

## BI-TOROID TRANSFORMER

This invention provides an improved transformer efficiency.

### BACKGROUND OF THE INVENTION

Conventional high performance transformer efficiency range is between 91 to 99 %. The quality of materials used is one factor which dictates this efficiency percentage, another factor is the mutual coupling coefficient between the primary coil and the secondary coil.

In a conventional transformer, mutual coupling is employed to ensure that all (or virtually all) of the Back EMF induced magnetic flux from the primary reaches the secondary. When the secondary coil delivers current to a load - Back EMF is induced in the secondary and the magnitude of secondary Back EMF flux is directly proportional to the load applied.

Secondary Back EMF flux couples back (mutually) to the primary and when it does it lowers the impedance of the primary causing more current to flow in the primary coil - thus causing more primary Back EMF to be induced. The load component of primary current increases with secondary load and maintains the transformer core flux at nearly its initial value. This action enables the transformer primary to take power from the source in proportion to the load demand, and to maintain the terminal voltage approximately constant.

At no load on the secondary no current flows and no power is dissipated but voltages are present at both the primary and secondary terminals. Primary (current increase) and power increase can only occur, and is completely dependent upon secondary Back EMF flux coupling back to the primary.

No secondary load = No Secondary Back EMF = No increase in primary power.

### SUMMARY OF THE INVENTION

As mentioned above, conventional transformers employ mutual coupling between the primary and the secondary coil. Conventional transformer design generally consists of one primary coil and one secondary coil.

The Bi- Transformer design also has one primary coil but it differs from conventional transformers in that it has two secondary coils. The two secondary coils are set on a Toroid shaped core with a reluctance which is maintained at a lower value than the primary core leg throughout the transformer's entire operating range. This can easily be accomplished by physically increasing the Toroid area or using transformer core material with a higher relative permeability.

For example; typical transformer iron has a relative permeability of about 200 or so. Permalloy, which is higher grade material has a relative permeability of around 100,000. If typical transformer grade iron is employed in the primary coil leg and permalloy in the second, then the Toroid (secondary coils) reluctance will be 500 times less than the primary.

Reluctance; is the metal's resistance to the flow of magnetic flux.

Relative Permeability; is a material's ability to contain and allow the flow of certain magnitudes of magnetic flux. without saturating.

Saturation; occurs when the material containing the flux becomes full and additional flux cannot be contained and it exits the material.

The higher the value of relative permeability of the material used - the less reluctance to the flow of magnetic flux it represents to the magnetic circuit.

It is important to note that the reluctance of a magnetic conductor rises with an increase in flux magnitude i.e. more flux = higher reluctance. Magnetic flux always follows the path of least reluctance.

Because the Secondary Coil(s) Back EMF cannot couple back to the Primary all of the current in the Primary Coil is Reactive current (also referred to as 'magnetizing current') and it is returned to the source. Net Power = 0

There is no (or virtually no) Secondary Back EMF magnetically coupling back to the Primary reducing the Primary's impedance and causing it to draw non reactive current from the source in response to secondary loads.

In simple terms the PRIMARY Power = 0 W (reactive current only - power factor = 0) and the SECONDARY Power =  W because all the Secondary induced Back EMF is trapped within the Secondary Toroid and cannot couple back to the Primary. Ideally there should be virtually NO REAL POWER dissipated in the Primary Coil except for that which is lost due to the Primary's DC coil resistance.

DETAILED DESCRIPTION OF THE INVENTION

Diagram 1 shows a conventional transformer design with a primary coil 2 and a secondary coil 5 which are both set on a ferromagnetic core material 4 and physically and magnetically coupled to one another. When the power supply 1 induces a voltage in the primary coil 2 according to Faraday's Law of Induction - a Back EMF induced magnetic field 7 is produced in the core material 4 at the same frequency of the alternating current supplied by the power source 1.

