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The Smart IOT Earth Leakage Circuit Breaker with Transformerless And SMPS Auto Recloser

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Abstract: Earth leakage Circuit Breaker (ELCB) is function as a protection device that shall install either in industrial or residential protect electrical appliance or user from electrical shock or current leakage. When ELCB fault is detected, mechanical switch trigger the system to trip the circuit breaker. The problem faced by the user are the need to access to distribution box (DB) when tripping occur to turn it on manually. Some home appliance such as computer and alarm system should always connected to supply to prevent data from crashing or system mulfunction. The Smart Internet of Thing (IOT) Earth Leakage Circuit Breaker with Transformerless and SMPS Auto Recloser is proposed in this project to solve the need of always standby near to the DB to turn on after trip. This project has been improved from previous study with some transformation of circuit and prototype design. Transformerless circuit develop on this project eliminated the need of bulky transformer which usually used on linear circuit to power the microcontroller for control system to automatically recloser ELCB. Microcontroller used on this project are ESP32 module link with the IoT module to access from another location within the range. The Switch Mode Power Supply (SMPS) circuit is design to power DC motor in order to recloser the ELCB. The transformerless and SMPS is designed in two separate circuit to prevent microcontroller from damage while starting the DC motor. The auto recloser is set for 15 time tripping to prevent continuously fault that protect wiring and appliance from danger.

Keywords: *Earth Leakage Circuit Breaker (ELCB),IoT, transformerless, microcontroller*

1. Introduction

Earth Leakage Circuit Breaker (ELCB) one of the protection device that shall install to all domestic wiring to protect equipment and end user. Refer on Suruhanjaya Tenaga 2008 rule 36(3) PPE 1994 it stated that the information of the installation equipment or electrical devices that touch by consumer with hand shall protect from earth leakage must be used ELCB below 30 miliampere [1]. Usually residential protection has ELCB and place on distribution box (DB). ELCB working when lightning strike, current leakage, electrical appliance leakage or electrical shock by human touch any live wire.

The previous project, Automatic Earth Circuit Breaker with Backup Supply circuit are linear circuit. Transformer one of the general component to complete circuit with step down voltage before thru other phase [2]. The disadvantage using transformers are circuit bulky and require large space for electronic component on product design.

In this study, collecting data on mechanical part for gearing, casing, type of motor and ELCB working principle important for recloser the ELCB. Next, the development of power supply using transformerless and SMPS concept to reduce cost and weight of power supply. Application Transformerless power supply circuit are commonly used on street light sensor and bulb. Transformerless circuit still on linear circuit concept just eliminate the bulky transformer. An application switch mode power supply (SMPS) commonly used on mobile charger are not suitable used to running motor continuously. Lastly, the development complete with

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implementation of microcontroller. The suitable microcontroller for this prototype is ESP32 because can control system and build in Internet of Thing (IOT) device.

2. Earth Leakage Circuit Breaker

Earth Leakage Circuit Breaker (ELCB) is design to detecting leakage current to prevent electrocution. The ELCB working principle are by using current transformer (CT) type of protection CT that working normally when measure balance current between two of conductor live and neutral. An ELCB open its contact when measure abnormal current value. The abnormal current supply and return current must become to zero, otherwise there is the leakage go thru to somewhere (grounding). In the United State, the NEC (National Electrical Code) require GFCI (Ground Fault Interrupter) devices intended work to protect people with interrupt circuit if current leakage over 25 milliseconds when current exceed a range of 4mA-6mA (Typically the trip setting is 5mA). An ELCB setting to protect equipment from leakage are allowed to trip when current exceed 30mA. In Europe, generally residual current detection (RCD) allowed to trip when current exceed 10-300mA depends on the sensitivity setting. [3][4]

2.1 Automatic Earth Leakage Circuit Breaker with Backup Supply

Fig. 1 show the previous project of Automatic Earth Leakage Circuit Breaker with Backup Supply are used linear circuit. The linear circuit used transformer to step down 240Vac to voltage desire [2]. To replacing the current mechanical switch for turn on, PIC16F877A added to system for control overall flow operation and operate the protection relay. When ELCB tripping ZCT transmitted data to black box include PIC16F877A and energize the motor for turn on. This project build in backup supply to make sure microcontroller always working. Alarm included on this circuit for indicator when trip occur. [2].

