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Anomalous power efficiency of a transformer driven by tuned duty cycle pulses

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Abstract

The author (O. Ide) has made a prototype of an inverter which makes efficient use of positive EMF (references [1] and [2]) to be caused by well-tuned duty square wave. And, it is observed that the power efficiency of the inverter prototype reaches 300% plus at maximum while easily exceeding 100% (reference [3]). The theme of the discussion of this report is the power efficiency characteristics of a transformer itself to compose an inverter, as the author thinks there is a possibility for it to be different from that of the total inverter unit which is already discussed in the above-mentioned references, while putting a focus on it as a single separate unit. In the result of a research based on the experimentally measured data, it has been discovered that the former is quite different from the latter. It has been also discovered that the value of the input power to the primary coil can be either positive or negative, depending on the value of the load connected to the secondary coil. In addition, it was recognized that there exists a critical point of the load value at which the value of the input power becomes zero. This means that at such a critical point the power efficiency of the transformer itself becomes infinite, and that in the negative region of the load value, the value of the input of the transformer must become negative. In other words, energy is flowing out even from the input terminals of the primary coil of the transformer. After an analysis of the wave form data experimentally obtained, it becomes clear that such a phenomenon occurs due to the phase difference between voltage and current of the primary coil of the transformer.

Keywords: positive EMF; inverter; transient phenomenon; infinite; efficiency;

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1. Introduction

The author (O. Ide) has made public a paper on a hyper-efficient inverter at the SPESIF-2011 forum (see reference [3]). This paper is to report the result of an extended investigation on the derivative characteristics of the hyper-efficient inverter.

In brief, reference [3] describes about a hyper-efficient inverter making advantage of positive EMF, which has been already discovered and reported by the author in references [1] and [2].

In reference [3], it is also reported that a prototype of a hyper-efficient inverter which is driven by well-tuned duty square wave, is developed and an investigation on its characteristics was made. It is also reported that the power efficiency exceeds 100% in the region where the load resistance exceeds a certain value; and that if the inverter is driven with quick pulse wave having a high repetition frequency, the so-called avalanche effect (see reference [3]) is caused to bring about a power efficiency exceeding 200%.

In the latest research, the author measured the DC output by rectifying the AC output, and compared it with DC input power. The result of DC power efficiency was in the range of 110-130%. This suggests that it might be possible to make a self-exciting system if the results can be confirmed.

In the experiments which is performed in this paper, the experimental set-up used, as well as the measuring devices Power analyzer PZ4000, are exactly identical to those described in reference [3]. The same driving pulse wave that is stated above is employed to drive the inverter.

The theme of this report is to measure the power efficiency of the transformer itself, regarding it as a single stand-alone unit although it not really is, and other than this point, there are generally no differences from that in the case of reference [3]. More precisely, the point to measure input power is set on the primary side of the transformer of an inverter, while in the case of reference [3], the output from the DC power supply unit is measured as the input power. That is, what is measured then is DC power to be supplied to the inverter. To mention further, it was the power to be input to the MOS transistor to drive the inverter.

In contrast to it, the input power discussed in this report, is the input power to the transformer composing the inverter. Namely, it is the output power from the MOS transistor to drive the inverter.

In the common sense, their values should be same when considering the fact that there exists nothing other than a MOS transistor between the two. But, as far as the inverter system that is discussed in this investigation, is concerned, the story seems to be a little bit different, and a phase shift seems to be caused between the input power pulse wave and the output power pulse wave from the MOS transistor.

The degree of the phase shift to be caused will depend on the value of the load resistance connected to the output side of the transformer of the inverter system.

In the result, it is discovered that there is a value of the load resistance at which the measured RMS value of the input power to the transformer becomes zero, and that there is even a range in which the said RMS value becomes negative. It means that the value of the power efficiency of the transformer becomes infinite, or negative, respectively, in such a condition.

