

MEMS Multi Sensor Intelligence Damage Detection for Wind Turbines

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ABSTRACT: Maintenance and repair of wind turbine structures have become more challenging and at the same time essential as they evolve into larger dimensions or located in places with limited access. Even small structural damages may invoke catastrophic detriment to the integrity of the system. So, cost-effective, predictive, and reliable structural health monitoring (SHM) system has been always desirable for wind turbines. A real-time nondestructive SHM technique based on multisensor data fusion is proposed in this paper. The objective is to critically analyze and evaluate the feasibility of the proposed technique to identify and localize damages in wind turbine blades. The structural properties of the turbine blade before and after damage are investigated through different sets of finite element method simulations. Based on the obtained results, it is shown that information from smart sensors, measuring strains, and vibrations data, distributed over the turbine blades can be used to assist in more accurate damage detection and overall understanding of the health condition of blades.

I. INTRODUCTION

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is specifically designed for a particular function. Industrial machines, automobiles, medical equipment, cameras, household appliances, airplanes, vending machines and toys are among the myriad possible hosts of an embedded system. Embedded systems that are programmable are provided with programming interfaces, and embedded systems programming is a specialized occupation.

Modern embedded systems are often based on a microcontroller that is central processing units with integrated memory and/or peripheral interfaces but ordinary microprocessors using external chips for memory and peripheral interface circuits are also still common, especially in more complex systems. In either case, the processor used may be types ranging from rather general purpose to very specialized in certain class of computations, or even custom designed for the application at hand. A common standard class of dedicated processors is the digital signal processor. Program memory in the form of ferroelectric random access memory or read only memory is also often included on chip, as well as a AVR small amount of random access memory.

The key characteristic, however, is being dedicated to handle a particular task. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, and largely complex systems like hybrid vehicles and others.

1.1 Millimeter-Wave Detection of Localized Anomalies in the Space Shuttle External Fuel Tank Insulating Foam

Author: Sergey Kharkovsky, Joseph T., Mohamed A. Abou-Khousa, Reza Zoughi, Fellow, and Frank L. Hepburn

The Space Shuttle Columbia's catastrophic accident emphasizes the growing need for developing and applying effective, robust, and life-cycle-oriented nondestructive testing (NDT) methods for inspecting the shuttle external fuel tank spray on foam insulation (SOFI). Millimeter-wave nondestructive testing techniques were one of the methods chosen for evaluating their potential for inspecting these structures. Several panels with embedded anomalies were

produced and tested for this purpose. Near-field and far-field millimeter-wave nondestructive testing methods were used for producing images of the anomalies in these panels.

The results of an investigation for the purpose of detecting localized anomalies in several spray on foam insulation panels. To this end, continuous-wave reflectometers at single frequencies of 33.5, 70, or 100 GHz representing a relatively wide range of millimeter-wave spectrum and utilizing different types of radiators were employed. The resulting raw images revealed a significant amount of information about the interior of these panels. However, using simple image processing techniques, the results were improved in particular as it relates to detecting the smaller anomalies.

1.2 MULTISENSOR Fusion and Integration AND Theories, Applications, and its Perspectives

Author: Ren C. Luo, Fellow, Chih Chia Chang, and Chun Chi Lai

The decision-making processes in an autonomous mechatronic system rely on data coming from multiple sensors. An optimal fusion of information from distributed multiple sensors requires robust fusion approaches. The science of multi sensor fusion and integration is formed to treat the information merging requirements. Multisensor Fusion Integration(MFI) aims to provide the system a more accurate perception enabling an optimal decision to be made. The wide application spectrum of multisensor fusion integration in mechatronic systems includes industrial automation, the development of intelligent robots, military applications, biomedical applications, and Micro Electro Mechanical Systems (MEMS)/Nano Electro Mechanical Systems (NEMS). The theories and approaches of multisensor fusion integration with its applications have more advantages. Furthermore, sensor fusion methods at different levels, namely, estimation methods, classification methods and inference methods, are the most frequently used algorithms. Future perspectives of multisensor fusion integration deployment are included in the concluding remarks.

