Indian J.Sci.Res. 4(2) : 199-204, 2013
ISSN : 0976-2876 (Print)
ISSN : 2250-0138 (Online)

THE IMPACT OF SATURATION PHENOMENA ON OVER CURRENT RELAY IN ELECTRICAL INTELLIGENT NETWORK

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ABSTRACT

During the past two decades, advances in technologies and protective relays structure as well as converting relays from analog to digital or intelligent, have influenced design guidelines in high voltage posts. Over current relays are the simplest ones which are capable of being structured by digital concepts. Saturation in current transformers, non-feeding, and stimulation of protective relays are along the major protective problems in power plants and high voltage posts. In this paper, through converting relays to analog or digital, we could made them intelligent against saturation in current transformers. Also, relays worked as needed.

KEYWORDS : Saturation, Protection, Relay, Intelligent Making

Power systems create communities' basic substructures of the century 21st. Distribution networks cover nearly all points in developed countries. These structures have got noticeable influence in developing countries as well. Recent advances caused the need for electricity with higher quality. Advances in industrial equipments and instruments have made this need even more important and sensitive. This need resulted in creation of an intelligent network. Intelligent network is a combination of communicative, software and hardware networks for measuring, monitoring, control and managing energy production, transformation, distribution, and consumption. Intelligent network is also introduced as the aggregation of power system substructures and wide telecommunication network (Benmouyal and Standey, 2002).

In other words, technological advances in electrical equipments mainly protective relays have caused the design and structure of high voltage posts to improve appropriately along with these advances (Farhangi, 2010). Exchanging Information and communication in stations and along the transmission lines between posts have made a major development in the structure of high voltage posts and lines' joint. In this paper, at first, digital protective relays are introduced, and then the role and impact of digital overcurrent relays and current transformers in the structure of high voltage posts are studied. At last, the simulation of an overcurrent relay and the impact of saturation on it will be examined.

Protective Relays Evolution

Increased world need for electrical energy has caused quick advances in power system designing in order to provide high quality, cheap and safe electrical energy for consumers. Due to increase in electrical energy consumption, load compression, electricity production sources and the necessity for quick and safe action of protective and control equipments, using digital protective equipments have become important. Electrical protection is one of the major issues in electrical industry. Since the beginning of this industry, electrical energy production, transmission, and distribution have been always along with probable errors and security problems. It means that, expensive equipments like generator, power transformers, and transmission lines should be protected against probable errors in order to protect these valuable properties and distribute electrical energy to consumers more confidently. Protective relays are to supervise quantities like current, voltage, power, frequency, and impedance and also to cut them off if necessary. The first protective relays are of electromagnetic and repulsive types. The main problem of these relays is that they belong to an electrical quantity; that is, if they are used for an overcurrent protection, they can not be used for voltage or frequency protection any more. Overcurrent relays also have their own classification. To do so, different standards are available.

Digital relays started in late 1960s (Ibrahim, 2006) At first, due to high cost of digital systems, low speed, and their high consumption power, there was no motivation to use these equipments instead of regular relays. How ever, nowadays, because of noticeable advances in digital systems, decrease in price, size and consumption power,

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and increase in speed and calculation power, it can be said that the most economical, technical and confident protective relays are digital ones. Therefore, the newest relay generation is the digital one. By using digital processing and microprocessor as processing unit in these relays, not only productivity and capability of relays have increased but also their size, weight and design and production cost have decreased. Design and production of digital or intelligent relays have been a great success in exact and reliable protection of modern complicated and wide networks.