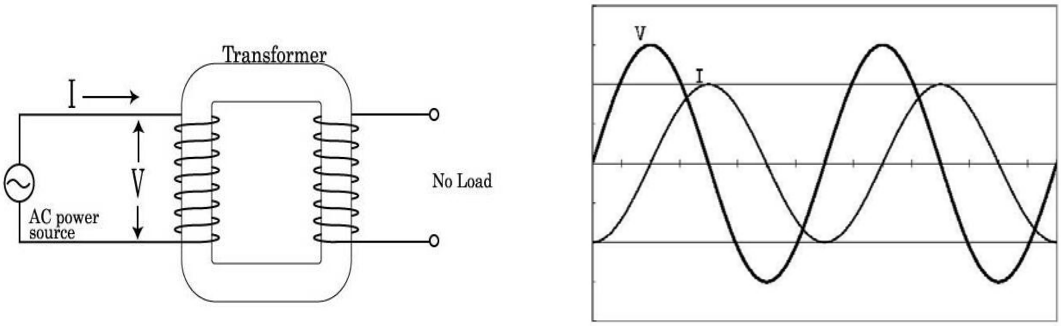

Fig. 1. The wave forms of the input voltage and the input current when AC power is supplied, in the condition that no load resistance exists on the secondary side of the transformer.

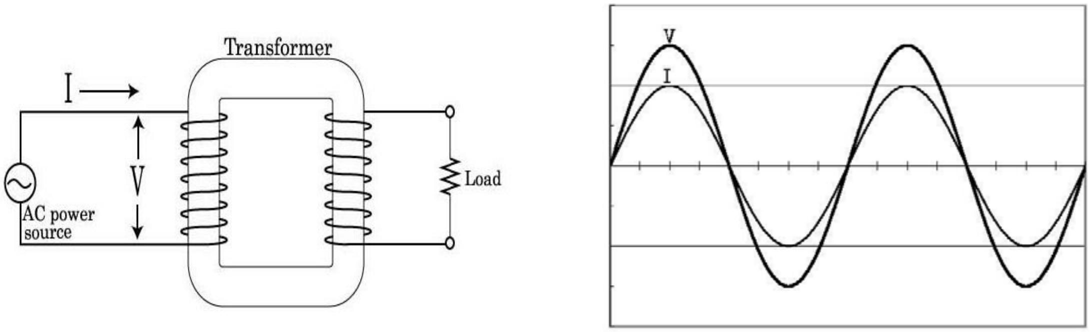

Fig. 2. The wave forms of the input voltage and the input current when AC power is supplied, in the condition that a load resistance exists on the secondary side of the transformer.

The above phenomenon is what usually cannot happen for an ordinary type of transformer. If voltage of sine wave form is input to input side of an ordinary transformer in the condition that no load resistance exists on the output side, it is of course that the input current is in the form of sine wave. However, it is well known that because the phase shift between the voltage and the current, is almost 90 degrees, the RMS value of the input power should become approximately zero as shown in Figure 1, if paying no attention to the portion due to the inner loss.

In the case that a load resistance exists on the output of the transformer as shown in Figure 2, it is a matter of commonly known that the value of input power observed will become what depends on the value of the load resistance, because of that the wave of the input voltage superpose that of the input current.

On the other hand, for the inverter discussed in this paper, it is found that the same situation as observed for an ordinary transformer bearing no load resistance on the secondary side will occur on the input side. Namely, the phase shift between the input voltage and the input current will become 90 degrees, and the RMS value of the input power will become absolute zero. Moreover, there can exist the state in which the value of input power becomes negative.

It is miraculous enough for the author to speculate that the MOS transistor existing there composing the inverter, may act as an inductor to cause a phase shift.

2. Experimental Setup

The experimental set-up and measuring devices used in the experiments for the investigation are exactly same as those used in the previous report, reference [3]. The layout of the experimental setup is shown in Figure 3. The captions to explain each part of the experimental circuit are common to those of Figure 3(a) of reference [3].

For the consideration to confirm the reproducibility, two units of ordinary transformers of identical specifications, transformer "A" and transformer "B", are prepared for the test. Namely, the specifications of them are exactly same as that of one shown in Figure 3(a) of reference [3].