Lower accuracy and additional phase delays in distributed tracking problems. High complexity and extensive memory requirements in large scale tasks. High computational cost comes with a larger number parameters in models. Lacking of transparency of results. The sensory data fused at the signal-level can be single- or multidimensional signal while the data being fused at the pixel level are multiple images. The sensory data under fusion at this level simply represents the output or the state of the plant. The signal-level fusion can be used in real-time applications, and can be considered as an additional step of the overall fusion process of the system. Due to the different sampling properties of multiple sensors, the multisensory data need to be synchronized and adapted before the fusion process. At this level, statistical estimation methods have been successfully used. They can be grouped into non recursive methods and recursive ones. Nonrecursive estimation methods, such as the weighted-average method and the least squares method, are normally used only to merge redundant data. Since these methods execute only once to get an optimal estimation, they are time efficient compared with recursive algorithms.

1.3 Data Fusion System Engineering

Author: AlanN. Steinberg Utah

The methods for the cost-effective development and integration of multi-sensor fusion technology. The methods presented extend the Correlation Data Fusion Engineering Guidelines with significant evolution. The key new insight is in formulating the system engineering process as a resource management problem; allowing the application of the Bowman's model of the duality between data fusion and resource management. Data fusion as a process of combining data or information to estimate or predict entity states. So-defined, data fusion pervades all biological cognitive activity and virtually every automated approach. Unfortunately, the very universality of data fusion has engendered a profusion of overlapping research and development in many applications.

1.4 A review of recent advances in wind turbine condition monitoring and fault diagnosis

Author: B. Lu, Y. Li, X. Wu, and Z. Yang,

The state-of-the-art advancement in wind turbine condition monitoring and fault diagnosis for the recent several years is reviewed. Since the existing surveys on wind turbine condition monitoring cover the literatures up to 2006, this review aims to report the most recent advances in the past three years, with primary focus on gearbox and bearing, rotor and blades, generator and power electronics, as well as system-wise turbine diagnosis. There are several major trends observed through the survey. Due to the variable-speed nature of wind turbine operation and the unsteady load involved, time-frequency analysis tools such as wavelets have been accepted as a key signal processing tool for

such application. Acoustic emission has lately gained much more attention in order to detect incipient failures because of the low-speed operation for wind turbines. There has been an increasing trend of developing model based reasoning algorithms for fault detection and isolation as cost-effective approach for wind turbines as relatively complicated system. The impact of unsteady aerodynamic load on the robustness of diagnostic signatures has been notified. Decoupling the wind load from condition monitoring decision making will reduce the associated down-time cost. Embedded temperature detector required. Expensive for online operation. Difficult to detect incipient faults. Sometimes low signal to noise ratio. Due to the variable-speed nature of wind turbine operation and the unsteady load involved, time-frequency analysis tools such as wavelets have been accepted as a key signal processing tool for such application.

1.5 Enhancement of damage-detection of wind turbine blades via CWT-based approaches

Author: Chin-Shun Tsai, Cheng-Tao Hsieh, and Shyh-Jier Huang

A continuous wavelet transform-based approach is applied to enhance the damage-detection capability of wind turbine blades. With the time--frequency localization features embedded in wavelets, the time and scale information of the acquired signals can be presented as a visualization scheme, where the condition monitoring of turbine blades can be better realized. Based on these sensor signals, this proposed approach was applied to discriminate the damaged structure from the healthy one under several scenarios. Test results have demonstrated the practicality and advantages of the proposed method for the application considered. As analyzed from the theory viewpoints, the wavelet can be formulated via a family of basis functions such that signals can be described in a localized time and frequency format. Hence, by employing the long windows at low frequencies and short windows at high frequencies, the wavelet transform will be capable of comprehending the time and frequency information simultaneously.