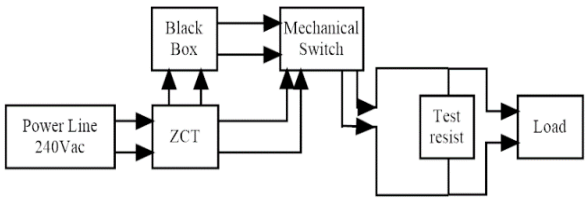


Fig. 1 - Component and structure of ELCB.

2.2 Linear Circuit

Fig. 2 show that linear circuit is power supply step down the high voltage AC into the low voltage AC using a transformer component or can be eliminate the transformer replace with Multilayer Metallised Polyester Capacitor (X-rated capacitor) depends on application. Then convert AC-DC using bridge rectifier either half or full bridge concept before stabilize the supply into desired voltage depends on load. Linear circuit divide by four phase is step down the voltage, convert AC-DC, filtering, and voltage regulate. When voltage regulator operates dissipates power because of ohmic losses. That causes temperature of voltage regulator rise up and requires heat sink for cool down a voltage regulator. Affect from the temperature of voltage regulator is transformer size, circuit size become bulky to use. Also, dissipation from this situation cause decrease the efficiency of linear power supply to 25-50% [5].

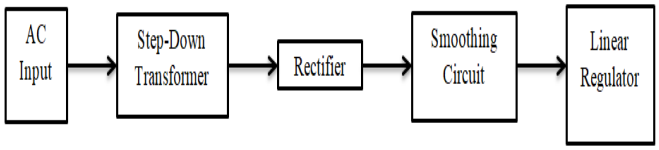


Fig. 2 - Block Diagram of Linear Circuit [5]

2.3 Switch Mode Power Supply (SMPS)

The SMPS circuit principle is based on switching technique using MOSFET. Firstly, AC low frequency from input AC voltage is converted first into DC signal. After that, chopper phase using chopper circuit. Chopper circuit consists switching component MOSFET transistor for chopper phase which turn ON and OFF with help from chopper controller. Now, AC low frequencies are already changed into high frequency. After gets higher frequency, step down transformer work to drop the DC high frequency voltages. In this case, transformer size will be small than linear circuit because of higher frequency. The advantage of SMPS circuit is the size of SMPS circuit not bulky and portable. The voltage regulation of SMPS circuit gets from feedback circuit. The feedback circuit work with takes the input from output from DC voltage and gives the output to the chopper controller. The chopper controller generates gate pulse refer by output DC. Another advantages of SMPS circuit are does not dissipate power and for sure are not require any sink to cool down temperature. Because not dissipate power the SMPS circuit will achieve efficiency 65-75% [5].

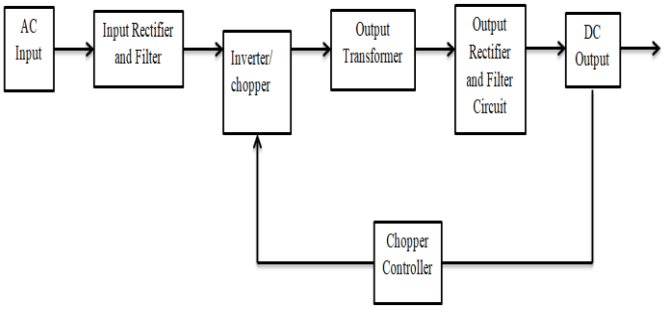


Fig. 3 - Block diagram of Switch Mode Power Supply (SMPS). [5]

2.4 Comparison between Linear Circuit and Switch Mode Power Supply (SMPS)

Table 1 show the comparison between the linear circuit and SMPS to analyse which one are suitable for the whole system.

Table 1 - Comparison between the linear circuit and SMPS

Parameter	Linear Circuit	SMPS

Definition	-Step down AC voltage first then convert AC voltage into DC voltage	-Convert the AC input signal into DC signal fi -Step down the voltage to desired level
Efficiency	-Low efficiency - 20% to 25%	-High efficiency - 60% to 65%
Voltage Regulation	Done by voltage regulator	Done by chopper circui
Weight	Bulky	Less bulky and portable
Reliability	More reliable in comparison to SMPS	Depends on the switchi

