Fiber Optics in Solar Energy Applications

White Paper

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Introduction

Solar energy has recently become a popular alternative energy source to meet demands around the world due to the fluctuation of oil/coal prices and global warming issues. Oil is a limited and diminishing resource, and because of this, the price surges when demand is high. Oil and/or coal powered generators, when converting fossil fuel into electrical power, produce enormous CO_2 and other pollutants that are harmful to the earth.

In a solar farm power generation system, large amounts of current are generated from the heat of the sun. In order to protect the equipment from huge current leakage, galvanic insulation becomes important to ensure the power system's quality and reliability. Fiber optics offer insulation protection from high-voltage/current glitches and unwanted signals into power equipment controls and communication. It is also feasible to use fiber optics to control the tracking capabilities of the solar panels. Fiber optics communication can cover longer link distance connections compared to copper wire. As the solar farms grow in size, monitoring and controlling all the solar panels requires long link distance connections, which is only possible with fiber optics cable.

Key applications for fiber optic components in solar energy systems include:

- Power electronic gate drivers for inverters
- Sun tracking control and communication boards
- Solar farm substation automation and protection relays

Solar Power Generation

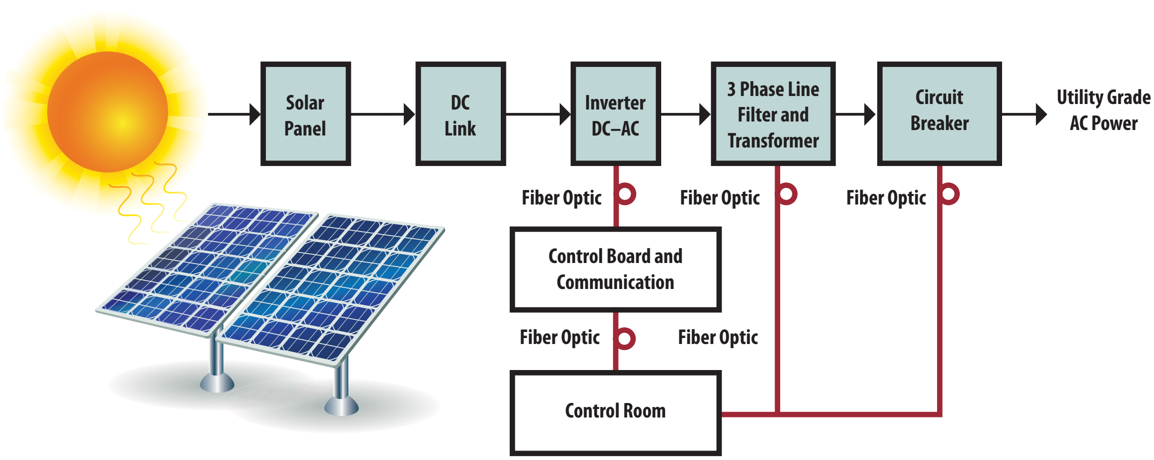

Figure 1. Solar Power Generation Block Diagram

Solar panels collect solar energy and convert it into electrical energy through photovoltaic modules or solar thermal collectors. In order to integrate the power generated from solar panels to the power transmission lines, the power needs to be converted into utility-grade AC power (Figure 1).

An inverter is used in the solar energy system to provide AC power, while the transformer increases the voltage to medium/high for connecting to the power transmission lines. Circuit breakers are also installed to protect the system when there is a fault in the transmission lines.

In order to produce the required AC power, the power semi-conductor devices are turned on/off at the right frequency to ensure clean and reliable AC power. The turning on/off signal is usually controlled by a DSP embedded controller via a fiber optic link, which allows high galvanic isolation capability.

Examples of power semiconductor devices available in the market:

- Insulated Gate Bipolar Transistor (IGBT)
- Gate Turn Off Thyristor (GTO)
- Integrated Gate Commutated Thyristor (IGCT)
- Symmetrical Gate Commutated Thyristor (SGCT)
- Emitter Turn Off Thyristor (ETO)

Fiber optic components are commonly used to control a high voltage and current switching device, with reliable control and feedback signals (Figure 2, Table 1).