1.6 Real-Time Data Fusion and MEMS Sensors Fault Detection in an Aircraft Emergency Attitude Unit ssBased on Kalman Filtering

Author: M. Carminati, G. Ferrari, R. Grassetti, and M. Sampietro

The design, realization, and experimental validation of an original avionic attitude estimation unit are presented. The core of the system is a nine-state extended Kalman filter that optimally blends complementary kinematic data provided by orthogonal triads of inertial micro-electro-mechanical systems sensors: rate gyros and accelerometers. The unit is embedded in a novel aircraft emergency guidance system based on miniaturized solidstate sensors. While achieving the required extreme compactness, state-of-the-art performance is preserved: 50 Hz update rate, 0.1° angular resolution, 0.5° static accuracy, and 2° dynamic accuracy 400 °/s max. angular rate, 10 gmax. acceleration, all experimentally verified and granted over the extended thermal range. The selection of the state variables has been carefully trimmed in order to maximize the performance/speed tradeoff for real-time running in an embedded processor. The adoption of the Kalman observer also enables the implementation of model based sensor fault detection with no extra computational cost.

Although MEMS inertial sensors provide low cost and extreme miniaturization, perfectly suitable for this application, their performance are significantly poorer when compared to traditional macroscopic sensors. The unit is embedded in a novel aircraft emergency guidance system based on miniaturized solidstate sensors.

1.7 Strain Transfer Analysis of Surface-Bonded MEMS Strain Sensors

Author: Maziar Moradi and Siva Sivoththaman

The transmission of strain fields in adhesively bonded MEMS strain sensors is analyzed. In strain sensors that are attached to host structures using adhesive layers such as epoxy, complete strain transfer to the sensor is hindered due to the influence of the adhesive layer on the transfer. An analytical model, validated by finite element method simulation, to provide insight and accurate formulation for strain transfer mechanism for bonded sensors. A shear-lag parameter has been introduced to account for the component geometry and properties. The model is capable of predicting the strain transmission ratio through a sensor gauge factor, and it clearly establishes the effects of the flexibility, length, and thickness of the adhesive layer and MEMS sensor substrate. Finally, modifications to sensor substrates, by the implementation of micromachined tapered edges and trench etching, are proposed in order to increase the strain transmission ratio. It has been found, for the selected case study, that the sensor sensitivity could be enhanced

by up to 30%. This work on bonding analysis is applicable for performance prediction and calibration in sensor systems design.

1.8 Fiber Optic Sensor in Structural Health Monitoring

Author: José Miguel López-Higuera, OSA, Luis Rodriguez Cobo, Antonio Quintela Incera, and Adolfo Cobo,

Structural Health Monitoring (SHM) can be understood as the integration of sensing and intelligence to enable the structure loading and damage-provoking conditions to be recorded, analyzed, localized, and predicted in such a way that nondestructive testing becomes an integral part of them. In addition, structural health monitoring systems can include actuation devices to take proper reaction or correction actions. Structural health monitoring sensing requirements are very well suited for the application of Optical Fiber Sensors (OFS), in particular, to provide integrated, quasi-distributed or fully distributed technologies. In this tutorial, after a brief introduction of the basic structural health monitoring concepts, the main fiber optic techniques available for this application are reviewed, emphasizing the four most successful ones.

Then, several examples of the use of optical fiber sensors in real structures are also addressed, including those from the renewable energy, transportation, civil engineering and the oil and gas industry sectors. Finally, the most relevant current technical challenges and the key sector markets are identified.

II. PROPOSED SYSTEM

To identify and localize damages in wind turbine blades using multisensor. Initially the structural properties of the turbine blade before and after damage are investigated. This is done by different sets of finite element method simulations. Based on the obtained results, from the smart sensor we can measure the following. Strains and vibrations data, distributed over the turbine blades are detected. This can be used to assist in more accurate damage detection.

A real-time non destructive structural health monitoring technique based on multisensor data fusion is proposed in this paper. The objective is to critically analyze and evaluate the feasibility of the proposed technique to identify and localize damages in wind turbine blades.

