

Protective relay circuits

This worksheet and all related files are licensed under the Creative Commons Attribution License, version 1.0. To view a copy of this license, visit <http://creativecommons.org/licenses/by/1.0/>, or send a letter to Creative Commons, 559 Nathan Abbott Way, Stanford, California 94305, USA. The terms and conditions of this license allow for free copying, distribution, and/or modification of all licensed works by the general public.

Resources and methods for learning about these subjects (list a few here, in preparation for your research):

Questions

Question 1

Protective relays are special power-sensing devices whose job it is to automatically open or close circuit breakers in large electric power systems. Some protective relays are designed to be used directly with large electric motors to provide sophisticated monitoring, shut-down, and start-up control.

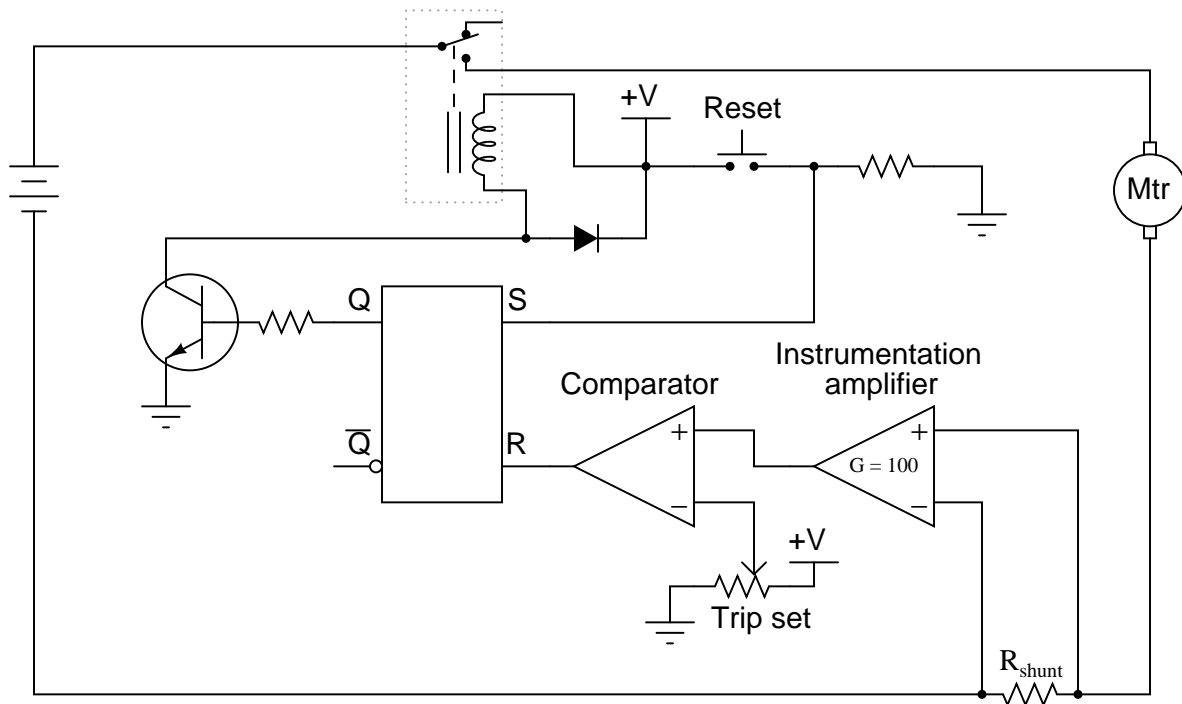
One of the features of these motor-oriented protective relays is *start-up lockout*. What this means is the relay will prevent someone from attempting too many successive re-starts of a large electric motor. If the motor is started and stopped several times over a short period of time, the relay will prevent the person from starting it again until a sufficient "rest" time has passed.

Explain why a large electric motor would need to "rest" after several successive start-up events. If electric motors are perfectly capable of running continuously at full load for years on end, why would a few start-ups be worthy of automatic lock-out?

