Dual Microcomputer Excitation Regulator Data Follow and Fault Switching

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Abstract. In this paper, the generator excitation regulator as the control object, studies the data tracking between the dual microcomputer excitation control system and bumpless transfer, in order to ensure the system real-time data tracking, the accuracy of fault detection and quick failover, especially the design of the control system of a redundant hot standby based on double DSP, through the eCAN communication network data through the eCAN network to follow, mailbox function complete dual data tracking, the proper use of the DSP interrupt service subroutine for fault identification, finally using DSP rich software functions of fault alarm and switching. The experimental test of generator excitation regulator of above ideas developed data follow and fault based switching system, operation results show that: the typical faults in the excitation conditions, system data real-time, accurate tracking, disturbance of high fault free switching, system reliability and maintainability improve.

Key words: dual microcomputer excitation regulator; data follow; fault switching; eCAN.

Generator excitation regulator is the main part and core part of excitation control system. It can sense the change of generator terminal voltage, generator terminal current or other parameters, and then exert control effect on excitation power unit. With the development of control strategy and the continuous emergence of new technology and new devices, the excitation regulation mode has developed from manual to automatic; the regulator function has developed from single voltage regulation to multi-function excitation control. Modern generator sets have higher and higher requirements for the reliability of excitation regulator. Single microcomputer excitation regulator control can not meet the requirements of reliability. At present, the dual microcomputer dual channel hot standby excitation system is mainly used. However, in order to ensure that the voltage and reactive power of the generator will not fluctuate during the switching process, the dual microcomputer dual channel excitation system is mainly used. The component parameters of hot standby unit and output characteristics of integrated amplification unit shall be consistent. The traditional dual microcomputer fault detection and switching usually uses...
peripheral logic circuit to judge the fault and cooperate with reasonable logic relationship to carry out fault switching. The principle of this method is simple and reliable, but the peripheral circuit is bulky and complex. In this paper, the abundant communication function of DSP is used to realize the data following between the two machines. The interrupt service subroutine of DSP is fully used to realize the data following between the excitation regulators of the generator set and the undisturbed automatic switching of typical faults in engineering application.

1. System composition of Double Microcomputer Excitation Regulator

The working channel and standby channel of dual microcomputer excitation regulator system are independent of each other. The hardware structure of the system is shown in Fig. 1. In the figure, DSP regulator a adopts TMS320F2810 chip, which is the main excitation regulator of the system. It is composed of analog data acquisition unit, switch input and output unit, human-machine interface unit, communication unit, etc., which mainly completes data acquisition, calculation, trigger pulse formation and data communication with hot standby machine B. DSP regulator B is the standby machine of dual microcomputer excitation regulator, The composition unit is the same as DSP regulator a, which works in tracking regulator a state and normal regulation state. When working in tracking state, DSP regulator B mainly completes data acquisition, electrical parameter calculation, data tracking and communication between two computers, trigger pulse formation and other functions; when in normal regulator state, DSP regulator B performs the same adjustment function as DSP regulator a. High efficiency eCAN communication is the biggest characteristic of dual microcomputer excitation regulator, which makes the two computers understand each other's working conditions and working states in real time, and exchange data information with each other. The switching circuit occurs in the normal operation of dual microcomputer excitation regulator. When the excitation regulator a of the main engine fails, the fault can be quickly detected by the interrupt response function of DSP, and the fault switching from a to B is completed through the switch output to the switching circuit. The switch input usually includes in screen input signal (shutdown de excitation, de excitation switch signal, excitation signal, signal common terminal), and external input signal (circuit breaker contact, central control room magnetization, central control room demagnetization, central control room removal). Analog input usually includes excitation current signal and excitation voltage signal.

