International Innovative Research Journal of Engineering and Technology
ISSN: 2456-1983 Vol: 4 No: 2 December 2018

# Equalization of the Current in a Three-Phase Electrical Power System

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**Abstract:** Single phase loads connected to three phase systems creates unbalance in the system. This paper aims at the development of certain techniques that could divide the power drawn by a single phase load to the three phases of a three phase system according to the current amount at which each phase is loaded. For accurate controls and power division, we use a DC link connected with converters at both the ends. The power flow is controlled by implementing controlled rectification in each phase. PWM inverters are used to produce perfect sine waves from this DC rectified output, and thus creating a controlled single phase supply from the three phases. The firing pulses for the thyristors are provided by a PIC microcontroller. Three Phase power converter found applications in every field of life where single phase loads are fed from a three phase supply. Implementing in domestic use can definitely keep the balance of the system even under severe neutral shifts due to failure in system. It increases the balance of the system whenever a new single phase load is operated in the system - just the opposite of what conventional methods do. It can also replace three phase wiring with a single phase wiring, hence cost effective and can drive heavy single phase loads such as X-ray machines, Induction burners etc. by replacing bulky and inefficient systems like phase reduction transformers and improving the balance of the system.

**Keywords:** H bridge, PIC microcontroller, PWM, Rectifier, Single Phase, Three phaser.

## 1. INTRODUCTION

Electric power is generated and transmitted in three phase. Usually supply is given to a consumer in three phase or in single phase as per requirement. Electric loads are connected to these supplies. Heavy loads are driven directly by three phase supply and light loads are fed with single phase supply. We can connect single phase loads on three phase supply by taking any one phase from three phases R, Y & B and the neutral. Connecting loads of different rating on each of these three phases creates imbalance of currents in each phase in the three phase supply system. Unbalance of current in these phases create problems in generator side and transmission side also. We aims to introduce a new device so as to balance the power drawn from each of the phases.

Three phase power converter is used to balance a three phase supply when a single phase load is to be driven by the supply. The converter uses power electronic switching technique so as to balance power in these phases. Current transformers are provided on each line monitors the amount of current following through it in each instant. The three phase ac supply is rectified according to the current value of power flowing through the line (controlled rectification), so as to generate DC supply. The current drawn from a line which is comparatively loaded with respect to other lines will be less. Thus each line is loaded with respect to the current it is already carrying. A line which is comparatively lightly loaded initially will be bearing most part of the single phase load being connected with this device. Sine wave inverters are being used to covert the DC from rectifier circuits back to drive the 1 phase load. A microcontroller is used to monitor and control the input and output of the device.

The main application of this converter is to balance the three phase power when a single phase load is being connected. One of the other main application of this power converter is that, this can replace three phase wirings with single phase wirings, which is being used in wiring of big buildings. It will reduce the cost of wiring. By using this, voltage regulation of the lines can be improved since the voltage drop created while turning on a single phase device is spread out to all the three phases and hence its impact is reduced. The voltage at the one phase output is regulated so that the need for separate regulators for each device is ruled out. This converter can drive heavy single phase loads such as X-ray machines, Induction burners etc. by replacing

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ISSN: 2456-1983 Vol: 4 No: 2 December 2018

bulky and inefficient systems like phase reduction transformers and improving the balance of the system.

This paper gives the entire description about the corresponding three phase power converter. Section II provides the circuit description and working of the system. In addition to that in the corresponding section gives some brief description about the overall block diagram of the system and its working stages. Section IV provides advantages and disadvantages of the system. Section V provides microcontroller program used in the system and we conclude in section VI.

## 2. CIRCUIT DESCRIPTION AND WORKING

### A. Block Diagram

Three phase power balancer is used to balance a three phase supply when a single phase load is to be driven by the supply. For this, current transformers are provided on each line monitors the amount of current following through it in each instant and it gives the values to the microcontroller. The three phase ac supply is rectified according to the current value of power flowing through the line (controlled rectification), so as to generate DC supply. This is done by taking supply from each line with neutral to rectifiers corresponding to each line. Sine wave inverters are being used to covert the DC from rectifier circuits back to drive the 1 phase load. A microcontroller is used to monitor and control the input and output of the device. And it also generates firing pulses for various operations. Figure 1 shows the basic block diagram of the system.

