127 mH. The design includes the Length \(2b\), Width \(2a\), Height \(2h\) of the Core dimensions and the air gap \(d\) according to figure 2. The dimensioning is performed at \(f=0\), which means in other words in DC [2].
Rearranging equation (14) we get,

\[
N = \frac{L(d+b_0+b_1)b^{0.5}}{2} = 145 \text{ turns} \quad \text{- number of turns}
\]

\[
Cu = \left( e \cdot f \cdot \frac{EF}{N} \cdot \frac{A}{pl} \right)^{0.5} = 0.0047 \text{ m} \quad \text{- wire diameter bare copper}
\]  

\[
R = 8(dRdl)N \left( (a + plw + \frac{e}{2}) + (b + plw + \frac{e}{2}) \right) = 0.1426 \Omega \quad \text{-DC resistance of the field winding}
\]

The Number of turns was calculated as 145 turns, the diameter of Bare Copper is 4.7 mm and the DC resistance of the Core is 0.1426 Ohms. The Yoke is laminated and made up of M-15 Steel, used for Electrical Purposes. The core material is made of 1006 Steel and has low electrical resistivity and very high Ductility. The windings are wound using AWG-10 Wire. It has a wire diameter of 2.58826 mm; the resistance is 3.27 Ohms for a length of 1 Km.

**THE INFLUENCE OF AIR GAP LENGTH ON THE EDDY CURRENT BEHAVIOUR:**

![Figure 16: 0.7 mm Air Gap (10 Hz)](image1)

![Figure 17: 1 mm Air Gap (10 Hz)](image2)

![Figure 18: 3 mm Air Gap (10 Hz)](image3)

![Figure 19: 5 mm Air Gap (10 Hz)](image4)
FEMM is used to simulate the Core design. Different air gap lengths: 0.7 mm, 1 mm, 3 mm and 5 mm were used for the simulation. The graphs of the Magnetic Flux Density (B) normal to the plane of reference, at the air gap, were observed. In figure 16, 17 and 18 and 19, the black plot is the amplitude of the induction, the blue plot is the component of the flux density in phase with excitation current related to the reactive power and the green plot is the flux density in quadrature with the excitation current related to the losses. The effect of the air gap length on the flux density level can be observed: the longer the air gap length, the lower the B level. On the other side, it is observed that the flux density profiles (the black plot) are not constant along the core cross section. This is due to the eddy current reaction. The induced eddy current is at the periphery of the core due to the skin effect. Their counter MMF (magneto motive force) opposes the exciting one due to the field current along with penetration depth. In fact, after a penetration depth towards left starting from 0.02 m and after a penetration depth towards right starting from 0.07 m, the induction is constant. Due to the fringing effect, a certain amount of flux escapes through the air gap and move sideward. Thus the Magnetic flux density at the sides is lesser (near zero) than at the air gap.

**THE EFFECT OF CORE LAMINATION ON THE BEHAVIOUR OF EDDY CURRENT:**

![Figure 20: 1 mm Air Gap (10 Hz) (1 Lamination)](image)

![Figure 21: 1 mm Air Gap (10 Hz) (2 Laminations)](image)

![Figure 22: 1 mm Air Gap (10 Hz) (4 Laminations)](image)

![Figure 23: 1 mm Air Gap (10 Hz) (8 Laminations)](image)
To reduce the Eddy current in the Magnetic Core, the material is divided into slices, in order to form a laminated core. The laminations make the length of the looping path for Eddy current longer, thereby increasing the resistance of their current paths. In the present analysis, the core is divided into 1, 2, 4 and 8 slices by maintaining the same overall cross-sectional area. The Magnetic flux density normal to the plane of reference increases with an increase in the number of laminations. By reducing the intensity of the Eddy current, their reaction against the main flux is reduced. It is observed in figure 20, 21 and 22 and 23 that the black plot of the flux density induction in the air gap is almost constant.

**THE INFLUENCE OF CORE LAMINATION ON THE EDDY CURRENTS:**

When the windings of the coil are supplied with current $I$, a magnetic field is created around the current carrying conductor, thereby inducing a Magnetic Flux (Main Flux) in the Core material. A time-varying flux produces a voltage by the Faraday's Law of Induction. The induced voltage produces circulating current in the core called Eddy Current. Eddy currents induce a magnetic field that opposes the magnetic field in the Core, thus producing an opposing flux to the Main field flux. The amount of Power loss in the system depends on the resistivity of the material, area of cross-section of the Eddy current loop and the extent of change in magnetic flux in the core material. Higher resistivity and longer paths increase the overall resistance offered by the material to induced voltage thus resulting in reduced Eddy losses[3].

The studied flux in the core is the fundamental of a non-harmonic alternated flux excited in the core by a sinusoidal excitation current of the same frequency. Since the current is assumed to be a real one (initial phase equal to zero) the lagging flux shows real and imaginary part. Nevertheless, as shown in Figure 9, the phasor of the current can be decomposed in two components, one in phase with the flux and one in quadrature with it. The flux and the component of the current in phase with it are responsible for the inductance of the machine. The current component in quadrature with the flux and in phase with the induced voltage is responsible for the absorbed active power.
From the current density plots in figure 24-27 it can be observed that the current density of the Eddy current decreases with increase in the no. of laminations. This confirms and explains that there is less opposition to the main flux and reduced losses in the system. The reduction in Eddy Power loss can be validated using Steinmetz’s theory in equation 20. As the thickness of the lamination reduces the losses decrease.

