Imbalanced Voltage Protection Circuit

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Abstract: This project enables the users to monitor the variations in input voltage either high voltage or low voltage, the reason to display the entities is several electronic and electrical equipment are voltage sensitive. This provides an inexpensive solution to protect the equipment from variating voltages within the mains supply. The project has several blocks which are sequentially placed to operate the certain load in good condition. It starts with input block followed by comparator circuitry, and then relay to operate the AC load. This circuit can directly be adopted between input mains and load as an automatic cut-off circuit.

Index Terms: Over Voltage and Under Voltage standards, comparator, transistors, relay, auto cut-off.

I. INTRODUCTION

This circuit technically provides solution to existing problem in the fields of industries as well as household appliances, to proceed further we need to discuss the standards of high voltage and low voltage levels. These are termed as over voltage and under voltage whose magnitude is compared with usual voltages, over voltage is defined as the rapid increase of V_{rms} compared to normal voltage and low voltage is defined as the rapid decrease of V_{rms} compared to normal voltage [1]. The graphical depiction is given in Fig. (1) and Fig. (2).

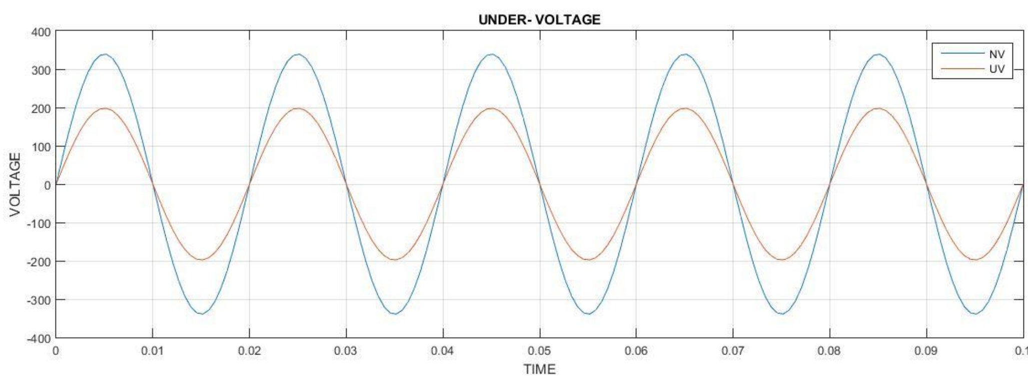

Fig. (1): Under Voltage compared to Normal Voltage

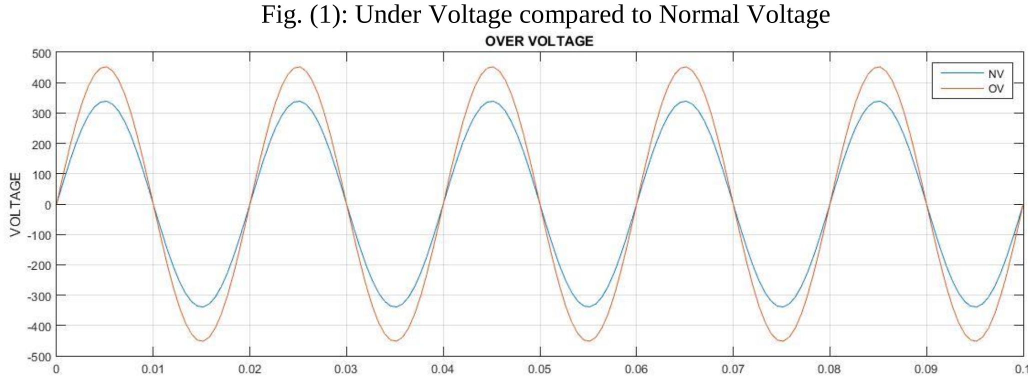

Fig. (2): Over Voltage Compared to Normal Voltage

Power factor of system is dependent on input rms voltage, significantly when rms voltage is either beyond or behind the standard voltage the quality of electric power decreases thus it effects the system from proper operation at that instant and in further cases also. There are several reasons for over voltage and under voltage from the AC mains where few are transformer energizing, bad weather factor, construction activities, poor voltage regulation, ferro resonance, etc. [2]. The mentioned factors can be classified as irresistible or unchangeable causes because they are beyond the capability to control or monitor. So, it requires us to propose new additional circuitry to monitor the input voltage and relate it to the load as an automatic cut-off circuit. The additional circuit operation is dependent on input AC voltage which works according to the preset values and allots the relay to operate the load with mains.