The characteristics of high-speed square wave to be output from a MOS transistor, and to drive the inverter, is same as that shown in Figure 4 of reference [3].

The input power to the transformer and the output power from the transformer were measured at the input terminals and the output terminals of the transformer, respectively, with the power analyzer PZ4000. The value of output power is equal to the power consumption by the load resistance connected to the secondary circuit on the output side of the transformer. In the other words, the only thing of the experimental set-up used this time, that is different from the case of reference [3], is the change of the points to measure the input power, which are the positions at which the probe of the power analyzer is set.

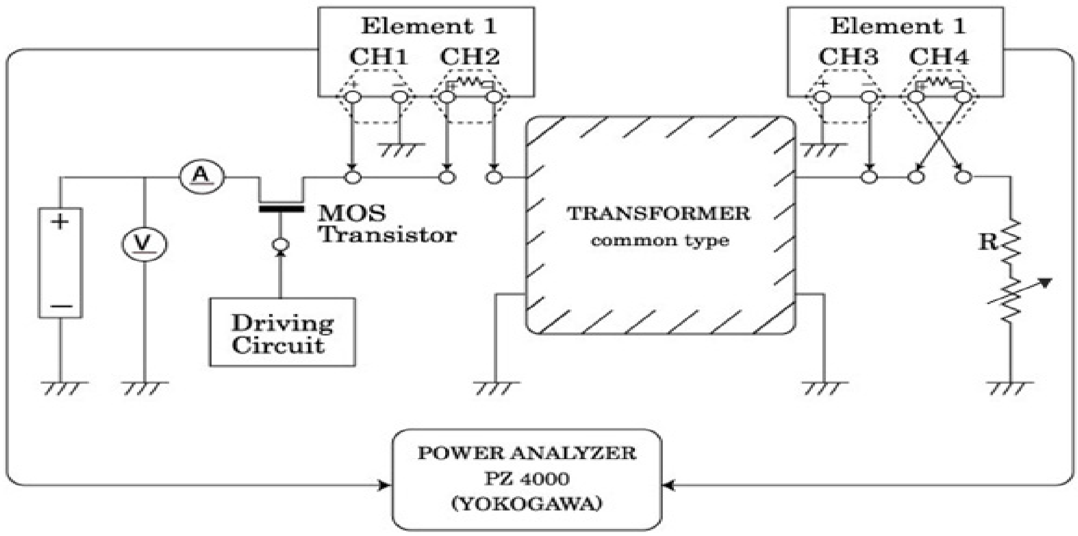

Fig. 3. The layout of the experimental setup

3. Results

The results obtained by the measurements, are shown in Figure 4 and figure 5. Each of the y-axis and the x-axis of Figure 4(a), corresponds to the power to be input to the primary side of the transformer and the load resistance that exists on the secondary side of the transformer, respectively. The RMS values of the input power, become zero at the two points X1 and X2 of the x-axis, which correspond to certain values of the load resistance, respectively.

In Figure 4(b), the y-axis corresponds to output power on the secondary side, and the x-axis, as is in

Figure 4(a), corresponds to load resistance existing on the secondary side of the transformer.

Each point of data plotted of the wave chart, is a mean value of the observed pulse waves which is in the range from 1600 to 4000 of repetition rate. It means that the number of samples (n) that are used for the calculation varies in the range from 1600 to 4000 of the repetition rate. Unfortunately according to the manufacturer of the PZ4000, this averaging does not affect the high amount of "uncertainty" in the readings the PZ4000 produces when it is trying to measure high amounts of noise in the circuit that are at frequencies higher than the highest sample rate of the PZ4000.

Figure 5(a) and 5(b) are the charts to indicate the dependency of the power efficiency on the load resistance, which are drawn based on the data values shown in Figure 4(a) and (b). The y-axis corresponds to power efficiency and the x-axis corresponds to load resistance. It is noticed that there are the critical points at the load resistance X1 and X2, where input power becomes apparently zero, the value of power efficiency becomes infinite to bring about a state of divergence.