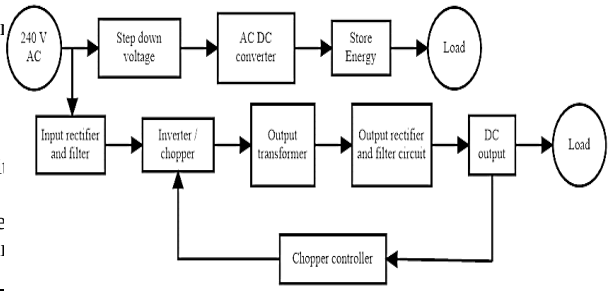


Fig. 5 - Block diagram separate transformerless and SMPS

3. Methodology

The modelling and the design process of the Smart IoT ELCB with Transformerless Circuit will be discussed as below. Study on the theory and literature review related to the project had been done from several resources then follow by analysis the data, understanding of previous literature review and lastly combination the knowledge to produce the controlled results.

3.1 Linear Circuit

Figure 4 show that the block diagram of The Smart IoT ELCB with transformerless and SMPS Auto Recloser. The Auto recloser will trace only the trip condition. When trip is detected, feedback circuit or hall sensor (A3144) trigger microcontroller and energize recloser circuit used DC motor until ELCB on.

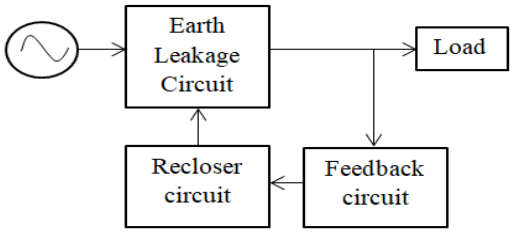


Fig. 4 - lock of The Smart IoT ELCB with transformerless and SMPS Auto Recloser

3.2 Circuit Power Supply

Development of auto recloser require suitable power supply circuit, microcontroller, and DC motor. Microcontroller can malfunction when overvoltage and undervoltage. To prevent device from damage the circuit, it should separate the transformerless microcontroller and SMPS circuit from DC motor when it is running due to a high current will be draw during the starting of the motor. This bring the effect to the device that in the same circuit with the motor such as the voltage drop and microcontroller life span shorted. Fig. 5 show that the circuit block diagram separate transformerless and SMPS.

Fig. 6 shows that the transformerless circuit to eliminate the transformer and change to Multilayer metallised polyester film capacitor or x rated capacitor with parallel resistor R1 to discharge the store current energy in the capacitor while switch turn off to preventing the electric shock. The resistor work for bleeder resistance. Further, to convert AC-DC using full bridge system to change signal. The full bridge rectifier used power diode. Resistor R2 function for rectification and capacitor C2 for filtering the ripple balanced. To regulation the voltage, this circuit require diode zener depends on circuit output voltage desire. The LED used just for indicator for precaution while turn off.

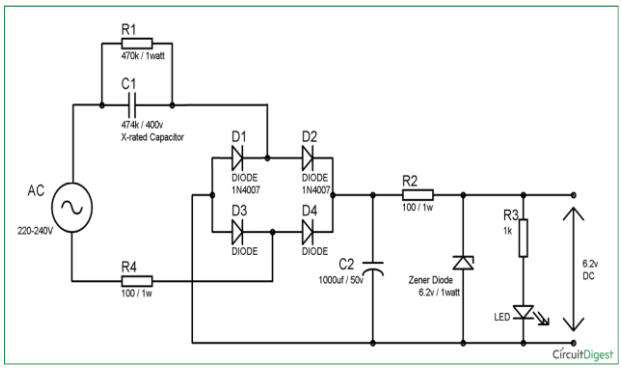


Fig. 6 - Conventional transformerless circuit

Table 2 show the multilayer metallised polyester capacitor (X rated capacitor) value commonly used. If require another value, x rated capacitor need connected in parallel to increase capacitance value. Each capacitor code has different output voltage and current. This project require 100mA for power microcontroller and suitable x rated are 225k and voltage can be step down used zener diode.

Table 2 - Multilayer metallised polyester capacitor (X rated capacitor)

Capacitor Code	Capacitor Value	Voltage	Current
104k	0.1uF	4V	8mA
334k	0.33uF	10V	22mA
474k	0.47uF	12V	25mA
684k	0.68uF	18V	100mA
105k	1uF	24V	40mA
225k	2.2uF	25V	100mA

3.3 Flow Chart of Microcontroller System

Fig. 7 show the flow chart for microcontroller ESP32 to control ELCB to recloser within automatically when trip occur. For the first time installation, reset button need to press to active system and DC motor will start recloser the ELCB until ELCB working normally. When trip, hall sensor 1 (A3144) will be high and transmitted signal into microcontroller ESP32. The auto recloser only can be set 15 time trip to prevent any damage as continuously fault as short circuit (wire touching). When ESP32 receive high from hall sensor 1 to trigger DC motor. A DC motor stop running until hall sensor 2 active.

