BLDC Motor Control System using ASK DC-link PLC Technology

Tao Yu* · Sung-Geun Song · Se-Min Kim · Kwang-Heon Kim · Sung-Jun Park**

Abstract

Power line communication or power line carrier (PLC) is a system for carrying data on a conductor and can also used for electric power transmission. Now the powers used in the motor drive system are mostly DC sources. Even AC powers in some systems are generated from DC sources by the inverter. It is can be forecasted that the DC-link PLC technology will be widely used in various industrial fields. In this paper a novel BLDC motor control system using ASK DC-link PLC technology is proposed. The characteristic of this system is that the communication only needs 2 DC lines and there are no additional lines to translate the reference signals. The number of signal cables can be minimized when the DC-link PLC method is applied in the multi motor control system and the slip ring design also can be simplified when this method is applied in rotation machines. The proposed motor control system is clarified by the PSIM and MATLAB simulations and tested through the hardware prototype.

Key Words : DC-link PLC, ASK Technology, BLDC Motor Control

1. Introduction

Along with the improvement of the living standard and the development of the industrial technology many kinds of pint-sized high efficiency motors are largely applied to some industrial equipment and the household electrical appliances. In the adjustable speed system compared with the induction motor, the BLDC motor is used more widely for its high efficiency, low noise and high torque under low speed. Particularly the permanent magnet BLDC motor is widely used in many related fields for its simple communication characteristic.

The PLC technology was presented at the beginning of 1960s in some papers[1]. Traditionally the PLC technology is mainly applied to the fields such as data signal transmission, remote monitoring, intelligent home system and industrial automatization etc based on AC power system[2]. Even today the research and development on the PLC technology are still mainly based on AC power system. It is just because that the power provided for the home and the industrial factory is mostly from the AC power

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Date of submit : 2009. 2. 9
First assessment : 2009. 2. 13
Completion of assessment : 2009. 2. 25

in the past years[3]. Someone researched the DC PLC method of the automobile system by using the FPGA and USB interface. The DC line communication protocol was improved and simplified based on the protocol of the conventional AC line communication method. In some papers the high efficiency ferrite core and switching amplifier were used to reduce the attenuation of the PLC communication signals[4]. Some engineers applied the DC PLC technology to the HVDC systems. The high frequency communication signals in the system are substituted with the low frequency communication signals and the feasibility of this method was also clarified through the analysis and the research[5]. Some mechanical electrical equipment in the industrial fields likes motors and most of the household electrical appliances are provided with DC power. So such electrical equipment generally needs an additional rectifier converter that coverts the AC power to the DC power. As a matter of fact this additional rectifier converter part takes the result that the price of these products have the lack of competitiveness at sell. Therefore, the future way to solve this problem is that the power system will be changed from the AC system to DC system. At the same time the PLC technology is also needed to be changed from the AC PLC method to the DC PLC method.

The objective of this research is to develop the integrative high efficiency BLDC motor control system by using ASK DC-link PLC technology. The conventional BLDC motor control system mainly consists of BLDC motor, driven inverter and the power supply. The real time position of the motor rotor can be know through the signals from the position sensor and the BLDC motor is driven through three power line, therefore the BLDC motor can be controlled as expected.

The system in this research overcomes the shortcomings of conventional high efficiency BLDC motor control system. And in order to be used more conveniently, the plug-in integrative motor system idea is presented in this paper. The basic concept of this system is shown in figure 1. In the conventional BLDC motor control system the power part provide the necessary power to the inverter to drive the BLDC motor, the proper parameters are set up by the information fed back from the each signal cable to achieve the expected control and performance of the BLDC motor. However this brought about a number of constraints on the applications of the high efficiency and good control performance BLDC motor in conventional industrial systems.

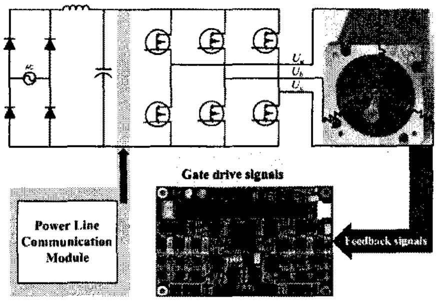

Fig. 1. Integrative configuration and PLC concept

The integrative BLDC motor control system with PLC function proposed in this paper has a lot of advantages. The reliability of the system is improved by reducing the number of signal cables like encoder feedback line, the manufacture process is simplified by reducing the external interfaces, and the price of the system is reduced at the same time. From the user's point of view this kind of BLDC motor system can be considered as similar as the conventional DC motor system because it only has 2 external DC lines.

