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Date: 2017/07/19
This is a part of the research results of the project: Study of Energy-Harvesting Wireless Sensor Node Design and Its Application to Industrial Environment Monitoring System

Grant No: MOST 105-2221-E-027-063

Period: 08/01/2016~10/31/2017
Outline

1. Motivation
2. Principle of using piezoelectricity
3. Sensor node with a piezoelectric energy-harvesting module
4. Environment monitoring system implementation
5. Conclusion
Motivation

In recent years, wireless sensor network technology has been improved rapidly, that sensor nodes have functions of self-sensing, self-computing and communication capabilities, so many research techniques have been proposed and applied in various application.

In various applications, the wireless sensor network mainly focus on:

- The stability of the network
- The operation time of the network
Motivation

- This paper mainly uses energy saving and low consumption, to extend the wireless sensor nodes and network life.

- Low energy consumption: When sensor node is too far away from base station, we use for multi-hop routing return the sensing data back to the base station to save energy consumption and distance problems during transmission.

- The nodes installed around the motor collect environmental information and convert the vibration energy on the motor into the basic operation of the energy supply node.
Principle of using piezoelectricity
Principle of using piezoelectricity

Through the standard piezoelectric equation and RC circuit equation, the relationship among the output power of piezoelectric energy harvesting circuit, input vibration frequency, and amplitude can be derived.

\[
P = \frac{V^2}{2R} = \frac{1}{2R} \times \frac{\left(\frac{2k_{31} t_c}{k_2}\right)^2 \frac{c_p}{\varepsilon} A_{in}^2}{\left[\frac{\omega_n^2}{\omega RC_b} - \omega \left(\frac{1}{RC_b} + 2\zeta \omega_n\right)\right]^2 + \left[\omega_n^2 (1 + k_{31}^2) + \frac{2\zeta \omega_n}{RC_b} - \omega^2\right]^2}
\]  

By the equation (1), when the piezoelectric energy harvesting module operates at the resonant frequency (\(\omega = \omega_n\)), its output power can reach the maximum.
Principle of using piezoelectricity

\[
P = \frac{m^2}{2k} \times \frac{RC_b^2 \left( \frac{2k_{31}}{t_c} \right)^2 \frac{c_p}{\varepsilon} A_{in}^2}{(4\zeta^2 + k_{31}^4) (RC_b)^2 k + 4\zeta k_{31}^2 RC_b \sqrt{km} + 4\zeta^2 m}
\]

Equation (2) shows that the output power will change due to the increase in the mass of piezoelectric material, so increase the mass of piezoelectric material can effectively reduce the resonance frequency, and increase the overall output power.
Sensor node with a piezoelectric energy-harvesting module
The node developed in this paper consists of two parts: the piezoelectric energy module and the wireless sensor node with vibration measurement.
Energy-harvesting module

- The designed module consisting of AC rectifier and voltage regulator can convert the voltage produced by the piezoelectric material into DC voltage supplying the node for vibration measurement.
According to the mentioned part, we have developed a fixture for piezoelectric energy-harvesting module, which can be used to make micro-electromechanical system compact.
Packet format

- In this paper, the communication between the sensor nodes and the base station is Zigbee protocol and the IC used is CC2420.
- To allow the system to more effectively interpret the content, the format of packet contains:
  - Control ID: Let the node and the base station interpret this packet type faster.
  - Sink ID: Let the server understand which sink sent back the data packet.
  - Node data (8bit)
Environment monitoring system
Environment monitoring system

- The system architecture includes sensor network, local server and cloud monitoring platform.
Environment monitoring system

Server: real-time monitoring interface

- The system server consists of real-time monitoring interface and motor diagnostic interface, the functionalities of monitoring interface are divided into:

```
Main functionalities

- Initial setup
  - User login

- WSN setup
  - Node reset
  - Other setup

- Data storage & alarming
  - Field data display
  - Database
  - Alarm broadcasting
```
Environment monitoring system

Login interface
Environment monitoring system

Real-time monitoring interface
Environment monitoring system

Detailed temperature and humidity information of node 2

Implementation interface
Environment monitoring system

Temperature, humidity history data trends

Implementation interface
Environment monitoring system

- The motor failure diagnosis system used in this paper is a smart motor variable speed rotation fault diagnosis system developed by the past research team combined with mixed discriminant analysis.