Figure 6 and Figure 7 indicate the wave forms of the input voltage and the input current to the transformer, and the wave forms of the output voltage and the output current from the transformer, when the load resistance on the secondary side of the transformer, has the value corresponding to either of the critical points X1 and X2 is, respectively.

The observed wave forms are what is displayed and recorded on Power analyzer PZ4000.

The numerical data indicated on the upper space of each figure, are the RMS values of the input power and the output value, which are calculated by Power Analyzer PZ4000 based on the wave form data recorded.

Figure 6 is the observed data when the transformer "A" has the load resistance of the value (R=22 ohm) corresponding to the critical point X1, on its secondary side. Mentioning to the detail, Figure 6(a) indicates the wave forms of input voltage and input current to the transformer "A". It is observed that a phase shift between the voltage spike wave and the current spike wave, is caused. It is also observed that current of spike form wave runs reversely in the direction from the primary side of the transformer "A" to the MOS transistor.

Figure 6(b) indicates the wave forms of output voltage and output current directing from the transformer "A" to the load resistance. In contrast to the case on the primary side, it is observed that there is almost no phase shift between the both waves.

The numerical data indicated in the upper space of each figure, mean that the output power is 17.1 watts even though the value of the input power is zero watt, within the range of the wave form chart shown below.

Figure 7 indicates the data measured in the condition that the load resistance (R=349.5 ohms) corresponding to the critical point X2, exists on the secondary side of the transformer "B". Mentioning to the detail, Figure 7(a) indicates the wave forms of input voltage and input current to the transformer "B". It is observed that a phase shift between the voltage spike wave and the current spike wave, is caused, just as in the case of Figure 6(a)

Figure 7(b) indicates the wave forms of output voltage and output current directing from the transformer "B" to the load resistance. In contrast to the case on the primary side, it is observed that there is almost no phase shift between the both waves.

The numerical data indicated in the upper space of each figure, means that the output power is 22.4 watts even though the value of the input power is zero watts as is shown in Figure 6, within the range of the wave form chart shown below.

