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Contactless Vectormeter Using Thyristors

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In order to measure the iron loss of the silicon steel plates, we produced a vectormeter using a thyristor and a gate turn off thyristor by way of experiment. This equipment is very useful, because the frequency range is improved very much in comparison with the vectormeter which is composed of the mechanical rectifying system using a synchronous motor, namely, is enlarged from 60Hz to 1kHz.

§ 1. Introduction

The vectormeter which was developed by Koppelmann, can be used to the measurement of the momentary value or harmonics of the measured wave, phase difference between two waves, AC-hysteresis loop of magnetic material, the core loss of silicon steel plates, etc.

But, as the mechanical rectifying system using a synchronous motor is applied to the vectormeter, it is useful only about commercial frequency. For this reason up to this time, the vectormeter is hardly put to practical use, in spite of having wide utility range.

In order to compensate this demerit, we produced a contactless vectormeter using a thyristor (*SCR*) and a gate turn off thyristor (*GTO*) in stead of a synchronous motor, and attained our expected purpose.

§ 2. Construction of circuits

The block diagram of the vectormeter which we made is shown in Fig. 1.

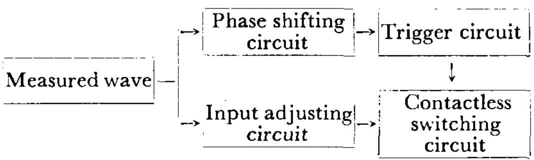

Fig. 1. Block diagram of the vectormeter.

(a) Input adjusting circuit ··· In this circuit, the connection is determined according as the measured wave is voltage or current, and the amplitude of the output voltage to the switching circuit is limited to adequate value.

(b) Contactless switching circuit ··· This circuit is the most important part of the vectormeter, and composed of an inverse parallel circuit using a *SCR* and a *GTO*, power sources to compensate the forward voltage drops of these semiconductors, and a meter circuit for measurement.

(c) Phase shifting circuit ···The phase difference between the switching angle of the semiconductor and the input wave is adjusted by this circuit.

(d) Trigger circuit ··· This is the trigger circuit of the *SCR* and *GTO*, and is composed to generate pulses (square wave) synchronizing with measured wave.

We can obtain other circuits by changing the combination of each circuit, for example, by exchanging the phase shifting circuit with the input adjusting circuit, and by connecting the output terminal of the input adjusting circuit to the phase shifting and switching circuit, etc.

(1) *Input adjusting circuit*

The input adjusting circuit is shown in Fig. 2.

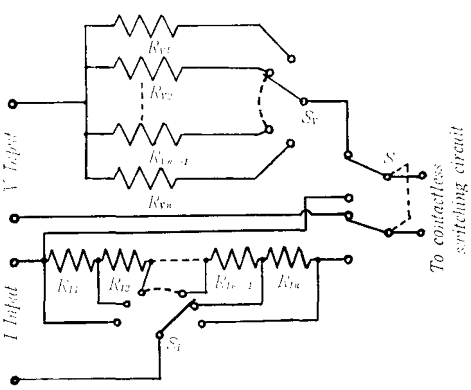

Fig. 2. Input adjusting circuit.

According as the measured wave is voltage or current, the switch S is changed up or down. The amplitude of the measured voltage or current is adjusted by the switch S_V or S_I which connects the tap to resistances R_{V1}, R_{V2}, $\cdots R_{Vn}$, or R_{I1}, R_{I2}, $\cdots R_{In}$, so that the applied voltage to the switching circuit is less than the rated value of the *SCR* and *GTO*. As the accuracy of these resistances affects that of measured value, the resistance values have to be high accuracy.

(2) *Switching circuit*

This circuit, as shown in Fig. 3, is composed of an inverse parallel circuit using a *SCR* and a *GTO*, power sources to compensate the forward voltage drops of these semiconductors and a voltmeter to read the measured voltage.

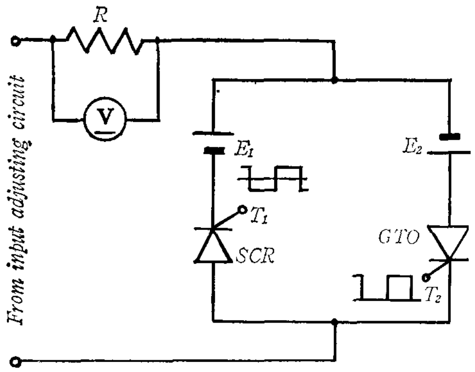

Fig. 3. Contactless switching circuit.

The operation of this circuit is explained from Fig. 4.

