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Hardware Design and Implementation of Power Line Carrier Communication for Medium Voltage Based on DSP

Sizu Hou[1, a], Yong Zhang[1, b]

[1] Electrical and Electronic Engineering Academy, North China Electric Power University, Baoding, Hebei, China

[a]housizu@sohu.com, [b]zhangy_ncepu@sohu.com

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Abstract. A hardware system based on digital signal processor (DSP) is designed for power line carrier communication (PLC) over medium voltage power line networks. This system is designed to realize better stability and reliability of data communication in electric system. This paper introduces PLC technology, and then discusses the composition of this system and gives design scheme. Finally, the DSP implementation is developed with analog front-end (AFE) and coupling circuit. This paper shows a new PLC and automatic management solution.

Introduction

Broadly speaking, PLC technology can be divided into high voltage PLC, medium voltage PLC and low voltage PLC. High voltage PLC is mainly used for inner power grid communication, for example, telemechanism control and relay protection of high voltage power transmission grid. Medium voltage PLC provides channels for the access of backbone, distribution network automation, user demand side management and rural telephone system, etc. with 10KV power lines as communication links. Low voltage PLC provides the access of Internet, home LAN, remote meter reading, smart home and so on for users with low voltage power lines as transmission medium [1].

With a series of advantages, PLC technology needs no wiring, covers a wide area, and has convenient connections. The using of medium voltage PLC can not only provide channels for distribution network automation of electrical power system, expand the coverage area of urban electric power communication network, lower the cost of investment, but also become important means of demand side management and promoting the development of network marketing. As a result, it is favored and admired by domestic and overseas technicians. However, the power network's complicated structure and frequent load access and cutting out lead to serious interference and attenuation. Complicated channel environment hinders the development of medium voltage PLC. Therefore, how to improve the signal reliability becomes domestic research emphasis. Although many institutions and companies are developing PLC technology vigorously at present in China, and many places are using PLC chips made in China, the effect of communication is not so good. EMC control in China is not as rigorous as European and American, so the communication environment is worse, thus making the application of foreign PLC chips and technology not so good in China. Research shows the efficiency of PLC meter reading system used widest in China can not achieve 100%. And in high speed PLC Internet connections, it can not achieve the described performance. So accelerating the research and application of medium voltage PLC technology is important. Aiming at the present situation, it is necessary to develop a new modulation and demodulation system to improve rate and reliability in turn to drive PLC development. The research emphases are transmission distance, transmission rate and coupled modes, etc. At the same time, research on information security and network management should be strengthened to increase the capacity of independent research and development and the whole standard of medium voltage PLC research and to set standard in advance.

System Design Solution

System Overview. The overall design of system framework is shown in Fig. 1. When sent, the data enters into the DSP chip via serial communication interface or Ethernet interface for digital signal processing, including encoding and modulation. Then the modulated digital signals are sent into AFE031 chip via SPI for filtering and amplification. During this process, digital signals are converted into analog signals at first by DAC in AFE031 and then the signals get through the low-pass filter in AFE031 in order to be analog sine waves. Because of the serious attenuation in power lines, the sine waves have to be amplified on power. The power amplification (PA) in AFE031 is used to complete this function. Finally, the processed signals are coupled to power lines through coupling circuit. When receiving signals, the coupling circuit acquires analog modulated signals from power lines. The signals become sine waves after getting through the filter and PA in AFE031 and then are converted into digital signals after being sampled by 12 bit ADC in DSP in order to be demodulated and decoded. The processed signals are required signals with information, and are sent out via serial communication interface or Ethernet interface.

