ABB Drives	AC DRIVE COMES WITH LOW LOSSES Technical Description	3AFE 6903 7241 00600659.DOC
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AC Drive comes with low losses

Following article deals with AC drive and motor losses even though the energy savings achievable with AC drives would be a more important issue. Both drive and motor losses as computed within engineering tools are explained assuming the reader is interested to know loss behaviour across the full speed range of drive.

Long ago AC drives were made from thyristors and GTO-thyristors and at that time drive losses were highest around 20 …40 Hz. Maybe from this reason the losses were shown in diagram format like in figure 1. Later on with IGBT the medium frequency range was not anymore dominant and less information was given to system engineers applying drive. The usual statement has been that drive at nominal power level efficiency is approximately 98% and for air conditioning purposes the worst case losses into air has been tabulated.
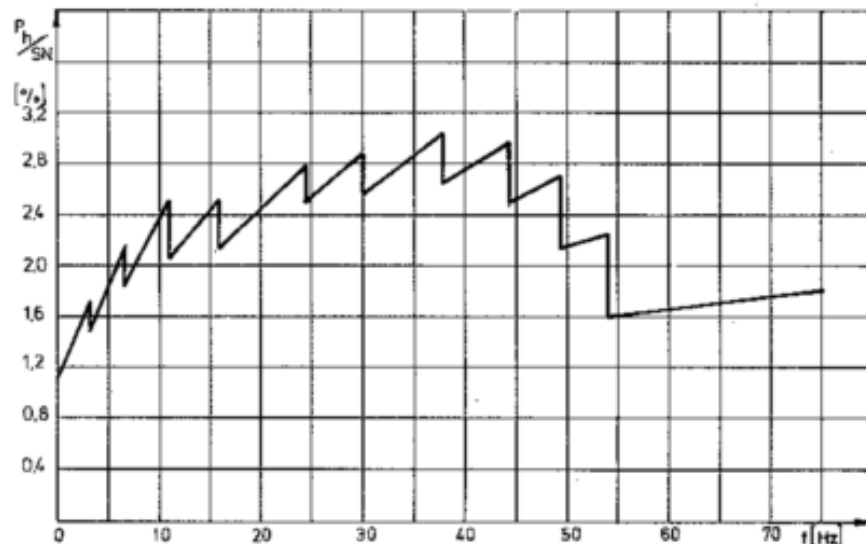

Figure 1.   Typical SAMI B power losses in a constant torque drive (EN5350396-0D)

The semiconductors of the inverter unit of the best modern drives are protected against over temperature by measuring heatsink temperature and by dynamically simulating the temperature rises from heatsink to semiconductors by embedded CPU. This means CPU is computing the losses of 12 semiconductors and it has also the thermal model of cooling. This is done cyclically every millisecond or faster. The simulated temperature shall not exceed the limit (125…140°C) - not at heavy start nor during any sudden overloads. The semiconductor data and cooling model is available also inside engineering tools. These are sometimes called dimensioning tools as well. One good example of such tool is DriveSize by ABB Drives.

To compute the losses of air cooled inverter some basic data is required: totally 8 parameters of IGBT and maybe two for passive components and then also variables dc-voltage and switching frequency. From the load we need variables: the output current, power factor, output frequency and voltage.   The list will be even longer, when rectifier or liquid cooling is included. The long variable list means that it is easier to compute the variables based on selected motor and its load than typing in the variables over and over again. The integrated motor and drive computing makes a lot of sense when computing the losses within when engineering AC Drive systems. The losses of AC Drive are best handled and understood when computing the losses related to motor shaft load.   Then at least the intermediate variables (frequency and currents) between inverter and motor can be skipped over.   Figure 2 illustrates the typical losses of an AC Drive as a function of motor speed.

Figure 2 also makes us conclude that losses of modern AC drives behave nicely and losses get even lower with lower speeds and torques.   This is the best way to provide good information of AC drive losses for system engineers and used in DriveSize too.   If multiple drives - having a power ration more than two - shall be shown in the same diagram for comparison then some kind of scaling is maybe necessary.
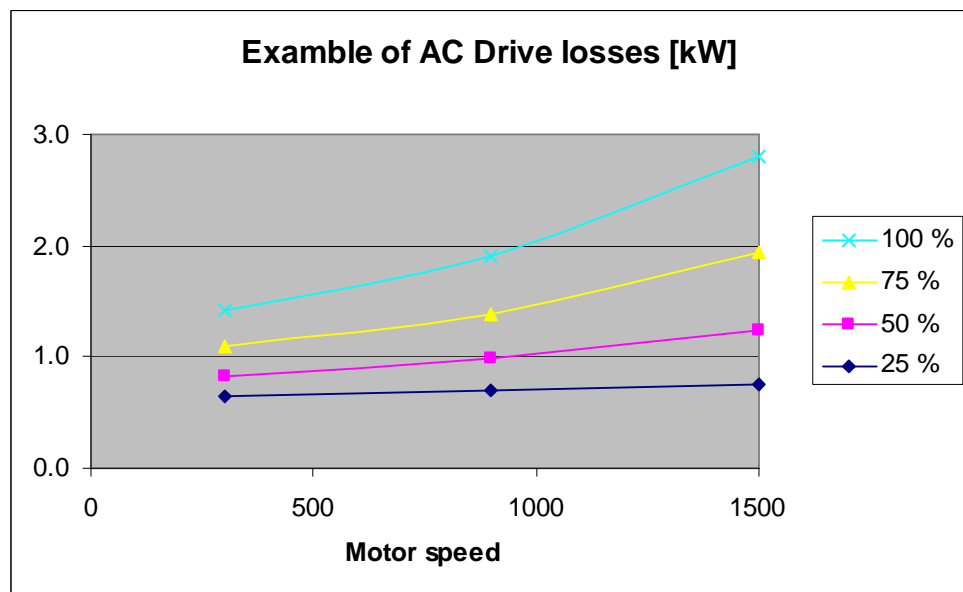

