OU Generators obtain energy from Atomic Sources

1. Motional Induction v. Transformer Induction

Current EM theory makes a distinction between *motional* induction and *transformer* induction.

As its name implies, transformer induction does not involve movement, merely the time change of the magnetic field **B**, and is usually expressed as the closed integral of the circular electric field (which gives volts per turn *V*) around an area *A* confining the **B** field (usually a core)

$$V = \oint \mathbf{E}.\mathrm{d}\mathbf{l} = -\frac{\mathrm{d}\left[\oint \mathbf{B}.\mathrm{d}\mathbf{s}\right]}{\mathrm{d}t} = -\frac{\mathrm{d}\Phi}{\mathrm{d}t} \qquad (1)$$

For the usual situation where **B** is uniformly distributed across the area *A*, the flux Φ is given by

$$\Phi = \oint \mathbf{B}.\mathrm{d}\mathbf{s} = BA \qquad (2)$$

On the other hand, motional induction occurs when a conductor is moving with respect to a static magnetic field **B**, and can be expressed by the **E** field so created, as the vector multiplication

$$\mathbf{E} = -\mathbf{v}\times\mathbf{B} \qquad (3)$$

where **v** is the velocity (the orientation of the three vectors in this vector multiplication is obtained by Fleming's right hand rule). Note that **B**, though static, is not necessarily spatially uniform, equation (3) simply gives the instantaneous value of **E** at that point in space. However, when a closed circuit moves through a non-uniform field, or rotates in a uniform field, the flux through the coil changes with time, and although (3) can be used to deduce the voltage induction in each elemental length of the conductor, then integrated around the closed loop, this is a complicated exercise. It is much easier to calculate the changing flux Φ in the coil, then use (1) to obtain the induction which does give the correct answer. Thus equation (1) applies to two situations, (a) where the flux is changing due to the source of that flux changing with time and (b) where the flux is changing due to movement through the field. A conductor can simultaneously receive both forms of induction, so it is necessary to modify (1) to include both. We can take Φ_t as the time varying flux for a stationary coil and multiply this by a non-dimensional function f_m to take account of the movement, then use the differential rule for products to get

$$V = \oint \mathbf{E}.\mathrm{d}\mathbf{l} = -\frac{\mathrm{d}\left[f_m \cdot \Phi_t\right]}{\mathrm{d}t} = f_m \frac{d\Phi_t}{dt} + \Phi_t \frac{df_m}{dt} \qquad (4)$$

As an example, for a coil rotating in a time varying field $B_{(t)}$, then $\Phi_t = B_{(t)} \cdot A$ while f_m is a sine wave.

2. A PM generator

Figure 1 shows a simple PM generator. For simplicity of analysis there are no soft cores, the only ferromagnetic component is the PM. The rotating field from the magnet produces alternating flux within the coils which induces voltage to drive

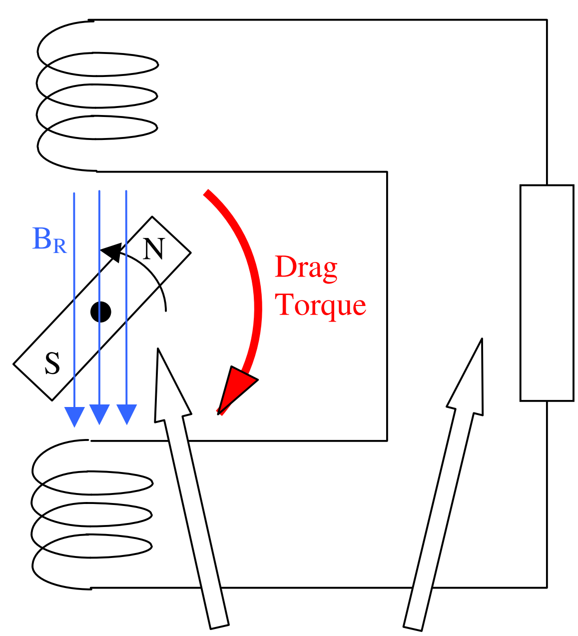

Figure 1

current through the load. The reaction field B_R from this load current is shown fixed in space but the point to be made here is that the source of this reaction field is not static, it is time varying. *Thus there is a component of transformer induction taking place which is not generally recognized.* At the magnet position shown, B_R is reducing in value and passes through zero when the magnet is vertical. B_R is responsible for the reaction torque on the rotor, which using classical theory (and assuming no losses) is a drag torque taking shaft power from the mechanical drive exactly matching the electrical power delivered to the load. *However this classical analysis takes no account of the transformer induction from B_R and its effect on the magnet.*