[file 03131](#)

Question 2

Explain how this motor overcurrent protection circuit works:



[file 04022](#)

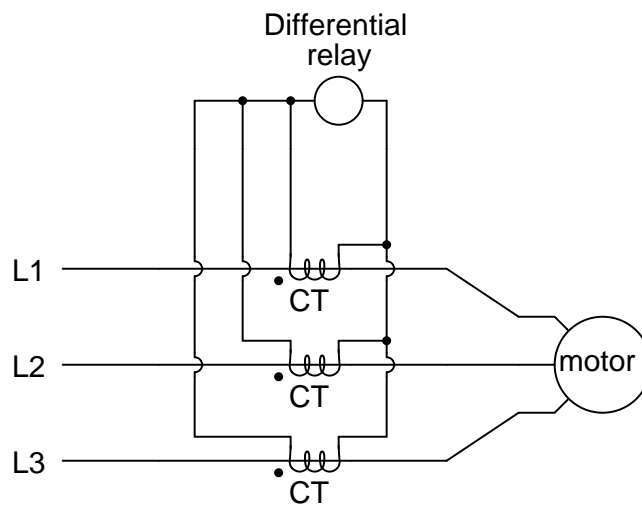
Question 3

A *differential relay* is a common type of protective relay used in power systems. One of the more common forms is the differential current relay. A very common example of a differential current relay – so common, in fact, that nearly every house is equipped with at least one – is the *GFCI*, or *Ground Fault Current Interrupter*. Explain what a GFCI is, and then in a larger context, explain what a differential relay protects against.

[file 04023](#)

Question 4

Explain what sort of electrical fault this differential current relay protects against:



Also, explain what this relay will do to protect the circuit if it detects this kind of fault.
[file 04024](#)

Answers

Answer 1

I won't give you a direct answer here, but I will provide a big hint: *inrush current*.

Answer 2

I'll let you and your classmates figure out this circuit! It is fairly straightforward to analyze.

Answer 3

The function of a GFCI is very easy to research, so I'll leave that to you. In a more general sense, a *differential relay* protects against conditions where two or more electrical quantities (usually current) are not in phasor balance. That is, a differential relay will trip when two or more electrical quantities do not precisely balance one another when they should.

Answer 4

The differential relay shown protects against *ground faults* inside the motor. Although not shown in the diagram, the protective relay will actuate a contact that will tell the motor's control circuitry to cut power to the motor in the event of a ground fault.

Notes 1

Inrush current is a factor with *every* motor type, AC or DC. It is easy to forget just how substantially larger a typical motor's inrush current is compared to its normal full-load current. When students consider the magnitude of the currents involved, and also the fact that most electric motors are fan-cooled and therefore lacking in cooling during the initial moments of a start-up, the reason for automatic lock-out after several successive start-up events becomes obvious.

Notes 2

If you want to add more challenge to this question, ask your students to come up with practical component values. Of course, you will need to provide some base values such as:

- Maximum motor current (locked-rotor)
 - Motor supply voltage
 - Relay coil current
 - Transistor β
-

Notes 3

This question affords students the opportunity to relate something they probably never have had exposure to (a differential protective relay) to something they may see every day (a GFCI-protected power receptacle). The purpose of this comparison, of course, is to give students a familiar context in which to understand something new.

Notes 4

At first, students may be dismayed at the appearance of the current transformers being short-circuited to each other. If so, remind them that it is perfectly *normal* to short the output of a current transformer. In fact, opening the secondary of a CT can be dangerous!

It should be noted that the protective relay itself is but a part of a complete protection system. On its own, it can only monitor for current differences. In order to actually protect anything, it must be tied into the control circuitry supplying power to the motor. That is, just like an overload contact (O.L.) tells a motor contactor to de-energize, the protective relay must command a contactor or a circuit breaker to open in order to actually interrupt power to the faulted section of a circuit.

I must say that I am indebted to C. Russell Mason's wonderful text, The Art and Science of Protective Relaying. Not only is it comprehensive, but also very lucid in its presentation.