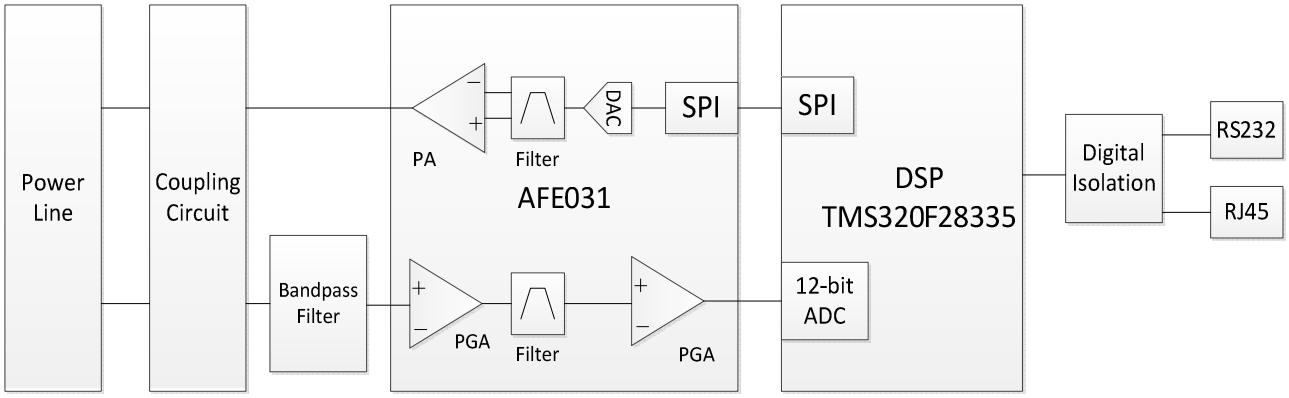

Fig. 1 Overall design of system framework

System Analysis. The AFE031 chip from TI company can complete filter and power amplification. It is completed and flexible, integrating many analog circuits PLC needs. It is low-cost, integrated, PLC analog front-end (AFE) device that is capable of capacitive or transformer-coupled connections to the power lines while under the control of a DSP. It is ideal for driving low impedance lines that require up to 1.5A into reactive loads. The integrated receiver is able to detect signals down to 20 μV_{RMS} and is capable of a wide range of gain options to adapt to varying input signal conditions. This monolithic integrated circuit provides high reliability in demanding PLC applications [6]. Therefore, AFE031 can achieve the needed function.

This system is mainly used in monitoring and management of power system equipment, so it requires real-time performance which decides the processing speed of a DSP should be high. The series of TMS320C2000 TI launches is mainly used for digital control and motion control with highly bit wide, highly precious and highly efficient AD conversion. The chip has enhanced event manager, enhanced pulse width modulation, enhanced multi-channel data sorting acquisition unit, OEP component, enhanced timing unit and multiple SPI and SCI, etc. Consequently, it is more conducive to control signals' variable and real-time acquisition and processing on the whole. This system chooses TMS320F28335. It has high-speed processing capability up to 150MHz, with 32-bit floating-point processing unit. Compared with the previous generation of DSC, its average performance improves 50%, and it is compatible with the fixed-point C28x controller software. The reliability is greatly improved, thus simplifying software development, shortening development cycle and reducing costs.

Hardware Design

Interface Design between DSP and AFE031. Communication between DSP and AFE031 is via SPI. In addition, there is a DAC module in AFE031.Both of them simplify the design of interface between them. The SPI connection is shown in Fig. 2.