To understand this effect let us replace the magnet by its electromagnet equivalent, as shown in figure 2. With the output of the generator unloaded there is no reaction, the flux within the electromagnet remains constant. But when the generator is loaded, the reaction field B_R produces a changing flux within the electromagnet coil, thus inducing alternating voltage across the current generator I_{ATOMIC}. The product of the DC current I_{ATOMIC} and this alternating voltage yields an alternating power waveform. *Energy flows back and forth between the I_{ATOMIC} source and the generator.*

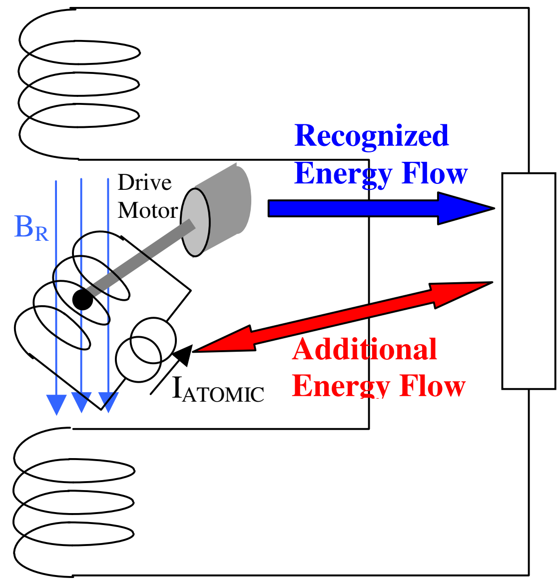

Figure 2.

Now go back to the PM, how can energy flow to or from this atomic source, where is that energy stored? It is known that the electrons responsible for the PM field store energy in their precession motion, and this is the answer to that question. *In a conventional PM generator there is a generally unrecognised alternating flow of energy to/from the atomic source. Normally this adds nothing to the overall efficiency of the generator, over a complete cycle the energy gained is totally recycled back to the atomic source. Can this symmetry be broken?*

It is instructive to examine the waveforms for this generator. In figure 3(a) the flux in the output coil is shown over one complete cycle, starting with the magnet horizontal. 3(b) shows the voltage induced in that coil, and the current also follows that wave shape. Power obtained by multiplying voltage and current is shown in figure 3(c). This waveform also applies to the shaft power delivered to the generator. So far this is the classical situation which ignores the transformer coupling to the atomic source.

