A NEW DESIGN OF AN ELECTRONIC PROTRCTOR FOR SINGLE PHASE ELECTRICAL EQUIPMENTS

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Abstract

This protected is designed of simple and discrete electronic devices. No transformer is used in the electrical circuit so the lumped set will be of small size, light weight, and cheap. The power consumed by the electronic circuit and the relay used is less than 15 watts. When the phase voltage of the power system is in the range of (199-241) volts r.m.s. value, the protector connects the load to the power system network, unless otherwise the protector will disconnect the load from the power network. This protector is protected against excessive over voltage. The protector waites a time of no more than 1/3 sec. during a sudden under voltage before disconnecting the load from the power network. This property makes the protector suitable when operating during the switching of heavy starting current loads.

Introduction

All electrical equiments are sensitive to overvoltage (4) and undervoltage variations of power system phase voltage. For example all electronic sets are very affected by overvoltage which may damage these sets. Also undervoltage will make these sets operate unefficienty of induction motor. So protection againsts overvoltage and undervoltage is required. The electronic circuit of this protector is designed according to the safe voltage levels requirements of the phase voltage of power network. The safe range of phase voltage levels is about 220v $\pm$ 10%. In our design we choose the range (199 - 241) volts r.m.s value which is very close to the safe voltage range of phase voltage.

All circuit components are chosen according to their power and voltage tolerances and they are all commercially available. The protector circuit consists of a relay which has the following properties:

a- The relay switch is normally open.

b- The coil resistance of the relay is 410 ohms.

c- The relay switch rating is 10 amps.

d- The voltage of the relay coil is about 6 volts.

Protector Performance

Let VL represents the r.m.s value of the power system phase voltage which has a frequency of 50 Hz and, N is the reference node. Figure (1) shows the whole circuit of the protector. The transistors Q1 and Q2 represent basic control stage of the protector, while Q3 and Q4 represent the inverting and the driving stage respectively. When the phase voltage is 199 volts the, Dc voltage at point B is 27.72 voltage, so Q1 will not conduct and Q2 will be completely ON. Since Q2 is driven into saturation region the voltage at point D will be approximately zero volt and hence Q3 is OFF, the base- emitter junction of Q4 is forward biased. Hence Q4 is completely ON and the relay swithch is closed which will connect the load to the power network. If VL is less than 199 volts the DC voltage level at point B will be less than 27.6 volts so both Q1 and Q2 do not conduct. Since Q2 is OFF the voltage at point D is slightly less than VB, so Q3 will be completely in saturation state. Q3 collector- emitter voltage VCE3 is less than 0.2 volt. Since the DC voltage at point E (VE=VCE3) is less than 0.6 volt Q4 is not forward biased and consequently Q4 is OFF. The off state of Q4 means the relay swithch is open and the load is disconnected from the phase voltage terminal.

For VL>241 V, VB will be greater than 33.7 volts. Since VB>33.6 volts, Q1 will conduct and the voltage at point C be less than 27.6 volts. Consequently Q3 is OFF and Q3 is ON. The voltage at the collector of Q3 is below 0.2 volt, so Q4 will be in cut off state and the load is disconnected from the power network. For 199V$\leq$ VL $\leq$241 V, Q1 is OFF, Q2 ON, Q3 OFF, Q4 On, and load is switched on to the power network.

Calculation and Results

The capacitor C1 charge through the 130 ohms resistor and D1 to the peak value of the phase voltage VL. Hence the voltage at point A is a positive DC voltage and its value is $\sqrt{2}$ VL. The Dc voltage at point B is (1), (2), (3):

$$VB = \frac{\sqrt{2}VL(3.3+0.056)}{68/56+(3.3+0.056} = 0.13932VL$$

The transistor used is BC 107A which is characterized by the following:

β= Collector current (IC)/ Base current (IB) ≈ 200 at low IC.

ICB0 = 0.01 uA at ambient temerature.

VBEmin = 0.6 volt.
ICmax = 100 mA.

Maximum reverse reptitive voltage for VCE is 90 volt.

As seen above, VB follows VL. The two cases below examine obviously the circuit operation during all the variations of VL.