Fig. 8 show that the wiring diagram for auto recloser. The main supply from incoming ELCB are separate to transformerless and SMPS circuit to prevent microcontroller from damage. A transformerless circuit to power the microcontroller ESP32. A SMPS circuit only work for power the DC motor to recloser the ELCB. Fig. 8 shows the microcontroller work to control all system to be automatically. A hall sensor (A3144) function for trace the condition of ELCB either trip or working normally. Fig. 7 shows the system only can be trip for 15 time only to prevent continuously fault that can be damage for wiring system.

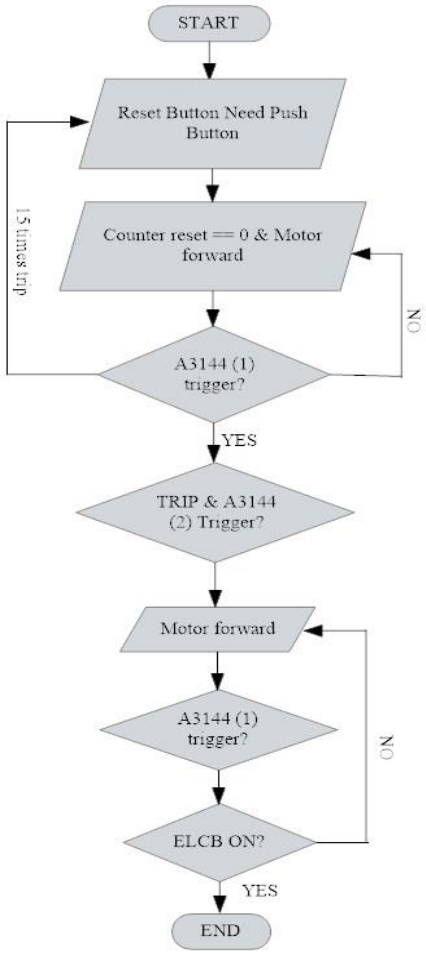


Fig. 7 - Flow chart of microcontroller

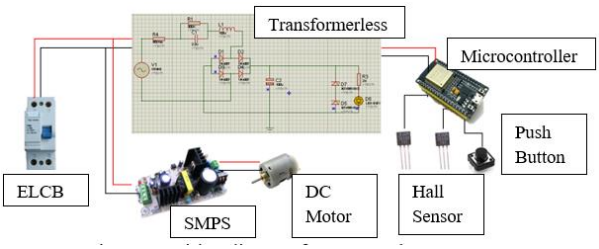


Fig. - 8: Wiring diagram for Auto recloser

4. Proposed transformerless circuit analysis

Some modification on the conventional transformerless circuit has been done to minimize current and an inductor has added on circuit for lagging the current in order to create continues load as shown in fig. 10. A 12Vdc is regulated by connected the zener diode in series to produce higher watt. DC-DC buck converter is use to produce 5V and 1A. Fig. 11 show that the wave form for AC input wave, AC output wave, and DC wave. It is prove that the transformerless can be used to eliminate the bulky transformer. Equation 1 is used to find current. Frequency and voltage should be follow every country regulation.

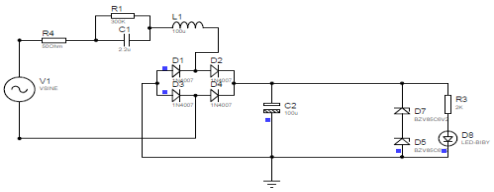


Fig. 10 - Proposed transformerless circuit

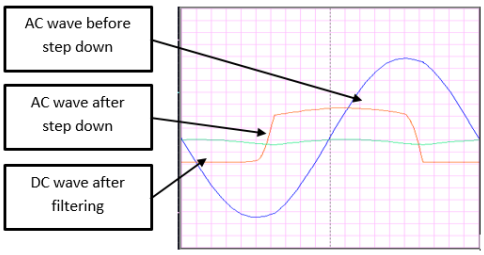


Fig. 11- Voltage wave form

$$X = \frac{1}{2x\pi xfxC}$$

Where,
X = Reactance of capacitor (1)
F = Frequency of AC (50 Hz)
C = Capacitance of x rated capacitor