Requirement to prevent the unnecessary fault in the load due to imbalanced voltage from AC mains there is a need to adopt the additional circuitry which operates between the mains and load. Basically, loads are classified into three categories based on their construction and current drawing capacity namely (a) Resistive load (b) Inductive load (c) Capacitive load.

Resistive Load: The loads which are purely resistive to electrical mains are considered as resistive loads. These include Tube lights, CFL's, Music Systems, Laptops, Phones, etc. When these are exposed to voltage fluctuations, according to ohm's law current is directly proportional to voltage so whenever there is a hike in the input voltage more current is drawn from the mains and then is supplied to load components, due to high current flow components may get damaged or in the other case it results in high power consumption. And similarly, during the drop of voltage from mains it draws less current which experiences abnormal operation of components these are not favorable [3].

Inductive Load: The loads which are purely inductive to electrical mains are considered as inductive loads. These include Air conditioners, Refrigerators, Ceiling fans, Mixer grinders, Washing machines and all the appliances which has a motor. Motor is considered to be building block of any inductive load, during the start of the motors they draw huge current from the mains so when dropped voltage is applied, they produce humming sound resulting in over heat and burning of the system. Thus, saving inductive load from under voltage is very important. Similarly, during high voltage it draws more current than the rated current resulting loss of the equipment [4].

Capacitive Load: The loads which are purely capacitive to electrical mains are considered as capacitive loads, these include Radio circuits, Synchronous motor, Buried cables, Telecommunication networks (CDOT), etc. These loads resist the change of voltage by making current to lead the voltage. So, there is no problem of voltage fluctuations in capacitive loads [5].

It is advised to adopt stabilizer technology to prevent the losses mentioned before, these stabilizers operate on current voltage transformer and pulse width modulation (PWM) [6]. The output of stabilizer is not pure sine wave form as like AC mains it is modified sine wave termed as pseudo sine wave [7]. Whose harmonics are affected, all the equipment is not designed to resist the harmonic distortion. By analysis it is prompted to equip the stabilizer in order to run the load even in voltage fluctuations. When voltage is applied beyond or behind the rated voltage of stabilizer it doesn't operate. The output wave form of the stabilizer is depicted in Fig (3).

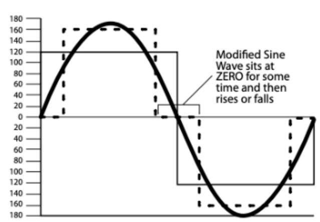

Fig (3): Pseudo sine wave.

II. PROPOSED MODEL

Proposed model is designed to operate as an automatic cut-off circuit between mains and load. It overcomes all the problems raised due to voltage fluctuations and its stabilizer's incapability. It is not only modeled for voltage fluctuation control but also operates for transient response and irregularities in the supply. It's an inexpensive alternative solution to the previously discussed problems it can be implemented by both industries as well as household appliances. The outlook of proposed model is given in Fig (4).

Block Diagram:

