A Novel Modularized Low Voltage Reactive Power Compensation Device Based on Controller Area Network

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Abstract: There are many ubiquitous shortcomings in the existing low voltage reactive power compensation device, especially the unreasonable centralized system structure. These deficiency lead to expensive equipment investment and other problems which will limit its application. Distributed system structure is better than centralized system structure for low voltage reactive power compensation device out of consideration for flexibility, reliability and expansibility. In this paper, a novel modularized low voltage reactive power compensation device based on Controller Area Network, routing bus and power bus is put forward. Under this new system topological structure, Controller Area Network bus links all the compensation modules for communication, the main circuit of all the compensation modules are linked as a whole system through the routing bus and power bus. The software program of this new device is also improved by means of integrated intelligent control principle and compensation capacity dynamic modification. The contrastive analysis and practical test show that the novel device has better compensation effect and performance index relative to the traditional product.

Key Words: Controller Area Network, Modularized, Topological Structure, Dynamic Modification, Routing Bus

1 INTRODUCTION

In power system, transmission of reactive power may cause energy losses, lower power factor and many other problems. The efficient measure to handle this situation is reactive power compensation. In low voltage power system, this kind of reactive power compensation device has wide application[1-3]. The common low voltage reactive power compensation device generally consists of controller, compensating capacitor, switches, fuse and machine cabinet, etc. There are a lot of ubiquitous shortcomings in the existing reactive power compensation device, suach as centralized system structure, complex connections, unprecise control, hard to maintain and compensation capacity extend. These deficiency lead to expensive equipment investment and other problems which will limit its application.

Distributed system structure is better than centralized system structure for low voltage reactive power compensation device out of consideration for flexibility and expansibility. In this paper, a novel system topological structure modularized reactive power compensation device based on CAN bus, routing bus and power bus is put forward. Under this new topological structure, CAN bus link all the compensation modules(main-module and sub-module) for communication, the main circuit of all the compensation modules(main-module and sub-module) are linked as a whole system through the routing bus and power bus. This new system topological structure has the improvement relative to the traditional device, including flexible configuration, easy connection, strong capacity of resisting disturbance, convenient compensation capacity extend and maintenance, high power density and reliability.

2 CONTROLLER AREA NETWORK

CAN (Controller Area Network) is a serial bus system, which was originally developed for automotive applications in the early 1980's. The CAN protocol was internationally standardized in 1993 as ISO 11898[4-6] and comprises the data link layer of the seven layer ISO/OSI reference model. CAN is by now available from around 40 semiconductor manufacturers in hardware, provides two communication services: the sending of a message (data frame transmission) and the requesting of a message (remote transmission request, RTR). All other services such as error signaling, automatic re-transmission of erroneous frames are user-transparent, which means the CAN chip automatically performs these services.

The Physical Layer defines how signals are actually transmitted and therefore deals with the description of Bit Timing, Bit Encoding, and Synchronization. Within this specification the Driver/Receiver Characteristics of the Physical Layer are not defined so as to allow transmission medium and signal level implementations to be optimized for their application. The MAC sublayer represents the kernel of the CAN protocol. It presents messages received from the LLC sublayer and accepts messages to be transmitted to the LLC sublayer. The MAC sublayer is responsible for Message Framing, Arbitration, Acknowledgment, Error Detection and Signalling. The MAC sublayer are supervised by a management entity called Fault Confinement which is self-checking mechanism for distinguishing short disturbances from permanent failures. The LLC sublayer is concerned with Message Filtering, Overload Notification and Recovery

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Management. The layered architecture of CAN according to the OSI reference model is shown in figure 1.