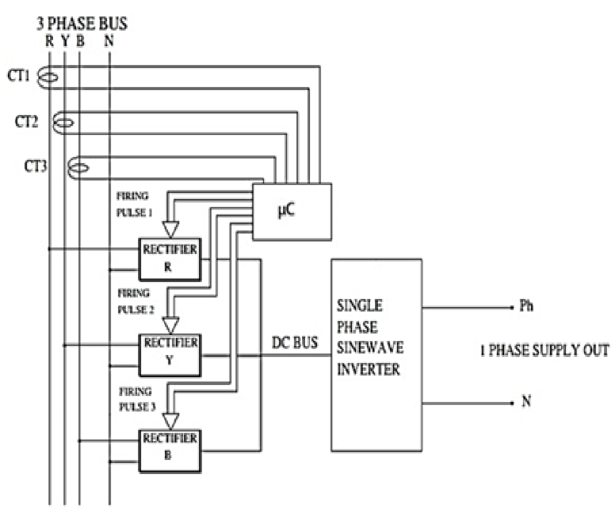


Figure 1. Block diagram of Three Phase Power Balancer

### B. Rectifier

Every phases rectifies separately by using controlled switches. ON/OFF is made and dc bus is made. The firing pulse required for FET is given by microcontroller. The firing of microcontroller depends upon the current measured by the CT in the buses i.e., R, Y, B and the dc voltage. High load driving IC are used to give the gate pulses of microcontroller. By using this pulses required rate of gate pulses can be given. Figure 2 shows the rectifier circuit of the system.

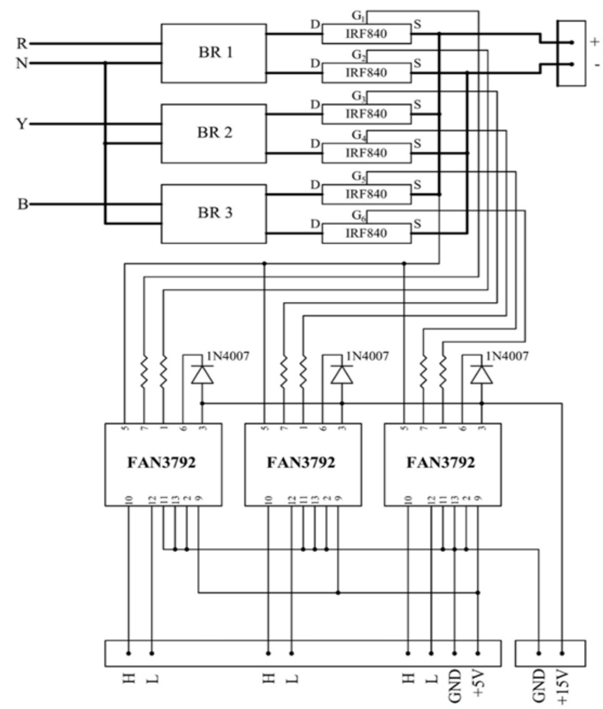


Figure 2. Rectifier circuit

### C. Sine Wave Inverter

The square wave type is the simplest method to produce AC from DC; however, it suffers from low frequency harmonics which causes difficulty in filtering out the noise to prevent these harmonics to return back to the primary side of the transformer. The PWM inverter, on the other hand, forces the harmonics to be way up higher than the fundamental (line) frequency; thus, easing up the filtering requirement of the inverter. However, the major drawback of the PWM inverter is the increased switching losses due to the frequent switching actions of the electronic switches within the inverter.

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There are many varieties of inverter designs. The most common topology uses what is referred to as the H-bridge topology. This topology is used in conjunction with either the square wave, or pulse width modulation (PWM) switching schemes. Figure 3 shows the sine wave inverter circuit of the system. As mentioned previously, PWM control signals can be used with the same H-bridge topography. The disadvantage of the PWM switching scheme is that it is more complicated than the square-wave switching scheme. Multiple, relatively complex control signals are needed to control the transistors of the PWM inverter. The advantage, however, of the PWM switching scheme is that it is able to generate a more perfect sinusoidal AC output, which some loads prefer.