- This paper integrates this motor failure detection function in the motor failure diagnosis interface to provide a complete diagnostic platform.
Environment monitoring system

- **WSN** → motor vibration measurement → estimate rotation frequency and rpm
- signal processing → data normalization and HDA
- **healthy motor vibration measurement** → mean and standard deviation calculation

### Real-time (measurement)
- **HTAIDSNN training** → HTAIDSNN classification
- Whether there is fault? (yes) → LV1 (no fault)
- Whether there is fault? (no) → LV2 (maybe fault)

### Real-time (diagnosis)
- SPC control chart monitoring
- Whether there is fault? (yes) → LV3 (fault)
- Whether there is fault? (no) → LV2 (maybe fault)

### Non-real-time (initialization)
- Motor vibration data
- Signal processing and feature extraction
- Hybrid Discriminant Analysis
- HTAIDSNN training

### Non-real-time (training)
- Mean and standard deviation calculation
- Real-time (measurement)
Environment monitoring system

Local sever: Motor failure diagnosis interface

Motor status interface

Real-time environment monitoring interface
Environment monitoring system

Local sever : Motor failure diagnosis interface

![Motor failure diagnosis interface](image)

<table>
<thead>
<tr>
<th>Data Base</th>
<th>Diagnosis System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Status</td>
<td>Neural network detection</td>
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<tr>
<td></td>
<td>Group</td>
</tr>
<tr>
<td>First</td>
<td>1</td>
</tr>
<tr>
<td>Last</td>
<td>0.5f</td>
</tr>
<tr>
<td>Up</td>
<td>3.7589</td>
</tr>
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<td>Down</td>
<td>1.5f</td>
</tr>
<tr>
<td>2.7685</td>
<td>7.0975</td>
</tr>
</tbody>
</table>

| Control Chart |
| Shewhart | 0.5f | f | 1.5f | 2f |

Motor failure diagnosis interface
Environment monitoring system

Cloud monitoring platform

- Cloud monitoring platform contains in addition to data storage, but also the field map display, latest node temperature and humidity data, temperature and humidity data according to the node number or date query, node temperature and humidity trends, and node vibration information.

- This platform uses MySQL tool phpMyAdmin to establish the database, and use PHP dynamic web page for data presentation. All are integrated together to achieve the goal of remote monitoring.
Environment monitoring system

Cloud monitoring platform

Latest temperature and humidity of node

Node ID: 2
Date: 2017-06-28 09:42:20
Temperature: 30.9225 °C
Humidity: 65 %
Environment monitoring system

Cloud monitoring platform

Motor fault diagnosis: Healthy motor

Lab506 Intelligent Factory Monitoring Platform

Vibration

Rotation Frequency: 29.9 Hz
Revolution Per Minute: 1794 rpm

The Latest Situation of The Motor:

Error

Result: Rotor Imbalance

<table>
<thead>
<tr>
<th>Type</th>
<th>Healthy Motor</th>
<th>Shaft Bending</th>
<th>Rotor Imbalance</th>
<th>Mechanical Looseness</th>
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</table>
Environment monitoring system

Cloud monitoring platform

Temperature trend of node 2
Environment monitoring system

Cloud monitoring platform

Lab506 Intelligent Factory Monitoring Platform

Node2 Humidity Figure

Humidity trend of node 2
Conclusion
In this paper, a wireless sensor node with piezoelectric energy module is developed by piezoelectric energy conversion technology and wireless sensor network technology. This node is placed on the vibration source and the harvesting module is able to rectify and regulate the power to produce 8.6 ~ 14.4 V DC voltage.

The wireless sensor node with the developed piezoelectric energy module is added to the wireless sensor network to carry out the environmental information sensing, and the information is transmitted to the server through the base station. The user can immediately monitor the environmental condition and make decisions according the situation.
Conclusion

Finally, the results will be uploaded to the cloud database, and the use of web pages to present information to achieve the purpose of remote monitoring.
Thank you for listening!!