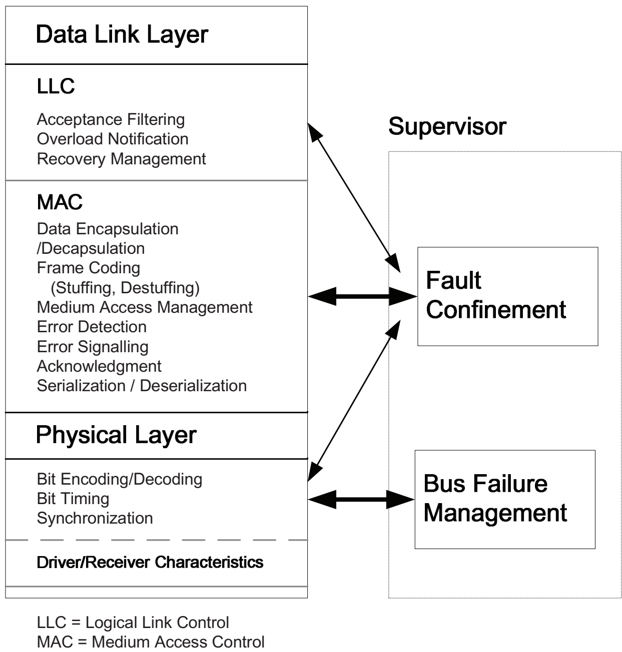

Fig. 1 OSI reference model layered architecture of CAN

The CAN bus concept of Broadcast Communication means that every station of the network can listen to the frames of the transmitting station. After receiving the frame it is the task of every node to decide if the message has to be accepted or not. So Acceptance Filtering has to be implemented in every CAN bus node. The CAN bus Broadcast Communication can be compared with a radio station transmitting information about traffic accumulation for vehicle drivers. Every driver has to decide if the messages are important for him dependent on the motorway he wants to use. The CAN bus protocol provides two communication services. This Write Object service transmits a Data Frame from one node (the producer) to one or more receiving nodes (consumers). This don´t implies that one node will accept the message meaning that some one is interested in this information. This service is the classic CAN bus communication service. The second communication service is to request a specific message. This Read Object service is initiated by one or more consumers. Therefore these nodes will transmit a so-called Remote Frame. The node, which owns the requested information will transmit the corresponding Data Frame.

The content-oriented nature of the CAN messaging scheme delivers a high degree of flexibility for system configuration.

New nodes that are purely receivers, and which need only existing transmitted data, can be added to the network without the need to make any changes to existing hardware or software. Measurements needed by several controllers can be transmitted via the bus, thereby removing the need for each controller to have its own individual sensor. CAN implements five error detection mechanisms; three at the message level and two at the bit level.

The number of nodes that can exist on a single network is, theoretically, limited only by the number of available identifiers. However, the drive capabilities of currently available devices imposes greater restrictions. Depending on the device types, up to 32 or 64 nodes per network is normal, but at least one manufacturer now provides devices that will allow networks of 110 nodes.

The rate of data transmission depends on the total overall length of the bus and the delays associated with the transceivers. For all ISO11898 compliant devices running at 1Mbit/sec speed, the maximum possible bus length is specified as 40 Metres, For longer bus lengths it is necessary to reduce the bit rate.

3 SYSTEM BASED ON CAN BUS

According to distributed system concept, the new system topological structure of low voltage reactive power compensation device is consists of one main-module, some sub-modules and sevral intelligent terminal module. Considering the actual compensation capacity need and volume restriction of single module, the maximum number of sub-module can be 32. There are only one main-module and it is necessary in every configuration. The number of sub-modules depends on the actual compensation capacity. The intelligent terminal module is optional for additional function. This new system topological structure is shown in figure 2.

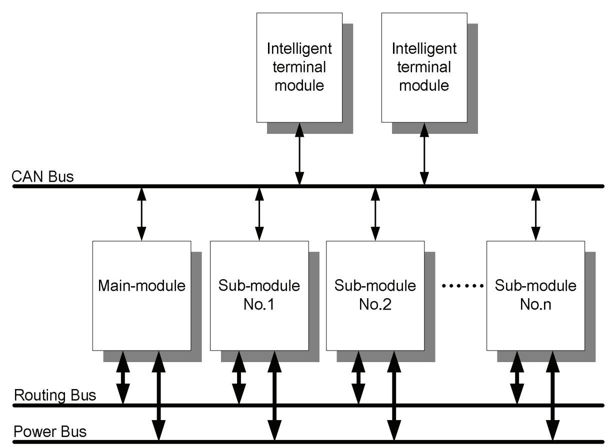

Fig. 2 System topological structure

All these modules are connected through CAN bus, the communication medium of CAN bus is unshielded twisted pair (UTP). Main-module includes main controller, display unit, silicon controlled rectifier (SCR) unit, compensating capacitor unit, electromagnetic switch unit.