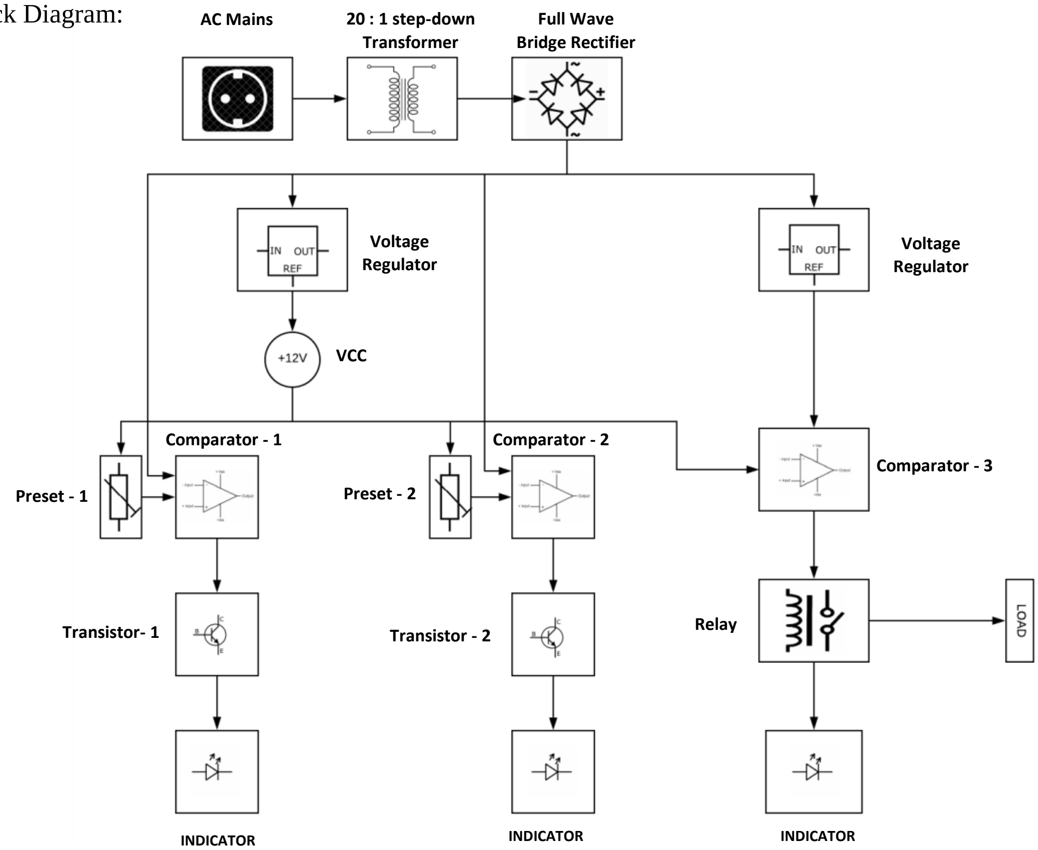

Fig (4)

The circuit starts with the AC mains which is the direct supply obtained from the electricity board of the concerned state or private organization. This supply is carried through transmission line with a voltage of around 440V as the losses in transmission of high voltage is less compared to direct transmission of 240V. The 440V is reduced to 240V using a step-down transformer near the localities. Finally, this voltage is carried out to homes, due to the 440V/240V transformer energizing and deenergizing voltage fluctuations are observed. To nullify or resist the effect we need to adopt additional circuitry in order to maintain the load properly. The mains voltage is taken as reference and is fed to the 20:1 Step – down transformer to convert the voltage of 240V AC to 12V AC, further this 12V AC is converted to DC using a rectifier circuit.

The rectified output is given to two voltage regulators to main the constant voltage irrespective of line voltage and load voltage. Then the reference voltage is compared with the preset voltages by a comparator circuitry, there are two comparators to detect the over voltage and under voltage. The transistor creates a voltage drop across the reference voltage whenever it detects the undervoltage or the over voltage, this voltage drop is compared with no load voltage by comparator – 3 to operate the relay. The load is equipped to the relay which is normally open circuit and is closed when no voltage fluctuations are detected. Then the three indicators are placed to monitor the status of input voltage to the circuitry or the equipment.

This circuit creates a certain delay to compare the voltage which is useful to protect the circuit from transient response and irregularities in power supplies. The circuit is designed and simulated using NI – MULTISIM – 14.1 for its operation and found to be successful.

III. CIRCUIT DIAGRAM and OPERATION

The input voltage standards of India are given as 220V-250V, and all the equipment are designed to operate in this voltage range. Any voltage beyond or behind this limit leads to damage the heavy equipment connected directly to mains supply. The circuit is developed with objective to compare the input voltage with the normal voltage in order to operate the equipment but is not feasible to compare the 240V AC supply directly by any comparator. So, it is required to convert it to less reference DC voltage, this is possible because the rectified output voltage will be different for the normal voltage, over voltage and under voltage. In order to operate the electronic components +VCC is required and it is impractical to embed the new DC source to operate it as +VCC.

