Re: Efficiency of Transformer, increasing output current

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- *From*: "Fritz Schlunder" <me@xxxxxxxxxxx>
- *Date*: Mon, 4 Apr 2005 10:05:49 −0700

"Larry Brasfield" <donotspam_larry_brasfield@xxxxxxxxxxx> wrote in message
news:9eb4e.6$Sd3.222@xxxxxxxxxxxxxxxxx
> "PeteS" <ps@xxxxxxxxxxxxxxxxxxx> wrote in message
news:1112617041.370157.209520@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
> > The efficiency will eventually go down for a number of reasons.
> >
> > 1. Copper losses will increase due to P = I^2R. Increase the current
> > and you increase the losses in the windings (notably by a square
> > factor).
> >
> > 2. The input and output windings will heat up, thereby increasing their
> > resistance (copper has a positive temperature coefficient). With a
> > higher resistance, you exacerbate the problem in (1)
>
> Agree with 1 and 2.

Also agree with 1 and 2. Item 1 is very real and makes a very tangible and
signicant impact and should not be ignored. The influence of item 2 however
is usually quite small for a normal transformer operated with a normal
temperature range. Since most loss and thermal rise calculations are
somewhat approximate anyway, item #2 can often be ignored.

> > 3. Core and eddy current losses in the magnetic core will increase.
> > Increased output current (which implies increased input current) will
> > increase the magnetic flux density. As you increase it, the losses in
> > the core will increase, up to magnetic saturation, where you can
> > effectively get no more current (the maximum energy through a
> > transformer is limited by the magnetics as well as the winding limits).
>
> It is not true that magnetizing losses increase with
> output current. They actually go down a little.
> This is because the increased IR drop in the primary
> reduces the amount of flux change necessary in the
> core to provide enough induced voltage to equal the
> applied primary voltage adjusted by the IR drop.

Agreed.

> For magnetization, you can think of the primary as a
> more or less pure inductor [1] in series with the primary
> resistance and in parallel with some real impedance
> representing the eddy current, hysteresis, (and radiated)
> losses. As the voltage across that inductor drops, so do
> its losses.
>
> [1. The inductor is usually non−linear, but its inductance
> is a monotonic function of current.]

I suppose that is one way to think about it. I think of it a little differently. Ampere's Law would have you believe the magnetic flux density B is proportional to the number of turns times the current flowing through those turns in any given magnetic device. Since a transformer is a magnetic device, it would seem logical that as the output current increases the magnetic flux density in the core also increases. This would suggest at some current level the transformer's core would saturate.

This is not the case however for a regular transformer (IE: one not a flyback transformer, they are different). What one must realize is that a transformer has two or more independent windings on a single core. Ampere's Law applies to the primary winding, and it also applies for the secondary. As the load current on the secondary increases you would tend to get more flux generated in the core. However, as the primary current increases to supply that secondary current, the primary winding also generates it's own flux. If you studiously apply the right hand rule, you will find that the flux will be in different directions for primary and secondary, and so they both serve to cancel each other out. As a consequence the flux density in the core is essentially independent of the load current of the transformer. In effect the maximum power output rating of a transformer is limited by the winding resistances, or by total thermal dissipation limits resulting in a given temperature rise. Practical transformers are thermal dissipation limited long before winding resistance limited. In theory a transformer made with superconducting windings could be made very small and output an outrageously huge amount of power (efficiently at that).

Flyback transformers are different, and have properties more like inductors than do regular transformers. In the flyback transformer current does not normally flow simultaneously through primary and secondary windings. At any given time only one of them conducts. As a consequence you don't get the flux canceling effect mentioned above for regular transformers. If you keep increasing the load on a flyback transformer it will eventually saturate the core.

As for the OP's original question, does the efficiency improve with

increasing or decreasing load current... Obviously at zero output current
the efficiency is zero since any transformer will waste some idle power
primarily due to core hysteresis and eddy current loss. As you apply a
heavier and heavier load the efficiency continues to improve, up to a point.
At some point the I^2*R loss effect will start to dominate and thus the
efficiency will start to decrease again. In practice, where this peak of
efficiency occurs depends on the design of the transformer. Typical
transformers will often be designed to have maximum efficiency somewhat near
(though often a little below) their maximum rated continuous output current.
The efficiency peak is relatively broad.

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- ***References***:
  - ***Efficiency of Transformer, increasing output current***
    - ◊ *From:* charles . macleod
  - ***Re: Efficiency of Transformer, increasing output current***
    - ◊ *From:* PeteS
  - ***Re: Efficiency of Transformer, increasing output current***
    - ◊ *From:* Larry Brasfield

- Prev by Date: ***Re: 555 to drive mosfet/igbt***
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