The compensating capacitor unit consists of two capacitors, every capacitor's maximum capacity is 20kVAR for the restriction of space. The composite structure of main-module is shown in figure 3.

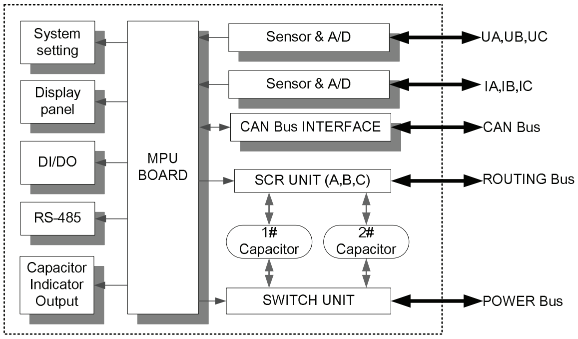

Fig. 3 Composite structure of main-module

Three phase voltage and current signals are convey to the CPU of chief controller in main-module through sensor and A/D conversion, the software program controls the capacitors switch action(on/off) chiefly based on the reactive power, and consider some other element such as voltage of bus bar, power factor, ambient temperature, switching value mode, etc. The control command is transmitted to the sub-module from main-module by CAN bus. Silicon controlled rectifier (SCR) unit in main-module supply the time division multiplexing channel to all the modules of the whole reactive power compensation device.

There are one distributed controller, two compensating capacitors and its corresponding electromagnetic switch unit in sub-module. The distributed controller receives control command from the chief controller in main-module through CAN bus, and controls the compensating capacitor's action of switch on/off. According to different compensating function, sub-module can be divided into three phase common-compensating sub-module and three phase respective-compensating sub-module. The composite structure of sub-module is shown in figure 4.

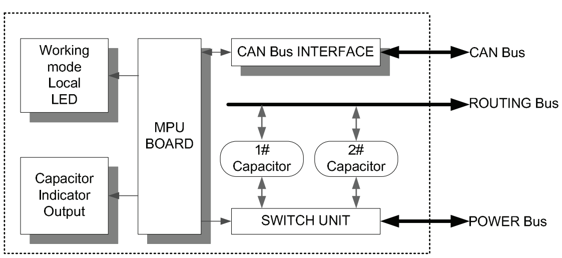

Fig. 4 Composite structure of sub-module

The external connection of main-module is the same as sub-module except sensor, RS-485 and display unit. The composite structure of main-module and sub-module is identical, the whole reactive power compensation device can be realized modularly.

Capacity of the compensating capacitor in main-module could be 0, 5, 10 or 20kVAR, the compensating capacity of main-module could be 5, 10, 15, 20, 25, 30 or 40kVAR. Capacity of compensating capacitors in sub-module is 20kVAR, the compensating capacity of sub-module is 40kVAR. Consumer can obtain conformable compensating capacity by select the suitable capacity of the compensating capacitor in main-module and the number of sub-modules. Some representative configurations are shown in table 1.

Tab.1 Representative configuration of compensating capacity

No.	Total compensating capacity of the device (kVAR)	Capacity of capacitor in main-module (kVAR)		Number of sub-module
		1#	2#	
1	10	5	5	0
2	15	10	5	0
3	20	10	10	0
4	30	20	10	0
5	40	20	20	0
6	60	10	10	1
7	70	20	10	1
8	80	20	20	1
9	90	5	5	2
10	100	10	10	2
11	120	20	20	2
12	160	20	20	3

Configurations shown above in Table.1 can meet various needs of different consumer and make all the sub-module in same structure.