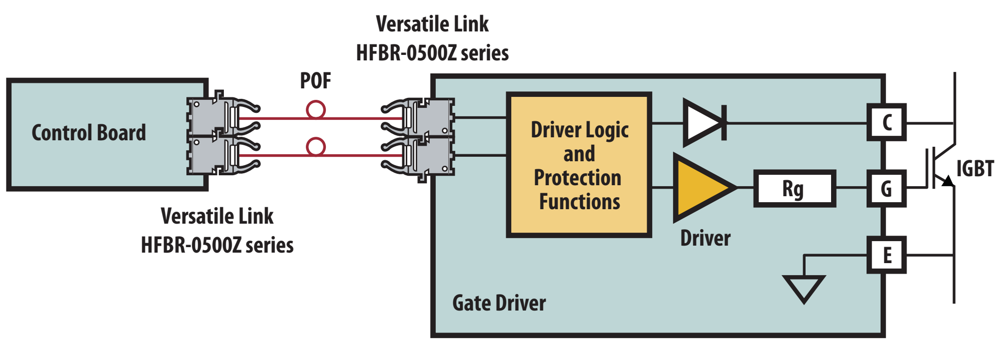

Figure 2. IGBT's Gate Driver Block Diagram

Table 1. Common Part Numbers for Control of Power Semiconductor Devices

			Distance*	
Part Numbers	**Description**	**Data Rate**	**POF (1mm)**	**HCS® (200µm)**
HFBR-1521ETZ	650 nm, Transmitter	DC – 5 MBd	20 m	
HFBR-2521ETZ	650 nm, Receiver			
HFBR-1522ETZ	650 nm, Transmitter	DC – 1 MBd	43 m	
HFBR-2522ETZ	650 nm, Receiver			
HFBR-1528Z	650 nm, Transmitter	DC – 10 MBd	40 m	300 m
HFBR-2528Z	650 nm, Receiver			
AFBR-1624Z, AFBR-1629Z	650 nm, Transmitter	DC – 50 MBd	50 m	
AFBR-2624Z, AFBR-2529Z	650 nm, Receiver			

* Optical link distance varies with operating data rate. Lower data rate allows longer optical link distance.
HCS is a registered trademark of OFS

Avago Technologies' versatile link product family (HF-BR-0500Z series) has been the most popular standard component for power semiconductor control boards. Its simple transmitter and receiver circuitry makes these components easily integrated into the system with TTL logic level. Figure 3 shows the common interface circuitry for a 5MBd data rate operation.

Solar Panels Control and Monitoring System

There are two main ways to maximize electrical power conversion from solar energy. One is to use the most efficient solar panel. The other is to track the sun's movements throughout the day. It has been shown that solar panels with tracking systems have higher electrical output compared to a fixed system.[1, 2]

As solar farms become larger to generate more power for utilities, they are equipped with intelligent features to monitor the performance of each solar panel. For example, to monitor the panels' electrical output and temperature to maximize the electrical output, controlling the angle and direction of the solar panels is very important. In the commercial solar farm that generates a few megawatts of power, the solar panels are installed in huge areas, where reliable controlling and monitoring networks are only possible with fiber optic networks (Figure 4, Table 2).