Advantages and Applications of Digital Relays

Protective relays are equipments which act based on received signals. In case of an unusual change in a physical quantity, they act and change position of themselves or any other instruments. Digital relays are of protective types which act based on signal digital processing. Digital relays compared to other protective relays (electromagnetic, electrodynamics, thermal) hold advantages as below (Ammin and Wollenberg, 2005)

- Ability to quickly identify errors and prevent their extension
- Capability of changing relay' s function and protection type along with relay' software change
- High productivity and reliability
- Low design and production cost
- Capability of recording systems' events due to having memory
- Having smaller size and lower weight

Different protective relays can be produced digitally. The most important and applicable ones include:

- Overcurrent and overloaded relays
- Distance relays
- Frequency relays
- Differential relays

Overcurrent Relays and Saturation Phenomena

Overcurrent relays are the simplest ones which can be made by digital concepts. Saturation in current transformers, non-feeding, and stimulation of protective relays are along the major protective problems in power plants and high voltage posts. In recent years, through converting protective relays from analog to digital, we could made relays intelligent against saturation in current transformers. And relays worked reliably. By making relays intelligent in order to prevent current transformers saturation and its impact on protective relays' reliable work, most of the protective problems were solved. In this paper, we also examine the way overcurrent relays are made intelligent against current transformers saturation. Protective relays' inactivity is also studied.

Operation of Intelligent Overcurrent Relays

Here, we discuss the operation of a digital overcurrent relay. Received signals to digital overcurrent relays are like current. This current is firstly rectified inside the relay and then by passing through a resistive network which is adjustable by a switch in front of the relay, is converted into voltages appropriate with input current to relay. This switch equals adjusting coefficient pin in electromechanical overcurrent relays and create a scale of input current. This scale is so that despite of adjusting current value, input current at adjustable level, would create the same internal voltage in relay. An analog to digital converter will convert this voltage to digital. Then, the models behind each other are rectified to find the value of sinusoidal wave peak. Then they are compared. Peak values are stored in peak recorders inside microprocessors. Four peak recorders are used to store the four recent peak values. Whenever a new peak value is added, all peak recorders are compared to find the highest peak value among the last four ones.

A timer and a counter are also used to count the number of peaks' alternation periods. As a peak appears, the counter restarts. Then the number of counting is multiplied by increased number to create a value in which trip time recorder is added. This process also occurs whenever a peak value appears. If trip time recorder exceeds a value K, then relays commands trip. K value is indeed the value of time adjusting coefficient. Relay's specific feature for example descending, ascending, instant, or… is obtained from increasing table which adjusts increased number. By this method, all types of overcurrent relays' features can be obtained (Frahang, 2010).

Overcurrent Relays Problems

According to presented guidelines in all standards, it is needed to consider the probability of current transformers saturation under the impact of fault currents in all protective circuits.

Saturation is seen in all current transformers of power plants and high voltage posts like current transformers installed in generator's station, unit transformer, helping transformers, internal distribution transformers, and internal distribution feeders.

In internal consumption networks and side equipments of power plants, overcurrent relays make the main protective relays which are of high significance. Meanwhile, saturation of each current transformer in abovementioned equipments, in return for fault currents flow, stops relays working. There are some conditions in which current transformers are chosen to prevent saturation in return for fault currents flow; these conditions include supplying load impedance or ZBurdan considering fault current characteristics and the type of current transformer.

At American National Standard Institution (ANSI), the condition in which load impedance is chosen in order to prevent saturation of current transformers in return for fault currents, is

$$Z_N I_B\left(1+\frac{X}{R}\right)\leq 20 \qquad (1)$$

Where Z_N is load impedance of current transformer per unit of load impedance of nominal transformers; IB is maximum fault current per unit of transformer's first nominal current; X/R is constant of fault current (DC). Coefficient of X/R shows the constant of DC. Saturation under the influence of DC is shown by "1+X/R" and is known as DC saturation. High domain of fault current represents another saturation factor. In case of high DC and limited current value, saturation is influenced by DC. On the opposite, high current value and low value of X/R, saturation is influenced by AC or it can be influenced by both. In power plants, both current domain and time constant are noticeable. Saturation happens regarding DC; $Z_N I_B(1+X/R)$is considered as the secondary voltage in return for fault current flow. According to magnetizing curve, this voltage is more than saturation voltage.

