A Progress Report on

Installation, Maintenance, and Upgrade of Strong Motion Accelerographs of SAFER CITIES Project

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Introduction

The SAFER CITIES project under COSMOS-WSSI (The Consortium of Organizations for Strong Motion Observation Systems and The World Seismic Safety Initiative), USA has provided 14 strong motion accelerographs (Kinemetrics SMA-1's) to IIT Kanpur for installation at different engineering college across the country.

Locations of installations

The instruments have been installed as per the procedure explained in the manual at the following locations:

1. Kanpur (2 instruments)
2. Allahabad (1 instrument)
3. Varanasi (1 instrument)
4. Lucknow (1 instrument)
5. Kurukshetra (1 instrument)
6. Kolkata (2 instruments)
7. Jhansi (1 number)
8. Bhopal (1 number)
9. Nagpur (1 number)
10. Indore (1 number)
11. Ahmedabad (1 number)
12. Vadodara (1 number)

Necessary training for the operation (calibration etc.) and maintenance (replacement of film, battery, etc.) were provided to the faculty members of the engineering colleges where the instruments are installed.

Procurement of film and batteries

For the maintenance of SMA's we have procured consumables like film and batteries for all the instruments and replaced these as per the maintenance schedule. The procurement of

photographic film was difficult since M/s Kodak India Ltd. was ready to supply the film only if there is a minimum quantity (70 nos. films) order for films. However, M/s Kodak India did send us some films as samples since our requirement was small and rest of the film we were able to manage from Indian Institute of Technology Roorkee who have the same instruments (more than 100 installations). We could purchase the equivalent battery for the instruments from a local supplier.

Data Recording

There is no strong motion event recorded till date from any of the instrument as the site of their installations were away from the earthquakes that occurred during this period.

Digital Upgrade of SMA-1

During the use of SMA-1's we have faced some problems associated with operation and maintenance of SMA-1. The event recording media i.e. 70 mm monochrome film rolls, being out of production, are required to be ordered for large quantity and also have limited shelf life (2 years). Further, it takes considerable time before the actual data processing in developing the photographic film and its digitization process.

In order to overcome the limitations and to salvage reliable SMA-1's, a low cost solution has been developed at IIT Kanpur to convert the existing analog SMA-1's into Digital Strong Motion Recorders and a prototype model has already been developed and tested at IIT Kanpur using a shake table. A brief write-up on the development work done at IIT Kanpur in this regard is attached along with this report. We are planning to replace all the 14 analog SMA-1's into digital SMA by the end of October 2006.

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Enclosure: A brief write-up on SMA upgrade

DIGITAL UPGRADE FOR ANALOG STRONG MOTION ACCELEROGRAPHS

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Introduction

Strong motion data recorded during an earthquake provides valuable information for design of earthquake resistant structures. Strong Motion Accelerograph (Model: SMA-1; Kinemetrics Inc., USA) is a reliable, battery operated analog strong motion instrument specifically designed to measure strong ground motions due to earthquakes and structural response. The sensors of SMA-1 are flexure type accelerometers in which the movement of mass is recorded using carefully designed optics on a photographic film when triggered by acceleration above .01g. The instrument calibration provides direct relationship between deflection of mass and acceleration. The SMA-1 is capable of recording a single earthquake or a sequence of earthquakes and aftershocks, lasting as long as 25 minutes, on a full roll of film (approx. 15 m in length). After an event is recorded, the film magazine can be taken to a darkroom for processing.

The Kinemetrics SMA-1 Strong Motion Accelerograph became the world standard with more than 8,000 supplied during three decades (1970s, 80s and 90s). These instruments were installed in more than 70 countries, with many still providing data today. A large percentage of the world's inventory of strong ground motion records has been recorded on the SMA-1 (reference: CUREE report on ***The Importance of the Development of Instruments In the History of Earthquake Engineering by Robert Reitherman***). IIT Kanpur has received 14 SMA-1's from SAFER CITIES project under COSMOS-WSSI (The Consortium of Organization for Strong Motion Observation Systems and The World Seismic Safety Initiative). These instruments have been installed at different engineering colleges across the country for ease in operation and maintenance.