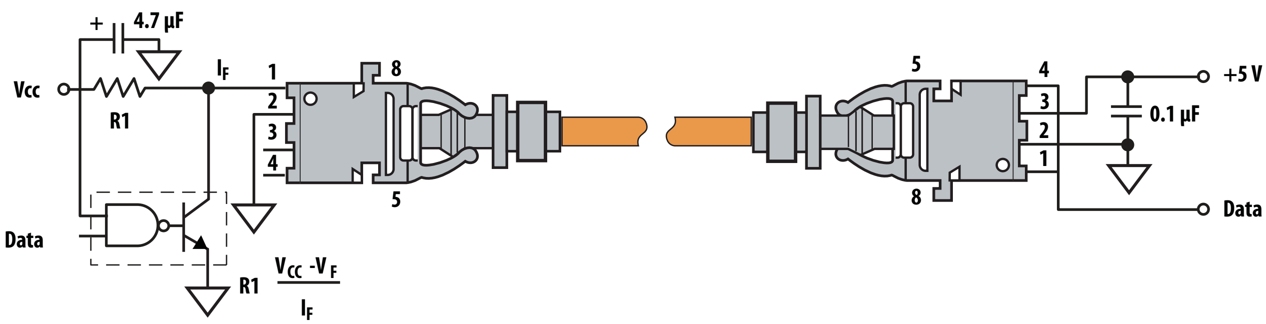

Figure 3. HFBR-1521Z/2521Z Circuit Diagram for 5MBd Data Rate

Table 2. Common Part Numbers for a Control and Monitoring System

			Distance*		
Part Numbers	**Description**	**Data Rate**	**POF (1mm)**	**HCS® (200µm)**	**62.5um/125um**
HFBR-1515BZ	650nm, Transmitter	DC – 10 MBd	40 m	200 m	
HFBR-2515BZ	650nm, Receiver				
HFBR-1505CZ	650nm, Transmitter	DC – 10 MBd	50 m	400 m	
HFBR-2505CZ	650nm, Receiver				
HFBR-1414Z	820 nm, Transmitter	DC – 5 MBd		1500 m	2000 m
HFBR-2412Z	820 nm, Receiver				
HFBR-1414Z	820 nm, Transmitter	DC – 20 MBd			2700 m
HFBR-2416Z	820 nm, Receiver				
HFBR-1414Z	820 nm, Transmitter	DC – 160 MBd			500 m
HFBR-2416Z	820 nm, Receiver				

* Optical link distance varies with operating data rate. Lower data rate allows longer optical link distance.

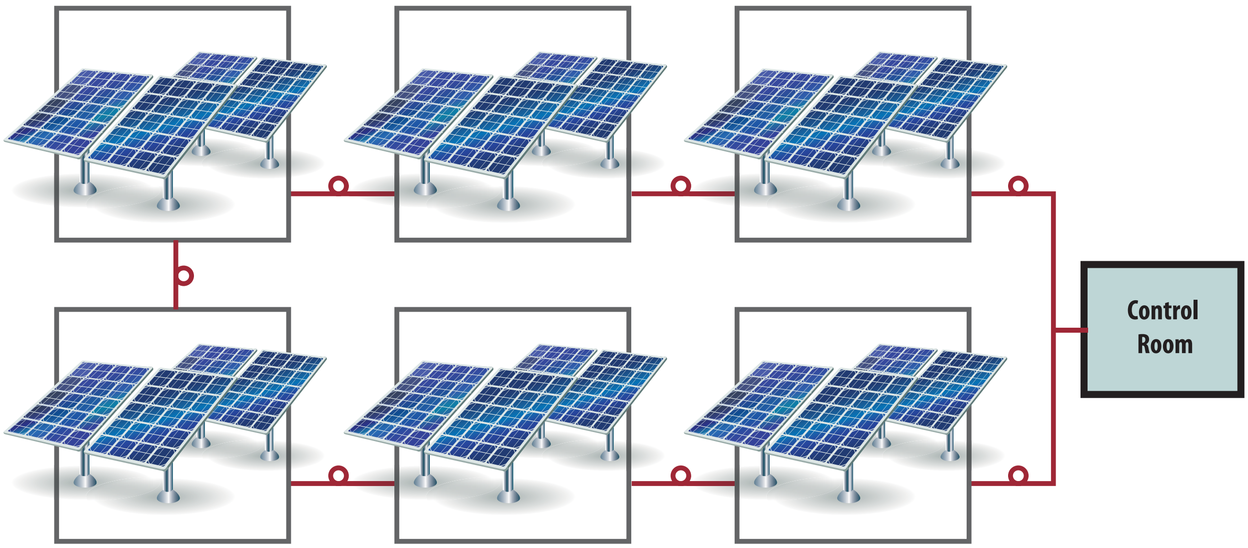

Figure 4. Solar Farm Control and Monitoring System with Fiber Optics

Substation Automation

Substations connect the power generated from solar farms to the utility grid for power transmission to the end consumer. Modern substation automation, which is based on the IEC 61850 standard, is designed to improve overall system reliability and significantly reduce the number of copper wires used [3, 4] (Figure 5).

Since most equipment (e.g., switchgear, transformers, circuit breakers, etc.) in substations operate at medium/high voltage, it is necessary to have galvanic isolation to provide protection for the low voltage devices connected to it. This equipment also generates a large electromagnetic (EM) field due to the high switching voltage and current. To ensure reliability control, the Standard requires communication lines that are immune to EM fields. In this instance, fiber optics is the best solution for such requirements in substation automation control and communication lines (Table 3).