In this paper a novel BLDC motor control system using ASK DC-link PLC technology is proposed. The characteristic of this system is that the communication only needs 2 DC lines. Furthermore in the proposed control system there is no signal transformer which is often used in the conventional power line communication system. So the cost of this system is reduced a lot. Finally, the proposed motor system is also clarified by the PSIM and MATLAB simulations and tested through the hardware prototype.

2. Structure of the proposed system

The number of the cable between the DC power supply part and the motor part is reduced. The line between the DC power supply part and motor part is used not only to transmit the data but also to provide DC power. Different from the conventional PLC structure DC line has the advantages of low noise and stable impedance. The communication cables transmitting the reference value and feedback value are leaved out. The power line and signals cable are combined, so the reliability of the system is also enhanced. The cable number can be minimized in the multi motor system.

The control command, encoder values and sensor information are all coded, modulated and then transmitted by the DC power bus. The DC power line here can be considered as the bifunctional line. Another important advantage of the DC PLC method is that the load change can be predicted. This is very helpful to design the signal modem. The high reliable communication condition can be assured when the system is on working.

In order to use DC PLC as an effective communication method, we try to design a scheme that can meet the requirement of the DC PLC. As modem is applied to the PLC system, the additional protection circuit, coupler and decoupler should also be included. The primary function of these components is to over lap the data signals effectively to the DC power line. At the same time we should also effectively isolate the communication unit from the DC voltage and current to avoid damage to the modem.

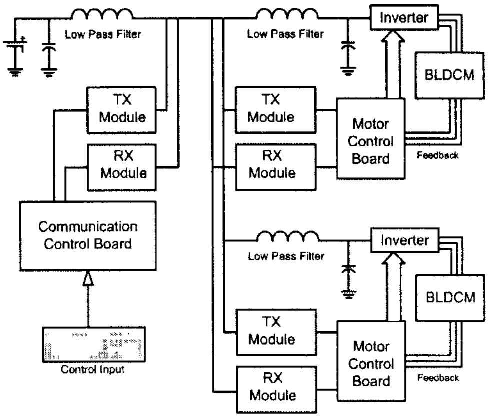

Fig. 2. Proposed system outline

We presented a new concept of modulation and demodulation where the photocoupler replaces the signal transformer in the conventional structure. The modulating and demodulating process are implemented by the microprocessor. Thus the system weight is reduced and the system reliability is improved. The outline of proposed BLDC motor control system using ASK DC PLC technology is shown in figure 2. The system consists of DC power part and BLDC motor control part. The control and sensor signals are transmitted between two parts through the DC line and the communication modem. The digital amplitude shift keying (ASK) technology is used to the design the modem. Here the digital modulation method was used. Digital modulation gets many advantages over analog modulation and is widely used in many kinds of systems.

The circuit concept of DC PLC communication part on DC source side proposed in this paper is shown as figure 3. As shown in the figure the DC power part consists of DC link, microprocessor

(AVR), photocoupler, filter and comparator. The reference signal that can drive the motor is generated from the control microprocessor. Then it is overlapped to DC link through AVR TX port, the photocoupler and transmitted to the motor part. The feedback signals (speed, current etc.) from the motor side are received in the RX port through DC-link, filter; comparator and then are digitalized. The digitalized feedback signals are received by the RS232 port of the AVR. Then the PWM reference signal that can drive the motor can be made through the PID controller in Microcontroller based on the feedback signals and the reference signal. Of course this work is also can be done by the controller in the motor part. The LPF L-C filter is used in DC-source side to avoid the communication signal leaking to the DC-source. Therefore the high frequency control signals can mainly be transmitted to the communication part of motor side because the impedance of DC-source side is large.

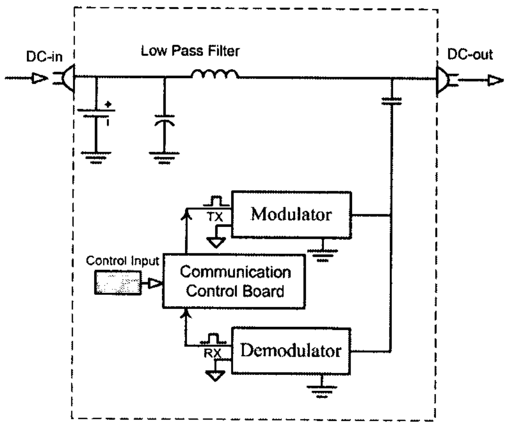

Fig. 3. Configuration of controller in DC power part

When a digital baseband signal is a binary waveform, which can be expressed as

$$x_{BB}(t) = \sum_{n} b_n p(t - nT_b) \tag{1}$$

Where b_n is the bit value in the time interval $[nT_b, (n+1)T_b]$ and assumes one of two values, 0 and 1. $p(t)$ is the sampling value. For a rectangular pulse shape, the receiver may simply decide whether the peak value of the waveform is less or greater than a threshold to detect the bit value. The modulated signal corresponding to each bit can be expressed as:

$$x_{ASK}(t) = A_c \cos\omega_c t \ \ (\text{if } b_n = 1) \tag{2}$$

$$x_{ASK}(t) = 0 \ \ (\text{if } b_n = 0) \tag{3}$$

Where A_c is the amplitude and ω_c is the frequency of the carrier wave.

Instead of the communication transformers, the photocoupler TLP250 is used to overlap the signal to the DC line. This, combined with their ability to drive IGBTs and power MOSFETs directly, makes system design easier, allows simpler circuit configurations and improves system reliability. Figure 4 shows the structure of the ASK modulator.

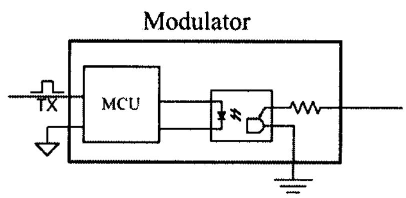

Fig. 4. ASK modulating method

The main function of the signal controller in the DC power part is to overlap the reference control command to the DC link in RS232 format. Real-time voltage value, speed value, current value of the motor are also requested here and displayed on the LCD.

The construction of motor control part is shown as figure 5. There is BLDC motor, DC-AC inverter, microcontroller (AVR), signal-receiving part, signal-transmitting part in the motor side. As the same as in DC-source side the RS232 signals are detected in the signal-receiving part. The real-time feedback signals of motor are overlapped on DC-link and sent to the communication part of DC-source through the photo-coupler in signal-transmitting part. Similarly the LPF L-C filter is also used in motor side to avoid the communication signal being leaked to DC-power part of motor. The DC power from the DC link line is provided to the inverter and control board through LC LPF.

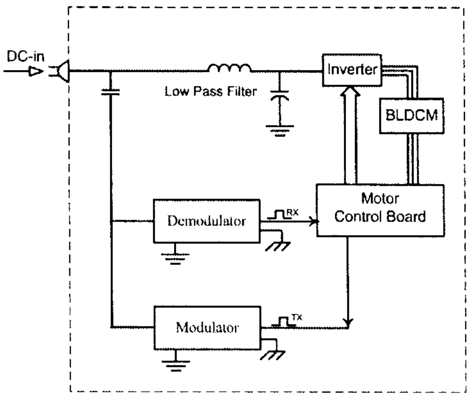

Fig. 5. Configuration of motor controller part

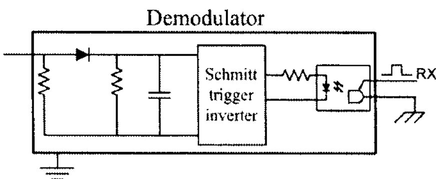

Fig. 6. ASK demodulating method

Here a schmitt trigger is adopted to demodulate the control information. The benefit of a Schmitt trigger over a circuit with only a single input threshold is greater stability. With only one input threshold, a noisy input signal near that threshold could cause the output to switch rapidly back and forth from noise alone. A noisy Schmitt Trigger input signal near one threshold can cause only one switch in output value, after which it would have to move beyond the other threshold in order to cause another switch.

3. Simulations

The ASK DC PLC systems are simulated through PSIM. Through the transmit-receive simulation process it is proved that the signals can be successfully transmitted from the DC power part to the Motor control part through DC link.

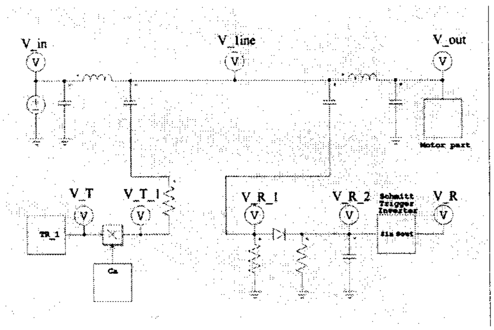

Fig. 7. Circuit of ASK Transmit-Receive simulation in PSIM

The feasibility of the proposed ASK DC PLC technology is proved through the transmit-receive simulation in PSIM as shown in figure 7.