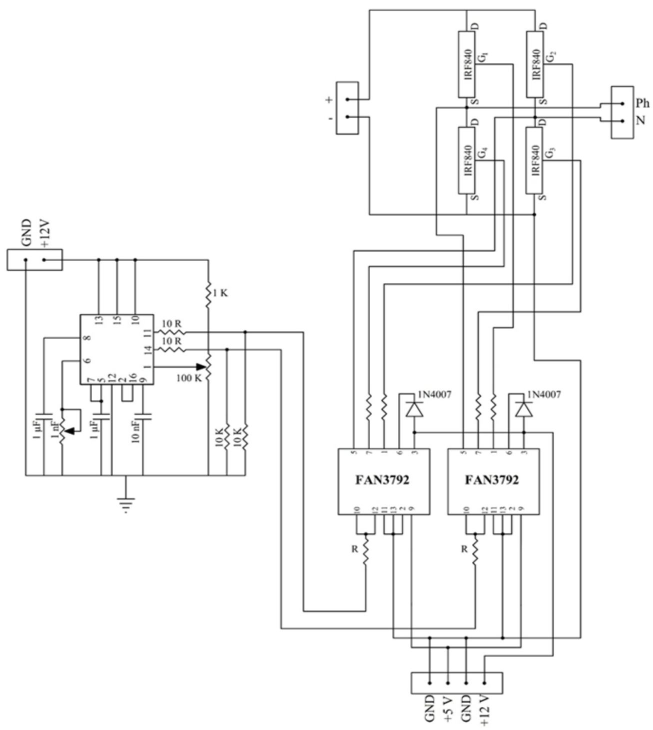


Figure 3. Sine wave inverter section

**D. PIC Connections**

For the proper working of PIC +5V is given from the power circuit. The Current transformer rms value from the current measuring circuit is provided to this PIC in order to do the manipulations and generate the firing pulses and the reference square wave according to program which is loaded in the PIC. The respective Pic and its connections is shown in figure 4.

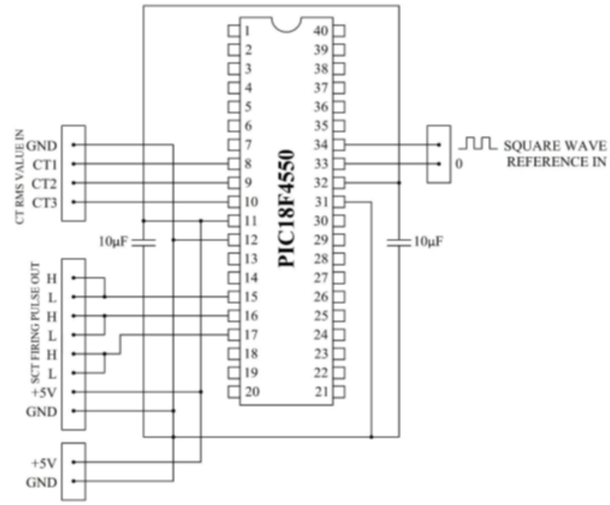


Figure 4. PIC and its connections

**E. Current Measuring Circuit**

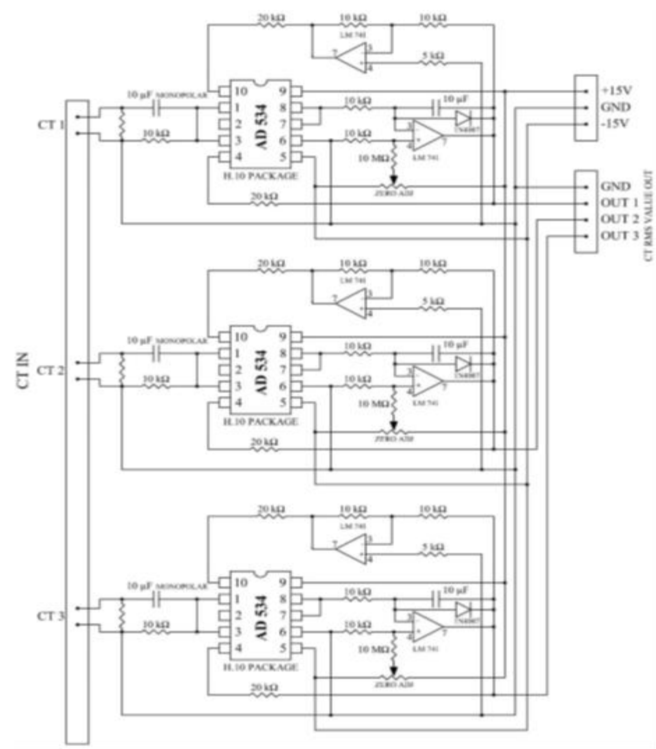


Figure 5. Current Measuring Circuit

**F. Firing Logic**

The firing pulses for the FET is provided based on four factors. Three currents in the bus and one feedback voltage of the dc bus (for voltage regulation). For a reference, we

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take the first phase from the supply and reduce the voltage using a 9-0-9 transformer. This ac waveform is fed to an op-amp comparator circuit and a square wave is generated. This square wave shows the time period of the first phase which is taken as a reference for the firing of the whole system.