This alternating magnetic field 7 also induces a voltage in the secondary coil 5 according to Faraday's Law of Induction. It should be noted that because there is no load on the secondary coil 5 as shown in Diagram 1 the primary coil 2 is dissipating a minimum amount of power because virtually all of the current flowing in the primary coil 2 is reactive current - stored in the inductor coil and then returned to the power source 1. The only real power dissipated by primary coil 2 is due to its DC resistance.

Diagram 2 shows that when a resistive load 8 is placed on secondary coil 5, a Back EMF induced magnetic field 9 is produced in secondary coil 5 and this magnetic field 9 couples back through the transformer core 4 and into the primary coil 2. The effect is the impedance of the primary coil 2 is reduced and tends to become more resistive and less inductive thus drawing real current as opposed to reactive current from the source power supply 1. The magnitude of real current taken from the source power supply 1 from the input primary coil 2 is directly proportional to the resistive load 8 placed on the secondary output coil 5

Diagram 3 shows the Bi-Toroid transformer with one primary coil 2 and two secondary coils - secondary coil 1 (5) and secondary coil 2 (11). The three coils (2, 5, 11) are set on a figure 8 shaped core made up of two Toroid cores 4 and 14 joined together in such a manner that magnetic flux can readily pass from one to the other. It should be noted again that the secondary Toroid core's 14 reluctance is always maintained at a lower value than the primary core 4 to ensure that all secondary coils' 5 & 11 Back EMF induced magnetic flux 9, & 13 cannot couple back to the primary coil 2.

At no load on secondary coil 5 in diagram 3 no current flows in secondary coil 5 and the power (magnetizing current) dissipated in the primary coil 2 is minimal and virtually all reactive current.

Diagram 4's operation is as follows in the 3 steps:

#### Step 1

Primary coil 2 induces a NO LOAD voltage into Secondary Coil 1 (5) according to Faraday's Law of Induction.

#### Step 2

Secondary Coil 1 (5) has an induced voltage in it also given by Faraday's Law of Induction.

Secondary Coil 1's (5) induced Back EMF 9 follows the path of least reluctance into Secondary Coil 2 (11). The Secondary Toroid CORE AREA 14 is twice that of the Primary Toroid 4 so the Secondary Toroid's 14 reluctance is half that of the Primary return flux path 4. Magnetic flux

always follows the path of least reluctance.

### Step 3

Secondary Coil 2's 7 induced Back EMF 13 also follows the path of least reluctance into Secondary Coil 1 2 and also CANNOT COUPLE BACK TO THE PRIMARY because the reluctance flux path is higher.

Because the Secondary Coil(s) 5 & 11 Back EMF 9 & 13 cannot couple back to the Primary all of the current in the Primary Coil is **REACTIVE CURRENT** and it is returned to the source 1. Net Power = 0

There is no (or virtually no) Secondary Back EMF 9 & 13 magnetically coupling back to the Primary 2 reducing the Primary's impedance and causing it to draw **non reactive** current from the source 1 in response to secondary loads 8 & 12.

In simple terms the PRIMARY Power 2 = 0 W (reactive current only - power factor = 0)

and the SECONDARY Power 5 & 11 =  W because all the Secondary induced Back EMF 9 & 13 is trapped within the Secondary Toroid 14 and cannot couple back to the Primary 1.

Our prototype is close to this but not quite (only > 3000% efficient) as can be seen from the data sheets where the primary current increases as the secondary load is reduced ( 1 ohms ) and the efficiency drops from 3000% down to only 146% or so. Ideally there should be virtually NO REAL POWER dissipated in the Primary Coil except for that which is lost due to the Primary's DC coil resistance.