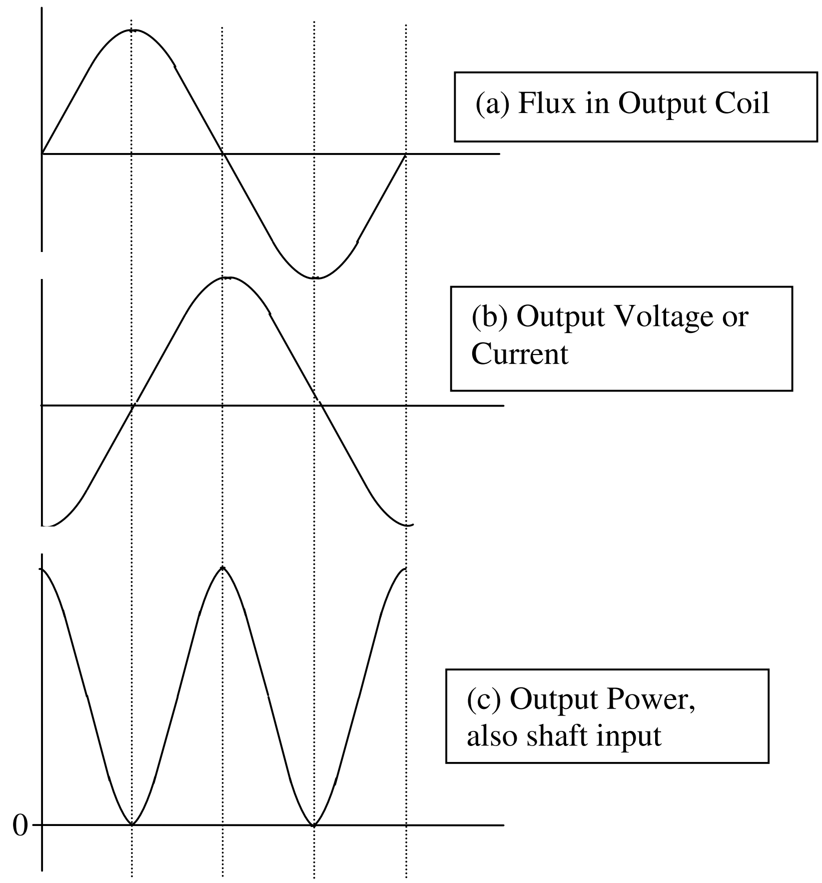

Figure 3

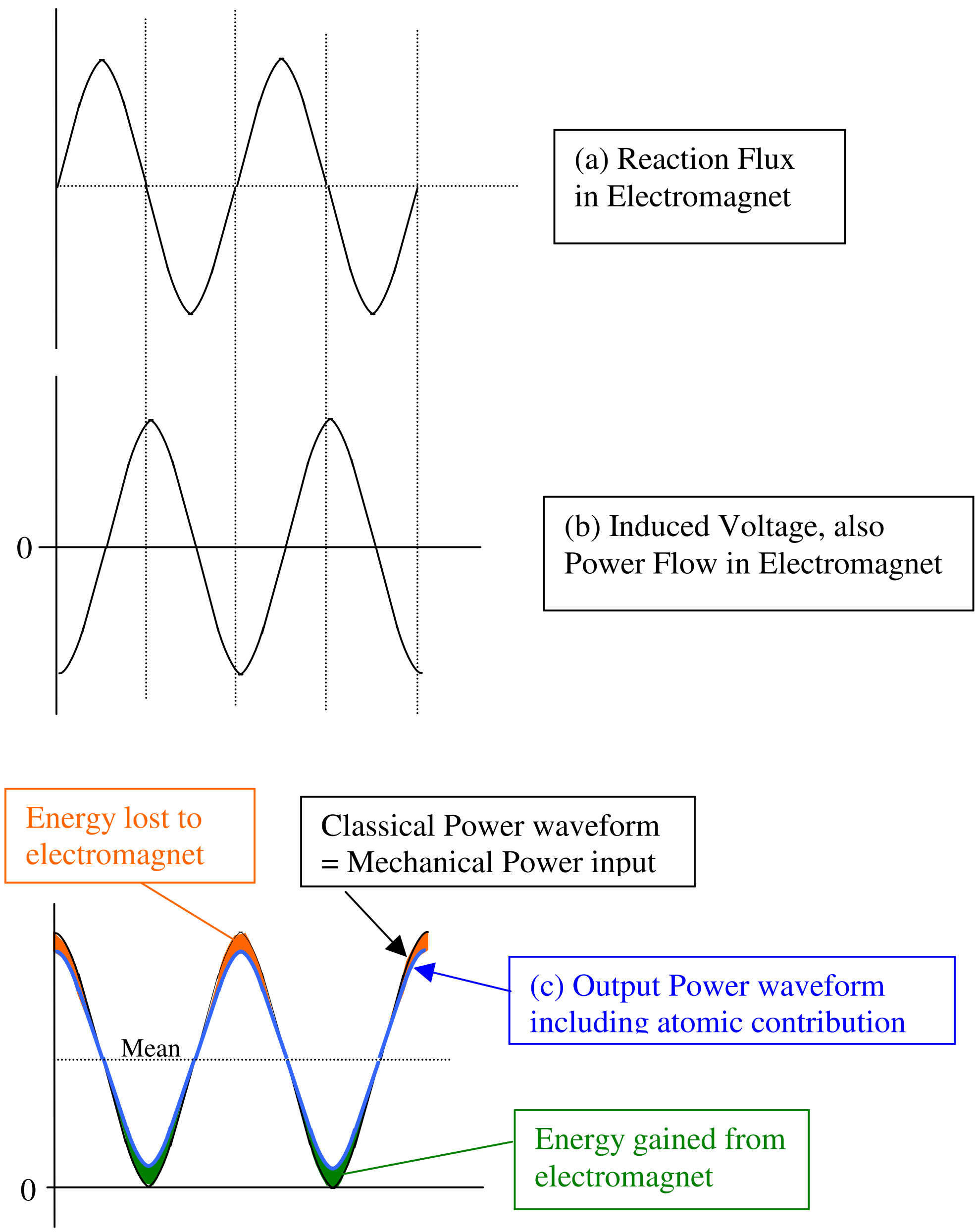

Figure 4

Figure 4(a) depicts the reaction flux (from the load current) which flows through the rotating electromagnet. It is zero when the magnet is horizontal (i.e. at 90 degrees to B_R) and also zero when the magnet is vertical (because B_R is zero at that point). 4(b) is the voltage induced into the electromagnet coil from this flux waveform, it cycles positive and negative at twice the rotation rate. When this voltage is multiplied by the constant current I_{ATOMIC}, the same wave-shape applies to the power flowing to/from this atomic current source. Some of this atomic energy flow goes by transformer action to/from the output circuit, thus adding or subtracting from the power there. 4(c) shows the power into the load with the added/subtracted atomic contribution [small 4(b) added to 3(c)]. The mean power level is not altered, but clearly there are OU regions [between 45° and 135° and again between 225° and 315°] and also UU (under unity) regions. What happens if we don't have the load permanently connected, but connect it only on those quarter cycles which are OU?