**ELABORATION OF FEMM ANALYSIS DATA:**

With reference to figure 9, the value of the field winding resistance $R_p$, Inductance $L_p$ can be calculated from equation (17) and (18).

$$R_p = \frac{\omega |\psi|}{I_w} \Rightarrow R_p = \frac{2\omega N f_{0.07}^{0.07} B dx dy}{-|I|sin\theta} ; \quad L_p = \frac{|\psi|}{|\mu|} \Rightarrow L_p = \frac{2N f_{0.02}^{0.07} B dx dy}{|I|cos\theta}$$

The value of Active power $P$ and Reactive power $Q$ is,

$$P = \frac{v^2}{R_p} \text{ or } \left(\frac{\omega N f_{0.07}^{0.07} B dx dy}{R_p}\right)^2 \quad (27); \quad Q = \frac{v^2}{X_p} \text{ or } \left(\frac{\omega N f_{0.02}^{0.07} B dx dy}{2n L_p}\right)^2 \quad (28)$$
The FEM simulations resulted in the data collection of Real and Imaginary parts of the flux, from which the Inductance and the Resistance were calculated respectively by equations (17) and (18). It is observed that for Air gap of 0.7mm, 1mm, 3mm, 5mm the Parallel resistance increases with frequency. At the same time, it can also be observed that as the Air gap length increases the parallel resistance offered by the winding decreases. The initial inductance offered by the winding is more for 0.7mm Air gap than 5mm Air gap which is quite intuitive. Even for the inductance, when the frequency increases the value of inductance offered by the winding offered decreases. The introduction of laminations in the core concludes that, as the length of the path for the Eddy current increases, more resistance is offered by the winding, thus reducing the amount of for the losses at same induced voltage. This is, therefore, an effective way of reducing the Eddy losses in the system. It must be observed that, for increased laminations at a given constant air gap, the inductance offered by the winding also increases. It means, that for the same excitation current more flux is admitted through the core. This makes sense since the demagnetizing reaction of the eddy current is reduced by the lamination.

Figures 29 and 30 show the variation of resistance and inductance with frequency for different Air gap lengths and laminations.

Figure 29: Different Air Gap- Resistance (Parallel)  
Figure 30: Different Air Gap - Inductance (Parallel)  

Figure 31: Laminations (1mm Air gap) – Parallel Resistance  
Figure 32: Laminations (1mm air gap) – Parallel Inductance
POWER LOSS IN CORE:

The Power loss curve for the Core material due to Eddy current is calculated by equation (27). From the graph, the power loss in the system increases with increase in frequency, independently from the air gap length. The first plot in Fig. 33 uses the flux, as it results by applying the same MMF (same excitation current) to all different core topologies. The second plot in Figure 34 instead normalizes the losses with reference to the same flux in the core material, keeping it constant and equal in all different core topologies (the one of the massive core is taken as a reference). It can be concluded that as the number of laminations increases, the Eddy losses in the material decreases thus validating the Steinmetz’s theory. For the most efficient and economical operation of the system, the Air gap length, number of laminations of the core, the resistance and inductance offered by the material, number of turns of winding are essential along with the proper design of the core and yoke.

![Figure 33: Different Flux](image1)

![Figure 34: Same flux](image2)
RESULTS AND CONCLUSION:

All electrical machines encounter Eddy current on a regular basis. It is impossible to eliminate Eddy current from the system completely but can be effectively reduced by adopting lamination of the magnetic path and by using highly resistive conductors. In that way, it is possible to avoid them

- Overheating of the machine (which reduces the efficiency and leads to power loss)
- Reduction of the main flux due to the eddy currents demagnetizing reaction.[4]

The effort to reduce Eddy currents in the core depends on the magnetic permeability, resistivity and thickness of the core laminations as well as on the Air gap length. The higher the magnetic permeability of the material, the more the magnetic field lines concentrate on the core material than in the surrounding air (less stray flux). Silicon steel is used for transformers and electrical machine cores since it offers very high magnetic permeability as well as high electric resistivity. In order to reduce Eddy losses, the core material is usually made into insulated thin laminations stacked parallel with the lines of flux. These laminations ensure that the eddy currents flow in narrow loops within the thickness of each lamination. The current in each eddy current loop is proportional to the area of the loop itself, thus the thin laminations ensure that the eddy currents are reduced to a small level. Also, the power dissipated by the eddy currents depends on the resistivity of the material and is inversely proportional to it.

The less known effect of Eddy currents affecting the magnetic Inductance of the excitation winding in a synchronous generator with salient poles has been studied. It has been done by means of a simple equivalent model. The results have shown that the magnetic inductance is not only dependent on geometry and magnetic properties of its related magnetic circuit but also on Eddy current. They have shown that it is also widely affected by the eddy currents. When the excitation circuit of a synchronous machine is designed for facing rapid current control, the core has to be designed carefully in order to reduce power loss and main flux attenuation due to the eddy currents. Many important aspects of Eddy current generation and mitigation have been analyzed in this project. The experimental evidence, gathered by measuring the AC impedance of a real synchronous machine field winding, has been confirmed by the FEM analysis conducted on a simple equivalent model. Measured and simulated value trends confirmed the justification of the analytical tools used for explaining the phenomenon.
REFERENCES


