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SCADA Over Fiber Optic Communications System

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***Abstract* – Impact of automation is visible in all areas of industry as well as in everyday life. Automation makes the process control more efficient, increases productivity of work, manufacturing quality, decreases manufacturing costs. Automation is still in development so that it could succeed in filling all requirements of today's technical advance. The role of the communication is exchanging of connection with a common computer in order to create and transmit the program to PLC and to transmit data to superior levels for operator's control of technology.**

The use of fiber optics in SCADA(Supervisory Control and Data Acquisition) systems has increased due to inherent advantages of using fibers. High data rates can be maintained without electromagnetic or radio frequency interference (EMI/RFI). Longer distances can be achieved over that of the copper wires. Ethernet will function with no difficulty over fiber as long as some simple rules are followed.This paper implies implementation of a SCADA system that utilizes an optical fiber link for the communications between the SCAD center and an industrial site for exchanging data between them.

***Keywords* – SCADA, Ethernet, PLC, Optical Fiber, Laser Diode.**

I. Introduction

Most of digital control systems used a Supervisory Control And Data Acquisition (SCADA) with Remote Terminal Unit (RTU) for monitoring the metering devices for the systems, while the other system used a Programmable Logic Control (PLC) technique for controlling and monitoring the system by professional engineers [1],[2].

SCADA systems are used to monitor and control a factory or plant like communications systems, water and waste control, energy, oil refining and transportation or any facility. These systems have the transfer of data between a SCADA central host computer and a number of Remote Terminal Units (RTUs) and/or Programmable Logic Controllers (PLCs), and the central host and the operator [1],[3].

Recent systems are monitored by aid by infrastructure of Local Area Network (LAN)/Wide Area Network (WAN). Also wireless systems are increasingly used as the infrastructure.

SCADA systems consist of one or more field data interface devices, usually RTUs, or PLCs, which interface to field sensing devices and local control switchboxes and valve actuators [1],[4], [5]

- A communications system used to transfer data between field data interface devices and control units and the computers in the SCADA central host. The system can be radio, telephone, cable, satellite, etc., or any combination of these.
- A central host computer server or servers (sometimes called a SCADA Center, master station, or Master Terminal Unit (MTU)
- A collection of standard and/or custom software [sometimes called Human Machine Interface (HMI) software or Man Machine Interface (MMI) software] systems used to provide the SCADA central host and operator terminal application, support the communications system, and monitor and control remotely located field data interface devices [1],[9].

The optical fiber is one of the choices to be used to transfer data between field data interface devices and control units and the computers in the SCADA central host. Since the fiber optic technology provides immunity to electromagnetic interference and radio frequency interference, elimination of spark hazards, immunity to ground faults and transients, increased signal capacity, secure transmission and very low attenuation coefficient compared to the media which makes transmission distances greater [1].

Fiber optics therefore can provide a cost effective way to transmit more information for longer distances with guaranteed safety. The optical link can operate at an acceptable low error rate only if the optical power at the receiver exceeds some minimum level P_R called the receiver sensitivity. The maximum loss limited transmission distance L_{max} is given by [6],[7]

$$L_{\max}\,\alpha = P_T - P_R - L_c - splice\,loss - m\arg in \quad (1)$$

Where P_T is the transmitted power, α is the fiber attenuation expressed in dB/km, L_c is the connector losses usually taken as 1 dB, and the system margin usually taken between 3-10 dB.

The SNR for the PIN photodiode receiver may be calculated as in below (7)

$$SNR(dB) = 20\log\left(\frac{i_s}{i_{th}+i_{shot}}\right) \quad (2)$$

The performance criterion for digital receiver is governed by the bit error rate BER, defined as the probability of incorrect identification of a bit by the decision circuit of the receiver [6]. A commonly optical receiver requires BER ≤ $1 * 10^{-9}$ [8].

The BER with the optimum setting of the decision threshold is obtained as in follows [7]:

$$BER = \frac{\exp(-SNR)}{\sqrt{2\pi SNR}} \quad (3)$$

The receiver sensitivity is then defined as the minimum average received power P_{rec} required by the receiver to operate at a BER of 10^{-9}.