The time period of this square wave gives the time period of the rectified three phase output from the uncontrolled rectifier. The firing pulse for the three FETs are provide for one by third of this time period. That is the firing pulse for the first phase is given from 0 to t/3 and for the second phase from t/3 to 2t/3 and for the third phase from 2t/3 to t. Each step waveforms are showed in figure 6, 7 and 8. For this trigger the timer of PIC for this square wave reference generated. The timer 1 is run at 16 bit mode. So that the total step will be 216. When the high pulse of the square wave comes, the timer starts. Then it is reset at the end of the cycle. Here we get a step of 216 = 65536.

The steps available for first phase is equal to 65536/3=21845.

That is for first phase: 0-21845, Second phase: 21845-43690 and Third phase: 43690-65536

The stepping value is computed according to the values of current in the bus and the feedback voltage in the dc bus.

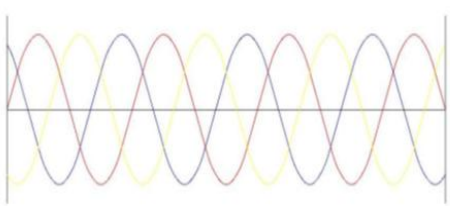

Figure 6. Three phase supply waveform

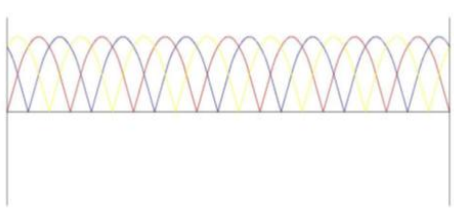

Figure 7. Full Bridge rectified output

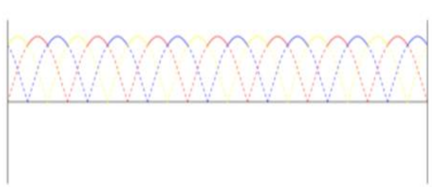

Figure 8. Loading waveforms

T = 65536

T/3=21895

2T/3=43690

We define three variables:

$r_c$ = current in R phase, $y_c$ = current in Y phase, $b_c$ = current in B phase

T = the sum of three currents = $r_c + y_c + b_c$

Then compute the values for another set of variables

$r = (y_c + b_c)/ (2r_c + y_c + b_c)$

$= (y_c + b_c)/ (t + r_c)$

$y = (b_c + r_c)/ (t + y_c)$

$b = (r_c + y_c)/ (t + b_c)$, for maximum nonlinearity in the output.

Average value of variables is computed as:

avg = (r + y + b) / 3

Then bus voltage is set to be the peak value of the AC output. Hence $V_{dc} = \sqrt{2} \times 240 = 339.4V$

α is the error between the optimal value of the dc bus and the actual value of voltage in the dc bus.

$V_p$ = voltage of dc bus and $V_s$ = 300

$\alpha = [((Vp/3)-(Vs-V))/Vp] \times 2000$

$\alpha' = 6666 - \alpha$

also the values of firing pulses for each phase

$r_s = 13333 - ((\alpha'/avg) \times r)$

$y_s = 19999 - ((\alpha'/avg) \times y)$

$b_s = 6666 - ((\alpha'/avg) \times b)$

Then the values of $r_s$, $y_s$, $b_s$ are computed and fired corresponding to each phase by taking the value of timer each time to determine which phase used to be turned ON at the current time.

### G. Power Supply Circuit

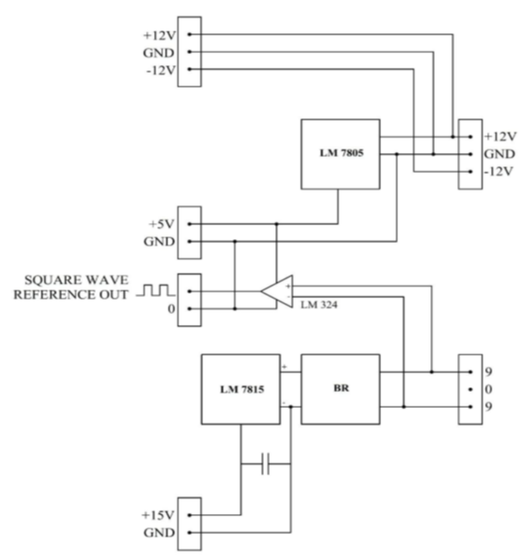


Figure 9: Power Supply Circuit

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By the help of the power supply circuit, we can obtain the various supplies. From the main supply, the single phase ac is taken to a 230/9-0-9V transformer and from this transformer the ac is then rectified to gate dc. For the working of PIC +5V dc is needed. So that using LM 324 +5V can be obtain +5V. Also +12V/-12V and +15V are also realized in the power supply circuit by the use of LM 7805 and LM7815 respectively.

