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Remote Monitoring of Structural Health Using Smart Sensing Technology

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Abstract—*Structural health monitoring (SHM) is emerging as a vital tool to help engineers improve the safety, maintainability and damage identification strategy of civil, mechanical and aerospace engineering structures. Previously the technology which was executed in the world only monitored the structures but our idea is to make it more advance & smarter than the older one. As we build future structures which have to work safely under severe conditions, it becomes imperative that these structures are essentially smart and sense their own structural health so their safety is never compromised.*

SHM combines of smart sensing technology with an embedded measurement controller to capture, log and analyze real time data and predict future of structure. Today's structure enormously depends on the use of embedded based smart sensing technology for real time structural health monitoring to measure multiple parameters like strain, vibration, temperature, pressure, chemical and biological effect of environment. In the past 10 years we have seen a rapid increase of interest in SHM and its associated potential for significant life safety and economic benefits has motivated the need of this idea for smart cities.

Keywords: *Structural health monitoring (SHM), smart sensing technology, embedded measurement controller, life safety, smart cities.*

1. INTRODUCTION

Structural Health monitoring system is the implementation of improving the maintenance of any structures like buildings, bridges, turbines, space station, etc. It encompasses damage detection, identification and prevention of structures from natural disasters like earthquake, landslides, etc [1]. The ability to continuously monitor the integrity of structures in real-time can provide for increased safety to the public, particularly for the aging structures in widespread use today. The ability to detect damage at an early stage can reduce the cost and down-time associated with repair of critical damage.

SHM systems, in principle, consist of smart sensors (e.g. accelerometers, temperature sensors, strain transducers) that are installed in the structure to collect response measurements caused by some external or internal stimuli. The measurements are then transmitted to a base station through zigbee protocol [3], which holds the responsibility for storing and processing the data collected from the sensors. Once being stored in the centralized computer, the data can be analyzed automatically by software programs or manually by human experts. Many data analysis approaches have been developed in assessing the integrity of a structure. A alert system will be there to notify people which will save human life's before devastation of structures.

In the 2014-15 year plan, Government of India has sanctioned the proposal of smart cities all across India. It is expected to invest $ 1Trillion in its various infrastructure projects under the scheme of FDI (Foreign Direct Investment) & PPP (Public Private Partnership),Keeping roads and bridges in a safe operating condition is a major financial burden on state departments of transportation as well as many local agencies. State and local agencies have to rely on limited data (primarily from subjective ratings provided by inspectors) to prioritize structures for repair and retrofit.

Much of the existing infra- structure in India has been in service for many years. These structures are still being used despite ageing and the associated accumulation of damage. Hence monitoring the condition of these structures to provide the necessary maintenance has become critically important to our society.

Tragic disasters on the civil structures, like the collapse of bridges or buildings, often result in a large number of casualties as well as social and economic problems [4]. Operational safety of infrastructures such as bridges, interstate highways and power grids, is a significant issue with immediate public safety ramifications, in addition to economic losses and road network disruption concerns.

2. LITERATURE SURVEY

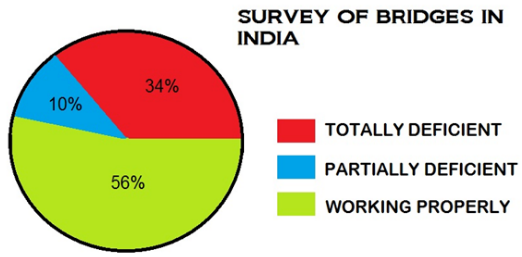

Fig. 1: Survey Of Bridges In India

Civil structures such as bridges, buildings, dams or wind turbines are complex systems that are vital to the well-being of our society. Safety and durability of civil structures play a very important role to ensure society's economic and industrial prosperity. Unfortunately, many of our ageing civil structures are deteriorating because of continuous loading, harsh environmental conditions, and, often, inadequate maintenance. For example, in India 6,07,000 public roads & bridges, about 2,06,380(34%) are structurally deficient & another 60,700(10%) are functionally obsolete & are not considered as safe . In US among 150,000 bridges – about 25% of the U.S. bridges – are considered structurally deficient.