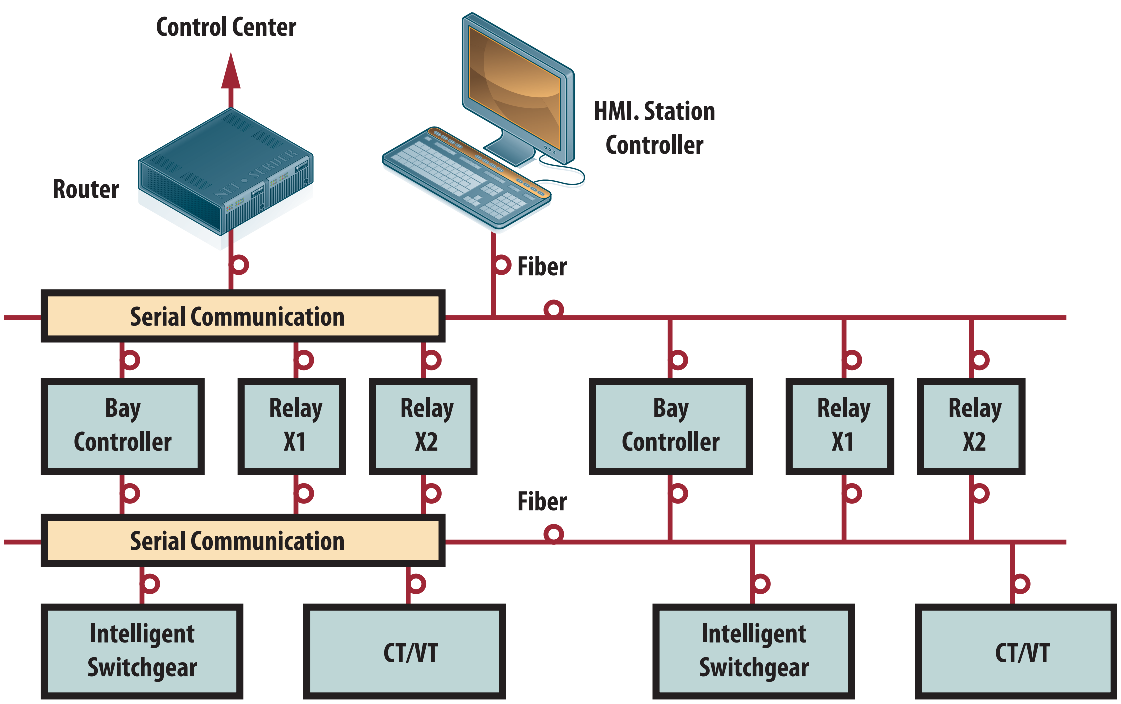

Figure 5. Substation Automation based on IEC 61850

Table 3. Common Part Numbers for Substation Automation

Part Numbers	Description	Data Rate	Distance*		
			POF (1mm)	HCS® (200µm)	62.5um/125um
AFBR-1624Z, AFBR-1629Z	650 nm, Transmitter	DC – 50 MBd	50 m		-
AFBR-2624Z, AFBR-2529Z	650 nm, Receiver				-
AFBR-5978Z	650 nm, Transceiver	125 MBd	50 m	100 m	-
AFBR-5972Z	650 nm, Transceiver	125 MBd	50 m		
HFBR-14X4Z	820 nm, Transmitter	160 MBd	-	-	500 m
HFBR-24X6Z	820 nm, Receiver				
HFBR-1312TZ	1300 nm, Transmitter	160 MBd	-	-	2 km
HFBR-2316TZ	1300 nm, Receiver				
HFBR-57E5APZ	1300 nm, Transceiver	125/155 MBd			2 km

* Optical link distance varies with operating data rate. Lower data rate allows longer optical link distance.
HCS is a registered trademark of OFS

Avago Technologies has many parts that suit IEC 61850 implementation based on 10/100/1000Mbps ethernet protocol. Figure 6 shows a typical circuit diagram for a Fast Ethernet fiber optic transceiver. Avago Technologies' HFBR-57E5APZ's input/output data signals (based on LVPECL) are easily connected to the common Ethernet PHY ICs available in the market today.