Example of AC Drive losses [kW]

Figure 2.   Example of AC Drive losses as a function of motor speed and torque as a parameter with constant torque load type.

Variable speed motor losses

Historically the VSD motor losses have been reduced by increasing switching frequency of drive. For smaller motor this is especially important. Naturally new motors are also designed for VSD usage.

Motor losses are typically somewhat bigger than AC drive losses and should be computed with same accuracy for engineers applying variable speed motors and drives.   The loss computing of motors for our purposes start with parameters like: measured stator winding resistance, rated temperature rise, no load losses, no load and full load current, full load efficiency and maybe an estimation about friction and ventilation losses.   As we know the motor losses can be separated into following categories: stator copper, rotor conductor, iron, friction and additional losses. The AC drive will modify all these.

The stator copper losses are a little effected by the ripple current generated by drive but follows mainly the rule $R \cdot I^2$. Here the main thing is to compute the motor current correctly.
In the rotor conductors the skin effect will create extra losses compared to nominal DOL conditions. To compute the rotor current at field weakening area is an issue.
The iron losses are dependent on flux density and frequency and clearly are highest at field weakening point and at other points lower.
Additional losses are affected the same things as for iron losses but also the motor current.
For IC411 motors the friction losses are highly dependent on mechanical speed – an exponent of 2.8 is commonly used. In the other hand IC416 motors can be assumed to have a constant fan loss and the rest of frictional losses will come down with lower speeds.

The procedure to compute the motor losses is best repeated by a computer. But again the basic way to show the results is losses as a function of motor speed and torque (figure 3). This has been selected also in DriveSize. It will nicely show that losses are reduced when speed comes down.
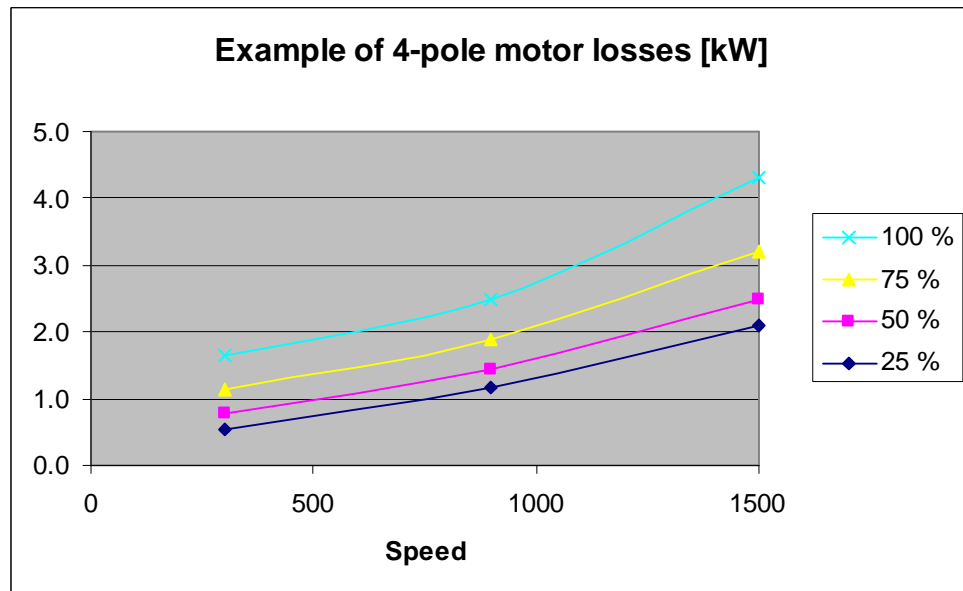

Figure 3. Example of 4-pole motor losses [kW] with constant torque load and torque level as a parameter.