![Fig. 1 hardware structure of dual microcomputer excitation regulator](image)

2. Data following

In order to realize data follow-up in dual microcomputer excitation regulator system, the communication between two excitation regulators A and B is required to realize the real-time exchange of state quantity and measured value between the two regulators. When regulator a operates normally, regulator B follows the operation state of regulator A. when regulator a fails and regulator B is put into operation, it can realize no fault switching. Because of disturbance switching, the communication ability between the two microcomputers will directly affect the reliability of the whole dual microcomputer excitation system. In this paper, the eCAN network communication mode provided by TMS320F2810 is adopted. Through the design of its mailbox distribution, the mutual communication between two microcomputers is finally realized.

eCAN module has 32 mailbox, which takes up 512 bytes of storage space. In other words, each mailbox has 16 bytes of storage space. Both a and B of the dual microcomputer regulator system need
to receive the data information sent by the other side while sending the local state quantity. The state quantity and data quantity needed to be communicated between two microcomputers include generator terminal voltage signal, generator terminal current and voltage setting value, excitation current, excitation current setting value, trigger control angle, and operation state of generator set. eCAN module supports multi node data sending and receiving. As long as the identifier of each mailbox is set reasonably, the data tracking between two microcomputers can be realized. The specific mailbox allocation is shown in Table 1 and Table 2.

**Table 1. A System mailbox allocation**

| Identifier | P.O.Box | point | purpose |
|------------|---------|-------|---------|
| 0X006100   | P.O.Box 1 | send out | Sending terminal voltage of system A Ua |
| 0X006108   | P.O.Box 2 | send out | Sending terminal current of system A Ia |
| ……        | ……      | ……    | ……      |
| 0X006120   | P.O.Box 7 | send out | Send A system trigger control angle |
| 0X006128   | P.O.Box 8 | send out | Sending the set value of terminal voltage of A system |
| 0X00612F   | P.O.Box 9 | send out | Sending the given value of excitation current of A system |
| 0X006130   | P.O.Box 10 | send out | Operation status of generator set when sending A system control |
| 0X006138   | P.O.Box 11 | receive | Receiving terminal voltage of B system Ua |
| 0X00613F   | P.O.Box 12 | receive | Receiving terminal current of system A Ia |
| ……        | ……      | ……    | ……      |
| 0X006158   | P.O.Box 17 | receive | Receiving B system trigger control angle |
| 0X00615F   | P.O.Box 18 | receive | Receive the set value of terminal voltage of system B |
| 0X006160   | P.O.Box 19 | receive | Receive the given value of excitation current of system B |
| 0X006168   | P.O.Box 20 | receive | Operation status of generator set when receiving control of system B |

**Table 2. B System mailbox allocation**

| Identifier | P.O.Box | point | purpose |
|------------|---------|-------|---------|
| 0X006100   | P.O.Box 1 | receive | Receiving terminal voltage of system A Ua |
| 0X006108   | P.O.Box 2 | receive | Receiving terminal current of system A Ia |
| ……        | ……      | ……    | ……      |
| 0X006120   | P.O.Box 7 | receive | Receive A system trigger control angle |
| 0X006128   | P.O.Box 8 | receive | Receiving the set value of terminal voltage of A system |
| 0X00612F   | P.O.Box 9 | receive | Receiving the given value of excitation current of A system |
| 0X006130   | P.O.Box 10 | receive | Operation status of generator set when receiving A system control |
| 0X006138   | P.O.Box 11 | send out | Sending terminal voltage of B system Ua |
| 0X00613F   | P.O.Box 12 | send out | Sending terminal current of system A Ia |
| ……        | ……      | ……    | ……      |
| 0X006158   | P.O.Box 17 | send out | Sending B system trigger control angle |
| 0X00615F   | P.O.Box 18 | send out | Send the set value of terminal voltage of system B |
| 0X006160   | P.O.Box 19 | send out | Send the given value of excitation current of system B |
| 0X006168   | P.O.Box 20 | send out | Operation status of generator set when sending control of system B |

3. Fault detection and automatic switching of follow-up system

In this paper, the eCAN network is used to realize the real-time data communication between two microcomputers. Therefore, eCAN network communication plays an important role in the excitation control of the dual microcomputer. When the eCAN network communication breaks down during the operation of the generator set, it will have a serious impact on the whole unit. The traditional method is to set up two eCAN network communication, as shown in Figure 2. When computer controller a and eCAN network communication failure occurs at the same time, the standby eCAN network communication hardware redundancy is used to realize the data following of microcomputer controller a and realize the undisturbed switching between the two computers. This method is simple in principle
and easy to implement in engineering, but its reliability is not high and the hardware circuit is cumbersome.