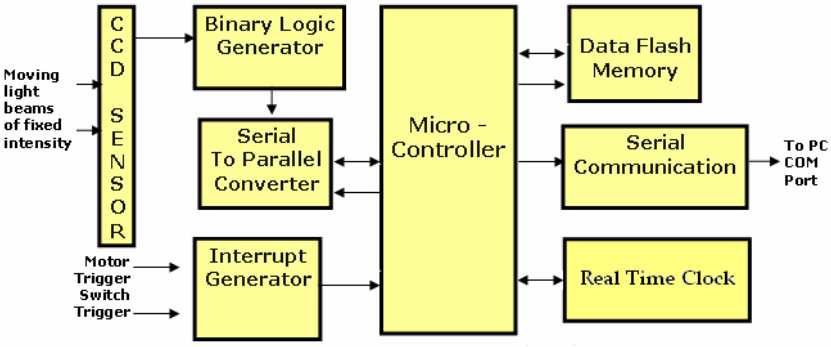
Though the analog SMA-1 is a reliable and rugged analog instrument, however, there are problems associated with its operation and maintenance. The event recording media i.e. 70 mm monochrome film rolls, being out of production, are required to be ordered for large quantity and also have limited shelf life (2 years). Further, it takes considerable time before the actual data processing in developing the photographic film and its digitization process. The price of the film (approx. USD 50 each) is also one of main cost for the maintenance of the instruments. Due to these limitations, the SMA-1's are being replaced by digital ones around the world.

Objectives

In order to overcome the limitations and to salvage reliable SMA-1's, a low cost solution has been developed at IIT Kanpur to convert the existing analog SMA-1's into Digital Strong Motion Recorders (DSMR). The following were the main objectives for the development of DSMR:

- *To design and develop an indigenous embedded system which scans the light beams from the optics of existing SMA-1 through a CCD sensor and store the scanned data files on digital memory which can be transferred to the computer as and when desired.*
- *To develop front end software, which reconstructs the waveforms, computes the g-values in each direction and stores these values on a excel sheet on the computer.*

The prototype DSMR developed in-house is an embedded system comprising of a CCD image sensor which is placed at the location of the photographic film and a flash memory which is used to store the scanned data. The sequence of operation is shown in the following block diagram.



Benefits

The problems associated with the data recording on photographic film and the procurement of the film itself, have been eliminated in the upgraded instrument. Moreover the power consumption has been reduced as the load of the motor is eliminated. Also as the microcontroller is most of the time in the sleep mode, it draws minimum current which is in the range of milliamperes.

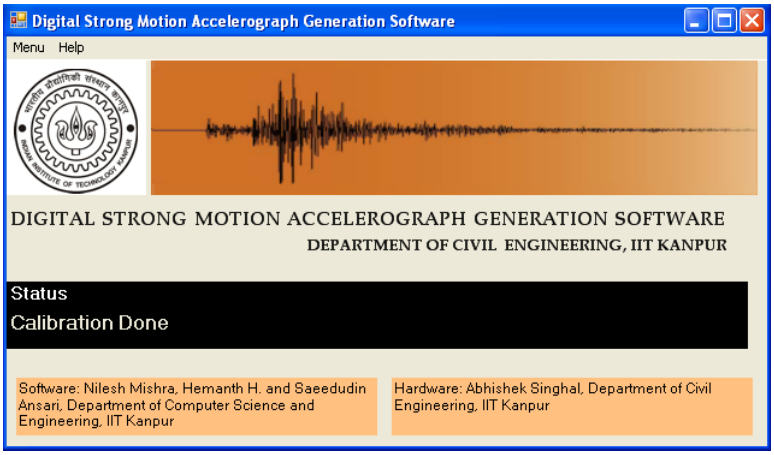
The digital retrofit kit being offered by the manufacturer of SMA-1 (Kinemetrics Inc.) uses altogether new sensor and digital recording media in the same box and costs about USD2,000 (including freight, taxes etc.) whereas the cost of consumables for the fabrication of prototype embedded system developed at IIT Kanpur for converting the analog SMA-1 in to a digital strong motion recorder (DSMR) is about USD 100 only which can be further lowered down when there is a large quantity requirement.

Technical Specifications

The main specifications of the modified DSMR are as follows:

- Sampling frequency: 155 Hz
- Bandwidth: DC -30 Hz
- Recording time: 14 minutes capacity, with multiple events read /writes.
- Resolution: 0.001g
- Power Consumption: 0.63 mA (Main Sleep Mode)

A Microsoft.Net based data collection and display software program has been written which takes the binary data from the text file and generates the required accelerogram image and the calibrated g-values along with actual time is written on a excel sheet simultaneously for further data processing.



Other Applications

The prototype embedded system developed to scan the light beams and obtaining the corresponding g-values in real time can also be used for many other applications requiring online data acquisition and monitoring from various sensors like sound, temperature, pressure, displacement etc. with slight modification in the hardware/software.