II. System Description

The ability to monitor water tank levels from a remote location can be very useful in certain circumstances. This is particularly true if you have several tanks or if the tanks are hard to access, or you want to include automatic pump control.

The block diagram of the implemented system was shown in the Figure(1). The PLC used in the work was CM3-SP32MDTE which has a feature of maximum three communications that can work simultaneously [Ethernet. RS232 andRS485], Cimon HMI, MODBUS RTU-TCP, PLC link. The Ethernet link is too short and its maximum length can not be more than 100 m. this is not enough in many applications. The control of the pump can be controlled by the PLC according to the status of the pump and the need of the work. The human detect system detects the existence of any person in the field of pump. It uses two motion detectors (AMN11112 from Mikro elektronika company) at the entrance of the field and records if anyone exists. These sensors were separated one meter from each other and isolated very well to detect any person passes between them in both directions. These sensors detect the infrared (heat) emission of bodies and detect change in infrared spectrum by using a quad-type pyroelectric element. The system then increases or decreases its counter according to the sequence of passages between the detectors. As the pump was needed to be operated, the PLC takes into account the reading of the counter of the human detect system. It gives audio and visual alarms before operating the pump to depopulate the field from any one.

The level monitoring system was used to check and measure the level in the tank in order to control the pump in accordance to its readings.

2.1. Communication Link:

The wireless communication link was implemented based on Wi-Fi technology using tow nanostations (5.8 GHz) which based on 801.11a OFDM technology as shown in the Figure(2). They can assure link upto 10 km. The nanostation 1 that connected to the PLC was configured as an access point.

Ethernet to fiber converter circuit makes an interface between the copper unshielded twisted pair UTP and the optical fiber cable. Figure (3 and 4) shows the link's layout and block diagram for one direction only but in the work it was full duplex system in two directions. The incoming electrical signal from the Ethernet was converted into optical signal using the laser diode at the transmitter side. Then it was sent over the optical fiber. At the receiver side, a replica of the original electrical signal was recovered. The receiver contains a clock recovery in order to reconstruct the clock that will be used in the data recovery part. The laser diode was biased just below the threshold current level.

The laser diode used as an optical carrier generator in the transmitter with an emitted optical power of -10 dB mat 1300 nm wavelength launched into the fiber at the high level voltage. The communication system uses the intensity modulation of the laser diode in which the output emitted power from the diode was varied according to the value of applied input electrical signal coming from the Ethernet output of the PLC.

The direct detection type was used in the receiver to detect the arrived optical signal at the photo detector. In this case the output current of the detector directly proportional to the incident optical signal. An InGaAs/InP PIN Photodiode with responsively of 0.36 A/W at 1300 nm was used at the receiver side.

Ten pieces of single mode optical fiber each of 2km length were used in the system as a channel of communications. So, the total length will be 20 km. these pieces were connected to each other by splices. Each splice has 0.035dB losses.

III. Results

The main results of the proposed system include the measurement optical power received at the detector, and calculating the signal to noise ratio at optical receiver then finding the BER according to the mentioned equations. The work includes usage of the optical fiber ten pieces each of 2km length. So, the total length will be 20 km.

A plot shown in the Figure (5) shows the relation between the SNR to the BER of the system. BER was calculated using equation 3. Figure (6) demonstrates the changes in SNR against distance of transmission calculated according to equation 2. The power budget calculations showed that the maximum length of the optical fiber can be 30.71.km.

IV. Conclusion

The suggested system offers working with increased length due to using of the optical fiber as transmission media and give good alternative to wireless system in term of cost and complexity. Also the fiber optics channel is known of better reliability the system operates properly with acceptable BER as indicated in the graphs.

