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Over Current Protection Relay Using Arduino Uno

Prof: Daniel Nixon, Syed Sarfaraz Ahmed, Abbubakar Siddique

Department of Electrical and Electronic Engineering, Navodaya Institute of Technology, Raichur, India

ABSTRACT: The FREEDM (Future Renewable Electric Energy Delivery and Management) system is a smart grid that enables wide integration between the Distributed Renewable Energy Resources (DRER) and Distributed Energy Storage Devices (DESD) with the conventional distribution system. This paper presents the design and implementation of an Arduino Uno microcontroller-based overcurrent relay with different characteristics (inverse, very inverse and extremely inverse) for FREEDM systems. An open source model with simple utilization of both hardware and software is created. A practical printed circuit board is designed with the required inputs and outputs to monitor and protect the branch connecting solid state transformer (SST) to the closed loop zones in the FREEDM system. A special program is designed using Proteus software package and easily integrated to the hardware card. To validate the proposed relay, the inverse, very inverse and extremely inverse overcurrent relay characteristics are tested using the proposed system simulator and compared with the characteristic recorded by the well-known IEC 60255-151standard. In order to guarantee the effectiveness of the system, a practical circuit including the proposed relay is formed, connected to a small load (motor) and normally inverse relay characteristic is tested. The proposed protection scheme proves high performance and accurate results.

I. INTRODUCTION

In 2008, the National Science Foundation (NSF) has formed a new smart grid networks supported with innovative facilities called FREEDM system to integrate the green DRERs, DESD's and the conventional power systems. The new networks form leads to best utilization of stored energy and high system reliability [1]-[3]. The major components of FREEDM system are shown in Fig. 1 [2]. Fault Isolation Device (FID), intelligent fault detection (IFD) and Solid-State Transformers (SST) are the three new major equipment in FRREDM system which improves the network protection and power quality. The major advantage of the three equipment is they are static elements controlled by digital control instead of the conventional equipment. SSTs are solid state thyristors or certain type of transistors controlled by digital signals instead of normal electromagnetic transformers. In addition to controlling voltage and phase angle with current, it allows the power to flow in both directions. It has the ability to limit the fault current to 2.0 p.u. by reducing the voltage [3]-[5]. FID is a new static equipment used to break and isolate high values of asymmetrical fault currents within microseconds instead of normal electromechanical circuit breakers which take milliseconds [2], [5]. Intelligent energy management (IEM) and intelligent fault detection (IFD) control schemes are combined in the FREEDM system to achieve effective power flow, fast fault detection and management [4]. The FREEDM closed loop leads to high short circuit levels, voltage dip and of power flow in two directions [2]. Pilot-differential protection using communication is used as primary protection capable to detect the faults in cycles whereas, overcurrent protection is used as a backup protection in case of communication problems/failures, [1]- [2]. Directional inverse time overcurrent relays are applied to detect the fault in the system as in [2], [6].

II. RELATED WORK

The overcurrent relays generations started with conventional electromechanical relays followed by static and digital relays. The last two generations prevent the overshooting errors and reduces time delay. Nowadays, microprocessor and microcontroller relays are introduced to eliminate their disadvantages. This leads to enhance power system protection; better reliability, reducing the impact on the electric power system equipment and facilitate power system automation. Microcontrollers deal with low voltage and current inputs and have good stability to the current variations. They

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contain RAM, ROM and other peripherals while microprocessors have only CPU [7]. In literature, Arduino Uno microcontroller was utilized for overvoltage and overcurrent protection of simple single phase-two terminal systems in [8] and for transformer protection in [7]. Differential protection of transformer technique was proposed using Arduino with GSM and voice circuit in [9]. The authors recommended to use Arduino in place of 8051 microprocessor as it is a low cost-effective device with very high speed and fine accuracy. A protective strategy was applied using Arduino controller to senses temperature and current and trip load at preset values [10]. Transformer differential protection was employed using Arduino in [11]-[13]. The Arduino senses the condition of transformer each and every second. If it founds any error, then it sends commands to the circuit breakers to trip the main potential transformer. Finally, Arduino was utilized to monitor and protect motors against overvoltage, over-current, overload, excessive heating, crawling and under-voltage [14]. A Proposed software was introduced and fed by the real time data of the power system using Arduino in [15]. The software was used to recognize and indicate different types of fault conditions based on pre-set values, and then disconnected the load side.