3. PROPOSED WORK:

3.1 Experimental Setup

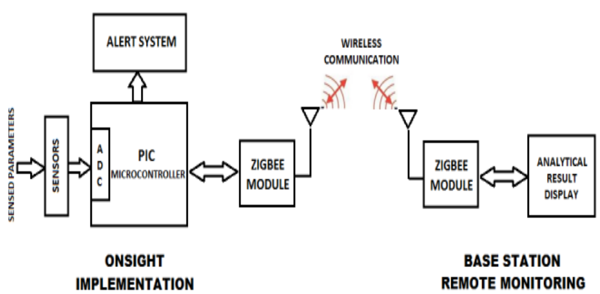

Fig. 2: Block Diagram

3.2 Description

The overall block diagram of proposed structural monitoring is illustrated in Fig. 1. Each unit has its own power module. So it is needed to convert the voltage into various levels to supply all the modules. Each sensor in the sensing module receives a fix current. Sensing module consists of different types of sensors, which is used to measure the different parameters that are affecting the health of the structures. Sensing module which acquires the signal from environment and then it will send to the acquisition module. It involves vibration analysis, damage detection & monitoring. Vibration analysis is used to predict the start of an earth quake.

Damage detection identifies the damage caused by an earth quake or any other external load. This analog data is then sent to microcontroller where it is processed. Microcontroller then sends the processed digital data to the monitoring centre via wireless protocol zigbee. At this base station the data is displayed on the screen graphically.

4. COMPONENTS DESCRIPTION:

4.1 Sensor

4.1.1 Accelerometer

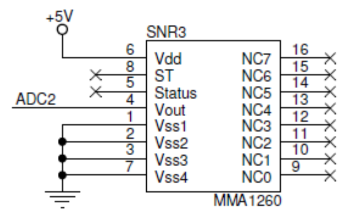

Fig. 3: Accelerometer MMA 1260

The MMA series of silicon capacitive, micro machined accelerometers feature signal conditioning, a 2-pole low pass filter and temperature compensation. Zero-g offset full scale span and filter cut-off are factory set and require no external devices. A full system self-test capability verifies system functionality.

4.1.2 Load cell

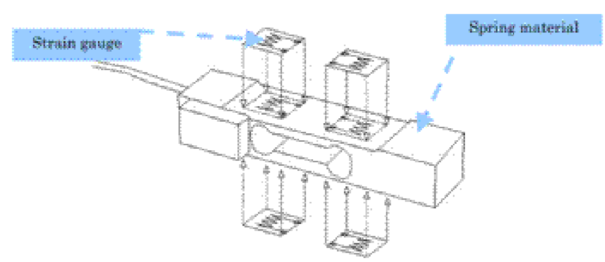

Fig. 4: Load cell

At the heart of electronic scales or weighing machines is a sensor called load cell. These sensors sense the force (or weight) of the items and the electronic circuitry processes the sensors output and displays it on the indicator. Load cells are highly accurate transducers which provide the user with information not generally obtainable by other technology due to commercial factors.

4.1.3 Temperature Sensor

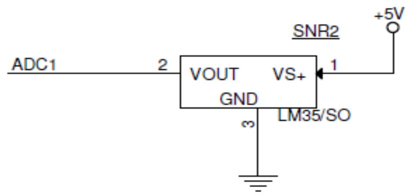

Fig. 5: Temperature sensor LM 35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA and LM35D are also available in the plastic TO-92 transistor package.

4.1.4 Pressure Sensor

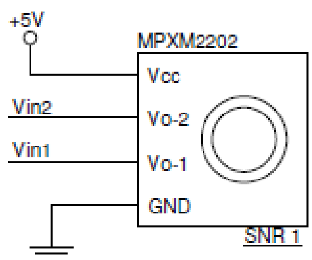

Fig. 6: Pressure sensor MPXM2202

The MPXM2202 device is a silicon piezo resistive pressure sensor providing a highly accurate and linear voltage output directly proportional to the applied pressure. The sensor is a single, monolithic silicon diaphragm with the strain gauge and a thin film resistor network integrated on chip. The chip is laser trimmed for precise span and offset calibration and temperature compensation.