The waveform of ASK method transmit-receive simulation is shown as figure 8. Transmitting Data is set to 0x55. Here V_T is the transmit signal of the DC power part. V_T_1 is the ASK modulated signal from the original signal. V_line is the voltage waveform on the DC link. Obviously the high frequency communication information is contained in V_line. V_R_1 is the high frequency signal received from the DC link through the capacitor. V_R_2 is the signal received from the DC_link in the motor part before the schmitt trigger inverter. V_R is the final restored signal after the schmitt trigger inverter. It can be known from the figure 8. that the signal V_T is faultlessly restored without distortion in the receive part through DC link.

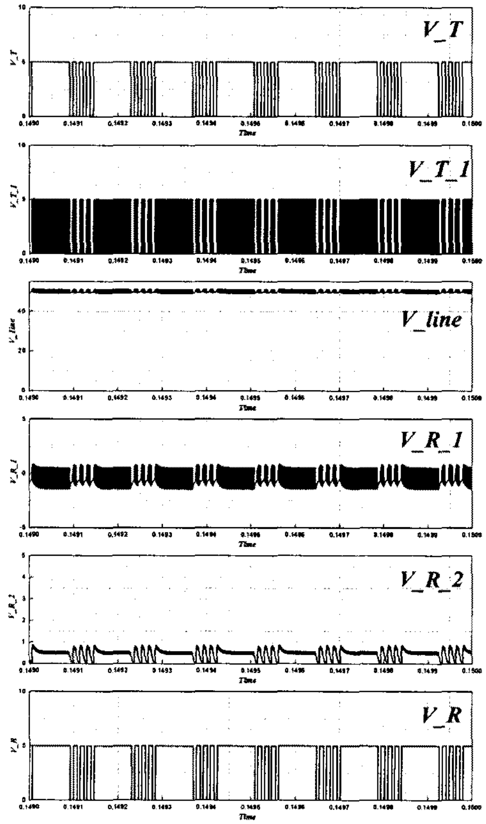

Fig. 8. ASK Transmit-receive simulation in PSIM

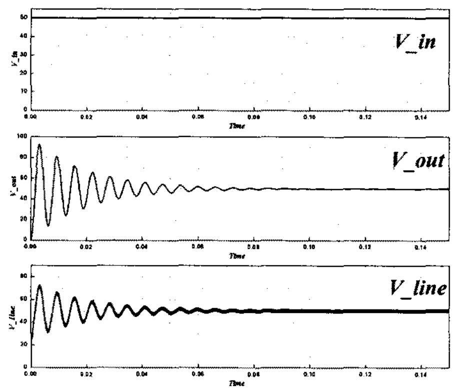

Fig. 9. Voltages of DC power part, Motor part and DC-link

The voltage of DC power part, motor part and DC link are shown in figure 9. There are no leakage signals in the DC power part and the motor part. The high frequency ASK communication signals are only added to the DC link. The possibility of the ASK modulating DC PLC technology is proved here.

4. Experiment results

The picture of the proposed BLDC control system using ASK DC PLC technology is shown in figure 10. The microprocessor Atmega128(AVR) chip of Atmel company are used in the transmit-Receive part, ASK modulating part, DC power part and motor control part. The AVR in transmit part plays the role of the master to control large numbers of BLDC motors. The AVR in receive part is used for communication and motor control. The BLDC motor used here is 5500 PITTMANS series.

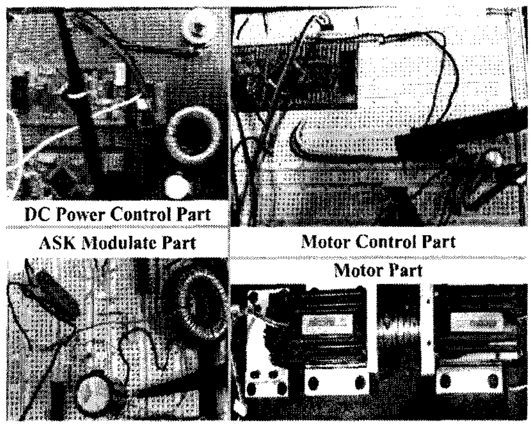

Fig. 10. Motor control system using ASK DC-link PLC

The experiment results of data transmission using ASK modulating method are shown in figure 11. The waveforms when data(0x05) is transmitted are shown in the figure. With regard to the simulation results though there is some phase difference between the transmit signal and receive signal, the shape of the signal is same. It is proved that the ASK modulating DC line communication is possible and the communication data can be well detected and restored even if the data is different.