![Figure 2. eCAN Hardware schematic diagram of communication network](image)

In this paper, the method based on software redundancy is used to solve the problem of undisturbed switching between two computers in eCAN network communication failure. Firstly, the can module of DSP chip is used to judge the fault of eCAN network communication. When working in eCAN mode, the sending or receiving interrupt can be generated in mailbox 0~31. Therefore, the "request response" mode is used to judge the fault. When the mailbox does not receive the message or send the completion message within the specified time, a timeout event will be generated. The bit tosn of the timeout status register Cantos and the bit mtof0 / 1 of the global interrupt flag register cangif0 / 1 will be set. If the mask bit MTOM in the cangim register has been set, the mailbox timeout will generate an interrupt. The corresponding interrupt line requests the pie control register and starts the timing register ticnt. When the receiving mailbox receives messages for several consecutive cycles, the timer register ticnt will generate a cycle interrupt with the set cycle register. At this time, the microcomputer processor responds to this cycle interrupt, indicating that the eCAN network is in trouble.

When the eCAN communication network fails, the software redundancy is used to realize the fault switching of the following system. The flow diagram is shown in Fig. 3.

![Fig. 3 Principle block diagram of software redundancy flow](image)

When the eCAN communication network of dual microcomputer excitation control system fails, the real-time communication between the two microcomputers cannot be realized. At this time, the position type PID algorithm is used to follow the original host control quantity, so as to realize the undisturbed switching between the two microcomputers. Equation 3-1 shows the basic principle of the position type PID algorithm.
\[ y_n(k) = K_p e(k) + K_i \frac{T}{2} \sum_{i=0}^{k} [e(i) + e(i-1)] + K_d \frac{T}{2} [e(k) - e(k-1)] \]  

(1)

Where: \( y(k) \) is the output control quantity at \( k \) time; \( e(k) \) is the deviation value at \( k \) time, \( e(k-1) \) is the deviation value at \( k-1 \) time, \( e(i) \) is the deviation value at \( i \) time (\( i=0-k \)); \( T \) is the sampling period; \( K_P \) is the proportional coefficient; \( K_I \) is the integral coefficient; \( K_D \) is the differential coefficient.

Although the standby microcomputer has not been put into operation in the unit, it has always been in the hot standby state. In this state, the microcomputer collects the terminal voltage, terminal current and other data in real time. However, the data collected by the microprocessor will be inconsistent due to the physical reasons such as peripheral hardware circuit. Generally, there is a huge difference between the data collected by two microcomputers. In order to avoid the voltage fluctuation caused by the difference of the data collected between the two microcomputers during the switching, the position PID algorithm is used to process the data collected by the standby unit, and the consistency of the data between the two computers is maintained when the host machine is switched to the standby machine. The digital output of the microprocessor is converted into analog output by Da circuit. The analog output is directly used to control the excitation current of generator excitation system. Therefore, whether the analog output meets the standard plays a decisive role. Generally, if the analog output is compared with the set output, if the deviation requirement is met, the system will continue to use the standby machine to control the normal operation of the main engine, and if the deviation is too large or too small, it will alarm.

Another method is to use the rich data AD sampling port of DSP Microprocessor to directly collect the analog quantity of Da analog output circuit when the host fails, and use the analog quantity directly for the initial value of standby machine. The principle of this method is simple and the data is reliable. However, tms320x2810 DSP processor has 16 AD sampling channels, so the control channel system without redundant AD sampling is no longer applicable.

4. System test experiment

In order to realize the state following between two microcomputers and automatic fault switching in fault mode, the communication between two microcomputers should be tested first. The main purpose includes: to ensure the real-time and accuracy of communication; after joining the communication, the data following condition of undisturbed switching between two computers can be met in fault mode.