## 3. ADVANTAGES AND DISADVANTAGES

The advantages of the three phase power balancer is as follows:

• To balance the 3 phase power when a single phase load is being connected.
• Three phase power balancer can replace 3 phase wirings with single phase wirings, which is being used in wiring of big buildings and so, can reduce the cost of wiring.
• By using this device we can isolate the consumer side completely from the distribution side. Hence problems occurring at any side will not affect the other side.
• The problem occurring in one consumer end will not affect the nearby consumer, due the isolation property.
• By using power balancer, voltage regulation of the lines can be improved since the voltage drop created while turning on a single phase device is spread out to all the three phases and hence its impact is reduced.
• The voltage at the one phase output is regulated so that the need for separate regulators for each device is ruled out.
• This device can drive heavy single phase loads such as X-ray machines, Induction burners etc. by replacing bulky and inefficient systems like phase reduction transformers and improving the balance of the system.
• This can be introduced in future implementation of single phase load so as to improve the stability of the power system.
• This can resolve many problems related to unbalanced power in distribution section as well as the generator section.

The main disadvantages of the three phase power balancer is follows:

• Some of components used in this device is not commonly used and its non-availability.
• There are two conversions are in the device. AC to DC and DC to AC.
• Output parameters will totally depends on the perfection of the inverter.

## 4. MICROCONTROLLER PROGRAM

```
#int_EXT
EXT_isr()
{
}
#int_EXT1
EXT1_isr()
{
set_timer1(0);
}
void main()
{
  int8 rC,yC,bC,v,vs,vp;
  int16 t,r,y,b,avg,alpha,alphad,tmr,rS,yS,bS,rE,yE,bE;
  rE=13333;
  yE=19999;
  bE=6666;
  vs=300;
  vp=339;
  setup_adc_ports(AN0_TO_AN7|VSS_VDD);
  setup_adc(ADC_CLOCK_INTERNAL);
  setup_psp(PSP_DISABLED);
  setup_spi(FALSE);
  setup_wdt(WDT_OFF);
  setup_timer_0(RTCC_INTERNAL);
  setup_timer_1(T1_INTERNAL|T1_DIV_BY_1);
  setup_timer_2(T2_DISABLED,0,1);
  setup_timer_3(T3_DISABLED|T3_DIV_BY_1);
  setup_comparator(NC_NC_NC_NC);
  setup_vref(FALSE);
  enable_interrupts(INT_EXT);
  enable_interrupts(INT_EXT1);
  enable_interrupts(GLOBAL);

setup_oscillator(OSC_8MHZ|OSC_INTRC|OSC_31250|OS
C_PLL_OFF);
  // TODO: USER CODE!!
  while(1)
  {
   set_adc_channel(5);
   rC=read_adc();
   set_adc_channel(6);
   yC=read_adc();
   set_adc_channel(7);
   bC=read_adc();
   set_adc_channel(0);
   v=read_adc();
```

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```
    v=v*(vp/5);
    t=rC+yC+bC;
    r=(yC+bC)/(t+rC);
    y=(bC+rC)/(t+yC);
    b=(rC+yC)/(t+bC);
    avg=(r+y+b)/3;
    alpha=((vp/3-(vs-v))/vp)*20000;
    alphad=6666-alpha;
    rS=13333-(alphad/avg)*r;
    yS=19999-(alphad/avg)*y;
    bS=6666-(alphad/avg)*b;

    tmr=get_timer1();
    if((tmr>=rS)&&(tmr<rE))
    {
     output_bit(PIN_C0,1);
     output_bit(PIN_C1,0);
     output_bit(PIN_C2,0);
    }
    if((tmr>=yS)&&(tmr<yE))
    {
     output_bit(PIN_C0,0);
     output_bit(PIN_C1,1);
     output_bit(PIN_C2,0);
    }
    if((tmr>=yS)&&(tmr<yE))
    {
     output_bit(PIN_C0,0);
     output_bit(PIN_C1,0);
     output_bit(PIN_C2,1);
    }
   }
}
```

## 5. CONCLUSION

This paper presents a new approach of balancing three phase power supply. We explained certain techniques that could divide the power drawn by a single phase load to the three phases of a three phase system according to the current amount at which each phase is loaded. By implementing controlled rectification in each phase the power flow is controlled. In the present research, this prototype is the first to be described. This can be introduced in future implementation of single phase load so as to improve the stability of the power system. This can resolve many problems related to unbalanced power in distribution section as well as the generator section. However more improvements can be achieved by further research in this topic.

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