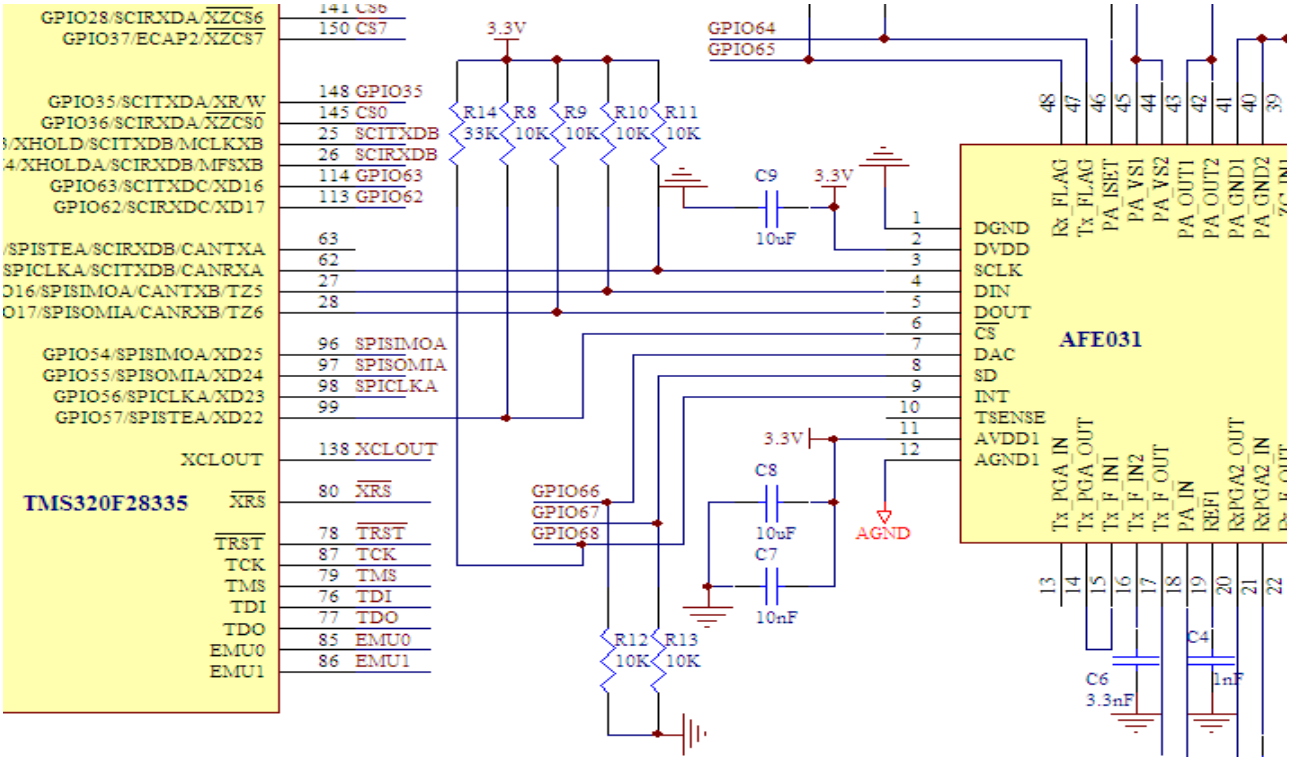

Fig. 2 Interface design between DSP and AFE031

Design of Coupling Circuit. Coupling circuit is a very important part. It realizes security isolation and impedance matching between communication devices and high voltage of power lines, couples the high frequency carrier signals efficiently and prevents noises and interference signals as far as possible. Low transmission attenuation and high coupling efficiency in power lines of low impedance are vital to the improvement of communication performance. As it is connected to high voltage power lines directly, security should also be concerned. Therefore the coupling circuit is mainly made up of filter capacitor, surge protector, coupling transformer and high voltage coupling capacitor. The design of coupling circuit is shown in Fig. 3. The transient voltage suppression diodes (TVSs) and Schottky diodes are used for transient overvoltage protection. It is the voltage divider formed by the HV Cap and winding inductance that divides down the ac mains voltage and reduces it to negligible levels.

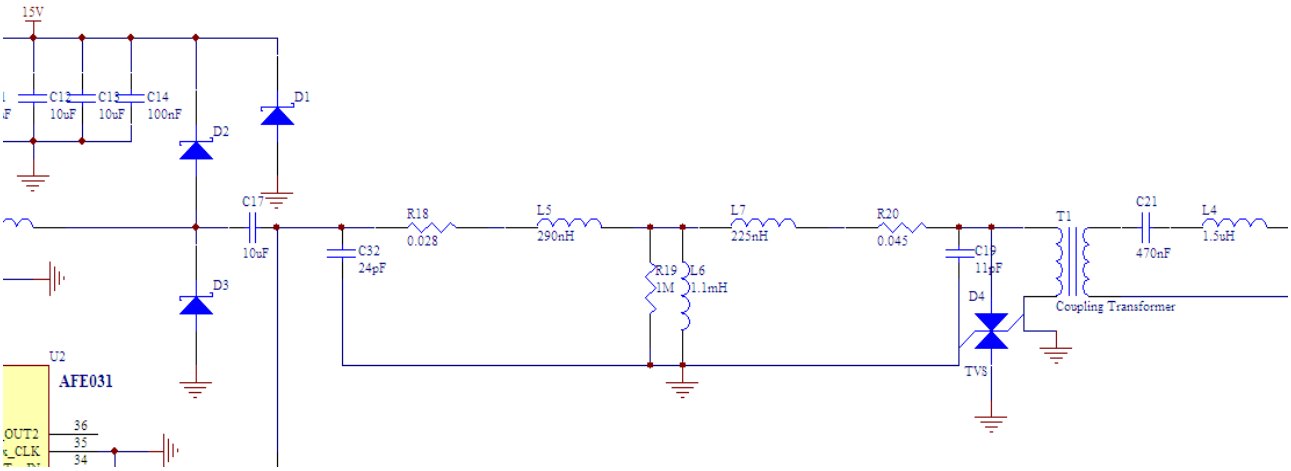

Fig. 3 Design of coupling circuit

Conclusions

This paper designs and realizes the hardware system. It has both Ethernet interface and RS232 serial communication interface to receive and send the needed data information. And the main communication channel is the power line carrier channel realized by this system with high speed processing data. It supports TCP/IP protocol and OFDM modulation which is compatible with PRIME and G3, and supports FSK and SFSK modulation.

Medium voltage PLC system gets stable and reliable network connection on the power lines. It supplies high speed, efficient and reliable channels for power management information thus meeting the data communication. And it shows brand new and powerful solutions to realize medium voltage PLC and distribution network automation management of industrial Ethernet.

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