Structural Health Monitoring of Bridges using Wireless Sensor Network

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Abstract— Structural Health Monitoring (SHM) helps to reduce the danger of collapses of structures and life threatening incidents and is reliable. This project developed a structural health monitoring system of bridges which utilizes the use of microcontrollers, wireless communication, transducer, sensors and cellular transmission that allows remote monitoring. Wireless sensors are low-cost data acquisition nodes that co-locate communication and computing functionality with the sensors. These sensors include strain gauge, water level sensor, anemometer, vibration sensor etc. Data acquired from the sensor is transferred through wireless network to destination. The processing of sensors consumes less power. The stability and usability of Wireless Sensor Network (WSN) is validated due to merits as such low cost, easy installation, and effective data management.

Key words: Structural Health Monitoring (SHM), wireless communication, sensors, reliability, bridges, low cost, wireless sensor network (WSN)

I. INTRODUCTION

In class of civil infrastructure mainly bridge structures are subjected to problematic condition Dead and live loads along with extreme loads are subjected on the bridges. Natural and man-made hazards are regarded as the most critical components in transportation infrastructure system. Sudden collapses of bridges can result in extensive human and economic losses; thus, appropriately maintaining their structural integrity over their lifespan is required to ensure public safety. So some technologies are developed for the monitoring of bridges to avoid human and economical losses.

Introduction of wireless sensor network in SHM of bridge is an evolutionary advancement made in civil structures. The microcontroller is the heart of whole SHM system which interprets the data received by sensors and processes it. Data that has been analyzed can be sent to for further indication to GSM module and displayed on LCD. Thus this project provides the required data as like vibrations, wind flow, water level etc for assessing the health of bridge making it less fragile to damage. Use of sensors makes our system cost effective and less needy for maintenance and saves human work. This technology is currently being used in developed countries as such USA, South Korea, Japan etc.

II. OBJECTIVE

Monitoring of all parameters is done by using LPC2148 ARM Microcontroller based on Embedded system technology. Sending the status of all parameters using GSM Module to Mobile Receiver of the authenticated person located anywhere. If status of any parameters is beyond the specified limit then it will generate the alarm. System sends the information using mobile network to operator to take appropriate actions before any damage occurs.

III. LITERATURE AND SURVEY

Dhivya. A#1, Hemalatha. M*2 developed a project which included earthquake detection before human acknowledgment. They used PIC 16F874A type of PIC microcontroller to process the signal acquired from the accelerometer and strain sensor which includes force balanced type, piezoelectric type and MEMS type sensors. It can measure the frequency range about 0-300 Hz. For damage detection the crack sensor was used that has fiber optic embedded in concrete. Then use of GSM is made.

Billie F. SPENCER Jr.1, Manuel RUIZ-SANDOVAL2 , Narito KURATA presented a paper on smart sensing technology evolving in SHM. A detailed study on, why smart sensor with signal conditioning is useful over traditional sensors was done. The main advantage brought by this technology and its design sample to application is miniaturization. MEMS features are typically on the scale of microns (10–6 m). MEMS devices can be found in a wide-range of applications from accelerometers for airbag deployment to electronic particle detector that helps for nuclear, biological, and chemical inspection.

Y. Fujino & D.M. Siringoringo paper describes an overview of research and development on structural health monitoring (SHM) of bridges in Japan. They studied, bridges in Japan more than 50 years of age which adds the concern to the problem of frequent earthquakes. The high intensity and frequency of loading generated by high traffic volume generates many problems in bridges. To monitor these bridges they included dense seismic measurement systems. The influence of train speed on the structure was studied using a non-contact measurement system by means of Laser Doppler Vibrometer (LDV)

DANIELE INAUDI, SMARTEC SA, Switzerland, Roctest Ltd, Canada IBC 09-45 overviewed the 40 bridges SHM project. They briefly concentrated study on structural safety, maintenance and operation. They mentioned that in bridge does lifetime exist, and new one requires different monitoring so as to reduce the budget of monitoring, installation, installed sensor, and customer needs were taken into account by the respective company owner.