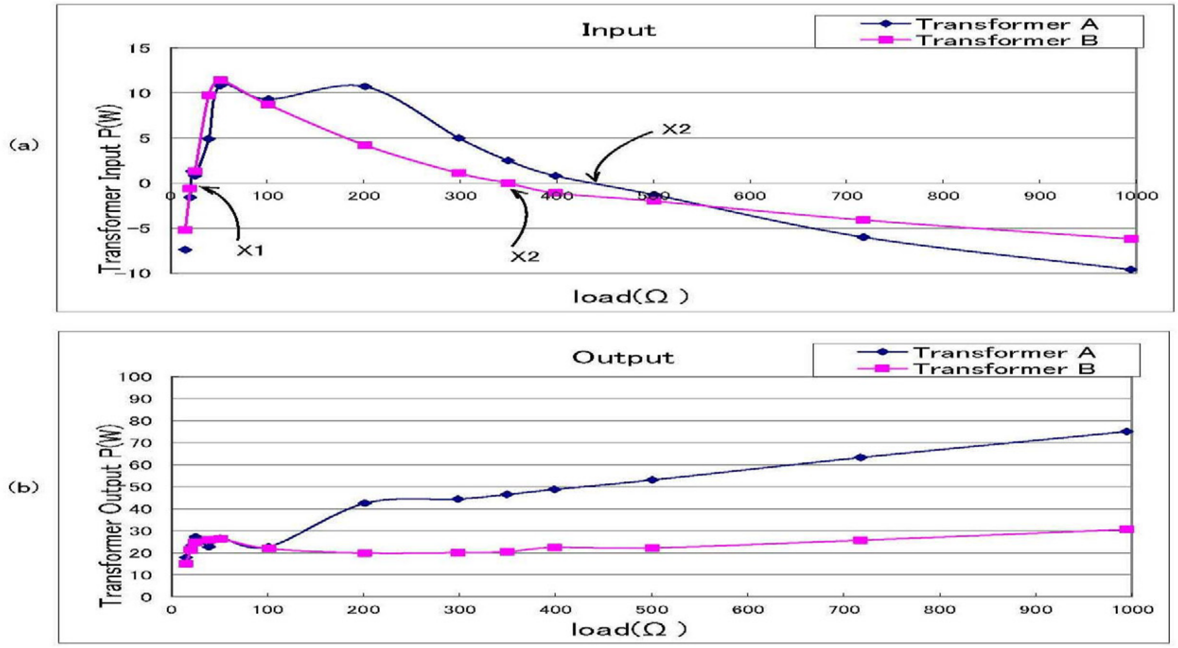

Fig. 4. The input and output power (y-axis) corresponding to the load resistance of the transformer (x-axis). (a) Input power (W), (b) Output power (W).

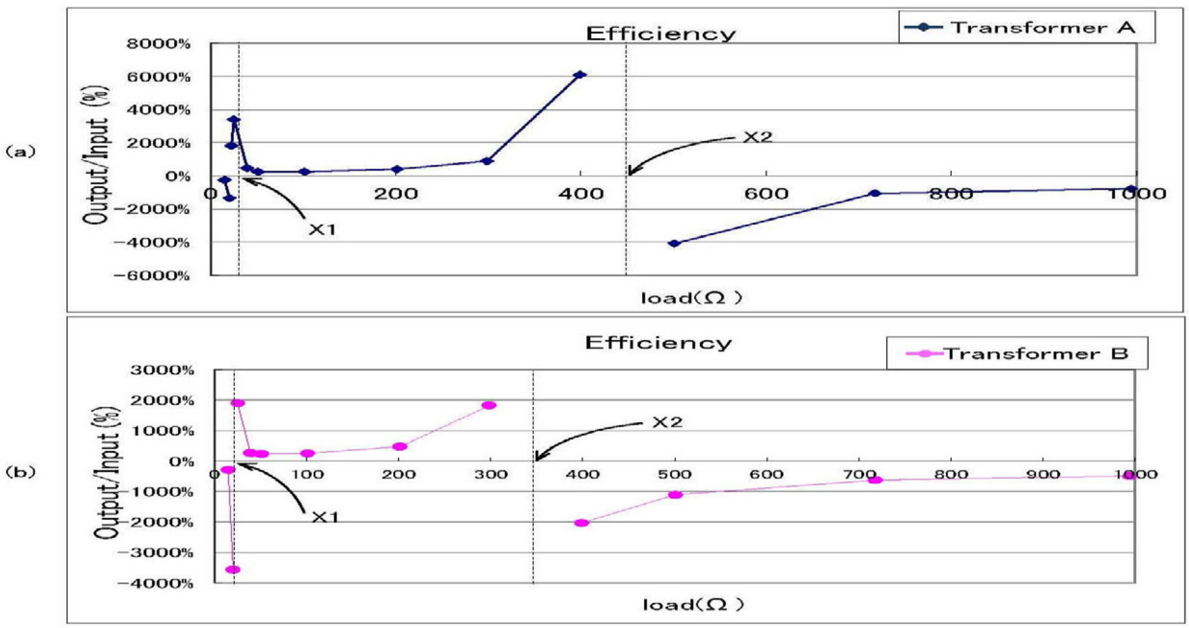

Fig. 5. The power efficiency (y-axis) corresponding to the load resistance of the transformer (x-axis), (a) Transformer A, and (b) Transformer B.