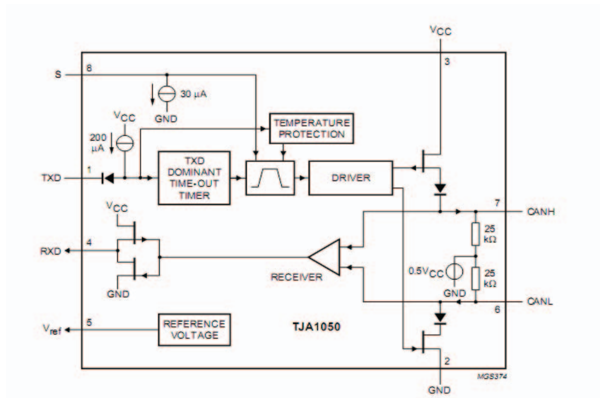

Fig.5 Block diagram of TJA1050

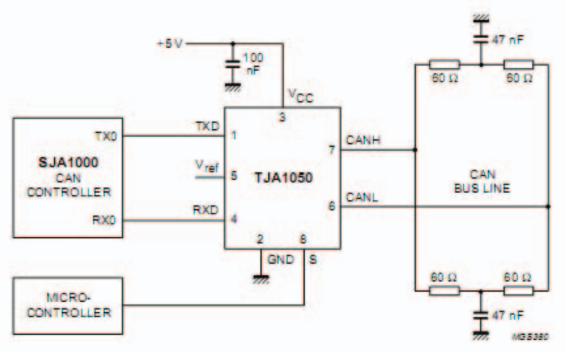

Fig.6 Application circuit of SJA1000 and TJA1050

The CAN bus interface chip include CAN Controller SJA1000 and CAN Transceiver TJA1050, the interface is fully compatible with the ISO11898 standard, at least 110 nodes can be connected. Some intelligent terminal module also can connect, such as: external display unit. The block diagram of TJA1050 is illustrated in figure 5. The application circuit of SJA1000 and TJA1050 is illustrated in figure 6.

The lower the binary value of the identifier the higher the priority. This is due to the larger number of leading dominant bits during arbitration. The number of transferred data bytes is defined by the data length code. The first bit transmitted is the most significant bit of data byte 1 at CAN address 19 (SFF) or CAN address 21 (EFF). The global layout of the receive buffer is very similar to the transmit buffer. The receive buffer is the accessible part of the RXFIFO and is located in the range between CAN address 16 and 28. Each message is subdivided into a descriptor and a data field[17]. The Example of the message storage within the RXFIFO of SJA1000 is illustrated in figure 7.

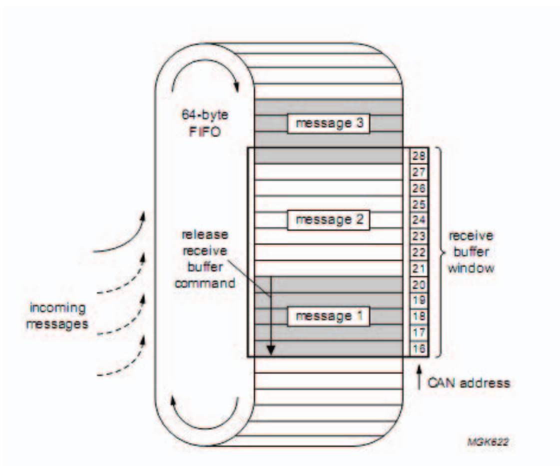

Fig.7 The message storage within the RXFIFO

4 SOFTWARE PROGRAM FEATURE

There are multifarious situations that may influence the reactive power compensation device has been considered in software program design.

1. Intelligent Identification

Main-module can identify all the sub-modules contected to the CAN bus. It makes compensating capacity extend simply. We only need connect the new sub-modules to the CAN bus when compensating capacity extend is needed, intelligent identification scan the nodes on the CAN bus automatically during the progress of system restart.

2. Compensating Capacity Dynamic Modification

Software program modifies the actual compensating capacity of capacitors according to real time bus bar voltage, this function can improve the accuracy of compensation.