IV. PROJECT INTEGRATION

Fig.1 Block Diagram for An approach towards an ARM controller board is shown. The block diagram shown depicts the hardware configuration of the complete system. It considers the monitoring of bridge for mainly following parameters in order to avoid hazardous effects: 1. Vibrations, 2. Load, 3. Water level, 4. Wind speed. So as to have a continuous health monitoring of bridge and detect any damage being made to it so as to take preventive measures in prior we have installed various sensors on different locations. Data (measures parameters load, vibrations, water level and wind speed) acquired from these sensor is conditioned and then sent to controller which further sends it to GSM module

which later transmit it to the GSM receiver at remote location also displays the data on LCD to overview it. A buzzer buzzes as soon as the limit exceeded. Actuator is being used to take immediate corrective action in situation of emergencies.

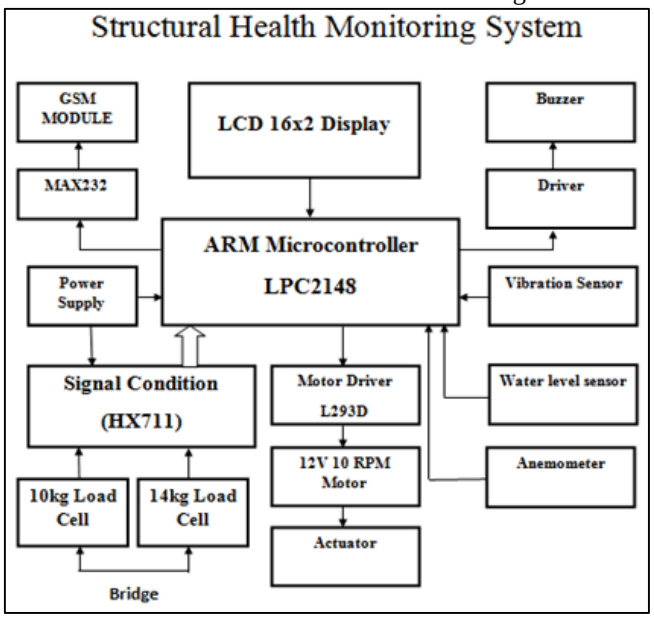

Fig. 1: Block diagram for an approach towards an ARM controller board is shown.

V. HARDWARE IMPLEMENTATION

A. *Power supply:*

Whole hardware of SHM with sensors and controller needs power supply to support the system. The DC power supply is used. Use of rectifier is made so as to have power supply of:

1. ARM: works on 3.3V,
2. Motor driver (L293d):5V.

All the circuit elements work on this power supply.

B. *ARM Microcontroller (LPC 2148):*

We use ARM due to its RISC architecture and its low power requirement. It is a 16-bit/32-bit microcontroller. It has 8 KB to 40 KB of on-chip static RAM and 32 KB to 512 KB of on-chip flash memory and 128 bit wide interface. Its processing is quite faster than other controllers. It takes data from various sensors and sends out the controlling signal to GSM, LCD and actuators to process as per the code written.

C. *Motor Driver (L293D):*

It has Output Current Capability -600-mA per driver and pulsed Current 1.2-A per Driver. It has wide Supply Voltage Range 4.5 V to 36 V also separate Input-Logic Supply allowing operation at lower voltage. It has two drivers that can run both clockwise and anticlockwise. It is needed to drive the motor used for the movement of actuator to stop the vehicles going on bridge in emergency cases.

