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Research Article

A FUNCTIONAL SENSOR PLACEMENT OPTIMIZATION METHOD FOR POWER SYSTEMS HEALTH MONITORING USING FPGA

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ABSTRACT

Health monitoring of complex power systems require multiple sensors to extract required information from the sensed environment and internal conditions of the systems and its elements which means monitoring the heart of power system that is transformers automatically with the help of different sensors placed on its different parts and using FPGA and GSM module. Electrical Power Transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between to windings. The various parts of the transformer are core, winding, tank, oil section and sensors are placed in these areas for monitoring problems. The FPGA based Design Flow is extensively used in today's world due to its following advantages – short design time, easy to market etc. GSM Modem can accept any GSM network operator SIM card and act just like a mobile phone with its own unique phone number

Keywords: Radio transceivers, Wireless sensor networks, Ad-hoc networks, FPGA, GSM)

INTRODUCTION

Electrical Power Transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between to windings. The transformer requires less care compared with other electrical equipment. The degree of maintenance and necessary inspection for its operation depends on its capacity, on the importance within electrical system, the place of installation within the system, on the weather conditions, and the general operating conditions. The parameters considered for maintenance in this paper are

- Transformer's temperature
- Inspection of oil volume
- Noise
- Loosening of the fixing pieces and the valves
- Oil leaks

Real time system is developed considering the above mentioned issues using FPGA and GSM module. The main of the project is to monitor the health of the transformer in a power system and informed to us with help of FPGA and GSM module. Proposed system is fixing the sensor in various parts of the transformer, such as core, winding, transformer tank, oil tank. Sensor is used to sense the oil level, temperature, any excess pressure of the power system transformer. Various sensors are placed in these subsystems in order to find the problems in the specified location. After finding the problem it will be captured by the FPGA controller. FPGA is a programmable digital logic chips. The GSM modem is used as the communication module which will accept the information and goes to the server through RS232.GSM Modem can accept any GSM network operator SIM card and act just like a mobile phone with its own unique phone number. Led will give the alert symbol by glowing. This paper provides a Bayesian Belief Network (BBN) –based sensor placement optimization methodology for power systems' health monitoring. The approach uses the functional topology of the system, physical models of sensor information, and Bayesian inference techniques along with the constraints. Information metric functions are used for optimized sensor placement based on the value of information that each possible "sensor placement scenario" provides

RELATED WORK

In general, there are two ways for monitoring of power transformers; offline and online methods, each with specific characteristics and control methods. If the measurement and testing of transformer and its components be done in the switch off mode, this type of transformers test called offline monitoring. This way, when the transformer is disconnected from the power network is done. Due to the availability of all the terminals of the transformer and no hazards in high voltage side, this method is simpler to implement. If the transformer is measured and tested during operation and service; this type of transformer test called online monitoring. The main advantage of this method to the offline method is the prediction of the important faults before its occurrence. The real time controlling is done on the basic features like gas level, oil aging and regulation of overload and temperature maintenance. These features are essential for effective power transmission and long life of industrial transformers. The monitoring and control of the transformer is done by using wireless communication techniques and sensors which checks the level of gas, aging of oil, overload and maintain temperature by regular observation. There are various transformer maintenance techniques but this paper gives a real time monitoring and controlling of transformers by using FPGA and GSM module in order to overcome the drawback of power consumed in other methods and also replace the bulky computers making it as embedded system. The design is to sense the features of transformer and send the information regularly to the processor, the processor in turn will makes the transmission through GSM to the client. So, this design makes possible to attain real time control and monitoring of oil, gas, overload and temperature range in the transformer.

Figure 1: Transformer

HARDWARE SETUP

The following components are used:

1. FPGA
2. GSM Modem
3. RS232.
4. Sensors (gas, temperature, current, voltage, pressure, humidity, mechanical)
5. Led

FPGA:

FPGA's are arrays of logic blocks, which can be linked together to form complex logic implementations. They are separated into two categories – Fine Grained and Coarse Grained. Fine Grained are made of sea of gates or transistors or small macro cells, while Coarse Grained are made up of bigger macro cells, which are often made up of flip-flops and Look up Tables to generate Combinational logic functions. These are RAM based devices i.e. these devices loose their configuration when power is switched off. Hence they have to be configured every time power is switched on.