### **TRANSFORMER DATA** from Magenn Power Inc.

**Nykolai Bilaniuk, Ph.D., P.Eng.**  
**Chief Engineer, Electrical Systems**  
**Magenn Power Inc.**

In our lab, I first measured the resistances of all the resistors. I took the liberty of marking the ones you hadn't already marked, and I measured them using a very accurate multi meter (our Hewlett Packard HP34401A). I wanted to confirm that their values are close to nominal. Their exact value would only have become important if the efficiencies appeared to be within a few percent of 100%. Here are the raw measurement results:

Short circuited probes on the HP34401A = 0.023 ohm (this value should be subtracted from the next six)

180ohm #1 = 178.72 ohms

180ohm #2 = 177.04 ohms

75ohm #1 = 75.078 ohms

75ohm #2 = 75.923 ohms

1ohm #1 = 1.013 ohm

1ohm #2 = 1.003 ohm

I have assumed that the resistors are all purely resistive, ie that their reactance is negligible. This is almost certainly close enough to the truth for our purposes. Next, I measured the voltages on the Perepiteia transformer with no loads connected:

$V_{\text{primary}} = 50.65 \text{ Vac}$

$V_{s1} = 51.80 \text{ Vac}$

$V_{s2} = 30.87 \text{ mVac}$

This too was measured using the above HP meter. Still under no-load conditions, I measured the phase angle between the voltage and current in the primary. This was accomplished by inserting an Isabellenhutte R500 laser-trimmed precision measurement resistor in series with the primary. The voltage drop across this 500 milliohm resistor is a measure of the current in the primary, and the phase angle across the resistor is equal to the phase of the current. The voltage drop across the Isabellenhutte resistor, and the voltage drop across the primary, were each connected to different channels of a two channel oscilloscope (a B+K Precision 1522). The phase angle is then measurable as the difference in time between the two waveforms. Bear in mind that at 60 Hz, one cycle is 16.666 milliseconds long. Under these no-load conditions, the voltage led the current by 1.2 ms. This indicates the load was somewhat inductive, as one would expect. The waveforms were clean sinusoids.

Next, I tried to reproduce the conditions present in the three JPEG sheets, which you have identified as Power\_CET data, i.e. those in which S2 is always loaded with a 1 ohm resistor, but S1 has, variously, a 180, 75, or 1 ohm resistor as the load. I used 1ohm#1 on S2 throughout, and resistors 180#1, 75#1, and 1#2 on S1. The current waveform on the primary side was visibly distorted (as seen on the scope) although the amount of the distortion changed depending on the load. Note the secondary currents were measured with lower accuracy hobbyist-grade DMMs (good to only about 3%, and not true RMS reading).

The results were as follows with 180 ohms on S1:

$V_{\text{primary}} = 49.82 \text{ Vrms}$

$I_{\text{primary}} = 0.34 \text{ Arms}$  (calculated from 0.24 Vpeak across the Isabellenhutte resistor)

$I_{s1} = 0.25 \text{ Arms}$

$I_{s2} = 0.15 \text{ Arms}$

$P_{r1} = 11.25 \text{ W}$

$P_{r2} = 0.0225 \text{ W}$

The results were as follows with 75 ohms on S1:

$V_{\text{primary}} = 49.27 \text{ Vrms}$

$I_{\text{primary}} = 0.68 \text{ Arms}$

$I_{s1} = 0.57 \text{ Arms}$

$I_{s2} = 0.33 \text{ Arms}$

$P_{r1} = 24.37 \text{ W}$

$P_{r2} = 0.11 \text{ W}$

The results were as follows with 1 ohm on S1:

$V_{\text{primary}} = 45.0 \text{ Vrms}$

$I_{\text{primary}} = 3.26 \text{ Arms}$

$I_{s1} = 2.98 \text{ Arms}$

$I_{s2} = 1.81 \text{ Arms}$

$P_{r1} = 8.88 \text{ W}$

$P_{r2} = 3.27 \text{ W}$

Sincerely,

Nykolai Bilaniuk, Ph.D., P.Eng.  
Chief Engineer, Electrical Systems  
Magenn Power Inc.