For current transformers which feed overcurrent relays, in case of saturation, there is no specific anticipation of relay structure; there is even no appropriate solution to install current transformers. In, DC value is considered 20 times more for each X/R comparing to nominal first current of current transformer in all standards. It is while in power plants, DC domains is 100 or 200 times more than load nominal current; value of X/R is considerable, current

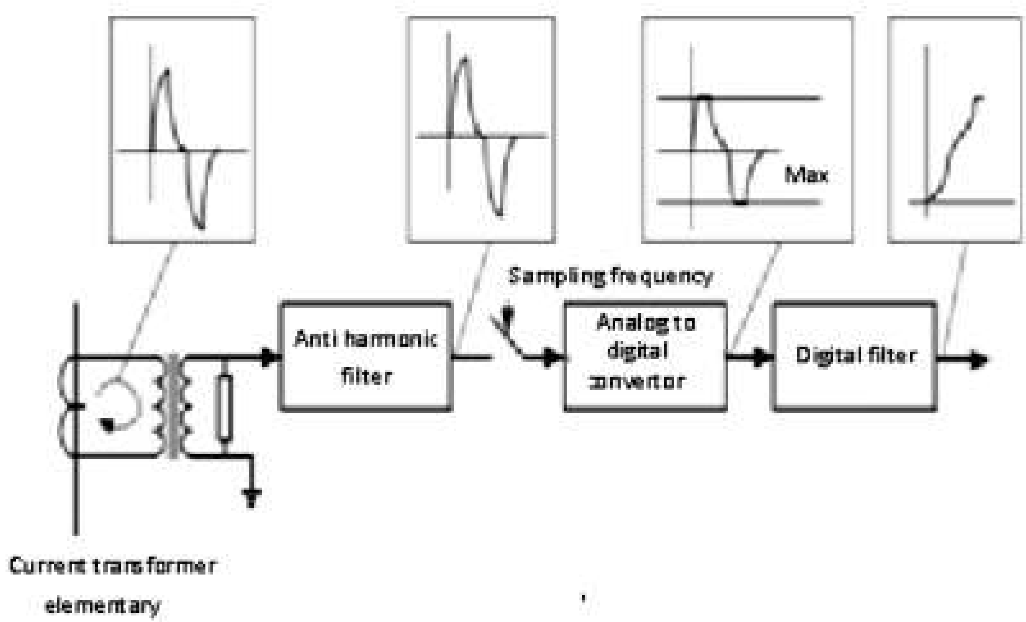

Figure 1: Overall diagram of intelligent overcurrent relay

transformers are saturated; and no current will run in secondary circuit or relay in return for DC flow. Therefore, there is no probability for fault detector relay to work.

To simulate intelligent overcurrent relay by software Matlab, we used the model shown in figure, 1. In this circuit, fault current, which was transmitted to secondary in relay circuit, changes to digital quantity. In figure, 1, the first element is current transformer; the second element is the appropriate filter eliminating all high frequency components from input signal; the third one converts analog quantities to digital; and the last element is a digital filter eliminating all high frequency components while determining main components.

Under Research Intelligent Overcurrent Relay's Structure

Regarding previous explanations about intelligent relays, here, we use software "Matlab" to discuss the way overcurrent relay is structured. However, we shouldn't forget to follow overcurrent relays standards.

(a) Simulation of Saturation Phenomena By Software Matlab

As mentioned before, the main reason for digital relays' unproductivity is a phenomenon called saturation. It means when a transformer enters this section and there is an error, relay can not afford to act and command.

Simulated circuit of a saturable nonlinear current transformer is shown in figure, 2. To simulate, a staircase current is given to transformer elementary.