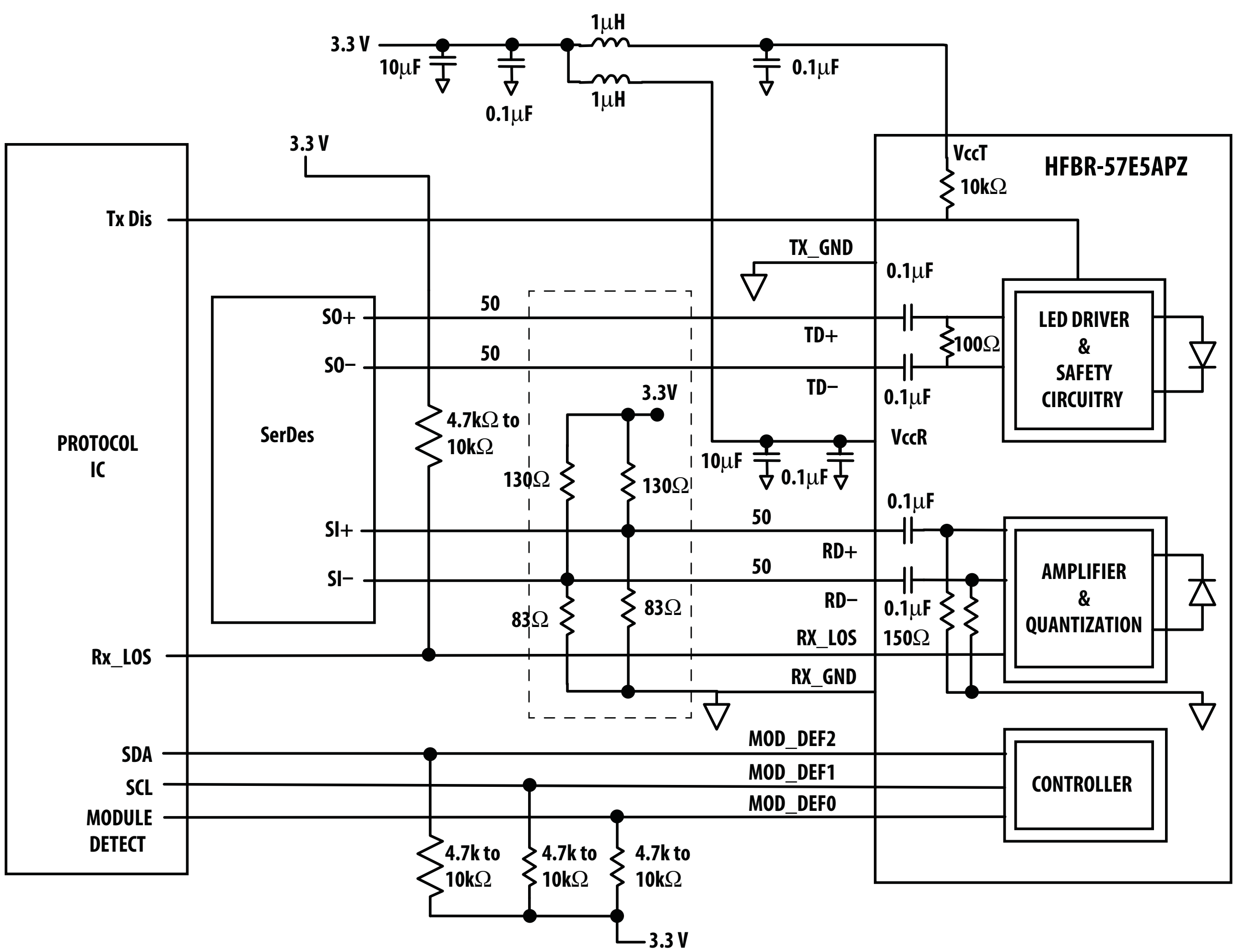

Figure 6. Avago Technologies' HFBR-57E5APZ Fast Ethernet Fiber Optic Transceiver Driving Circuitry

References

1. Armstrong, S.; Hurley, W.G. *"Investigating the Effectiveness of Maximum Power Point Tracking for a Solar System."* IEEE, Power Electronics Specialists Conference, 2005.
2. Piao, Z.G.; Park, J.M; Kim, J.H.; Cho, G.B.; Baek, H.L.; *"A Study on the Tracking Photovoltaic System by Program Type,"* Electrical Machines and Systems, 2005. ICEMS 2005. Proceedings of the Eighth International Conference on Vol 2, Pages: 971 – 973, Sept 2005
3. L. Andersson, Ch. Brunner and F. Engler, *"Substation Automation based on IEC 61850 with New Process Close Technologies,"* IEEE Powertech Bologna, June 2003.
4. Ch. Brunner, *"IEC 61850 Process Connection—A Smart Solution to Connect the Primary Equipment to the Substation Automation System,"* ABB Switzerland, Zurich, Switzerland.

Additional Resources

IEC 61850 Standard
http://www.iec.ch/

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