Case 1:-

First, assume VL= 199 volts, than

VB = 0.13932 * = 27.725 volts. Q1 is clearly OFF because the voltage at point B is less than 33.6 volts, but Q2 is conducting and its base current is (1), (3):

$$IB2 = \frac{(27.725 - 27 - 0.6)}{100k} =$$
$$0.00125mA = 1.25\mu A$$

The saturation collector current of Q2 is (3):

$$IC2sat = \frac{27.725V}{120k} = 0.231mA$$

IB2sat = IC2sat/b = 0.231 mA/200 = 1.150 uA.(3)

Since the actual base current of Q2 is greater than its base saturation current (IB2sat). (3), Q2 is completely driven into saturation state. Cosequently VCE2 is less than 0.2 volt. The negligible DC voltage at D means that Q3 is OFF and Q4 conducts. The base current of Q4 is:

IB4 = (27.724-0.7)V/ (120+100)K = 0.123 mA

Note : we assume VBE4 = 0.7 volt because VBE increases with IB and holded approximately at 0.8 volt (1), (3).

IC4sat = 6.2 volt/ 0.41K = 15.1 mA. (3)

IB4 sat = IC4sat/ b= 15.1 mA/200= 0.075 mA.

The actual base current of Q4 is greater than IB4sat, hence Q4 is saturated and its collector current is IC4sat=15.1 ma this value of IC4 is sufficient for the relay coil to switch on the load to the power networ . Any value of VL greater than 199 volts will ensure than Q2 is ON,Q3 OFF ,and Q4 ON . Second , assume VL=198 volts, than VB = 0.3932 * 198 = 27.58 volts. Since VB is less than 27.6 volts both Q1 and Q2 are OFF. Q3 is conducting and its base current:

IB3= (27.58-0.6)V/ (1800+120)K = 0.014mA = 14uA

IC3sat = (27.58V/120K) = 0.23mA, IB3sat/b = 1.15 uA

Since IB>> IBsat(3), Q3 is deeply operating in saturation region, and its collerctor voltage is approximately dropped to zero. As a result Q4 is OFF, and the load is switched off from the power network. Any value of VL<198V ensure that Q1, Q2, Q4 are OFF and Q3 is ON. The OFF state of Q4 means that the load is switched off from the power network.

Case 2:

First assume VL = 241 volts, then VB = o.13932*241 = 33.57 volts. Since VB is still below 33.6 volts, Q1 is OFF, but Q2 is ON and completely driven into saturation state. The voltage at D is less than 0.2 volt which is less than 0.6 volt required for Q3 to conduct. Hence Q3 is OFF. Obviously Q4 is On and completely driven in saturation state. The relay switch is closed and the load is connected to phase voltage terminal. Second, assume VL = 242 volts, then VB = 33.72 volts. Since VB>33.6 volts Q1 conducts and its base current is:

IB1= (33.72-33.6)V/ 120K = 0.001mA = 1uA

The collector current of Q1 is (3):

IC1 = b*IB1 = 200 * 0.001 = 0.2mA

The voltage at point C is (1):

VC=VCE1 = 33.72-0.2*100 = 13.72 volts.

Since VC is less than 33.6 volts Q2 is OFF. Consequenty Q3 is ON and is completely driven into saturation. The voltage at the collector of Q3 is dropped below 0.2 volt. As a result Q4 is OFF and the load is disconnected from the power network. It is seen clearly from the previous caculations that for $199V \leq VL \leq 241V$, the transistors Q1 and Q3 are OFF. Also Q2 and Q4 are ON, which in turn switch on the load to the power network. For VL>241V, (Q1,Q3) are ON and (Q2,Q4) are OFF which in turn switch off the load.

The above calculations are summerized by the plot shown in figure(2).

In case of sudden overvoltage, the capacitor C1 will charge fastly to the peak value of this overvoltage and VB will hold a corresponding value which in turn switches off the load from the power network.

In case of sudden undervoltage, VB is not dropped immediately to a corresponding value, but gradually decreases till it reaches that value. So the load is not switch off immediately during sudden undervoltage. The time taken by the protector in order to switch off the load during sudden undervoltage is determined by the time constant of the DC voltage VB and the value of VB directly before the instance of undervoltage occurrence.

The time constant of VB is T = C1 * R.

Where C1 = 47 uF and R = 56/68 + (3.3+0.056)=34 K

Maximum time that protector waites during sudden undervoltage is when VL = 241 volts and suddenly dropped below 199 volts. During such undervoltage VB will vary with time or we can write that (3):

$$VB(t) = 0.13932*241*\exp(-t/RC)$$

Where t is time in seconds

At t=0, VL=241 volts and VB = 33.57volts.