The structural properties of the turbine blade before and after damage are investigated through different sets of finite element method simulations. Based on the obtained results, it is shown that information from smart sensors, measuring strains, and vibrations data, distributed over the turbine blades can be used to assist in more accurate damage detection and overall understanding of the health condition of blades. Data fusion technique is proposed to combine these two diagnostic. A coherent representation of objects combining modalities enables us to have meaningful perceptual experiences. Indeed, multisensory integration is central to adaptive behavior because it allows us to perceive a world of coherent perceptual entities

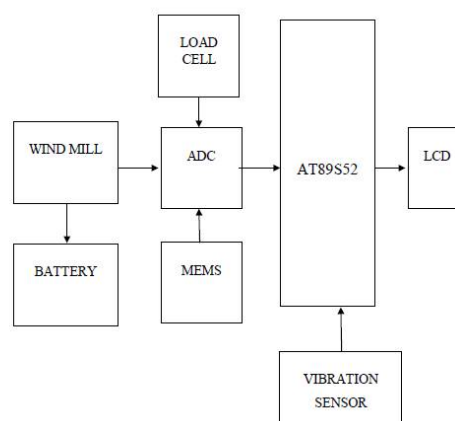


Fig 2.1 Block Diagram

2.1 MEMS MULTI SENSORY DEVICE

Multisensory integration, also known as multimodal integration, is the study of how information from the different sensory modalities, such as sight, sound, touch, smell, self-motion and taste, may be integrated by the nervous system. A coherent representation of objects combining modalities enables us to have meaningful perceptual experiences. Indeed, multisensory integration is central to adaptive behavior because it allows us to perceive a world of coherent perceptual entities. Multisensory integration also deals with how different sensory modalities interact with one another and alter each other's processing.

Regardless of terminology, the uniting factor of a MEMS device is in the way it is made. While the device electronics are fabricated using 'computer chip' IC technology, the micromechanical components are fabricated by sophisticated manipulations of silicon and other substrates using micromachining processes. Processes such as bulk and surface micromachining, as well as high-aspect-ratio micromachining selectively remove parts of the silicon or add additional structural layers to form the mechanical and electromechanical components. While integrated circuits are designed to exploit the electrical properties of silicon, MEMS takes advantage of either silicon's mechanical properties or both its electrical and mechanical.

Multi-modal perception is a scientific term that describes how humans form coherent, valid, and robust perception by processing sensory stimuli from various modalities. Surrounded by multiple objects and receiving multiple sensory stimulations, the brain is faced with the decision of how to categorize the stimuli resulting from different objects or events in the physical world. The nervous system is thus responsible for whether to integrate or segregate certain groups of temporally coincident sensory signals based on the degree of spatial and structural congruence of those stimulations. Multi-modal perception has been widely studied in cognitive science, behavioral science, and neuroscience

Despite MEMS being an enabling technology for the development and production of many new industrial and consumer products, MEMS is also a disruptive technology in that it differs significantly from existing technology, requiring a completely different set of capabilities and competencies to implement it. MEMS involves major scaling, packaging and testing issues, and, as a disruptive technology, faces challenges associated with developing manufacturing processes that no longer fit established methods. For the true commercialisation of MEMS, foundries must overcome the critical technological bottlenecks, the economic feasibility of integrating MEMS-based components, as well as the market uncertainty for such devices and applications. Cost reduction is critical and will ultimately result from better availability of infrastructure, more reliable manufacturing processes and technical information as well as new standards on interfacing.

2.1.1 MICRO CONTROLLER

Program memory in the form of ferroelectric random access memory or read only memory is also often included on chip, as well as a AVR small amount of random access memory. A microcontroller is a small computer and it is fabricated on a single integrated circuit and in this it containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption single-digit milliwatts or microwatts. They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping central processing unit clock and most peripherals off may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor, with higher clock speeds and power consumption.

External Memory Microcontroller – When an embedded structure is built with a microcontroller which does not comprise of all the functioning blocks existing on a chip it is named as external memory microcontroller. For

illustration- 8031 microcontroller does not have program memory on the chip. Embedded Memory Microcontroller – When an embedded structure is built with a microcontroller which comprise of all the functioning blocks existing on a chip it is named as embedded memory microcontroller. For illustration- 8051 microcontroller has all program & data memory, counters & timers, interrupts, I/O ports and therefore its embedded memory microcontroller.