20:1 Step Down Transformer:

Transformer is an electrical equipment which produces output with input voltage depending upon the EMF ratio depending on the turns of primary coil and secondary coil. The ratio is given as transformer's ratio,

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

Where V_2 is the secondary coil voltage and N_2 is the number of turns in secondary coil
V_1 is the primary coil voltage and N_1 is the number of turns in primary coil
It reduces the input voltage of 240V AC to 12V AC [8].

Full Wave Bridge Rectifier circuit:

It is the bridge arrangement of diodes used to rectify the altermatic supply to direct supply with high efficiency of 81.2%. It rectifies both positive half cycle and negative half cycle, the ripples are very low and it is independent of load. Peak inverse voltage is also high for full wave bridge rectifier. These specifications allow the circuit to be adopted for better operations [9].

Voltage Regulators:

These IC's source the voltage to the load irrespective of line voltage and load voltage, and capacitors are adopted to compensate the voltage fluctuations in the input voltage [10]. The pin-diagram is given as

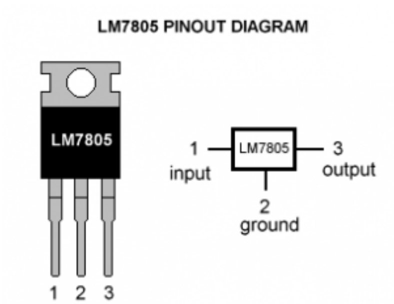

Fig (5). LM7805 Pin Diagram

Potentiometers:

These are variable resistors which are given one input as +VCC and other as GND the output is chosen in such a way that it acts as reference voltage to compare the difference voltage.

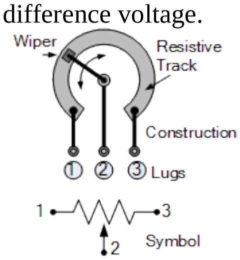

Fig (6): Potentiometer internal diagram

Comparator:

This is the fundamental block of the whole circuit which is used to compare the converted AC mains with the reference voltage and produce certain output according the input pins and configuration. The most dominant type of comparator is LM 324 IC which has four operating comparators embedded inside a single IC [11].

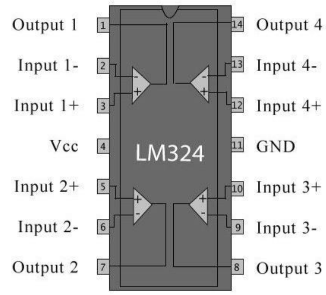

Fig (7): LM 324 Pin diagram

Transistor:

Here, Transistor is used as a switch with basic operation to close the circuit whenever input base voltage is above the transistor reference voltage and to open the circuit when the voltage is not beyond the reference voltage. The n-p-n transistor is CE configuration is adopted.

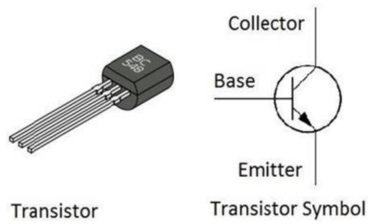

Fig (8): BC 548 pin-out

Relay:

It is a switch being operated by an electro-magnetic coil when the coil is energized with the reference voltage it closes the switch otherwise open the switch [12].

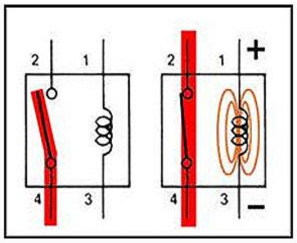

Fig (9): Relay internal construction

Indicators:

LED’s are used as indicators to determine the various voltage conditions either normal or over or under voltage.

The proposed circuit diagram at different instants, for

1. Under Voltage
2. Normal Voltage

3. Over Voltage

is shown in Fig (10), Fig (11) and Fig (12) respectively.