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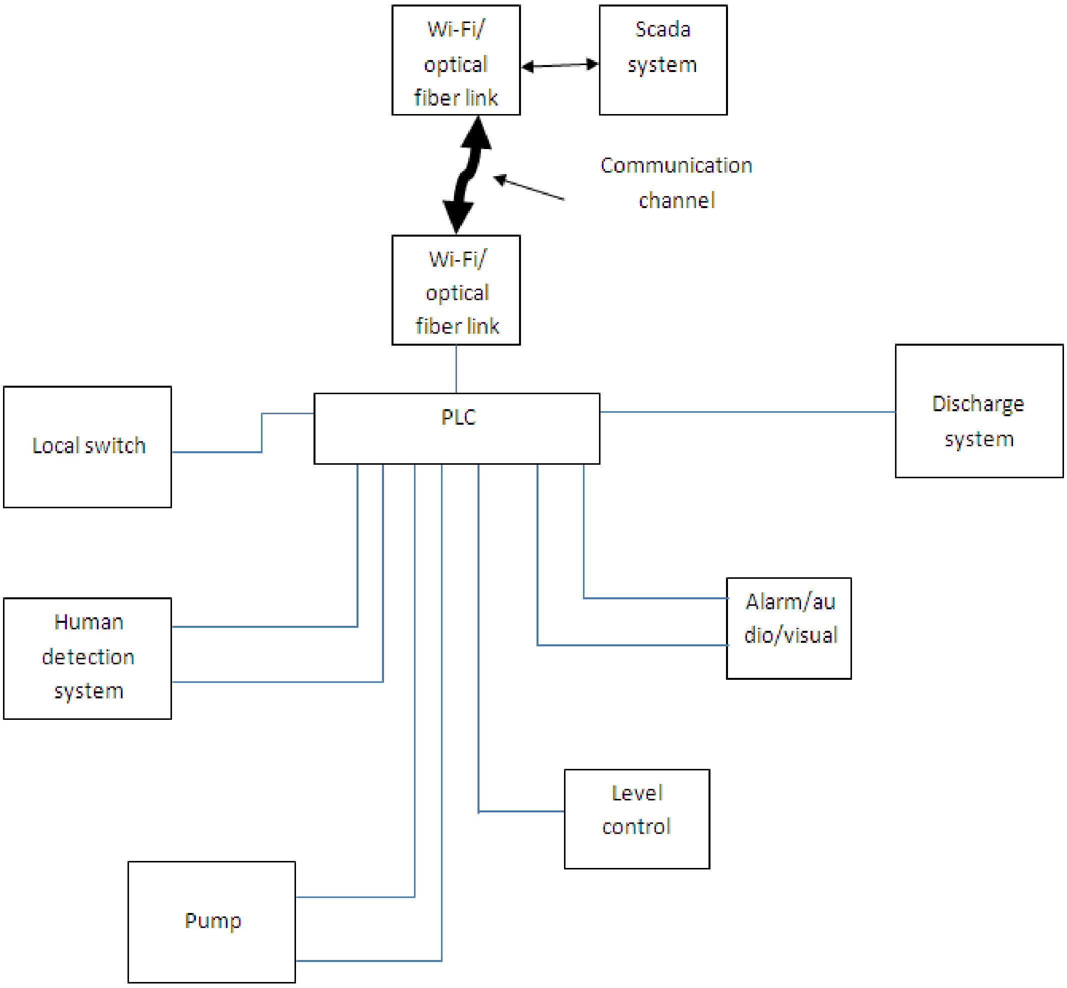