Figure 5 is a repeat of figure 3 assuming the load is switched in between 45° and 135° and again between 225° and 315°, during the remainder of the cycle the output coil is open circuit. Clearly the mean output power is much reduced, but none the less remains at a significant level. *Note that this switching is not half wave rectification*. The switching occurs at peculiar angles not associated with obtaining maximum power from the machine, and the output power occurs in small spikes. However, without the atomic energy contribution, this regime is not OU, the input torque will also be spikes giving shaft power equal to output power.

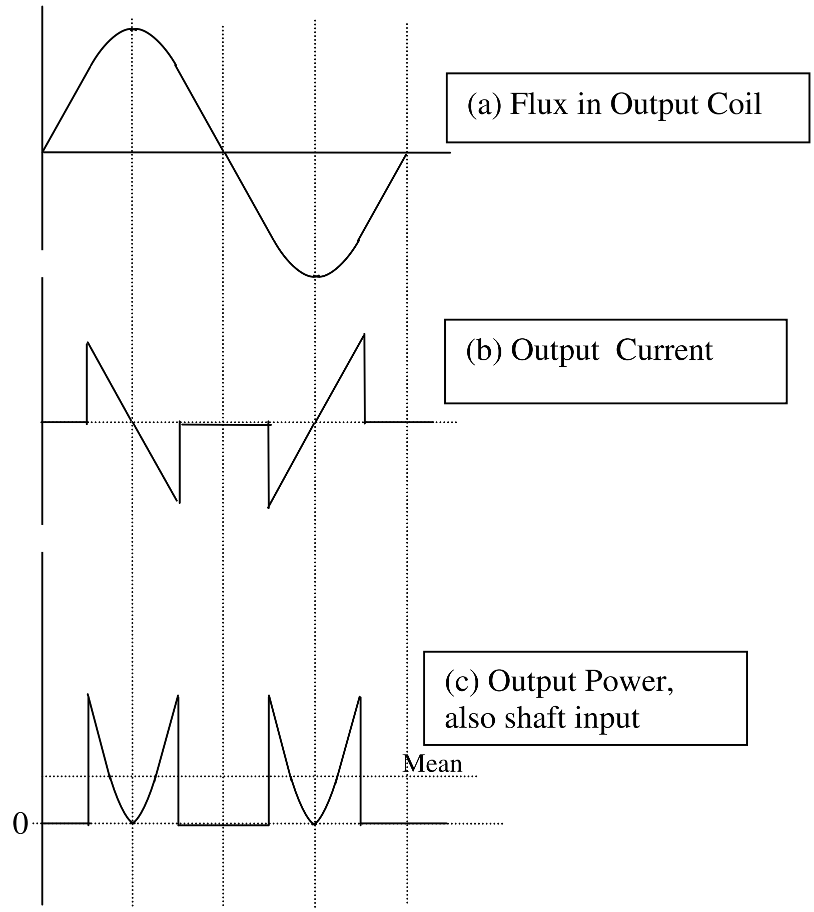

Figure 5

Figure 6(b) shows the voltage, hence power, at the atomic source, where the voltage spikes at the load switching points are math delta functions (infinitely narrow but having an area related to the flux change). Energy is recycled back to the atomic source during these delta functions, *but since there is no appreciable energy content at the load, the energy can't be clawed back from there.*

Figure 6 (e) shows the output power including the atomic contribution. Clearly there is OU present, output power exceeds shaft input power.