2.1.2 MEMS

Micro electro mechanical systems are the technology of very small miniaturized devices; and it merges at the nano-scale into nanoelectromechanical systems and nanotechnology. MEMS are also referred to as micro machines or micro systems technology. Micro electro mechanical systems is the technology of very small devices; it merges at the nano-scale into nanoelectromechanical systems and nanotechnology. MEMS are also referred to as micromachines in Japan, or Micro Systems Technology (MST) in Europe.

MEMS are separate and distinct from the hypothetical vision of molecular nanotechnology or molecular electronics. MEMS are made up of components between 1 to 100 micrometres in size i.e. 0.001 to 0.1 mm, and MEMS devices generally range in size from 20 micrometres to a millimetre i.e. 0.02 to 1.0 mm. They usually consist of a central unit that processes data the microprocessor and several components that interact with the surroundings such as micro sensors. At these size scales, the standard constructs of classical physics are not always useful. Because of the large surface area to volume ratio of MEMS, surface effects such as electrostatics and wetting dominate over volume effects such as inertia or thermal mass.

Micro-electromechanical systems is a technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. Paul Saffo of the Institute for the Future in Palo Alto, California, believes MEMS or what he calls analog computing will be "the foundational technology of the next decade." MEMS is also sometimes called smart matter.

MEMS are already used as accelerometers in automobile air-bags. They've replaced a less reliable device at lower cost and show promise of being able to inflate a bag not only on the basis of sensed deceleration but also on the basis of the size of the person they are protecting. Basically, a MEMS device contains micro-circuitry on a tiny silicon chip into which some mechanical device such as a mirror or a sensor has been manufactured. Potentially, such chips can be built in large quantities at low cost, making them cost-effective for many uses.

The interdisciplinary nature of MEMS utilizes design, engineering and manufacturing expertise from a wide and diverse range of technical areas including integrated circuit fabrication technology, mechanical engineering, materials science, electrical engineering, chemistry and chemical engineering, as well as fluid engineering, optics, instrumentation and packaging. The complexity of MEMS is also shown in the extensive range of markets and applications that incorporate MEMS devices. MEMS can be found in systems ranging across automotive, medical, electronic, communication and defence applications. Current MEMS devices include accelerometers for airbag sensors, inkjet printer heads, computer disk drive read/write heads, projection display chips, blood pressure sensors, optical switches, microvalves, biosensors and many other products that are all manufactured and shipped in high commercial volumes.

The potential of very small machines was appreciated before the technology existed that could make them Richard Feynman's Plenty of Room at the Bottom. MEMS became practical once they could be fabricated using modified semiconductor device fabrication technologies, normally used to make electronics. These include moulding and plating, wet etching and dry etching, electro discharge machining, and other technologies capable of manufacturing small devices. An early example of a MEMS device is the resonator electromechanical monolithic resonator. MEMS, an acronym that originated in the United States, is also referred to as Microsystems Technology (MST). Regardless of terminology, the uniting factor of a MEMS device is in the way it is made. While the device electronics are fabricated using 'computer chip' IC technology, the micromechanical components are fabricated by sophisticated manipulations of silicon and other substrates using micromachining processes. Processes such as bulk and surface micromachining, as well as high-aspect-ratio micromachining selectively remove parts of the silicon or add additional structural layers to form the mechanical and electromechanical components. While integrated circuits are designed to exploit the electrical properties of silicon, MEMS takes advantage of either silicon's mechanical properties or both its electrical and mechanical properties. In the most general form, MEMS consist of mechanical microstructures, micro sensors, micro actuators and microelectronics, all integrated onto the same silicon chip. Micro sensors detect changes in the system's environment by measuring mechanical, thermal, magnetic, chemical or

electromagnetic information or phenomena. Microelectronics process this information and signal the micro actuators to react and create some form of changes to the environment. MEMS devices are very small; their components are usually microscopic. Levers, gears, pistons, as well as motors and even steam engines have all been fabricated by MEMS. However, MEMS is not just about the miniaturization of mechanical components or making things out of silicon (in fact, the term MEMS is actually misleading as many micro machined devices are not mechanical in any sense). MEMS is a manufacturing technology; a paradigm for designing and creating complex mechanical devices

2.1.3 ADC

An analog-to-digital converter is a device that converts a continuous physical quantity to a digital number that represents the quantity's amplitude. An analog-to-digital converter is a device that converts a continuous physical quantity that is usually voltage and to a digital number that represents the quantity's amplitude.