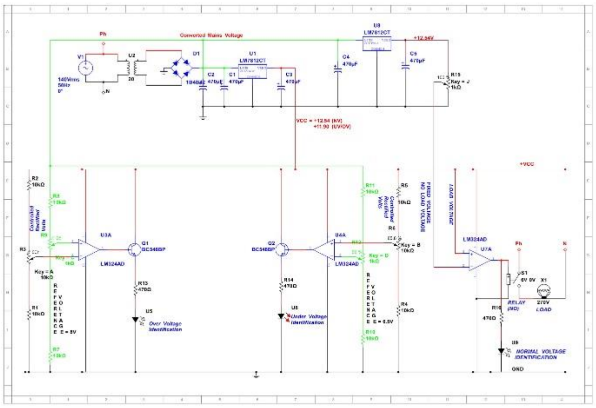

Fig (10): Circuit operation for Under Voltage

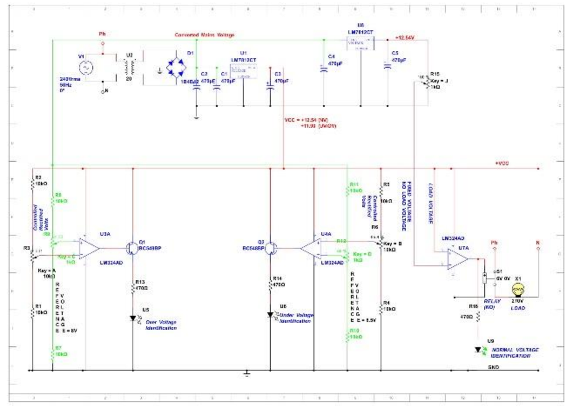

Fig (11): Circuit operation for Normal Voltage

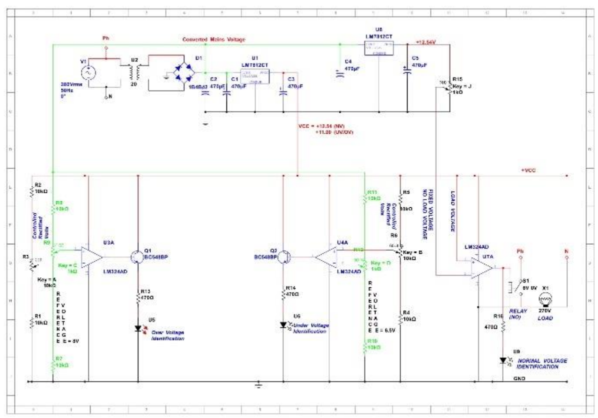

Fig (12): Over Voltage Circuit operation

IV. METHODOLOGY

From the Fig (10), Fig (11) and Fig (12) it can be observed that the load is being operated only when normal voltage which is within the limit of 220V – 250V and in remaining cases it is showing indications of under voltage or over voltage. During this it opens the switch of relay to obstruct the operation of load connected to mains. Prior to the construction of the circuit trail reading are noted for the reference to differentiate the high, normal and low voltages, the readings obtained after AC to DC conversion are given in table (1).

S.no	V_{rms} (AC)-volts	$V_{dc\,-}$ volts
1	140 (LOW)	12.623
2	240 (NORMAL)	15.687
3	280 (HIGH)	18.396

Table (1): Trail values after DC conversion.

From table (1) it is clear that the observed voltages are beyond he saturation points which are required to be controlled in order to make the comparators work. As shown in circuit diagram a resistor network is created to decrees the voltage levels, the values are given in table (2).

S.no	V_{rms} (AC) – volts	V_R - volts
1	140	6.288
2	240	7.687
3	280	9.126

Table (2): Trail values after controlling voltage.

From table (2), the reference voltage for higher voltage is taken as 8V and the reference voltage for lower voltage is taken as 6.5V, the higher voltage reference is fed to negative terminal of first comparator and lower voltage reference is fed to the positive terminal of second comparator. Each comparator is associated with a transistor and an indicator (here LED), the first indicator indicates over voltage and second indicator indicates lower voltage. The third comparator's negative terminal is associated with usual set VCC and the positive terminal is given from the second voltage regulator.