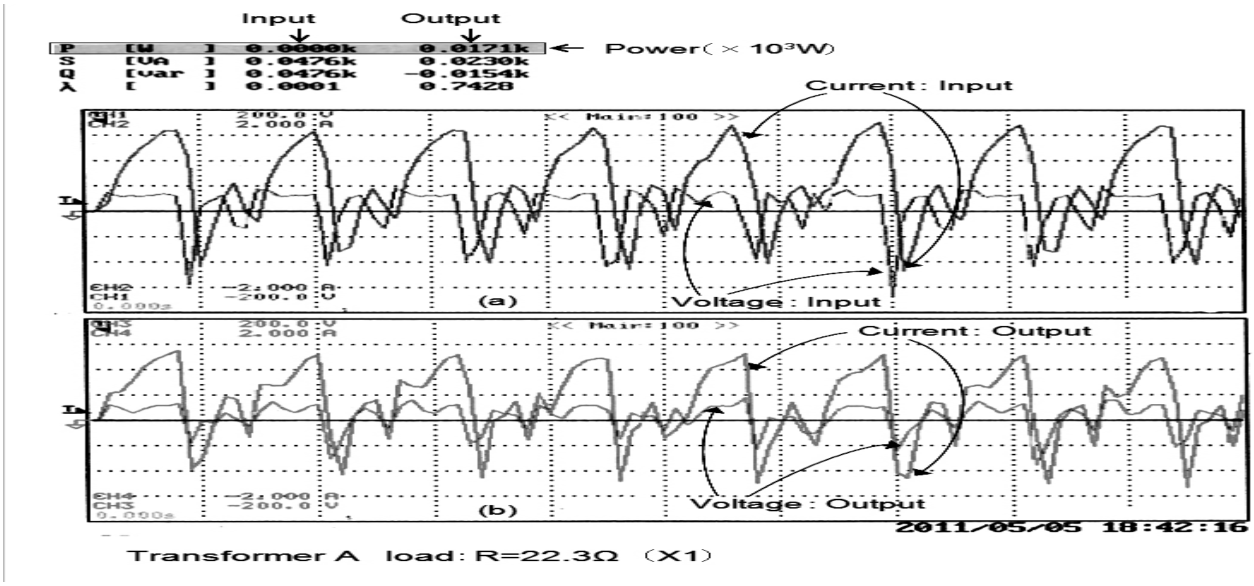

Fig. 6. In the condition that a load resistance of the value corresponding to the critical point X1, exists on the transformer "A", (a) The wave form of the input voltage and the input current, and (b) The wave form of the output voltage and the output current.