FPGA Design Flow:

The FPGA based Design Flow is extensively used in today's world due to its following advantages – short design time, easy to market etc. FPGA based Design Flow allows one to implement his/her VLSI design in a very short duration, cater to customer needs and make last minute changes. The FPGA based Design Flow is

1. Design Entry
2. Synthesis
3. Simulation
4. Implementation
5. Programming.

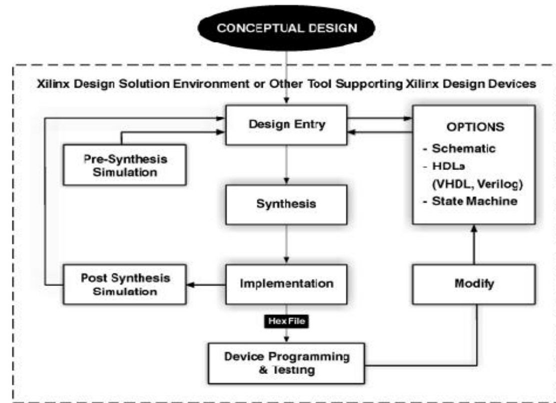

Figure 2: Xilinx Design

1. Design Entry:

User can enter the design by writing the descriptions of any digital system using **HDL** (Hardware Description Language), which can be written in two Languages such as :-

- VHDL (Very High Speed Integrated Circuit HDL)
- Verilog HDL

2. Synthesis:

Synthesis is the process, which converts HDL CODE into Gate level circuit in the form of NET LIST. This process is Target Technology dependent hence user must select proper Device, Family, Part Number and Speed Grade. Also user may select Synthesis Settings like Clock Frequency, Optimization for Speed or Area.

3. Simulation:

Simulation, user can verify the functionality of his design by applying various input signal combination and observing the output results. The simulation is performed on gate level Netlist.

4. Implementation:

Implementation is the process in which the design is passed through various stages by TRANSLATE, FIT, and Programming file generation. For locking input and output signal to particular pins of the device, user must write UCF (User Constraint File) before implementation and guide the same file to implementation tool through the option set control files. Output of implementation is .Hex file.

5. Programming:

This is the process by which user can physically download the architecture from computer to target device using programming cable. Use SANDS FPGA/CPLD Development Platform to Download the Data to the FPGA trainer. Use only the cable, which is supplied along with the kit.

GSM:

GSM stands for Global System for Mobile Communication service. GSM is a cellular network which accepts a SIMcard and operates like mobile phone. It is connected to a computer and which in turn communicate over mobile network

RS232 cable:

RS232 stands for Recommend Standard 232and defined as the interface between data terminal equipment and data communication equipment using serial binary data exchange. This definition defines data terminal equipment (DTE) as the computer, while data communications equipment (DCE) is the modem. A modem cable has pin-to-pin connections, and is designed to connect a DTE device to a DC device.

SENSORS:

A sensor converts a physical parameter to an electric output. It respond to an input quantity with the help of an electrical or optical signal. The various parameters like gas, humidity, temperature, pressure, oil level are detected by the corresponding sensors and convert it to an electrical signal.

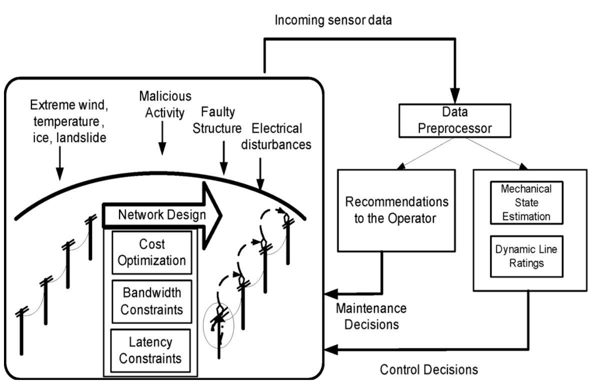

Figure 3: Framework of sensor network

PROPOSED SYSTEM

This project will monitor the performance of a transformer. Electrical Power Transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between to windings. It transforms power from one circuit to another without changing its frequency but may be in different voltage level. Transformer contains core, windings, tank,oil section as the subsystem. In this project various sensors are placed in this subsystem in order to find the problems in the specified location. After finding the problem it will captured by the FPGA controller. FPGA is a programmable digital logic chips. Then the GSM modem is used as the communication module will accept the information and goes the server through RS232.GSM Modem can accept any GSM network operator SIM card and act just like a mobile phone with its own unique phone number. Also led will give the alert symbol by glowing. This paper provides a Bayesian Belief Network (BBN) –based sensor placement optimization methodology for power systems' health monitoring. The approach uses the functional topology of the system, physical models of sensor information, and Bayesian inference techniques along with the constraints. Information metric functions are used for optimized sensor placement based on the value of information that each possible "sensor placement scenario" provides.

ALGORITHM

The term neighbor node refers to the node that is present close and in the wireless transmission region covered by a node. The term neighborhood is used in this paper to denote the nodes that is present in the wireless coverage area. Dijkstra algorithm is adopted for transmitting the signal in the shortest and desirable path.