Fig.1. Block diagram of the proposed system

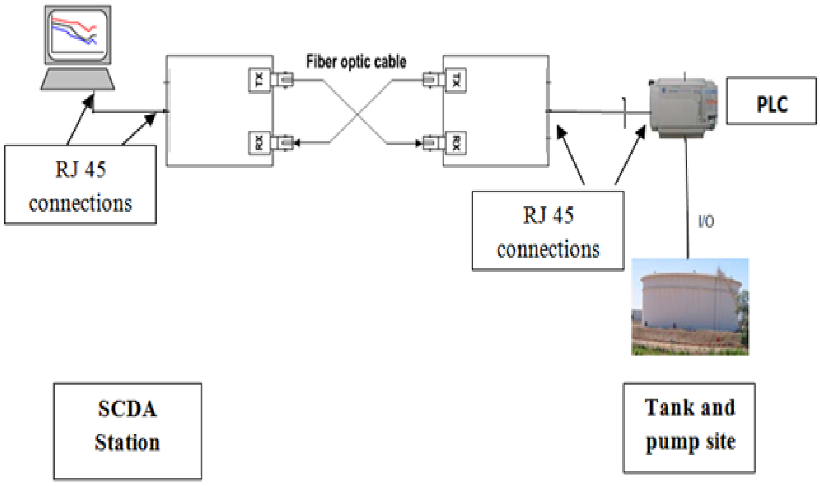

Fig.2. Proposed system layout based on wireless communications link

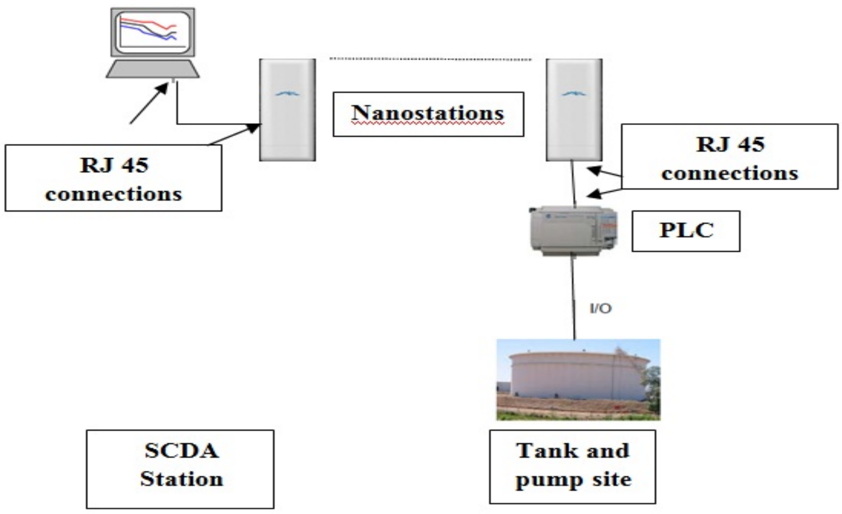

Fig.3. Proposed system layout based on Fiber Optic communications link

