Design and Implementation of Wireless Voltage Monitoring System Based on Zigbee

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ABSTRACT

This paper proposed a low cost wireless monitoring system based on ZigBee wireless transmission, and designed a new floating voltage sensor which is suitable for the monitoring of medium voltage and high voltage (MV/HV) public equipment. The system used TI-CC2530 as the controller, proposed a new moving average voltage sensing (MAVS) algorithm by reasonable assumptions, and adopted algorithms to perform the theoretical analysis for the single phase and three-phase voltage. At last, the author carried out a practical experiment on the wireless floating voltage sensor under the voltage up to 30kV, the experimental results showed that the proposed low cost wireless sensor can achieve a good voltage monitoring function, and the error is less than 3%.

KEYWORDS

MAVS Algorithm, Voltage Monitoring, Voltage Sensor, Zigbee

1. INTRODUCTION

The main function of the sensor is to provide important parameters for current, voltage, temperature and other specific public equipment.

With the aid of voltage parameters, public undertakings can monitor the performance of equipments and system operation interrupt, and save money by energy saving and voltage reducing (CVR). The traditional way is to use potential transformers (PT) and capacitive coupling voltage transformers (CCVT) to monitor the voltage in the public network (Wheeler et al., 2013). However, PT and CCVT requirements for insulation are higher, usually need to use oil to cool or insulate, and it needs regular maintenance, so the price is very expensive. Some public facilities have been equipped with EOVT, as its high cost and limited service life, the use has been limited (Gong et al., 2013).

In the study of the application of the floating sensor in high-voltage equipment, it can be seen that the performance of the new technology is better as it does not need high voltage insulation treatment. In Song, Wang, & Wei-Bing (2014), the authors proposed a circular overhead line sensor which can use the electric field around conductors to monitor the voltage, the complete components of the sensor can be applied in high pressure environment, but the design process of them are very complicated. In Xu, Send, Paprotny, White, & Wright (2013), the author proposed a simpler and more compact design associated with self powered sensors, which could only be used in overhead lines and used to monitor temperature; Zhang et al. (2014) described a new method of measuring voltage based on the Zigbee sensor, but the calculation of the voltage sensing algorithm was very large. A moderate accuracy voltage sensor is not only useful for transmission equipments, such as transmission lines.
but also beneficial to distribution equipment such as cables, transformers, switches and capacitor banks. In these applications, cost is the main driving factor, so it is necessary to develop low cost voltage sensing technology to provide cost saving solutions for a wide range of sensing applications.

In view of some applications such as event monitoring, power failure management and current condition monitoring, this paper proposed a new low cost voltage sensing solution. This paper is based on the current and temperature sensor which is self-powered and based on ZigBee proposed in (Zhang et al., 2014) and (Moghe, Lambert, & Divan, 2012) and the sensor attaches to the sensor architecture and the information for power requirements. Due to the limited range of ZigBee, so suppose there is an ideal application system with sensor clusters (such as smart substations), and the application system can achieve the range expansion by transmitting the ZigBee signals between multiple sensors (Chou et al., 2009).

2. PRINCIPLE OF FLOATING VOLTAGE SENSOR

As shown in Figure 1, if a low-cost voltage sensor has two flats, then, for the standard overhead transmission lines, with the increase of \( D \) (Mousavi, Bozorg, & Cherkaoui, 2013), the \( d \) value is only a few millimeters to centimeters. Compared with the change in \( C_2 \), the change in \( C_1 \) will be more obvious and if using low-pass RC filter in the \( C_1 \) end to measure the voltage of \( C_1 \), then, the displacement current value can be obtained by the following equation:

\[
i_D = \frac{V_i}{jwC_2} + \frac{1}{jw(C_1 + C)R}
\]

(1)

Assuming that \( wCR \) is much greater than 1, then, \( C \gg C_2 \). In the same way, \( C_1 \gg C_2 \). \( i_D \) can be simplified as:

\[
i_D = jwC_2 V_i
\]

(2)

As \( wCR \) is much greater than 1, from

\[
V_i = \frac{C_2}{C} V_i
\]

(3)

The voltage in the capacitor \( C_2 \) can be obtained.

Can be seen from the above equation, the voltage \( V_{C_1} \) through capacitors is proportional to the line voltage \( V_i \) and the capacitance \( C_2 \) between the lower plate and the ground, \( C_2 \) is the distance function between wires and the ground, as the decrease (increase) of distance will cause the increase (decrease) of capacitance, the distance changes will lead to changes in measuring voltage (Zhou, 2011) so the measured voltage \( V_{C_1} \) contains wire migration and voltage information, at this time, decoupling the voltage of capacitor \( C_2 \) in the wire is very difficult.

And if we take into account the three-phase and three wire systems (as shown in Figure 2), as each wire with alternating current shows a 120 degree distribution in three phase system, so other
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