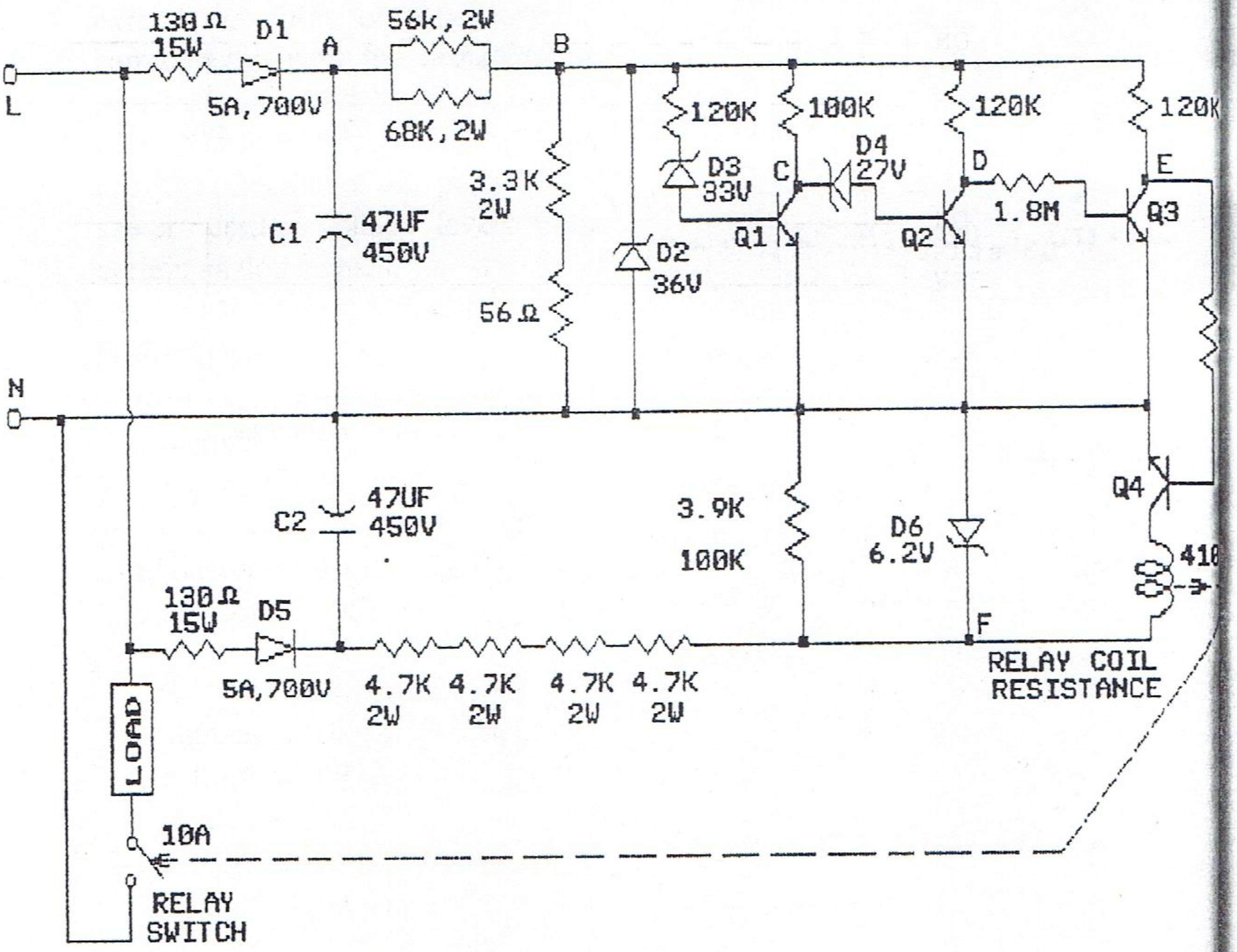
The load will be switch off if VB(t) is dropped to 27.6 volts, i.e:

$$27.6= 33.57*\exp(-t1/1.6).$$

t1= 0,31 second.

Where T=RC1= 1.6 second and T1 is the maximum time waited by the protector befor switch off load during a sudden undervoltage case, provided that VL= 241 volts directly before the instance of undervoltage. This property makes the protctor do not respond to sudden undervoltages caused by the switching of heavy starting current loads.

The zener diode D2 is used to protect the protector itself against excessive overvoltage. Two 130 ohms, 15 watts resistore are used to limit the charging currents of C1 and C2 in order to protect D1 and D5 from excessive charging currents (1),(3).



Figure(1) The whole protector scheme.

