Fiber Optic Applications in Solar Power Plant
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Abstract—The solar power is one of the fast growing renewable energy source in India and in the world. India, in particular, has solar power generation with present installed capacity of over 1400 MW. A modern solar plant requires sensing and controlling various parameters like temperatures of moving parts. Fibre optics with its electrical isolation and being light weight characteristics can have great potential to sense control parameters of solar panel and to communicate to the control unit. Fibre optic sensors are precise and reliable under electrical hazardous environment of solar power plant. Fibre optic technology has proved itself in present communication system. The same high speed long, distance communication networking can apply in solar farm. This paper discusses the application of fibre optic technology and its benefits in the operation of solar power plant.

Key words: Solar Farm Power Generation System, Fibre optics in solar power plant, fiber optic system

I. 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 the price surges when demand is high. Oil and/or coal powered generators when converting fossil fuel into electrical power and produce enormous CO2 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. Fibre optics offer insulation protection from high voltage/current glitches and unwanted signals into power equipment controls and communication. Electrical isolation of dielectric optical fibre and also can be used as reliable sensors in electrically hazardous environment. Fibre optics overcomes the common issues to fulfill the need for speed in real-time monitoring, while providing a more stable conductor and better data security than copper components. Optical fibres are used in solar power system as:
- Monitor and control
- Sensors for sensing

In this paper section II addresses the principle of fiber optic in solar power plant and discusses the components and advantages of fiber optic system in solar power plant. The section III is related to the application of fiber optic sensors used in solar power plant. The section IV describes the application of fibre optics data link in a solar power plant and its networking to interconnect solar panels for communication and control in a solar farm. It also describes the application of fibre optics in substation automation in which fiber optic components are commonly used to control a high voltage and current switching device with reliable control and feedback signals. The section V serves as a conclusion of the paper and discusses the importance of fiber optics in integration of solar power plants with the grid.

II. PRINCIPLE OF FIBER OPTIC IN SOLAR POWER PLANT
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. As the solar farms grow in size, monitoring and controlling all the solar panels require long-link distance connections which are only possible with optical fiber cable. Fig. 1 shows fiber optics in solar power system. Fiber optic components are commonly used to control a high voltage and current switching device with reliable control and feedback signals. 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.

A. Fiber Optic Advantages in Solar Power [1]:
Some of the main advantages of fiber optic in solar power are listed below.
1) Immunity to Electromagnetic Interference:
Fiber optics is immune to this EMI since signals are transmitted as light instead of current. Thus, they can carry signals through places where EMI would block transmission.
2) Eliminating Spark Hazards:
One tiny spark can create a big explosion; potential spark hazards seriously hinder data and communication in such facilities. Fiber optic cables do not produce sparks since they do not carry current.
3) Ease of Installation:
Increasing transmission capacity of wire cables generally makes them thicker and more rigid. Such thick cables can be difficult to install in existing buildings where they must go through walls and cable ducts. Fiber cables are easier to install since they are smaller and more flexible.
4) High Bandwidth over Long Distances:
This allows more channels to go over the same cable.
5) Non Conductive Cables:
Metal cables can encounter other signal transmission problems because of subtle variations in electrical potential. Electronic designers assume that ground is a uniform potential. Any conductive cables can carry power surges or ground loops. Fiber optic cables can be made non-conductive by avoiding metal in their design.
6) Thinner and Less Weight:
Optical fiber can be drawn to smaller diameters than copper wire. An optical cable weighs less than a comparable copper
wire cable. Fiber-optic cables take up less space in the ground.

7) **Less Signal Degradation:**
The loss of signal in optical fiber is less than in copper wire.

![Fig. 1: Fibre optics in solar power plant.](image)

**B. Components of Fiber Optic System [2]:**
Fiber optic system consists of optical, mechanical and electronics subsystems; Fig. 2 shows the component use in fiber optic communication system.

1) **Transmitter:**
Optical transmitter consists of semiconductor light source to convert electrical signal onto corresponding intensity of light (LED or Laser Diode) and driver circuitry to drive light source.

![Fig. 2: Components of fiber optic system](image)

2) **Optical Fiber Cable:**
An optical fiber cable is a cable containing one or more optical fibers that are used to carry light. The optical fiber elements are typically individually coated with plastic layers and contained in a protective tube suitable for the environment where the cable will be deployed. Optical fiber consists of a core and a cladding layer, selected for total internal reflection due to the difference in the refractive index between the two.

3) **Receiver:**
The receiver converts the received optical power back into electrical one. Semiconductor photodiode (PIN or APD photodiode) serves the purpose of conversion at receiver.

4) **Connectors:**
An optical fiber connector terminates the end of an optical fiber, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers.

5) **Couplers:**
A fiber optic coupler is a device used in optical fiber systems with one or more input fibers and one or several output fibers. Light entering an input fiber can appear at one or more outputs and its power distribution potentially depending on the wavelength and polarization.

### III. APPLICATIONS OF FIBER OPTIC SENSORS IN SOLAR POWER PLANT [2]
Fibre optics sensors becomes a preferred choice in megawatt rated solar power as it offers much higher voltage and current isolation properties compared to other similar counterparts. Optical fibre is used as a sensing element to monitor and control various physical parameters of the solar power plants. Some of the main fibre optic sensor application area in solar power includes:

- Strain of solar panels
- Temperature sensor for solar panel
- Displacement sensor
- Ice and moisture control for solar panel

**A. Types of Fiber Optic Sensors Used In Solar Power Plant:**
As shown in Fig. 3, a fiber optical sensor system consists of an optical source (laser, LED, laser diode etc.), optical fiber, sensing or modulator element transuding the measured signal to an optical signal, an optical detector and processing electronics (oscilloscope, optical spectrum analyser etc.). The advent of laser opens up a new world to researchers in optics.