If it is assumed, that the measured wave form is sinusoidal as shown in Fig. 4(a), and also the phase relation between trigger input wave to gate of the *SCR* and the measured wave form is as shown in Fig. 4(c) and 4(b), that is, the trigger voltage has lag than the measured wave by θ_2-θ_1, the *SCR* is fired at θ_2. In this case, if the trigger voltage is the pulse whose width is short, the *SCR* will turn off when the amplitude of the measured wave becomes less than the holding current of the *SCR*, in other words, the *SCR* will turn off before the measured wave becomes to zero. This phenomenon causes also a measuring error. Therefore the pulse duration must be longer than θ_3 and shorter than $(\theta_1+2\pi)$. Moreover the trigger amplitude affects fire and turn off time, therefore it is desirable that the trigger wave has a width from θ_2 to θ_4 and a voltage enough to fire the *SCR* and less than the breakdown voltage. If such a kind of trigger voltage is applied, the *SCR* will continue to operate till the measured wave becomes to zero (θ_3). If, at a certain angle being between

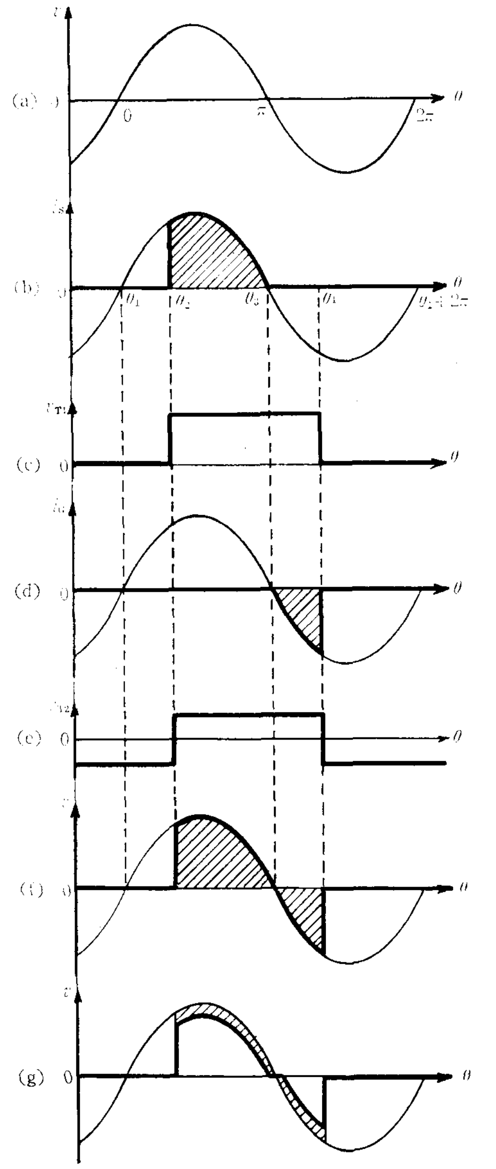

Fig. 4.
(a) Measured wave form.
(b) Current wave form of the *SCR*.
(c) Trigger voltage of the *SCR*.
(d) Current wave form of the *GTO*.
(e) Trigger voltage of the *GTO*.
(f) Terminal voltage wave form of the resistance *R*.
(g) Terminal voltage wave form of the resistance *R*, when the forward voltage drops are uncompensated.

θ_1 and θ_3, a plus trigger voltage is applied to the gate of the *GTO* as shown in Fig. 4(e) (in Fig. 4 the trigger voltage is applied at θ_2.), the *GTO* is fired at θ_3. When the negative trigger voltage is applied to the gate of the *GTO* at θ_4, the *GTO* turns off. Consequently the duration appearing the terminal voltage of the resistance R is from θ_2 to θ_4 as shown in Fig. 4(f) (part of oblique lines).

Then the mean terminal voltage of the resistance is expressed as follows.

$$V = \int_{\theta_2}^{\theta_4} v\,d\theta$$

From this equation, it is found the terminal voltage which DC-voltmeter indicates is proportional to the difference between the areas shown in Fig. 4(f).

If this circuit is composed of only an inverse parallel connection of the *SCR* and *GTO*, the terminal voltage of the resistance becomes as shown in Fig. 4(g), depending on the forward voltage drops of these two semiconductors. This is also a cause of measuring error, then, in order to compensate this error, DC-voltage E_1, E_2 are added to the switching circuit as shown in Fig. 3. Accordingly, a satisfactory wave form is obtained as shown in Fig. 4(f).

(3) *Phase shifting circuit*

This circuit exists to adjust the phase difference between the trigger voltage and the measured wave. The phase shifting angle must be changeable from zero to 360 degrees for the purpose of measuring the phase difference between two measured waves. In case of measuring the momentary value or harmonics of the measured wave, it is sufficient only to change 180 degrees. But changing the polarity of the trigger wave, it can be reduced to half.

(4) *Trigger circuit*

The conditions required in this circuit are following two.

(a) The trigger pulse has to be a square wave having same period as the input wave.

(b) The pulse width must be changeable.