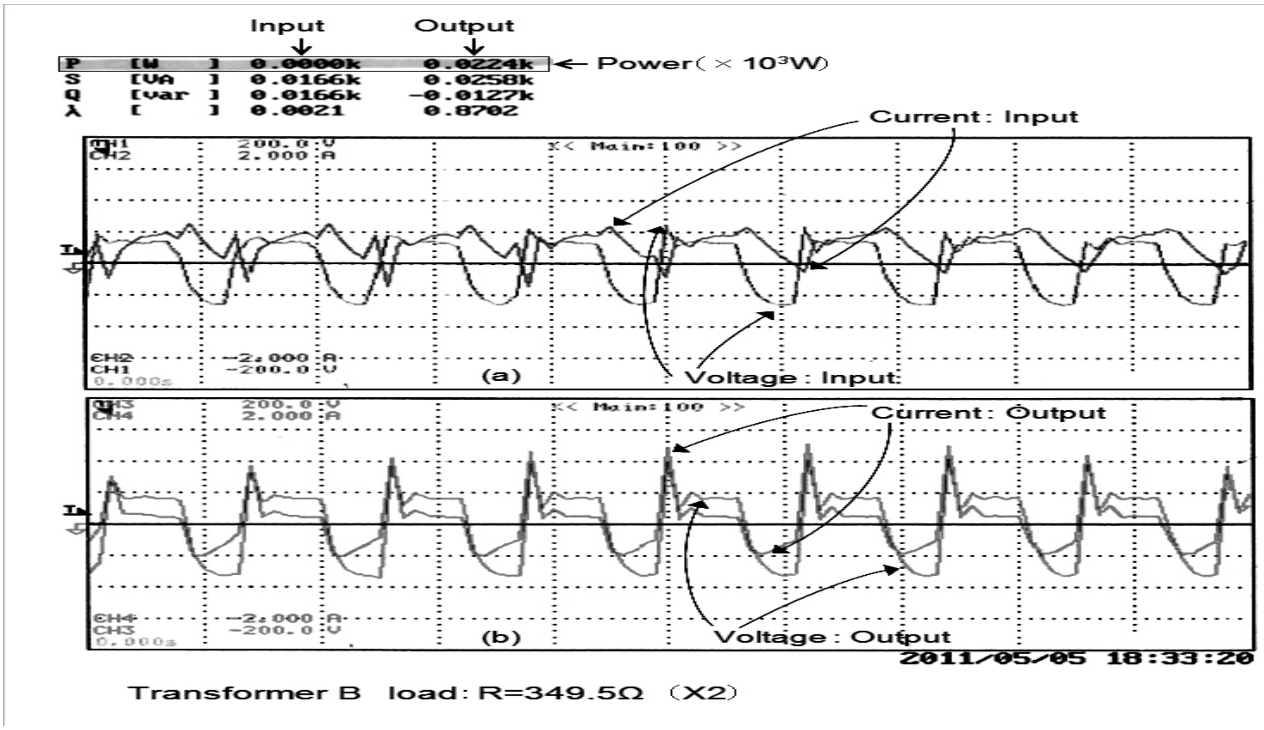

Fig. 7. In the condition that a load resistance of the value corresponding to the critical point X2, exists on the transformer "B", (a) The wave form of the input voltage and the input current, and (b) The wave form of the output voltage and the output current.

4. Consideration

Although the intrinsic reason to explain the phenomenon mentioned above has not become clear, the results of a series of experiments performed in this research, including the wave charts shown in Figure 6 and Figure 7 in particular, tell and prove that there absolutely exists such a phenomenon.

By seeing Figure 6(a) and Figure 7(a), which are the wave chart of voltage and the wave chart of current to be input to the transformer, respectively, it is obviously recognized that there exists a phase shift between the two charts to occur at the critical points X1 and X2 of the value of the load resistance at which input power will apparently become zero.

In addition, it is also recognized that there exists zones in which the direction of the input voltage is reverse to that of the input current. The fact could be interpreted as that power flows in the direction back to the MOS transistor from the input terminal of the transformer.

Based upon the above mentioned wave charts, it is possible for us to speculate that the RMS value of the input power becomes zero after the balance between the absolute values of the positive power and the negative power, to be input to the transformer, is maintained.

On the other hand, it is generally true that in the case of an ordinary transformer, to the secondary side of which a load resistance is connected, no shift will be caused between the phase of the input voltage to the transformer and that of the input current to the transformer, and that no such a phenomenon can occur.

Also, in the case of an ordinary inverter which is in the state of operation, the wave form of the current from the DC power supply source to the inverter should be identical to that of the current to flow from the MOS transistor to the transformer. However, in the case of the inverter investigated, it has been observed that the two wave forms are different from each other.

Figure 8 indicates a comparison of the wave form of the output current from the DC power source, to that of the output current from the MOS transistor that is the input current to the transformer. It is recognized from Figure 8, that the two wave forms are different from each other to a considerable extent. It seems that something most conspicuous there, is the phase shift. In other words, it seems that the MOS transistor acts as if it were a variable inductance to shift the phase of the input current. However, this phenomenon may not be caused only due to the MOS transistor, but rather it may be due to the mutual effect between the MOS transistor and the transformer.