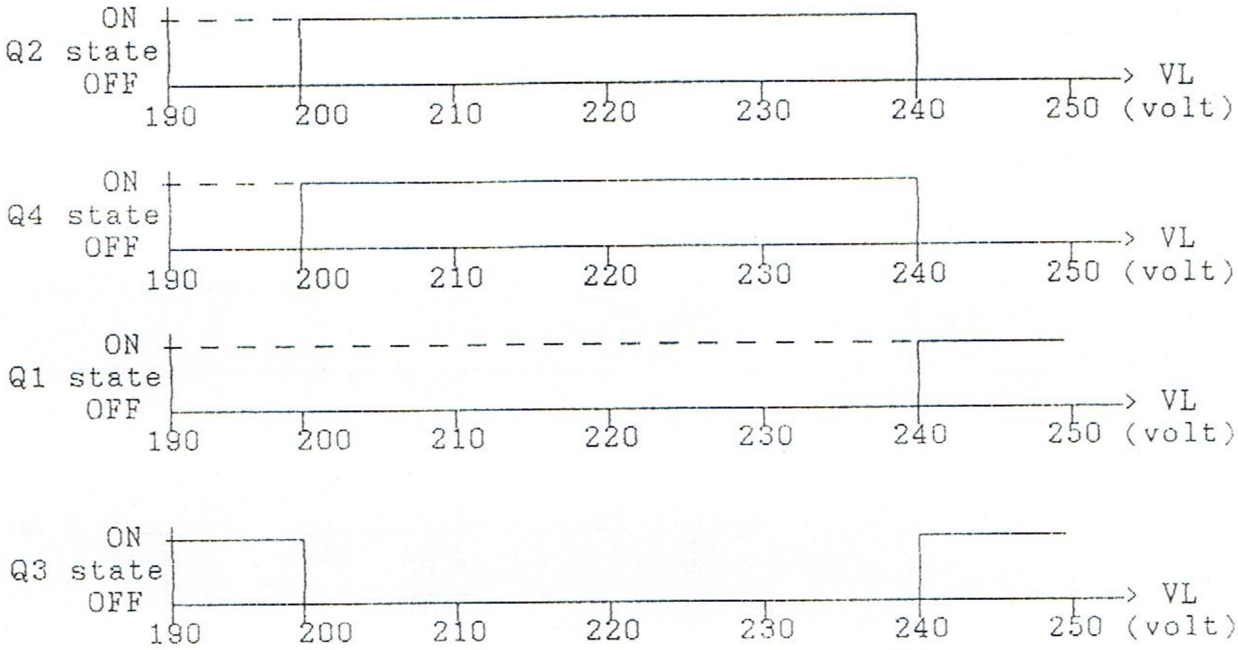


Figure (2) The transistors states during the variation of phase voltage

Conclusion

This protector can be modified to be used with heavy loads by making the relay switch control the coil current of a high power AC contactor. Also it is possible to extend the utility of this protector can be employed for protection of AC and DC power upplies. Finally it is possible after some changes to use the principle of this protector to select certain voltage levels from certain analog signals.

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تصميم جديد لجهاز حماية الكتروني للاجهزة الكهربائية ذات الطور الواحد

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الخلاصة

في هذا البحث تم تصميم وبناء جهاز حماية الكتروني للاحمال ذات الطور الواحد بأستخدام مكونات الكترونية بسيطة. الدائرة الالكترونية لهذا الجهاز لاتحتوي على محولة كهربائية مما يجعل الجهاز المصمم صغير الحجم، وخفيف الوزن وقليل التكلفة.

القدرة الكهربائية المستهلكة من قبل الدائرة الالكترونية والمرحل (Relav) هي اقل من ١٥ واط.

عندما تكون فولتية الطور للشبكة الكهربائية في حدود (٢٤١-١٩٩) فولت يقوم جهاز الحماية بربط الحمل الى الشبكة الكهربائية، وعندما تكون فولتية الطور خارج هذه الحدود فأن جهاز الحماية يقوم بفصل الحمل عن الشبكة الكهربائية.

نظام الحماية هذا مصمم بحيث يمكن حمايته من الزيادة المفرطة لفولتية الطور. وفي حالة وجود انخفاض مفاجيء في الفولتية فأن نظام

الحماية ينتظر زمنا لايتجاوز ثلث ثانية قبل ان يقوم بفصل الحمل عن الشبكة الكهربائية. هذه الصفة تجعل هذا النظام يتلائم مع العمل مع الاحمال ذات التيارات الابتدائية العالية اثناء ابتداء تشغيلها.