The variation of angular frequency and the capacitance value are fairly slight under normal working conditions, so the chiefly element affect Q_c (compensating capacity of a capacitors) is U_c(voltage of the capacitor), i.e. the system voltage.The voltage amplitude variation leads to corresponding variation of Qc, i.e. the capacity of compensating capacitor. In program of traditional reactive power compensation device, the output compensating capacity is calculated by the rating value of capacitor, the influence of voltage amplitude variation isn't taken into consideration. Because reactive power compensation is step by step, so the compensating capacity error will produce following the voltage variation. Sometimes, the compensating capacity error is fairly evident, and could bring bad influence to the compensating effects. The compensating accuracy can be improved by compensating capacity software dynamic modification in the software program of the new device. The program flow chart of compensating capacity software dynamic modification is shown in figure 8.

3. Integrative Control policy

The control policy of capacitors switch chiefly bases on the reactive power, and consider some other element such as: system voltage, power factor, load current, ambient temperature, switching value mode, etc.

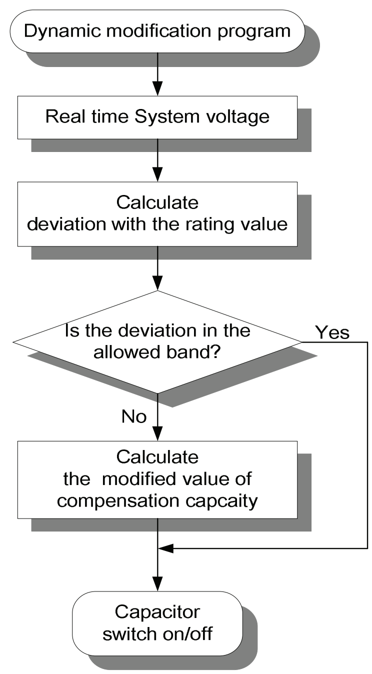

Fig.8 Compensating capacity software dynamic modification

5 ANALYSIS AND PRACTICAL TEST

In a consumer substation, the distribution transformer is 630kVA, a traditional compensation device has been installed three years ago which capacity is 320kVAR (20kVAR×16). According to the principle of same capacity and same grade, a new compensation device is configured and installed: main-module is 20kVAR×2, sub-module is 20kVAR×2×7, total compensating capacity is 320kVAR. The new device keep running for 30 days, the bus voltage, load current, power factor were recorded. The waveforms of operating data are shown in figure 9.

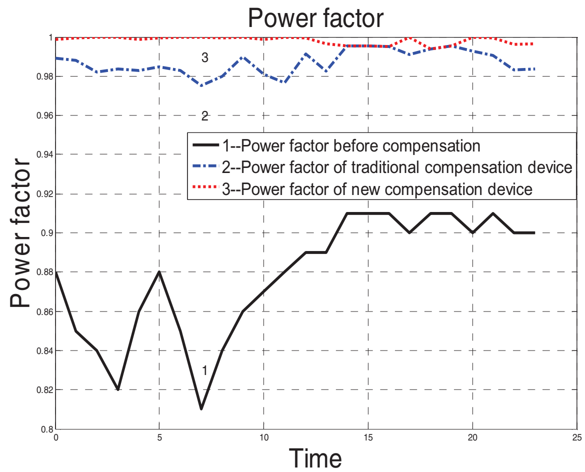

Fig. 9 Waveform of power factor

The waveform in figure 9 illustrated that the novel system topological structure modularized reactive power compensation device based on CAN bus has better compensation effect than the traditional device in the same configuration. There are many practical operating data similar to Figure 9, and the operational aspect in following time also speak volumes for this.

6 CONCLUSIONS

With consideration of better flexibility, reliability and expansibility, distributed system structure is used instead of centralized system structure in low voltage reactive power compensation device, a novel modularized low voltage reactive power compensation device based on Controller Area Network, routing bus and power bus is put forward in this paper. Controller Area Network bus, new system structure, main-module, sub-module, application circuit of CAN interface and software program design are introduced.

The contrastive analysis and practical test show that this new type of low voltage reactive power compensation device overcomes those shortcomings of traditional product satisfactorily and has better compensation effect.

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