As shown in figure, 3, simulation results hold two parts: elementary current to current transformer (the upper diagram) and current transformer's secondary current (the lower diagram). If current flows more than nominal current, transformer enters saturation section and the secondary

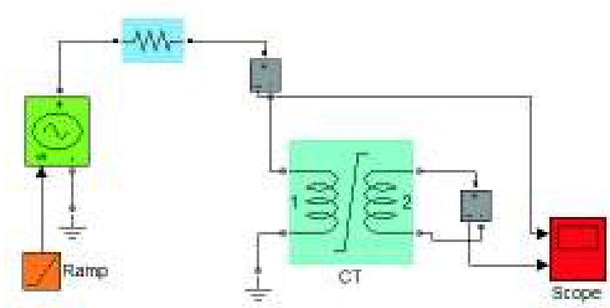

Figure 2 : Simulated curcuit of a nonlinear current transformer

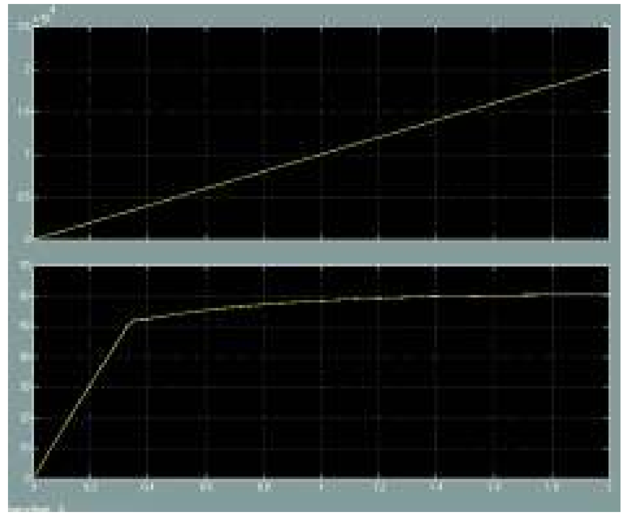

Figure 3 : Simulation Results Of Nonlinear Current Transformer

current value of current transformer changes nonlinearly which is considered an error in protective relays' activity. However, in digital relays, it is possible to prevent its impact on relays' inappropriate acitivity.

(b)Simulation of Intelligent Overcurrent Relay By Software Matlab

To simulate the relay in figure 4, following elements are used in Matlab: nonlinear transformer, ohmic resistance, nonideal diode, voltmeter and ammeter, current source and voltage, analog filter, sampler and keeper, memory elements, NAND and AND gates, pulse generator.

Simulation circuit of a intelligent overcurrent relay is shown in figure 4. Relay's default value is set on 10; so that if the signal from current transformer's secondary is more than this value then, relay commands cutting the defected circuit. Relay's output is normally logical zero. In case of error, the output changes to logical 1.

Simulation through Matlab gives us the following results shown in figures, 5 and 6. We will discuss them briefly.

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Figure, 5 shows transmitted current from current transformer's secondary to relay. As you see, current signal includes two parts of normal and defected conditions. The first part of wave indicates normal situation in system; this situation is set in the time interval of 0-0.06 seconds and is