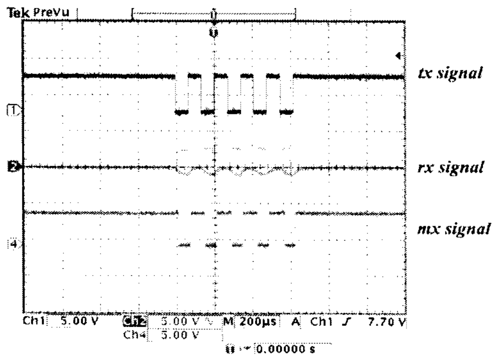

Fig. 11. Waveforms in transmit-receive test

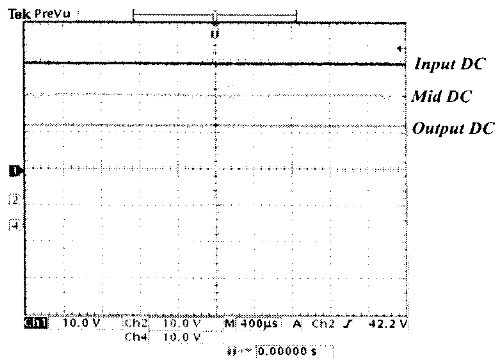

Fig. 12. Input, communication part and output on DC link

The voltages of DC power part, DC-link and input of the motor inverter are shown as figure 12 when ASK modulating method is used. It is obvious that the communication signal does not appear in transmit part and inverter while only exists in DC-link. So it is adequately possible to actualize the PLC in DC-link by the method we proposed.

The current of each phase to verify the starting characteristic of the BLDC motor controller is shown in figure 13. As shown in the figure it can be known that the current changes smoothly from 0[A] to 7[A] and the controller is in good condition.

The currents of the A phase and phase B at load change are shown in figure 14. As shown in figure the phase difference is followed as the load change and the controller works well.

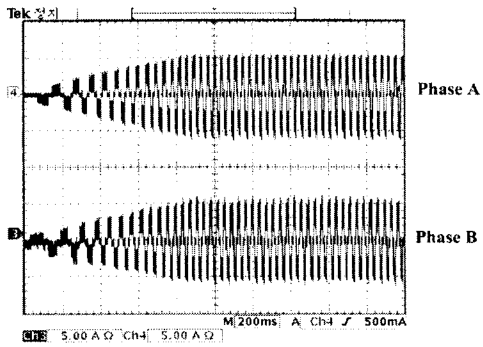

Fig. 13. Phase current waveform at starting

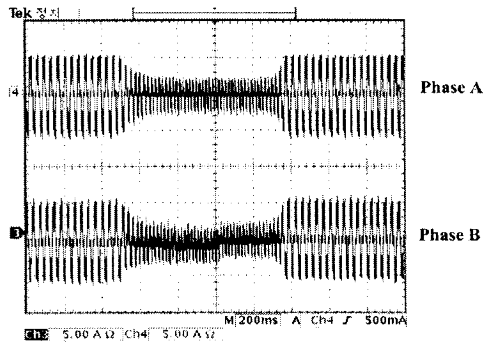

Fig. 14. Phase current waveform at load change

5. Conclusion

In this paper the optimum design is presented to reduce the cables which are necessary for the conventional BLDC motor drive system. Thus the DC PLC plug-in type BLDC motor drive system is proposed here. The proposed motor system is clarified by the PSIM and MATLAB simulations and tested through the hardware prototype. The characteristic of this system is that the communication only needs 2 DC lines. There are not additional lines to translate the reference signals. And the reliability of the system is ensured especially under some terrible circumstances. With respect to the ASK modulating method it is certain that the communication process can work well when communication frequency is set to 340k Hz. The signal can successfully overpass the DC line and also the performance of DC PLC and BLDC motor control is possible. Similarly the communication frequency here can also be selected according to the real need of the locale disturb and system.

Acknowledgements

This work is the outcome of a Manpower Development Program for Energy & Resources supported by the Ministry of Knowledge and Economy(MIKE). This research was financially supported by the Ministryof Education, Xcience Technology (MEST) and Korea Industrial Technology Foundation (KOTEF) through the Human Resource Training Project for Regional Innovation.

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