$$X = \frac{1}{2\ x\ \pi\ x\ 50Hz\ x\ 2.2\ x^{-6}} = 1446.86\text{Ohm}$$

$$I = \frac{240Vac}{1446.86\ \text{Ohm}} = 165.87\text{mA}$$

Fig. 12 shows the AC current measurement from simulation that same as calculation above by using x rated capacitor 225K which produce the current of 100mA and the current afterstep up.

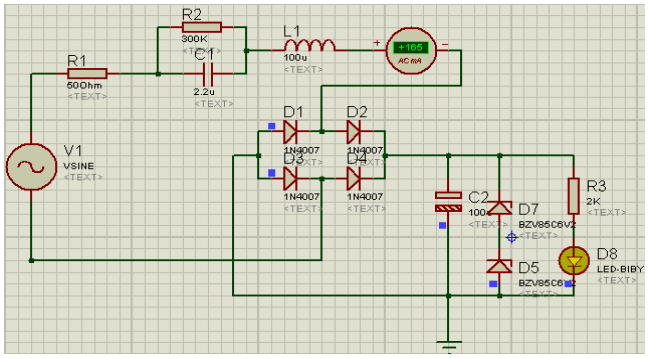
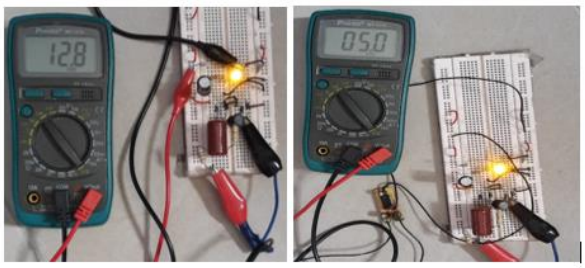


Fig. 12 - Transformerless output current

4.1 Voltage measurement

Fig. 13(a) shows that the output voltage measured fromtransformerless circuit. Fig. 13(b) show that output voltage 5Vdc step down by the DC-DC buck converter by using IC AD85063D to produce 1 Ampere to power microcontroller. A Buck converter is added with the transformerless circuit to step up the current due to the output current from transformerless is 165 mA.



(a) **(b)**

Fig. 13 - (a) 12V output voltage from transformerless circuit (b) 5V output voltage from DC-DC buck converter

Fig. 14 shows the final product of the Smart IoT ELCB with Transformeless and SMPS Auto Recloser assemble with ELCB. The LED 1 is used for precaution indicator while turn off. It is because discharge the stored current energy in x rated capacitor while turn off needs few second to discharge to prevent the electric shock. The power supply switch is used for turn on and turn off the circuit. Reset button implement on this project is to reset the system if enough 15 time tripped. Switch assemble with ELCB to reclose the ELCB automatically when trip happened.

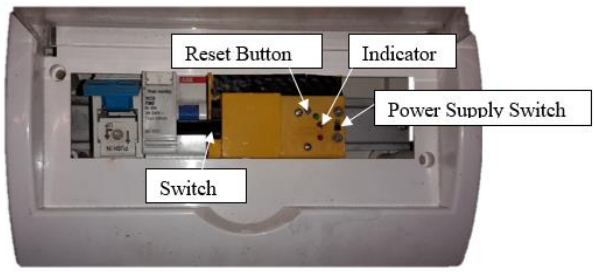


Fig. 14 - Auto recloser assemble with ELCB

5. Conclusions and Recommendations

In conclusion, Auto Recloser Earth Leakage Circuit Breaker using combination transformerless and SMPS circuit power supply is developed to power the device and DC motor to reclose the ELCB. Also, a X-rated capacitor and resistor is used to eliminate the bulky transformer from circuit to discharge current while turn off. To produce continuos current, an inductor is added to lag the current before fall to zero. Ein addition, the system is improved by the automatically control and able to monitor without near the distribution box with added Internet of Thing. For recommendation, Auto recloser system can be added with GSM module to monitor and control from other location. Besides, to compact the circuit and decrease the size of recloser, surface mount device (SMD) component can be replace the THT component to produce smaller then this size product.

6. Acknowledgement

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