The conversion involves quantization of the input, so it necessarily introduces a small amount of error. Furthermore, instead of continuously performing the conversion, an analog-to-digital converter does the conversion periodically, sampling the input. The result is a sequence of digital values that have been converted from a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal. The presence of quantization error limits the dynamic range of even an ideal analog-to-digital converter.

An analog-to-digital converter is defined by its bandwidth the range of frequencies it can measure and its signal to noise ratio how accurately it can measure a signal relative to the noise it introduces. The actual bandwidth of an analog-to-digital converter is characterized primarily by its sampling rate, and to a lesser extent by how it handles errors such as aliasing. The dynamic range of an analog-to-digital converter is influenced by many factors, including the resolution the number of output levels it can quantize a signal to, linearity and accuracy how well the quantization levels match the true analog signal and jitter small timing errors that introduce additional noise. The dynamic range of an analog-to-digital converter is often summarized in terms of its Effective Number Of Bits (ENOB), the number of bits of each measure it returns that are on average not noise. An ideal analog-to-digital converter has an ENOB equal to its resolution. Analog-to-digital converter s are chosen to match the bandwidth and required signal to noise ratio of the signal to be quantized. If an analog-to-digital converter operates at a sampling rate greater than twice the bandwidth of the signal, then perfect reconstruction is possible given an ideal analog-to-digital converter and neglecting quantization error. The presence of quantization error limits the dynamic range of even an ideal analog-to-digital converter, however, if the dynamic range of the analog-to-digital converter exceeds that of the input signal, its effects may be neglected resulting in an essentially perfect digital representation of the input signal.

An analog-to-digital converter may also provide an isolated measurement such as an electronic device that converts an input analog voltage or current to a digital number proportional to the magnitude of the voltage or current. However, some non-electronic or only partially electronic devices, such as rotary encoders, can also be considered analog-to-digital converters. The digital output may use different coding schemes. Typically the digital output will be a two's complement binary number that is proportional to the input, but there are other possibilities. An encoder, for example, might output a Gray code. The inverse operation is performed by a digital-to-analog converter.

2.1.4 MOTOR DRIVER

Motor Driver IC which is used to drive DC on either direction. It is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control two DC motor with a single L293D IC. Dual H-bridge Motor Driver integrated circuit. The l293d can drive small and quiet big motors as well.

A motor driver IC is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver ICs act as an interface between microprocessors in robots and the motors in the robot. Motor Driver ICs are primarily used in autonomous robotics only. Also most microprocessors operate at low voltages and require a small amount of current to operate while the motors require a relatively higher voltages and current . Thus current cannot be supplied to the motors from the microprocessor. This is the primary need for the motor driver IC.

It can drive small and quiet big motors as well. As long as the conditions are safe the motor runs smoothly. The motor runs accordingly based on the direction of wind and it is found that using virtual terminal it can be noticeable. Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz,

for low power consumption single-digit milliwatts or microwatts. They will generally have the ability to retain functionality while waiting for an event.



Fig 2.2 Motor Driver IC

III. RESULTS AND DISCUSSION

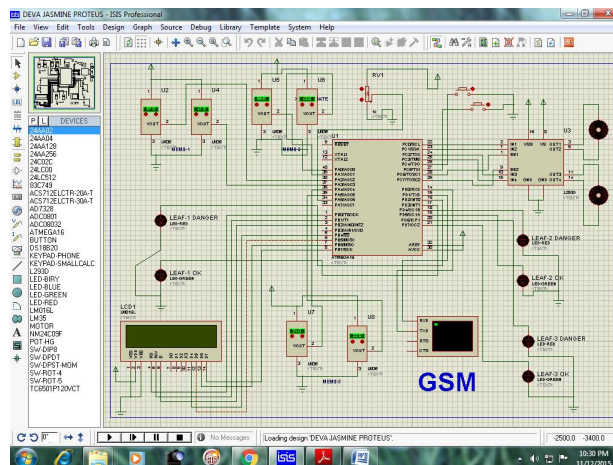


Fig 3.1 Overall design

The above figure shows the overall design in which it includes three MEMS which are placed in the blades of windmill incorporated in a microcontroller along with the motors. It also includes the wind sensor which senses the wind and turns the direction accordingly. It is also acknowledged to the user/owner using the GSM technique.