4.2 Microcontroller (PIC18F4520)

PIC18F4520 is 8-bit microcontroller. Operating Frequency DC – 40 MHz. Program Memory (Bytes): 32768. Program Memory (Instructions): 16384 Data Memory (Bytes): 1536. Data EEPROM Memory (Bytes): 256. Interrupt Sources: 20. I/O Ports: Ports A, B, C, D, E. Timers: 4. Capture/Compare/PWM Modules: 1. Enhanced Capture/Compare/PWM Modules: 1. Serial Communications: MSSP, Enhanced USART. 10-Bit Analog-to-Digital Module. 13 Input Channels. Instruction Set: 75 Instructions; 83 with Extended Instruction Set Enabled. Packages: 40-Pin PDIP,44-Pin QFN,44-Pin TQFP.

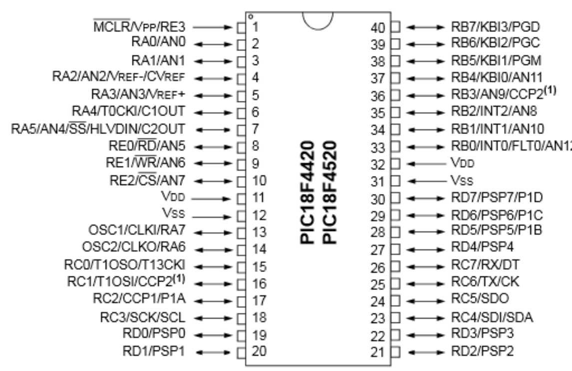

Fig. 7: PIC18F4520 Pin Diagram

4.3 Zigbee

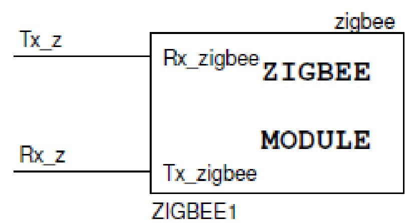

Fig. 8: Zigbee Module

Specification for low-power, low data-rate radio based on IEEE 802.15.4 standard. Most recent specification: ZigBee 2006.Smaller, cheaper than Bluetooth. Price point for ZigBee transceiver: US $10. Operates in the 2.4 GHz, 915 MHz and 868 MHz ISM band. In 2.4 GHz band, 16 5-MHz channels and up to 250 kbps raw data rate (per channel).CSMA/CA.Mesh network architecture.

5. WORKING PRINCIPLE

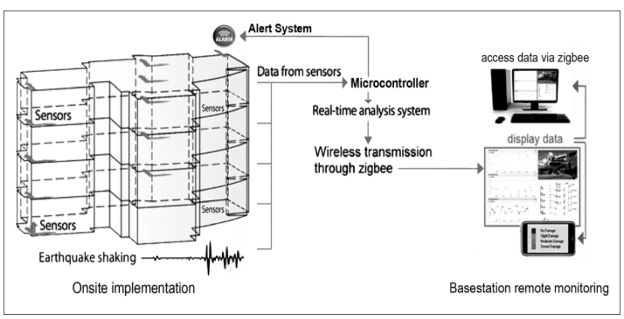

Fig. 9: Working Process

Various sensors are implemented at particular nodes of the structure, which continuously monitors the structural health as these sensors sense various parameters such as vibrations, strain, temperature, pressure, etc. that has adverse impact on the structure. This analog data is then sent to controller for processing and analysis purpose. Thus controller plays a crucial role in this process.

After the processing of data by the micro-controller, data in digital form is send to a zigbee module. A similar zigbee module is used to collect the data at the base monitoring center and the analytical results are displayed graphically for monitoring purpose. At extreme conditions, some predefined limits of the parameters are stored in the micro-controller. As the value of the sensed parameters exceeds the pre-set limits, a signal is sent to alarming system to alert the people in that particular structure. Thus it contributes for a life-saving scenario in worst case.