![Fig. 3: Components of fiber optic sensor system.](image)
Light sources used to support fiber-optical sensors produce light that is often dominated by either spontaneous or stimulated emission. A combination of both types of emission is also used for certain classes of fiber optical sensors. There are basically following classification of sensing mechanism in fiber optic sensors.

1) According to sensing region
   - Intrinsic
   - Extrinsic

2) According to optical modulation mechanism
   - Intensity modulated
   - Phase modulated
   - Wavelength modulated
   - Polarization modulated

Major different types of fiber optics sensors used in different application are listed in Table I.

IV. FIBER OPTIC COMMUNICATION APPLICATION IN SOLAR POWER [3]

As solar farms become larger to generate more power for utilities so they are equipped with intelligent features to monitor the performance of each solar panel. Modern substation automation is designed to improve overall system reliability and significantly reduce the number of copper wires used.

![Image](image_url)

Table 1: Different Types of Fiber Optic Sensors Used In Application

<table>
<thead>
<tr>
<th>Name of Fiber Optic Sensor</th>
<th>Description of Sensor Type</th>
</tr>
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<tbody>
<tr>
<td>Intrinsic</td>
<td>Optic sensor has a sensing region within the fiber and light never goes out of the fiber</td>
</tr>
<tr>
<td>Extrinsic</td>
<td>Optic sensor has light has to leave the fiber and reach the sensing outside and then comes back to the fiber.</td>
</tr>
<tr>
<td>Intensity Modulated</td>
<td>According to there will be a change in light injected from one end to another and this will make the intelligence for measuring quantity amplitude.</td>
</tr>
<tr>
<td>Phase Modulated</td>
<td>Phase modulated sensors are used to make change in emitted light regarding the change in information signal.</td>
</tr>
<tr>
<td>Wavelength Modulated</td>
<td>There is change in measuring parameter, this kind of optical sensor will make change in their wavelength of light generation.</td>
</tr>
<tr>
<td>Polarization Modulated</td>
<td>Change in refractive index due to stress or strain is also known as induced refractive index. Thus there is an induced phase difference between different polarization directions.</td>
</tr>
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</table>

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. Fig. 4 shows the solar power monitoring and control system. 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 semiconductor 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.

![Image](image_url)

Fig. 4: Solar plant monitoring and control 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. Fig. 5 shows solar farm monitoring and control with control room.

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.

![Image](image_url)

Fig. 5: Solar farm monitoring and control with control room

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.

A. Substation Automation with Fiber Optics [4]:

Substations connect the power generated from solar farms to the utility grid for power transmission to the end consumer. Modern substation automation is designed to improve overall system reliability and significantly reduce the number of copper wires used. Since most equipment (e.g., switchgear, transformers, circuit breakers, etc.) in
substrations 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. Fig. 6 shows the substation automation with fiber optic system. In this instance, fiber optics is the best solution for such requirements in substation automation control and communication lines.

![Substation automation with fiber optic system](image)

**Fig. 6:** Substation automation with fiber optic system

### B. Insulated Gate Bipolar Transistor (IGBT)’s Gate Driver System with Fiber Optics [5]:

Fiber optic components are commonly used to control a high voltage and current switching device with reliable control and feedback signals. The link product family has been the most popular standard component for power semiconductor control boards. It’s simple transmitter and receiver circuitry makes these components easily integrated into the system with TTL logic level. Figure shows the common interface circuitry for a 5MB data rate operation. Fig. 7 shows IGBT’S gate driver system with fiber optics.

![IGBT’s gate driver system with fiber optics](image)

**Fig. 7:** IGBT’s gate driver system with fiber optics

### C. Fiber Optic in Solar Power Plant Networking [6]:

Networking of solar power plant is also useful for real-time surveillance and status monitoring of solar power plants. A lite-managed Ring Ethernet switch can be connected to the photovoltaic solar panels. Fig. 8 shows fibre optic in solar power plant networking.

![Fiber optic in solar power plant networking](image)

**Fig. 8:** Fiber optic in solar power plant networking

For enhanced and highly secured network traffic handling, a Thunder Rack Full-Gigabit Ethernet switch can be used to collect data from multiple units of lite-managed Ethernet switches, which are connected and configured in proprietary flexible add-on network topology configuration called O-Chain. Then multiple units of Thunder Rack Gigabit Ethernet switches and the control center can be connected altogether to form a ring topology and be protected by redundant ring protection also with less than 10 ms of recovery time (IES managed or lite-managed series). Furthermore, Ethernet switches support device binding, state-of-the-art network security and health-check technology that actively blocks hacker attacks and ensures the well-being of data streaming and bound devices. Selected Ethernet switches support optical fiber links which provide the following important features for solar power plant networking:

- Extended transmission distance,
- Secure signal transmission and
- Immunity to electromagnetic interferences.

### V. Conclusion

The immunity to electromagnetic interference, ease Of installation, high bandwidth over long distances, thinner and less, less signal degradation compared to copper cables and above all, immunity to high electric power, fibre optics are proving its significant role in automation of solar power plant. The signals that carry optical fibre provide reliable information for monitoring and controls of solar power plant.

Older solar power plants can also be modernized using fibre optic technology for reliable, efficient and stable performance of various subsystems. In future advance signal processing and fibre optic network technology will improve the precision and cost of fibre optic technology in high power solar power plant. The presence of fiber optics within a solar power plant communicates each subsystem of solar panel to corresponding control units. It is also widely used to transmit data that interconnect solar panel and central control unit of a solar farm. This paper addresses the use of fast, reliable, EMI noise free fiber optic networking which...
can encourage the designer and manufacturer to develop
dulti megawatt green energy solar power.

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