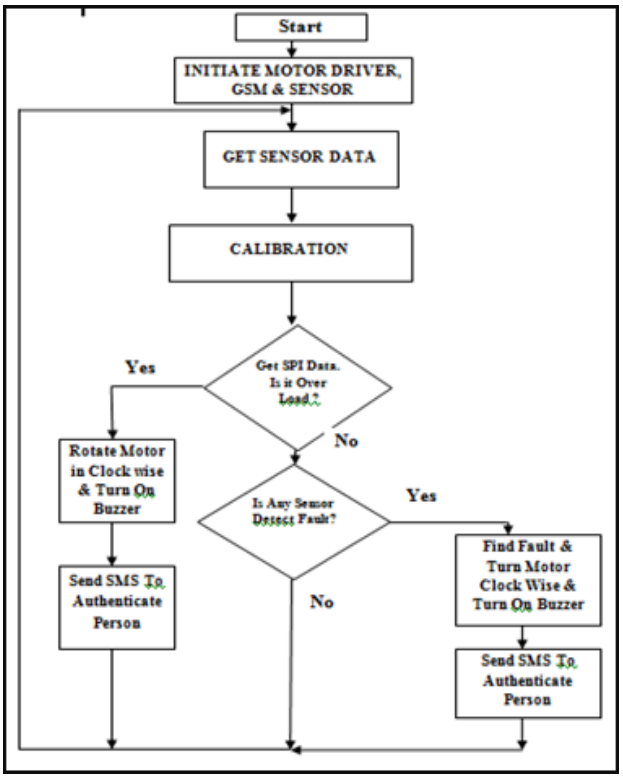

Fig. 2:

D. *Logic Level Convertor (MAX 232):*

It is used for GSM module and ARM compatibility logic level conversion .Also used for voltage level shifting. In TTL logic0: +3v to +15v; logic1: -3v to -15v.There are two Drivers and Two Receivers and can accept up to ±30V inputs. Low Supply Current of 8 mA is required.

E. *Vibration sensor:*

For testing the impact force the vibration sensor is used. Its vibration detection sensitivity is high. The elements used in vibration sensor are piezoelectric element, spring oscillator, Sensitivity adjustment knob, and LED. Sensitivity can be adjusted using knob. It measures the number of volts produced per vibration. It has Frequency Response: 1Hz-10KHz. And Sensitivity: 100mV/g.

F. *Anemometer:*

It is used for measuring the wind speed in Kmph. An anemometer measures wind speed as well as wind direction. The anemometer is an important tool used to predict the weather and record the current weather conditions. The arms are attached to the vertical rod. The cups rotate making the rod spin as the wind blows. The speed of the spinning of rod directly depends on the wind speed. It counts the number of rotations or turn which is used to calculate wind spin. So we can sense the wind speed that might damage the bridge.

G. *Load Cell (10kg and 14kg):*

A load cell is one of the transducer which is used to create an electrical signal and its magnitude is directly proportional to the force being measured. These load cells are particularly stiff with good resonance values and tend to have long life cycles in application. The working principle of strain gauge is that the strain gauge (a planar resistor) deforms/stretches/contracts when the material of the load cells deforms appropriately. The change in resistance of the

strain gauge provides an electrical value directly proportional to the load. Rated capacity-10Kg and 14 Kg, Rated output-2 mV/V. Used for measuring load on bridge.

H. Water level Sensor:

The water level sensor is used to detect the level of the liquid. Here we can set the minimum and maximum water level limit. When water crosses the maximum limit, this sensor gives the indication. It is non corrosive type of water level sensor.

VI. CONCLUSION

Bridge health condition monitoring has been a popular issue in civil environment. This research project represents a new SHM system that is being used to monitor the civil bridges and it overcomes the drawbacks of traditional SHM methods. Here a wireless sensor network (WSN) system is developed. With the help of the wireless technology many problems due to data cables and expensive optical cable are now minimized. In the structural monitoring techniques presented in this paper is particularly on vibration-based bridge monitoring, applied load, water level, wind speed. The GSM transmission scheme helps in better way of communication which provides data transmission effectively between the GSM module and receiver. Also the use of ARM7 microcontroller makes the system real time embedded system and favors low power consumption.

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