The working is given for three different voltage levels:

1. Low voltage: For reference V_{rms} is taken as 140 V the DC converted voltage is +12.623 V and the controlled voltage is +6.288 V the output from the first voltage regulator is +12.54 V which is taken as VCC the reference voltage of +8 V and + 6.5 V is fed to the comparators. So, when 140 V AC is supplied the controlled voltage is +6.288 V which is compared by the first comparator with a reference voltage of + 8 V as the negative terminal potential (+8 V) it produces no output (0 V) which makes the transistor inactive and the indicator does not glow. And the same + 6.288 V is fed to second comparator which compares with the reference voltage of + 6.5 V as the positive terminal potential is high it produces output ($+V_{sat}$) which makes transistor active and further indicator glows during this course the transistor drops certain voltage which is found to be + 11.90 V from +12.54 V the margin is less due to voltage regulator, the third comparator's positive terminal is fed by this dropped voltage and the negative terminal is supplied by no load voltage from the second voltage regulator, so the third comparator does not produce any output as positive terminal is at low potential compared to negative terminal which makes the relay inactive therefore load gets disconnected.

2. Normal voltage: For reference V_{rms} is taken as 240 V the DC converted voltage is +15.687 V and the controlled voltage is +7.687 V, the voltage is compared by the first comparator as a negative terminal input with the reference voltage of +8 V and produces no output. Transistor is open circuit, similarly, by the second comparator, the controlled voltage is given to the negative terminal and is compared with reference voltage of +6.5 V and produces no output. The second transistor is also inactive, further there is no voltage drop in the circuit and the third comparator produces output which makes the relay active, load is thus connected to the mains.

3. High voltage: For reference V_{rms} is take as 280 V the DC converted voltage is +18.396 V and the controlled voltage is +9.126 V is compared by the first comparator as positive terminal potential. Negative terminal potential (+8 V) is lesser compared to positive terminal potential and thus first comparator produces output which makes transistor active, further leading to indication. The same voltage does not affect the second comparator output it mean there is no output produced from the second comparator which makes transistor inactive and no indication. During the entire process voltage drop is observed and is detected by the third comparator producing output, hence relay gets inactive making load to disconnect.

V. CONCLUSION

Contrasting the above results, it is certain to adopt this proposed model over the existing techniques which is independent of input frequency and free from harmonic distortions. It has wide applications including inductive equipment's like microwave oven, motors, household items and single-phase operated machinery. This circuit also enables the users to monitor the fluctuations. It is the inexpensive solution to control the voltage fluctuations. The circuit can be interfaced with microcontroller for advanced peripherals operation.

VI. REFERENCES

[1]. P. Pillay, P. Hofmann "Derating of induction motors operating with a combination of unbalanced voltages and over-or undervoltages" in 2001 *IEEE Power Engineering Society Winter Meeting*. Conference Proceeding.

[2]. Ravindra Arora, Wolfgang Mosh, "*High Voltage and Electrical Insulation Engineering, 1/e, Wiley-VCH Publishers, 2011*".

[3]. William H. Hayt Jr., Jack E. Kemmerly, "*Engineering circuit analysis, 7/e, McGraw Hill Publications, 2007*".

[4]. A. Sudhakar, Syammohan, S. Pillai, "*Network Theory, 2/e, Tata McGraw Hill Publications, 2012*".

[5]. John A. Malley, *"Basic Circuit Analysis, 2/e, Schaums Outline Series, McGraw- Hill Professional, 2011*".

[6]. M.A Pai and Sauer.W, "*Power System Dynamics and Stability, 2/e, Pearson Education, 2006*".

[7]. M D Singh, K B Khachandani, "*Power Electronics, Tata Mc Graw Hill Publishers, 2007*".

[8]. Bhag S. Guru, Huseyinr Hiziloglu, "*Electric Machinery and Transformers, 3/e, Oxford University Press, 2010*".

[9]. Adel S. Sedra, Kenneth C. Smith, Arun N. Chandorkar, "*Microelectronic Circuits, 6/e, Oxford University Press, 2013*".

[10]. S. Salivahanan, V.S. Kanchan Bhaskaran, "*Linear Integrated Circuits, Tata Mc Graw Hill, 2008*".

[11]. Ramakanth Gayaward, "*Op-amps and Linear Integrated Circuits, 4/e, Pearson Education, 2007*".

[12]. Krishna Kant, "*Computer Based Process Control, 1/e, Prentice Hall of India, 2010*".