Study on the Automatic Positioning for Cable Insulation Failure Based on Digital Bridge Method

Wu Zhu, Hua-Fu Zhang, Wei-Ya Ma, and Yuan Gui
Shanghai University of Electric Power

***Abstract*—To against the problem of the difficult for indentifying the reflected wave of traveling wave and the need of plentiful practical experience and operation skills, this article focuses on designing and developing a digital cable insulation automatic fault locator. The instruments which can locate the fault without the data of length of the cable is based on the principle of HV bridge method and consist of bridge use for measuring cable length and bridge use for locating cable insulation fault. It can automatically improve voltage output of the high-voltage power through constant current detection circuit. To make sure the abilities of high accuracy,stability and fast for this instrument, This article introduces high-precision digital potentiometer, optical isolation and self-balancing bridge.The optical isolation between high and low pressure not only can achieve a complete electrical isolation,but also improve the anti-interference for the system.**

***Index Terms*—self-balancing bridge, digital potentiometer, optical isolation**

I. Introduction

With the power cable is widely used in the power system, cable fault become more obvious. Although compared to overhead lines, the actual operation probability of the cable failure is much smaller than the overhead lines, cable insulation aging is prone to breakdown and overhead line failures is relatively easy to locate [1]. The unobservable characteristic of cable fault determines the complexity of cable fault location. Therefore, when the cable faults come out, the problem of how to position the fault location and reduce the repairing cost and outage cost as soon as possible in the field of power engineering research community is increasingly concerned about [2].

At present, the cable fault location for practical engineering application are mainly two types of traveling wave method and impedance method [3]. Theoretical research from home and abroad published a lot of articles about cable fault location. Without transition resistance and the impact of the type of fault, traveling wave method are higher accuracy in theory, but the identification for fault test waveforms of the traveling wave method has been the problem for cable fault testers, so it requires practitioners own skilled testing techniques and a wealth of practical experience [4]. Impedance method which needs the cable length of the data with larger transition resistance will affect its accuracy. This study improves from the traditional bridge method such as improve bridge voltage, use multi-tap, high-precision digital potentiometer for self-balancing bridge, it will greatly reduce time for location.

II. The Implementation of the System

The overall scheme of the locator system is shown as below, the whole system is composed of high and low voltage bridge structure, low voltage bridge is used for measuring cable length, while high voltage cable is for insulation fault location which needs the length of cable data, through the reed switch to switch the high and low electric bridge. The system mainly includes a high voltage DC source module, a constant current control circuit, bridge zero detection circuit; DC high voltage source supplies power for high voltage bridge, MCU will control DAC chip put out analog voltage signals to control the output of high voltage power which can maintain circuit loop constant current; judged whether differential voltage signal from bridge is zero, MCU will send out signals to control the digital potentiometer slide to balance bridge automatically. With the linear relationship between the cable core wire resistance and cable length can locate cable insulation fault.

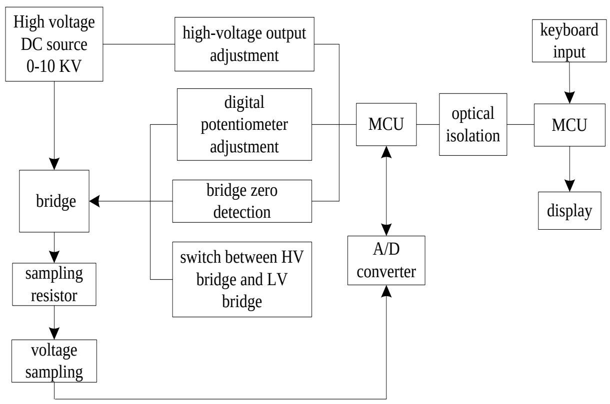

Figure 1. System scheme

III. System Hardware Circuit Design

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A. High Voltage DC Source Module

If Cable insulation faults occur, insulation resistance still reaches megohm level, Stable balanced condition for the bridge is that the loop current is maintained at 1 mA , thus the system require a high voltage power that can supply ten thousand volt to meet the above requirements, without burning through the cable insulation to reduce insulation resistance, it can locate the fault[5]. The high voltage DC power module of this positioning apparatus adopts basic design principle which combines an adjustable linear DC voltage-stabilized power source with a high frequency inverter. The output of high frequency and high voltage inverter come out through the positive or negative doubling voltage rectifier, finally send the output voltage to sampling circuit of front-stage DC linear regulated power. Its principle diagram is shown as below:

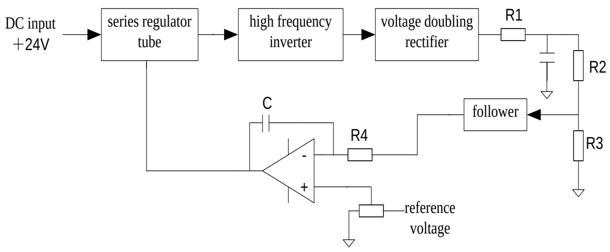

Figure 2. Schematic of high voltage DC source

The high frequency and high voltage inverter inverter 24V DC input power, then boost into a high-frequency high-voltage AC signal, enlarge the voltage amplitude about 30 times to 700V; Secondly, with the doubling voltage rectifier circuit, the voltage is boosted further to 10000V. The MCU called 89C51 outputs 0-5V through the DAC chip to reference voltage which showed Fig 2 to control the output of the power voltage.

B. Constant Current Control Circuit

To improve the measurement accuracy, the full-bridge current should maintain at 1mA. Therefore, it requires a small sampling resistor connected in series in the loop, compared the sampling voltage signal with setting voltage [6], it can judge whether the current is 1mA. While sampling voltage responses circuit loop current. Current sampling circuit diagram is shown below, the generated sampling voltage through the sampling resistor is amplified through the signal conditioning circuit, then be sent to port P2.1 on 89C51 as follows after the A / D converter.

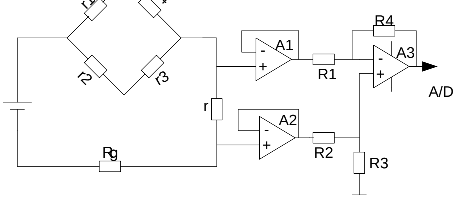

Figure 3. Current sampling circuit diagram

MCU 89C51 receives the sampling voltage signal, to be compared with the set voltage value, and then gives the 0-5V analog voltage signal to control the voltage output of the high voltage DC source to achieve a constant current, while the MCU does not have a D/A converter module ,Therefore, an external DAC chip-MAX531 is connected to MCU. The chip uses a unipolar output, while the reference voltage is set to 5V. The relationship between the input encoding and output, while the reference voltage is set to 5V. The relationship between the input encoding and output voltage is shown as below:

$$V_{OUT} = \left(\frac{code}{4096}\right) * V_{REF} \tag{1}$$

code means input voltage code from DIN-ended, V_{REF} refers to reference voltage.

The connecting circuit diagram of MAX531 and 89C51 is shown in Fig 4. The MAX531 has ability to transform a 12-bit D/A and serial input number. The digital information is sent to pin DIN which is connected with p1.0, and then complete the D/A converter. Pin SCLK refers to clock port, the voltage signal from pin VOUT can achieve control linearly output voltage of the high-voltage power module.

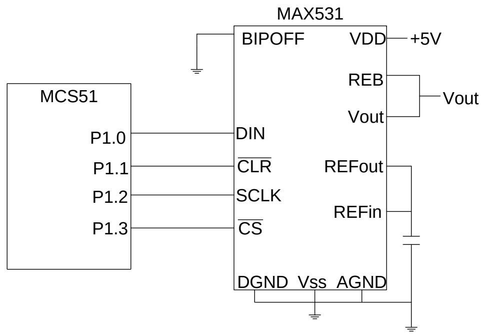

Figure 4. D / A conversion circuit diagram

C. Zero Detection Circuit of Bridge Design

The balance of the bridge is the core of the system work normally, so how to adjust precisely the balance of the bridge as soon as possible is an important part of this article [7]. To against the problems of large Error and time-consuming resulting from adjusting manually with traditional mechanical potentiometer, the locator uses a 1024 tap digital potentiomter called max5481 it can choose SPI-compatible interface or increase or decrease the digital interface to adjust the balance of the bridge. Its zero detection circuit is shown as figure 5.