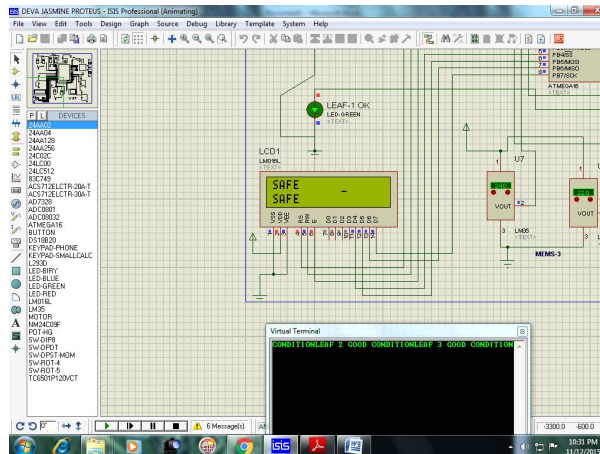


Fig 3.2 Value of MEMS

In the above figure, it determines the value of MEMS and shown that condition is safe. It accurately shows the strain distribution in vicinity of the crack from simulation results of healthy and damaged blades.

In the damaged blade, sudden decrease of strain magnitude is easily detectable even at locations as far as one meter on either side of the crack. This important result underlines the usefulness of strain field analysis in determining the configurations for sensor deployment. Strain sensors show smooth variation of strain distribution based on their locations and vibration frequency shift is very low. Therefore, indicators show healthy status.

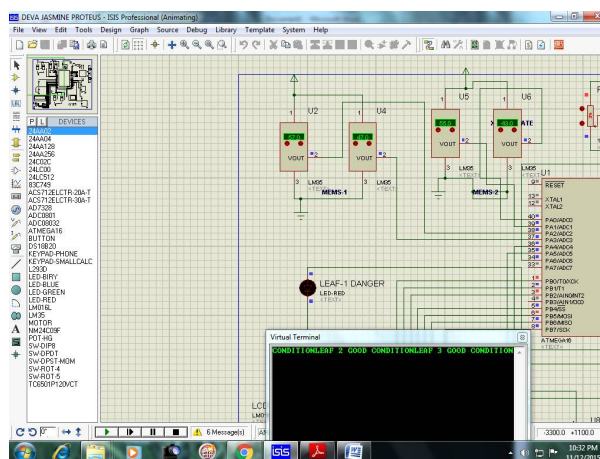


Fig 3.3 Condition of the blade

In the figure 3.3, ,MEMS is shown along with the virtual terminal in which the condition is shown. The decision fusion node, either for strain sensors or vibration sensors, can also use data on material properties, load history referred to as external knowledge to produce accurate indicators.

Since deflection is large and may result in nonlinear behavior, geometrical nonlinear analysis was required in the simulation. The acknowledgment message is received. The effect of the centrifugal force creating a restoring force on the deflecting blade is ignored. The condition of the blade is shown in this step.

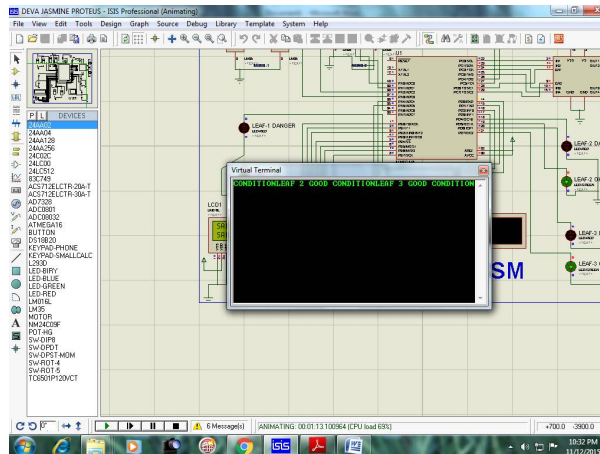


Fig 3.4 Virtual terminal

Virtual terminal is used to receive the acknowledged messages from the windmill. Strain and vibration sensors send their reliable measurements through some data fusion nodes to F1 and F2 which outputs the variables .