6. RESULT ANALYSIS

6.1 Accelerometer Practical Readings:

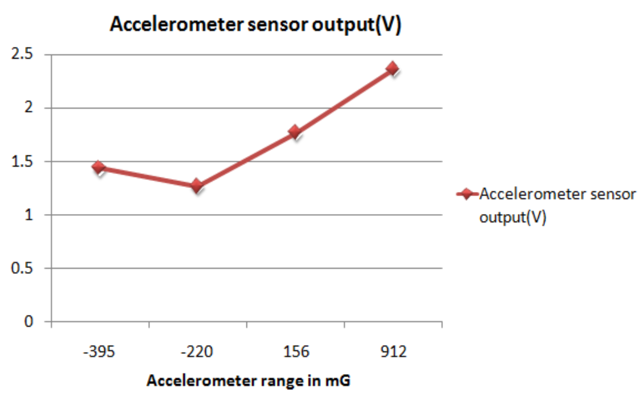

Fig. 10: Graphical display of accelerometer sensor

6.2 Load cell Practical Readings:

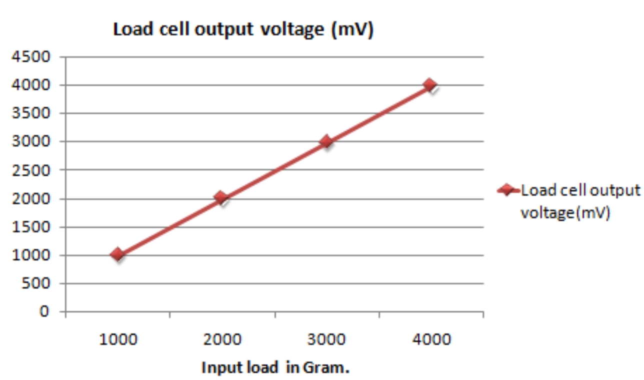

Fig. 11: Graphical display of load cell sensor

6.3 Temperature Sensor Practical Readings:

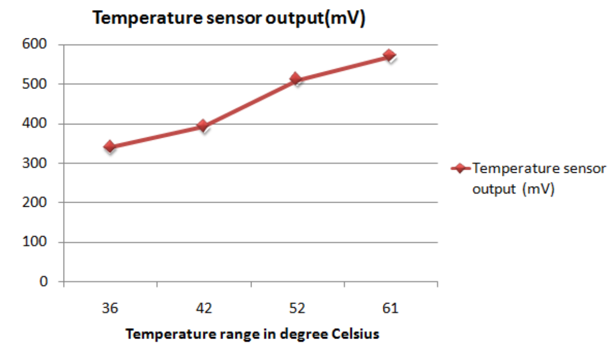

Fig. 12. Graphical display of temperature sensor

6.4 Pressure Sensor Practical Readings:

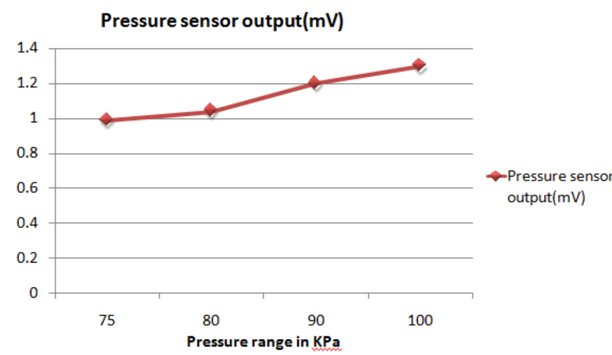

Fig. 13: Graphical display of pressure sensor

7. CONCLUSION

Thus from this project we are able to successfully identify the damages and monitor the structural health of an engineering structure from a remote base station with the help of a working model and contribute towards society for the cause of public safety.

8. ACKNOWLEDGEMENTS

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