III.BLOCK DIAGRAM

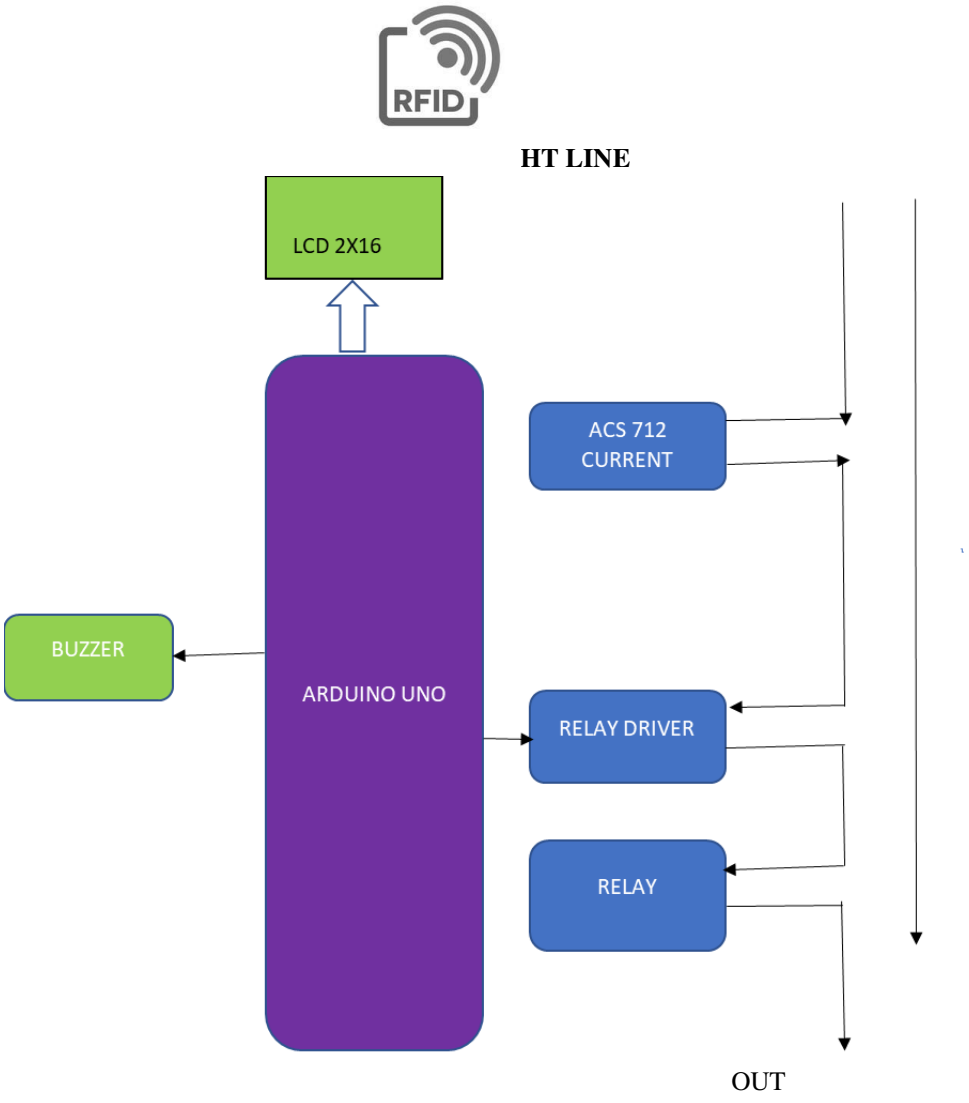

Fig.1: Block diagram of Over Current Protection Relay

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IV.SOURCE CODE

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);

const int sensorIn = A0;
int mVperAmp = 190;           // use 100 for 20A Module and 66 for 30A Module
float offset = 0.09;
double Voltage = 0;
double VRMS = 0;
double AmpsRMS = 0;
float watt = 0;

#define D_load1   8
#define D_load2   9
#define K_load1   10

//*********************************************************************************
void setup()
 {
   Serial.begin(9600);
   lcd.begin(16, 2);          // 16 characters, 2 rows
   lcd.clear();
   lcd.home ();        // 16 characters, 2 rows
   pinMode(sensorIn, INPUT);
   pinMode(D_load1, OUTPUT);
   pinMode(D_load2, OUTPUT);
   pinMode(K_load1, OUTPUT);
   digitalWrite(D_load1, LOW);
   digitalWrite(D_load2, LOW);
 }
```

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```
//*****************************************************************************************
void loop()
 {
   lcd.setCursor(0, 0);
   lcd.print("Load:");
   Voltage = getVPP();
   VRMS = (Voltage / 2.5) * 0.707;  //root 2 is 0.707
   AmpsRMS = (VRMS * 1000) / mVperAmp;
   //Serial.println(AmpsRMS);
   watt = 208  * (AmpsRMS - 0.047);
   if (watt < 1.0) { watt = 0;  }
   lcd.print(watt);
   lcd.println(" Watt  ");


//.....................................................
 if(watt <= 100)
  {
   lcd.setCursor(0, 1);  lcd.print("Domestic Line   ");
   digitalWrite(D_load1, LOW); digitalWrite(D_load2, LOW);
  }


 else if(watt >= 110 && watt <= 200)
  {
   lcd.setCursor(0, 1);  lcd.print("Domestic Line   ");
  }


 else if(watt >= 250 && watt <= 400)
  {
   lcd.setCursor(0, 1);  lcd.print("Over load Trip  ");
   digitalWrite(D_load1, HIGH); digitalWrite(D_load2, HIGH);
  }
```

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```
}

//*****************************************************************************************
float getVPP()
{
 float result;
 int readValue;          //value read from the sensor
 int maxValue = 0;        // store max value here
 int minValue = 1023;        // store min value here

  uint32_t start_time = millis();
  while((millis()-start_time) < 8000) //sample for 1 Sec
   {
    readValue = analogRead(sensorIn);
    if (readValue > maxValue) { maxValue = readValue; }
    if (readValue < minValue) { minValue = readValue; }
  }

  result = ((maxValue - minValue) * 5.0)/1023.0;
  Serial.println(result);
  result = result - offset;

  return result;
 }
 //*****************************************************************************************
```

V. CONCLUSION AND FUTURE WORK

Now A days the protection and control of equipment plays a very important role. To avoid electrical failure we use fast responding circuit breakers because of its considerable accuracy in fault detection and cut off- time, and also its smooth operation compared to conventional type. An Overcurrent relay was designed using Arduino Uno microcontroller. Software program has been created through protos package using C language. To ensure the capability of the proposed Overcurrent protection relay performance to a FREEDM system, software simulator and hardware circuit has been developed.

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