The trigger circuit shown in Fig. 5 which we produced by way of experiment, satisfies only the condition (a), but the condition (b) can be easily satisfied by adding the pulse width adjusting circuit to the input of the trigger circuit.

In Fig. 5, only one trigger circuit is shown, actually, two same kind of trigger circuits are provided and connected to the gate of the *SCR* and *GTO*, respectively.

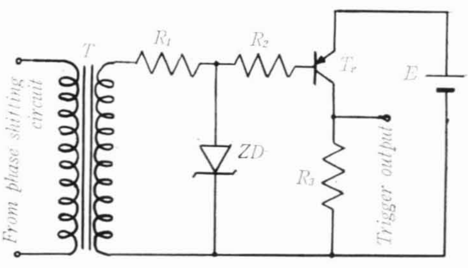

Fig. 5. Trigger circuit.

The operation of this trigger circuit will be explained as following. The output voltage obtained from the phase shifting circuit, is supplied to the primary circuit of the transformer T. The reason to use the transformer is that the two trigger voltages supplying to the gates of the *SCR* and *GTO* must be insulated, respectively. The constant voltage must be supplied to the base of the transistor T_r in the satulated amplifier for obtaining a constant trigger output, but, as the secondary voltage of the transformer T is not constant, supplying voltage to the base is stabilized by using a zener diode *ZD*. But there are some space for consideration about this trigger circuit.

The photographs of the wave form obtained by using this equipment are shown in Fig. 6.

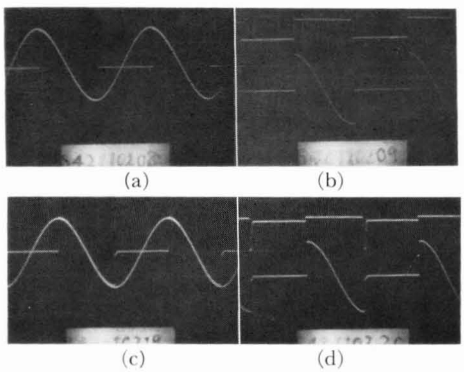

Fig. 6.

(a) The wave form of the terminal voltage of R and the measured wave form at 100 Hz.

(b) The wave form of the terminal voltage of R and the trigger voltage wave form at 100 Hz.

(c) The wave form of the terminal voltage of R and the measured wave form at 1 kHz.

(d) The wave form of the terminal voltage of R and the trigger voltage wave form at 1 kHz.

These photographs are taken by putting the terminal voltage wave form of the resistance R in Fig. 3 upon the measured wave form or the trigger voltage wave form.

§ 3. Discussion

In this equipment, the causes of the measuring error are delay time until the *SCR* and *GTO* operate after the trigger signal was applied, and the rise time. From the measured result, it is found that the mean delay time of the *SCR* and *GTO* is about 0.1% of the period of the measured wave respectively. The delay time of a semiconductor (*SCR* or *GTO*) is independent of frequency, therefore the error of the delay time is in the trigger circuit itself.

According to our experiment, the rise time is $2\mu s \sim 20\mu s$ being independent of frequency in the range of 60 Hz ~ 1 kHz. This time is also affected by the wave form of the trigger signal. Inherent rise time of the *SCR* and *GTO* is only a few μs. Taking this into consideration, if the rise time is assumed to be $2\mu s$, the upper limit of the measured wave frequency becomes about 1 kHz to take the error less than 1%. Though, in our product, *C-R* phase shifters are used for the phase shifting circuit to each measured frequency, it is preferable to make a phase shifting circuit which is composed of one phase shifter and does not vary the shifting angle for the frequency. One example is shown in Fig. 7.

In our equipment, the switching circuit is composed of the *SCR* and *GTO*, but other ways can be considered, for example, the way of using a turn off circuit of *SCR* in stead of *GTO*, the way to use the switching circuit which is composed of transistors, etc.

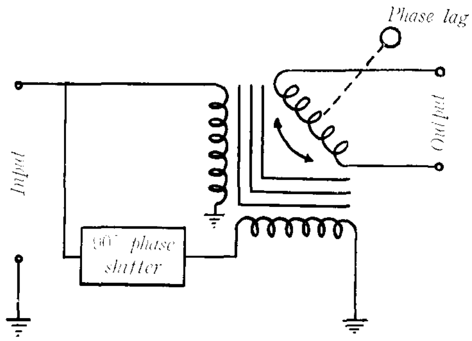

Fig. 7. Phase shifter.

§ 4. Conclusion

In this paper, we described that the vectormeter can be produced by using a *SCR* and a *GTO*. Though the frequency range of vectormeter using a synchronous motor is only about commercial frequency, the frequency range of ours is enlarged to about 1 kHz. Moreover our equipment has following merits.

1) It has no consumption part.
2) The life will be longer than that one.
3) Being small type, it is easy to deal with.
4) It is easy to maintain.

References

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