In this paper, the eCAN communication test experiment is to send the state data collected by the host regulator \( a \) to the standby machine regulator \( B \) through eCAN communication. By comparing the state data of the standby machine regulator \( B \) with the measured data of the host regulator \( a \), table 1 is obtained. The experimental data in Table 1, such as terminal voltage, terminal current and terminal voltage, are given in standard unit value format, and trigger control angle is in name value format. It can be seen from table 1 that the accuracy of eCAN communication network can reach 99.7%, which meets the accuracy requirements of data following.

| name                      | Regulator A | Regulator B | Error value |
|---------------------------|-------------|-------------|-------------|
| Terminal voltage          | 1.02614     | 1.02524     | 0.2%        |
| Terminal current          | 0.9451      | 0.9448      | 0.3%        |
| Terminal voltage setting  | 1.002       | 1.003       | 0.1%        |
| Trigger control angle     | 65.348      | 65.357      | 0.014%      |

After the eCAN communication test is completed, the switching experiment will be carried out for the core system automatic switching function of the dual microcomputer excitation system. The system switching under two kinds of faults which are most likely to occur in engineering, the undisturbed switching under the normal condition of eCAN communication mode and the fault undisturbed switching when the eCAN communication mode and the host computer fail simultaneously will be simulated.
4.1. Undisturbed fault switching under normal eCAN communication mode

The eCAN communication mode is normal in this test. When the excitation regulator a of the simulation host fails, whether the system can detect the fault in time and switch to the standby regulator B without disturbance; there are many types of failure of regulator a, and the test assumes that regulator a has power failure to simulate the failure of main engine regulator a. For the excitation system controlled by a single microcomputer, if the regulator has a power failure accident, the regulator will not be able to send out the trigger pulse. As shown in Fig.4, the generator set of single microcomputer system is in no-load state, and the terminal voltage of generator set is recorded in the figure. It can be clearly seen that the voltage drop of generator terminal rapidly drops to 0 through recording graph.

![Single microcomputer controlled terminal voltage waveform at fault time](image1)

**Fig. 4** Single microcomputer controlled terminal voltage waveform at fault time

For the excitation system with dual microcomputer control designed in this paper, when such an accident occurs, the system will quickly switch to the standby system regulator B, as shown in Fig. 5. When the accident is simulated, the generator terminal voltage waveform quickly reaches a stable state, basically realizes the undisturbed switching, and obviously improves the system reliability.

![Double terminal voltage waveform control of Microcomputer](image2)

**Fig. 5** Double terminal voltage waveform control of Microcomputer
4.2. Undisturbed switching of eCAN communication mode in case of failure

In this test, when eCAN communication mode and host excitation regulator a fail at the same time, whether the system can detect fault in time and switch to standby regulator B without disturbance. The failure mode of main engine is also in power failure mode, and eCAN communication network adopts direct disconnection to simulate eCAN communication failure. Figure 6 shows the output waveform of generator terminal voltage under normal operation of dual microcomputer excitation system, and Figure 7 shows the output waveform of terminal voltage when eCAN network communication and host excitation regulator a fail at the same time.

![Figure 6. Output voltage waveform of generator terminal controlled by dual microcomputers in normal operation](image1)

![Figure 7. Output waveform of terminal voltage controlled by dual microcomputer for fault switching](image2)

Through the comparison of figures 6 and 7, it is found that: when the simulated accident occurs, the voltage waveform at the generator terminal does not change significantly from that under normal operation, and it can reach the stable state again in a short time, and the undisturbed switching is basically achieved.

5. Conclusion

This paper studies the data following of excitation system of generator set under fault mode by eCAN communication network of dual microcomputer system controlled by DSP; aiming at typical faults
found in engineering application, undisturbed switching of two machines is realized by abundant interrupt service subroutine of DSP; simulation fault experiment is used to verify the switching between two computers under normal and fault modes of eCAN communication network The correctness of the strategy shows that compared with the traditional hardware circuit, the proposed method not only maintains the reliability, but also significantly reduces the complexity of the peripheral circuit of the whole microcomputer controller. The method in this paper can be widely applied to the control system of generator set with high reliability. In practical engineering application, the prediction and prediction of generator excitation system fault have practical significance. How to achieve fault prediction under the existing hardware and software resources will be an urgent problem to be solved in the follow-up research.

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