Motor Design Workshop: Week-2

Table of Contents

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Specifications

- **Single Phase, 50 Hz Transformer**
- **Primary Winding Voltage:** 34.5 kV
- **Secondary Winding Voltage:** 400 V
- **Rated Power:** 1 MVA
- **Switching Frequency:** 50 Hz

Efficiency is targeted as 99%. Therefore Rated power will be used as ~1.01 MVA.

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The RMS value of primary side current is 29.28 A.

The RMS value of secondary side current is 2.53 kA.
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Choosing Operation Flux Density

For the first phase of design, it is going to be choosen operation flux density. Let's consider over the formula below:

$$e = -\frac{2*\pi}{\sqrt{2}} N 2\pi f B_{peak} * A$$

If only selectable parameters are considered, it is possible to see the trade-off between number of turns, flux density and area. Selecting high number of turns come with dificulties of cabling and copper losses. Cable size is decided over current values so it is constant in this discussion. Area is important for transformer's size and weight values. It also effects cable length and core loss (over weight). Flux density is directly related with core losses.

Therefore design will be done for a value between 1 T and 1.5 T and results will be compared.

Determination of Cable Thickness

Independetly from core dimensions and number of turns, diameter of cable might be determined.

Here is a practical AWG table : https://en.0wikipedia.org/index.php?q=aHR0cHM6Ly9lbi53aWtpcGVkaWEub3JnL3dpa2kvQW1lcmljYW5fd2lyZV9nYXVnZQ

For the primary side AWG 10 can be used. Secondary side's rms current value is very high. Therefore 11 paralleled AWG 4/0 cable will be used.

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Cross-section area of a AWG 10 wire is 5.260 mm^2.

AWG 4/0 wire's is 107.219 mm^2. Eleven of them will be used.
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For each operating flux density values, different core cross section areas will be tested and logical number of turnes will be calculated in each phase. After each steps are completed, copper and core losses will be calculated and minimum loss condition will be choosen.

Let us take a core cross section are interval between 4 cm^2 and 3600 cm^2.

Specifications

All of these calculations shows that

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It is better choose operating flux density as 1.0 T.

Primary side turns becomes 345 and secondary becomes 4.

Cross section are is 717 cm^2  and core length is 12.7 m.

Mass of the core becomes 7098.86 kg. It means 7.10 kW of core loss.

Length of the primary side cable is 615.87 m. Its resistance is 1.99 ohm.

Secondary side's length is 7.14 m and its resistance is 0.10 miliohm .

Total mass of the copper is 104.49 kg.

So the total mass is  7203.34 kg.

Inductance is calculated as 844.88 mH and leakage is 33.80 mH.

Copper lose is  2.36 kW and efficiency becomes 99.06 % as targeted.

Copper cost is  1044.85 $ and core material cost is 21296.57 $.
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