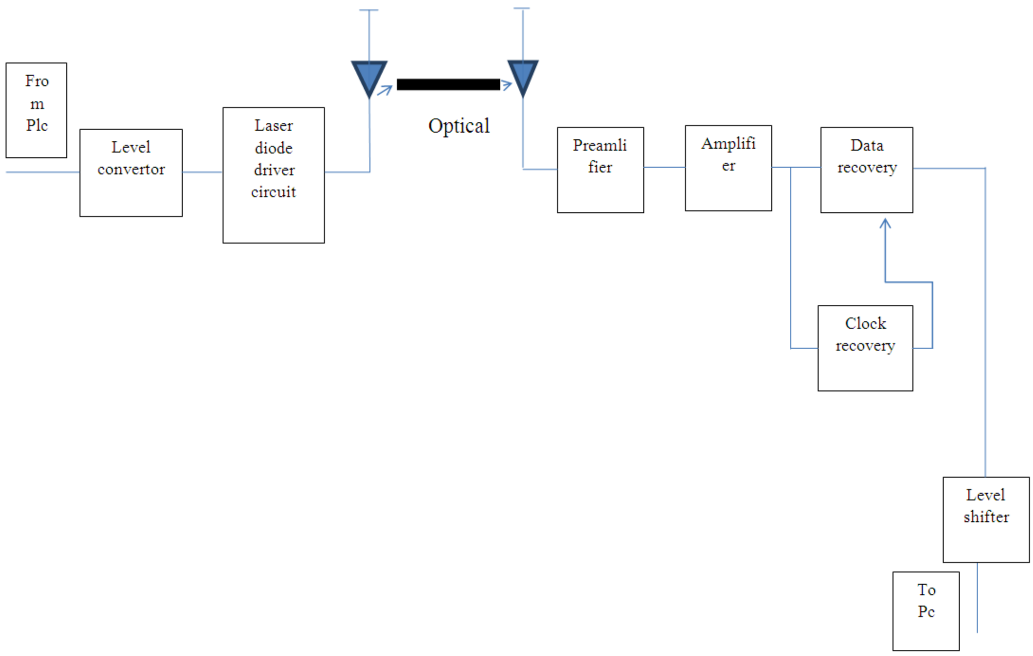

Fig.4. Block diagram of the Ethernet to optical fiber converter system

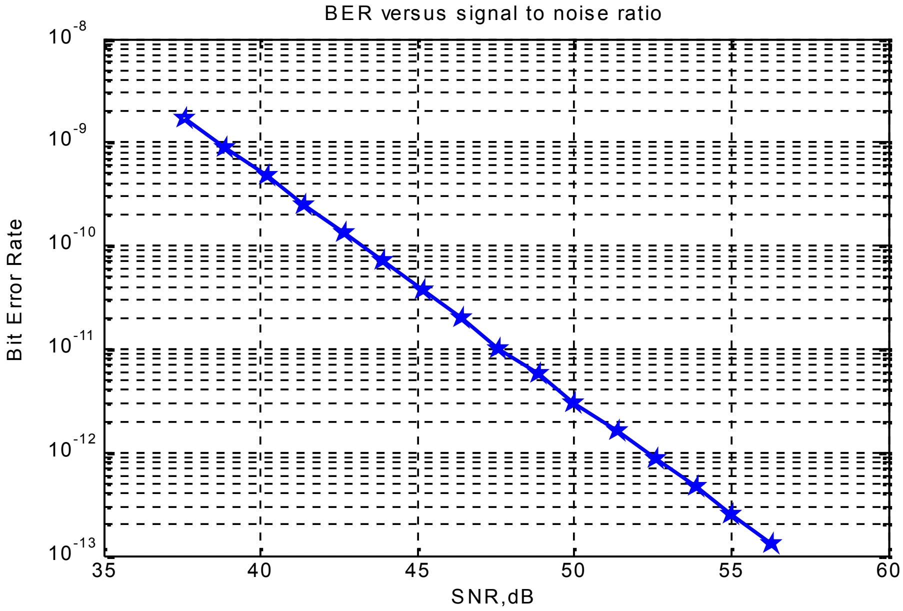

Fig.5. BER versus SNR

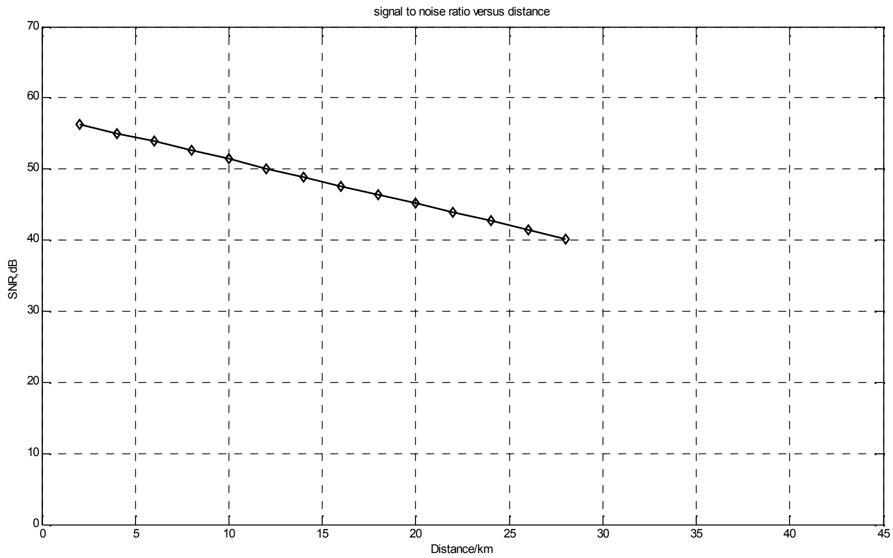

Fig.6. SNR versus length of optical fiber link