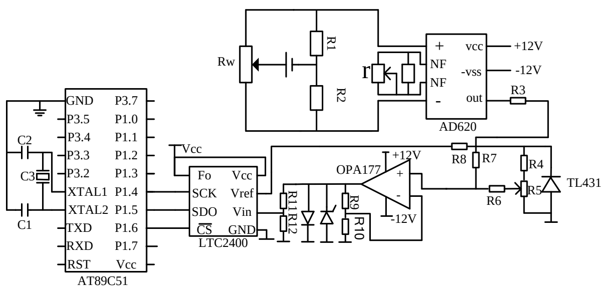

Figure 5. Zero detection circuit of bridge

The voltage signal from both ends of bridge is sent to AD620 which can convert differential signal into a single-ended signal, while AD620 is a low-power, low-drift amplifier. If the single-ended signal is directly sent to A/D converter, the result will have low accuracy [8]. Therefore, the signal from AD620 should be sent to Operational amplifier called OPA177 which has low temperature drift and low offset input voltage, then transformed by LTC2400, Finally, MCU will analysis and process to balance bridge automatically[9].

IV. THE REALIZATION OF THE CABLE INSULATION FAULT LOCATION

Cable insulation fault location has two steps, the first step is to measure the length of the cable that can achieve the data from adjusting the low-voltage bridge, then locate insulation fault with the length data of the cable through transfer switch. Positioning system schematic is shown as below:

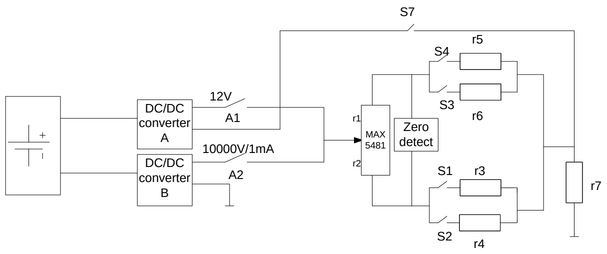

Figure 6. Positioning system schematic

1) Cable length measure

The operation for measuring the length of the power cable: close switch A1, close S2 and S4. The electric bridge-arm resistors are r1, r2, R4 and R5. According to the cable wire resistance is proportional to its length[10], the length of the cable can be calculated. Equivalent circuit is shown in Fig7.

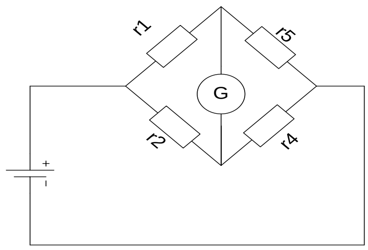

Figure 7. Equivalent circuit of measuring the length of power cable

2) The cable insulation fault location

The operation for locating the cable insulation fault location: disconnect A1, S7, S2 and S4; close A2, S1 and S3. The equivalent circuit diagram is shown as follow:

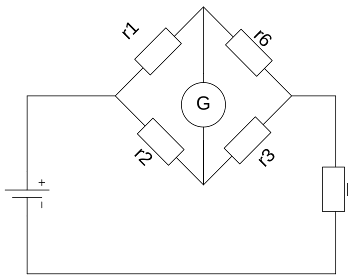

Figure 8. Equivalent circuit of cable insulation fault location

V. CONCLUSIONS

This article introduces the design of equipment for the cable insulation fault location, the instrument is based on the traditional positioning system[11],the improvement is using multi-tap, high-precision digital potentiometer to adjust automatically the balance of the bridge, adjust the output of the power to achieve the constant current output. Finally, balance bridge reliably. Compared with the original bridge method, this instrument not only improves the accuracy of positioning, but also greatly reduces the time for positioning.

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Wu Zhu, was born in September 1969, received Doctorate of Harbin Institute of Technology in 1999. The research directions at present are: power quality analysis ;cable insulation fault diagnosis; electromagnetic compatibility; intelligent instrument. He has been a professor at Shanghai University of Electric Power in 1999.He also adjuncts Shanghai Electrical and Electronic Association and the electronic instrument director of special committee of the Shanghai Association of Electrical and Electronic .

Huafu Zhang, was born in February 1988, is a postgraduate at Shanghai University of Electric Power now.the research direction is cable insulation fault diagnosis.

Yuan Gui,was born in February 1988, is a postgraduate at Shanghai University of Electric Power now. the research direction is control system design of infrared temperature measurement for power Equipment

Weiya Ma, was born July 1987, is a postgraduate at Shanghai University of Electric Power now. the research direction is detection and identification of power quality disturbance