A number between 0 and 1, indicates damage severity, a confidence variable associated, which can be obtained from the variances. The cell F receives input data and generates the decision signal as output. The thresholds variables can be calculated using a history models or experiments and are regarded as external knowledge.

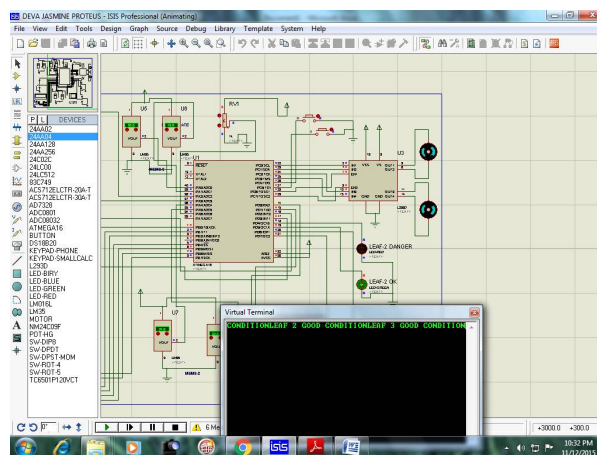


Fig 3.5 Motor

In the above figure ,the motor is shown. Motor driver integrated circuit which is used to drive DC on either direction. It is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control two DC motor with a single L293D IC. Dual H-bridge Motor Driver integrated circuit.

It can drive small and quiet big motors as well. As long as the conditions are safe the motor runs smoothly. The motor runs accordingly based on the direction of wind and it is found that using virtual terminal it can be noticeable.

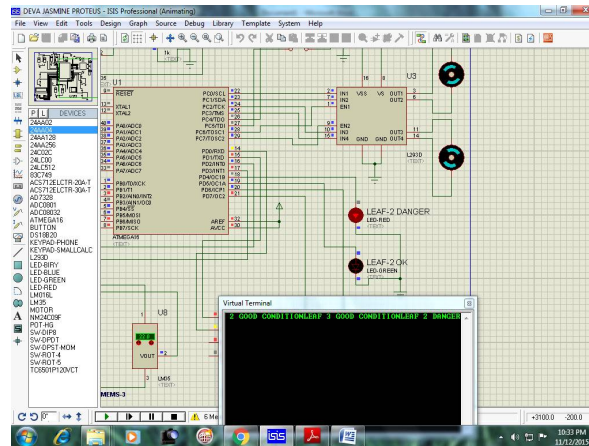


Fig 3.6 Danger signal

In the above figure, danger signal is shown by street lights as soon as the faulty streetlights are identified. It may stop the motor and gives the acknowledgment signal to the user/owner. Both strain sensors and vibration signals show very small perturbation which is less than the threshold or with low confidence values which causes only a warning condition. Although strain sensors show normal condition but vibration frequency shift is more than threshold which causes the final decision indicator goes to one and sounds damage blade condition alarm. If both strain sensors signal and vibration signal indicates existence of a damage which produces a status of damaged blade alarm.

IV. CONCLUSION

A new methodology to nondestructively locate and estimate the severity of damage in wind turbine blade structures has been presented. The method is based on strain field distribution analysis combined with natural frequency variation detection which provides global as well as local information on structural health condition. The proposed technique does not require direct human accessibility to the structure, is cost effective, easy to operate, and has the enhanced capability for realtime damage detection. A major advantage of this method is that it uses one type of sensor, a MEMS strain sensor, to measure both vibration and strain signals and leads to accurate readings and much less noise. From the simulation results, we demonstrated that the proposed technique was successful in the turbine blade damage detection under various scenarios. Another advantage of this method is that it can be implemented without the detailed knowledge of material properties or prior models and responses. One of the challenges of the technique is the ability to identify minor cracks or to differentiate the type of damages on composite structures.

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