Efficiencies are widely used and energy efficiency in commonly used term. If the losses are computed like in DriveSize it is easy and convincing to give combined efficiency figures as shown in figure 4. But efficiency curves does not illustrate the behaviour of losses nor link directly to computing saved CO2. Refer the following equation, where losses are hidden in denominator.

$$efficiency = \frac{output}{ouput + losses}$$
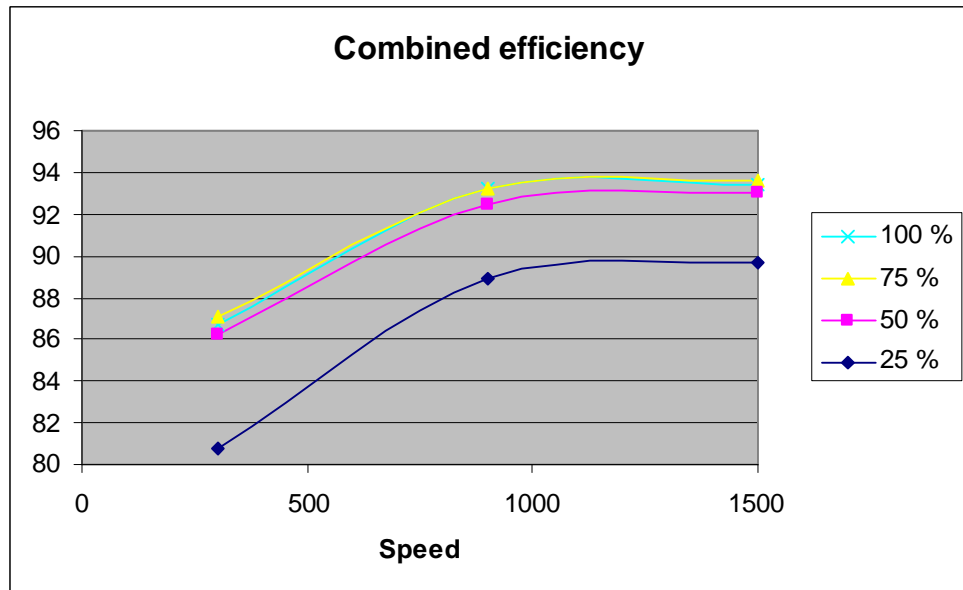
Combined efficiency

Figure 4. Combined efficiency of the motor and drive. The base power is 100 kW at 1500 RPM.

If relative loss curves are preferred a good proposal is to have the actual losses divided by rated motor power like in figure 5 or even losses/base power.
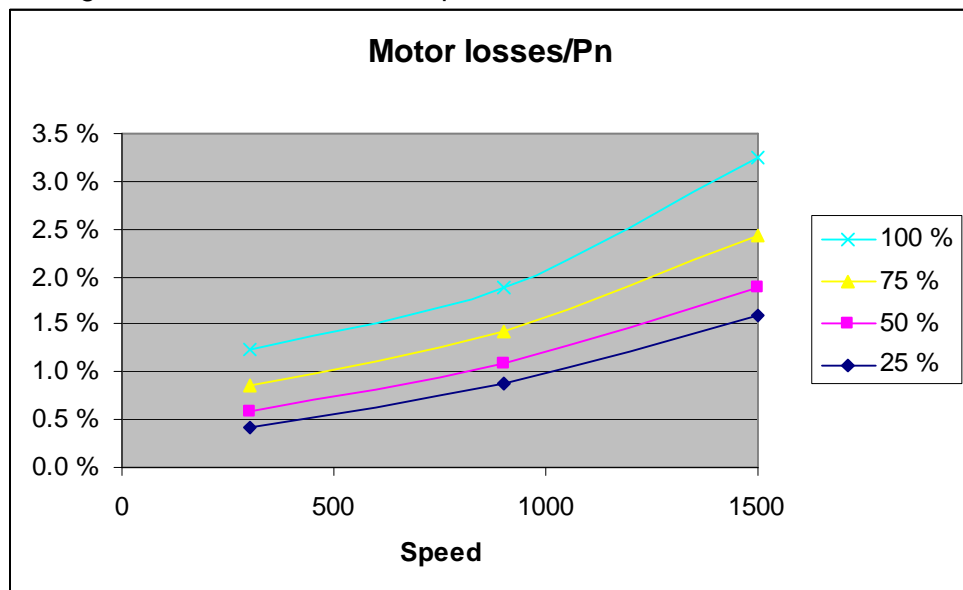
Motor losses/Pn

Figure 5. Example of motor losses divided with rated motor power as function of motor speed and relative torque as parameter with constant torque load.

An important topic is the tolerances.   The semiconductors are not identical even within a group of same drive type.   Their parameters are different.   A device with lower on state losses will probably have higher switching losses and vice versa.   A tolerance of +-10% should be enough. With motors the loss model is simplified and some manufacturing tolerances also apply.   This is why it is important to distinct the typical /average losses and worst case losses in loss calculations.   This is also done within DriveSize by ABB.

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