Scheme of Squirrel-cage Asynchronous Motor Soft Start Triggered Thyristor Alternating Voltage Regulation

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Abstract. The thyristor alternating voltage regulation circuit often appear out of control phenomenon in application even though the principle of is simple. A lot of literatures show this kind of phenomenon from the stability of the transition process. As a matter of fact, it is also related to the trigger mode. In this paper, four kinds of trigger modes were analyzed, and carried on the comparison of the trigger modes to get a suitable one for the squirrel-cage asynchronous motor soft start trigger circuit.

Keywords: Alternating voltage, soft start, asynchronous motor, trigger signal.

1. Scheme of the alternating voltage regulation of thyristor

The synchronizing signal triggered by alternating voltage regulation of thyristor was formed a conduction circuit by the ways of the supply voltage, phase current or terminal voltage of the thyristor. Two thyristors were triggered simultaneously during the formation of a conduction circuit, double pulse trigger or wide pulse trigger selected accordingly. There are several commonly used trigger schemes: the supply voltage synchronous double pulse trigger scheme, supply voltage synchronous wide pulse trigger scheme, current synchronous double pulse trigger scheme, etc.

1.1 The supply voltage synchronous double pulse trigger scheme

In this scheme, the crossing point of phase voltage was chosen to be the synchronizing signal. The double pulse was composed of two narrow pulses separated by 60 °, which reissued a pulse to the former thyristor during the triggering of each thyristor. Meanwhile, the logically contributing trigger was the first trigger.

This kind of the scheme was separated to three cannula trigger circuit and six cannula trigger circuit according to the topology of the trigger circuit. We defined the three cannula trigger when each phase of the two opposite thyristors shared a set of trigger pulse, and the six cannula trigger was defined as that each of the six thyristors had their own separated trigger pulses. Due to the nature of easy to implement, the circuit of the three cannula trigger will save hardware resources relatively. However, the scheme of six cannula trigger can reduce the loss of control electrode of the thyristor, and it can put an end to the spurious triggering of the positive trigger pulse to the negative thyristor with a clear trigger logic.

In the scheme of three cannula trigger, the two opposite thyristors shared a set of trigger pulse and the second pulse laged behind the first one by 60°. When $\alpha>120°-P$, the second pulse of the double pulse appeared with $\alpha>180°-P$. The delay of 180 °at the back porch aroused the spurious triggering of each thyristor when $\alpha=0$. Thus, a current waveform different from the normal waveform emerged and it caused the confusion of logic. The purpose of gaining parameter α was to reduce the output current. However, when the opposite thyristors were spurious triggered, an output current close to the maximum value appeared consequently. In order to avoid the occurrence of this phenomenon, the scope of phase shift was:

$$\Phi\text{-}P\text{-}P\ \min<\alpha<120°-P \quad (1.1a)$$

However, in the scheme of six cannula trigger, the spurious triggering phenomenon would not happen, the scope of phase shift was:

$$\Phi\text{-}P\text{-}P\ \min<\alpha<150° \quad (1.1b)$$

Where α is the firing angle, Φ the power-factor angle, P the pulse width, and P min the minimum pulse width.

1.2 The scheme of voltage synchronous double pulse trigger with the limit of current signal

The principle of the voltage synchronous double pulse trigger with the limit of current signal is to add the limit measures in the trigger pulse formation circuit. Thus, the type 1.1 was established. This kind of design can prevent the unstable condition during the triggering, and it also can avoid spurious triggering of the positive trigger.

Obviously, the lower limit of firing angle is $\alpha \geqslant \Phi$. In the current continuous critical cases, the current lagging angle is $\Phi=\varphi$. The detection of the current zero-crossing point takes advantage of the angle Φ of real-time monitoring and makes sure $\alpha \geqslant \Phi$ in the mediation process. Thus, the trigger instability phenomenon can be prevented.