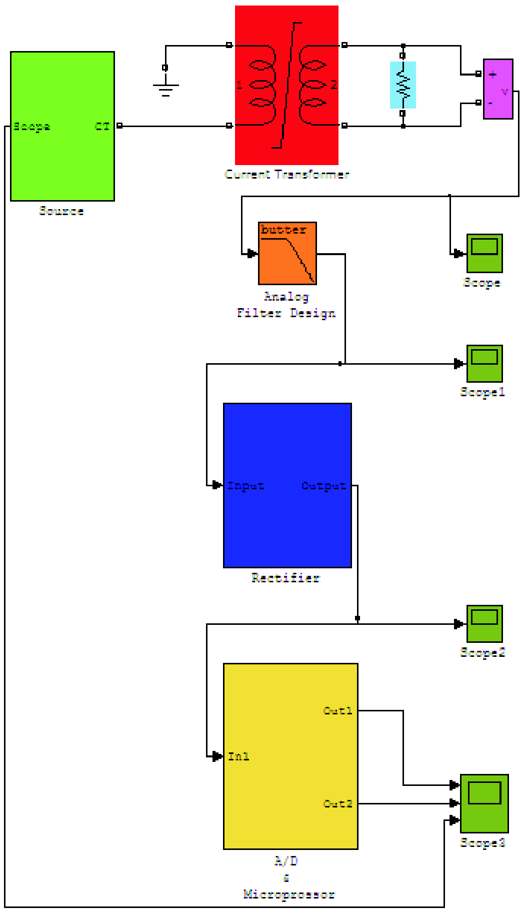

Figure 4 : Simulation Structure Of Intelligent Overcurrent Relay

like an extra non-harmonic sinus. The second part of the wave represents a fault in system and happens between 0.06 0.12 seconds and has an extra harmonic besides the main frequency. Therefore, this signal is transmitted to relay in order to be checked.

By transmitting the signal to relay and checking that, the following results appear which are shown in fig (6). This figure is the output of intelligent relay and includes lower, middle, and upper parts. The lower part shows the transmitted current to relay; the middle part features the signal changes after passing analog filter, diode bridge rectifier, sampler and keeper amplifier; and the upper part shows relay output.

As seen in Figure 6, in case of error, relay output changes from logical zero to logical 1. After required chages, this signal is transmitted to power switch or expected system switch to send the defected part out of

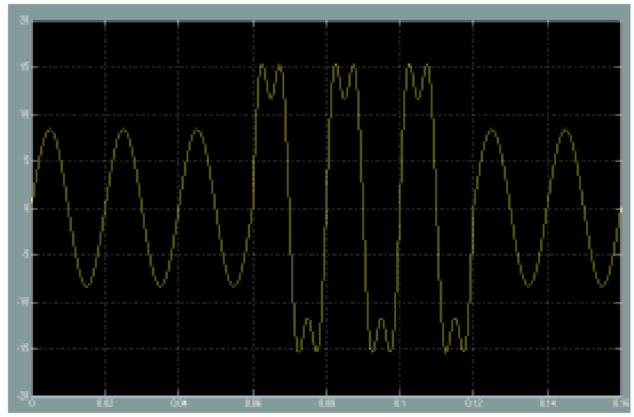

Figure 5 : Transmitted current signal to relay for detecting error

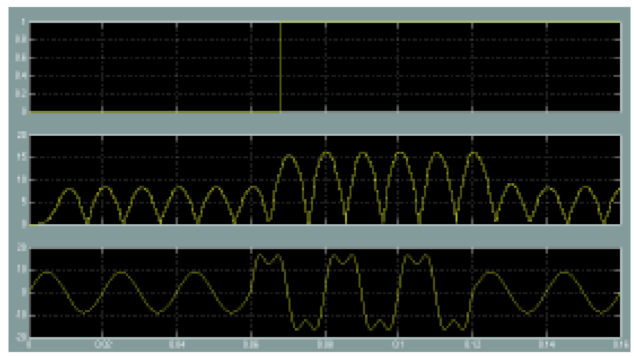

Figure 6: Transmitted Signals To Relay, Its Chages, and Relay Output

curcuit.

CONCLUSION

Regarding all efforts in production, transmission, and distribution, modern systems can not afford all humans' needs. Therefore, there is a need for substructures and modern networks. In addition, investment should take place to run intelligent networks.

Due to increase in electrical energy consumption, load compression, and electricity generator sources as well as the need for quick and safe work of control and productive equipments, using digital protective equipments especially digital relays is both necessary and essential in protecting power systems. These relays are reliable devices in protecting equipments and electrical systems because they are able to early detect errors and prevent their extension, change their function and protection type based on relay software change, and prevent sampler transformer's saturation effecting inappropriate work of relays. By making protective relays intelligent in order to oppose current transformers' saturation or prevent this saturation impact on protective relays' safe and appropriate work, most of the protective problems are solved.

Regarding the abovementioned information about intelligent protective relays, the followings are proposed for more researches:

- Studying events in powerplants and the impact of modern protective relays on decreasing them
- Procedures of deacreasing the impact of electromagnetic interference in order to increase modern relays' application
- Studying the way of using gathered data from modern protective relays in order to repair in advance.

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