Information Routing

The data transmission occurs only when the user exceeds the specified value. The data should reach the EB office as soon as the line is tripped by the system and hence high priority should be given to it. The path taken by the data should be minimum and with less hop count. Different scenarios are considered that should be taken into account while designing the network and routing path.

1. Maximum hop count with maximum distance should be avoided so minimize delay and loss of date. The data transmitted is delay sensitive and of high priority.
2. Minimum hop count with maximum distance should also be avoided as the delay is reduced but the increase in distance results in loss of signal or addition of noise or error. This however can be taken as an option when the line is congested or failure occurs.
3. Maximum hop count with minimum distance is a more opted option than the above during failure of a line or high traffic. The maximum hop count may lead to delay of data but that is acceptable to a certain level when compared to loss of data as in above case.
4. The perfect way is fixed by considering minimum hop count and minimum distance. Data is routed in this path with minimum delay and minimum error.

The algorithm is designed according to the above said points. The routing of data from source to destination is shown in figure. The routing is based on dynamic routing protocol. That is the data does not follow a fixed path. Each time a data is transmitted the path is determined by referring the routing table that has minimum hop count and distance.

When the network is set up the nodes communicate with each other by sending a test packet. Fig 4 shows the path calculation and updating the routing table as a result. The source packet sends a packet to each path that it is connected with. The motes or nodes update the hop count by 1 in the routing table of the packet. Once the packet reaches the destination, the nodes end the packet again to source that via the path that has least hop count. Thus the node updates its path information and routing table.

The dynamic routing of data has an added advantage in the times of high traffic or failure of a link. When there is a node misbehaving or congested with data or failure of node may lead to loss of data. By dynamically routing the data each time to the destination the loss of data due to undesired or unexplained situations can be avoided.

However there will be delay in data reaching the destination due to dynamic routing as the path in which the data should be transmitted is determined each time. Time taken each time can be avoided using fixed path routing but the failure of link or during congestion may lead to loss of data. Hence this method is much suitable for this application as loss of data cannot be tolerated.

The motes when get an alert to transmit data, using their transceiver it transmits and receives the signal. The strongest signal that is received from the node is determined and the node shares its routing table and the number of hop counts are determined. If the number of hop counts is lesser than the number of hop counts in its routing table. If not then the signal with the second strongest signal and the process is repeated.

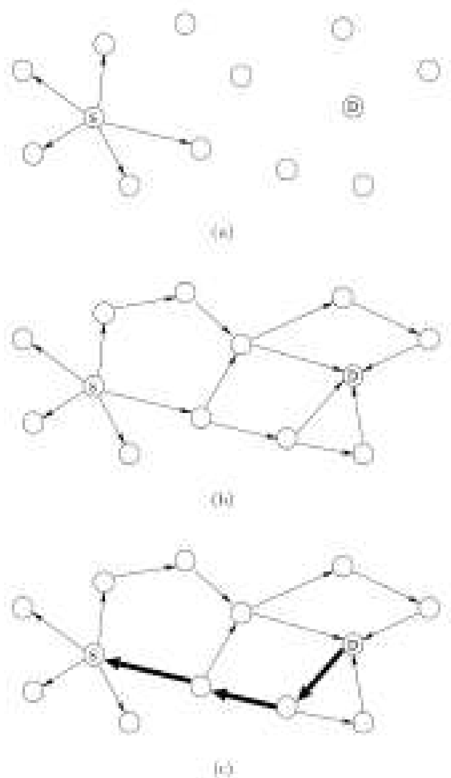

Figure 4

Shortest path calculation by sending a packet from source node S to the destination node D. For each node the hop count in the routing table is incremented by 1. The destination node sends the packet back to the source node via the path that has least hop count.

The Received signal strength indicator- RSSI and link quality indicator- LQI also plays an important role in determining the path. Depending on the RSSI value and LQI value the path is determined. High RSSI and high LQI shows that the mote is the nearest and noise is minimum.

ADVANTAGES

1. Eliminating unnecessary maintenance and shut downs.
2. Increase the life time of the system.
3. Easy to navigate the problem of the system.
4. Possible to exact parts of the system problem.

APPLICATIONS

1. Nuclear power plants transformers health monitoring based on observing the vibration of transformers.
2. Power transformer health monitoring.
3. Combustion turbine diagnostic health monitoring.

CONCLUSION

The proposed system works well under pre-determined circumstance however when the external factors becomes more influential, the behavior of the system is undetermined. The coverage area of the system is less due to the sensors deployed when covered to the cellular systems but installation and maintenance cost favors this system.

The symmetric nature of the system makes the system easier to use and maintain which does not require more technical knowledge and training. The algorithm implemented is also is easy to develop. The most important feature of this system is flexibility. The system adapts itself to the newly installed system and updates its routing table which does not require any special programming or update.

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