There are two cases for the upper limit of firing angle, the three cannula trigger request the firing angle $\alpha<120°-P$, and the six cannula trigger request the firing angle $\alpha<150°$. Then, the spurious triggering of the positive trigger can be prevented. The lower and upper limits are constants, and both of them can pre-set without requiring real-time detection.

1.3 The supply voltage synchronous wide pulse trigger scheme

Wide pulse trigger which is controlled rectifier used a pulse width whose phase was greater than 60 ° to replace the original double pulse. Nevertheless, it was not sufficient to fit the alternating voltage circuit. The width of the pulse must made the type (1.1) established on the left side, $\alpha>\Phi-P-P$ min or $P>\Phi-\alpha+P$ min. Meanwhile, the above instability phenomenon can be avoided. Parameters of Φ and α in the type (1.1) should be taken the maximum and minimum respectively Formula of A and in the whole process. Then, the standards of the pulse is

$$P>\max(60°, \Phi \max - \alpha \min + P \min) \quad (1.3a)$$

After the parameters of main loop and the output voltage were selected, the three parameters on the right side of type (1.3a) can be calculated. Then, the width of the pulse can be identified. When α min=0, Φ max=90°, and P=90°+ P min, in such limiting cases, the opposite thyristors of each thyristor had their current zero-crossing point for any $\alpha \leqslant \Phi$. Therefore, the current was still continuous and the design effect was equal to that of when $\alpha=\Phi$.

However, after widened the pulse, the upper limit of parameter α was greatly restricted for the three cannula trigger. By the right side of the type (1.1), we can get

$$\alpha<120°-P=120°-\max(60°, \Phi \max + \alpha \min - P \min) \quad (1.3b)$$

The limiting case is: $\alpha<30°-P$ min. This range was so small that the scheme of wide pulse three cannula trigger was useless. Whereas the six cannula trigger scheme can maintain theα max + P=240°+ P min<360° even the firing angleα max=150° and pushed the spurious triggering away.

1.4 The current synchronous wide pulse trigger scheme

This kind of trigger mode chose the zero-crossing point of the opposite thyristors as reference point. Trigger pulse was emitted with delaying an angle γ' ($0° \leqslant \gamma' <120°$). Thus, the given pulse by this way always happened on or after the zero-crossing point of the opposite thyristors, and the current cut-off angle γ was equal to the delay angle γ'.

This trigger scheme can ensure the strictly decreasing of the current or voltage with the increase of cut-off angle until the effective values of the current or voltage is zero. Real-time tracking the change of the power factor angle and change the time of emitting pulse can ensure the smooth change of voltage and current.

2. The comparison of various trigger scheme

In the scheme of supply voltage synchronous double pulse trigger, the synchronization signal of trigger signal is power supply voltage and it is not necessary to detect current signal in real time. However, for the insurance of the pulse width, the capacity of pulse transformer should be large enough. It is a flaw of this trigger mode. In order to overcome this shortcoming, a pulsed column is select to instead of wide pulse.

There are two shortages in the scheme of current synchronous wide pulse trigger. Firstly, the boot process must be triggered by the synchronization of voltages and it will be switched to the synchronization of current after the establishment of the current. Secondly, due to the current waveform and synchronization signal will be destroyed when the synchronizing signal from current is disturbed. The errors of synchronization signal then leads to trigger chaos andthe circuit will be completely out of control.

3. Conclusion

In the four kinds of scheme above, it wouldn't be guaranteed to reveal a reliable work only by the voltage synchronous double pulse trigger. The other three schemes can work properly without the effect of the interference, and in the case of the interference, the supply voltage synchronous wide pulse trigger scheme with the six cannula trigger and the power of pulse transformer big enough is the most reliable. The reliability of the voltage synchronous double pulse trigger with the limit of current signal scheme depends on the current signal, and the current detection circuit and the limit circuit are needed during the trigger process. Therefore, this scheme is more complicated than the previous one. The reliability of the current synchronous wide pulse trigger scheme relays on the current detection circuit, besides, the performance is very reliable as long as the trigger without disturbance.

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