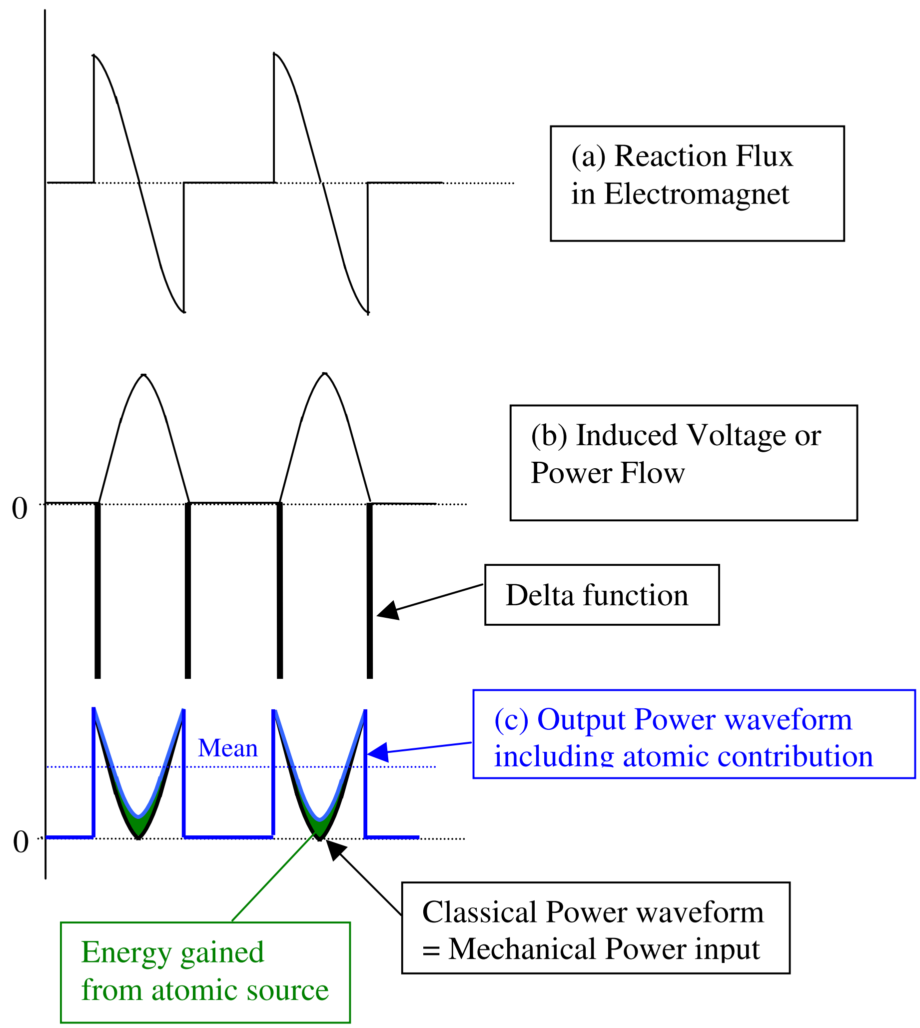

Figure 6

3. Conclusion

In a PM generator there is a generally unrecognised alternating energy flow to/from the atomic current sources responsible for the PM field. Some of this energy can transformer couple to the output coil, thus influencing the power delivered to the load. Normally this adds nothing to the generator efficiency, the atoms claw back as much energy as they give up. However when the power waveform is examined in detail, it is seen that OU exists in alternate quarter cycles, and UU in the other quarter cycles. It appears that this symmetry can be broken by only connecting the load during the OU quarter cycles. This is an unusual regime where the generator power is deliberately not maximised and the power is delivered in energy spikes, but does offer OU operation.