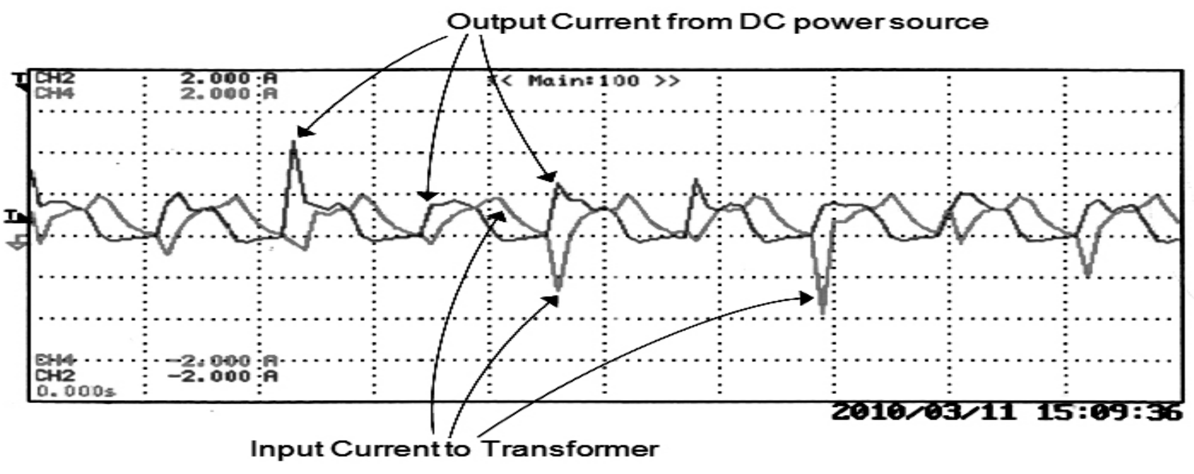

Fig. 8. In contrast of the wave form of the input current from the DC power source, to the wave form of the input current to the transformer composing the inverter that is in operation for investigation.

It can be suspected that this phenomenon is related with the fact that this inverter investigated this time, indicates hyper-efficient performance. On the other hand, we may use it as a hint for the further development of an ideal inverter of self-excitation type, which requires no energy to be supplied from a DC power supply source.

In the end, this phenomenon is merely one of the interesting characteristics of this inverter investigated. It is necessary to be made for further in-depth and comprehensive investigations not only on the phenomenon, but also on the other phenomena which seem to suggest other unbelievable and unexplainable characteristics, being already reported in reference [3] (Chapter 4 "Unexplainable Phenomenon On The Inverter By This Invention").

5. Conclusions

The working characteristics of an inverter which is driven with well-tuned duty cycle nearly-square pulse wave, was investigated. In this investigation, the authors set a focus on measuring the values of input power to the transformer that is integrated in the inverter system as a component, and of output power from the same. From the results of measurement which is made in the condition that the transformer is in operation bearing a load resistance on the output side of it, the following was discovered:

- Phase shift that cannot occur for an ordinary transformer to be driven with sine waves, is caused between the observed waves of the input voltage to the transformer and the observed input current to the same.
- The degree of the phase shift between the voltage wave and the current wave to be input to the transformer varies depending on the value of the load resistance existing on the secondary side of the transformer.
- Accordingly, the RMS value of the input power to the transformer can vary in the range from the positive axis zone to the negative axis zone, encompassing zero.
- Consequently, the apparent power efficiency of the transformer itself as a single unit, can take not only a positive value, but also a negative or even infinite value.

6. Co-author’s Comments

At the time of publication of this paper, the co-author discovered the PZ4000 the author used to create all of the data graphs in this paper has excessive amounts of inaccuracy when measuring the frequency of signal plus noise that is common in the circuit of this paper. This was confirmed by a spreadsheet that calculates “uncertainty” for the PZ4000 that was supplied by Yokogawa, the manufacturer of the PZ4000, using input waveform parameters from a higher bandwidth oscilloscope. This high “uncertainty” is due to the fact that the PZ4000’s highest sample rate of 5 MHz is only 10 to 15 times faster than the operation of the circuit in this paper (depending on the selected circuit frequency) and the circuit produces significant amounts of noise at frequencies that are more than 10 times the circuit’s main operation frequency. This was confirmed by the co-author’s replication of the circuit in this paper, which did not show comparable results. The highest efficiency the co-author has obtained from subsequent testing of the author’s complete setup is 96% in limited repeatable testing at lower input voltages so far. Since there are at least two known ways to improve this circuit’s efficiency, considerable hope remains to confirm the viability of the approach and method described in this paper.

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All the figures and charts used in this paper were prepared by Takayuki Funabashi and Honami Ichinose.

The English translation of the whole text of this paper was rendered by Eiichi Yamamoto from Yama Trans Co. Ltd.

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