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Numerical Techniques For Bus Bar Protection

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Abstract: -
With the advancement in power system and increasing demand of interconnected grid system, the security/protection has become a major concern. As busbar being the coupling point of many circuits in the power system, it has led an interest towards protection of busbar. Keeping this in view several numerical techniques have been developed. This paper contains an overview of numerical techniques that have been proposed for busbar protection.
Keyword: - Busbar protection, numerical techniques.

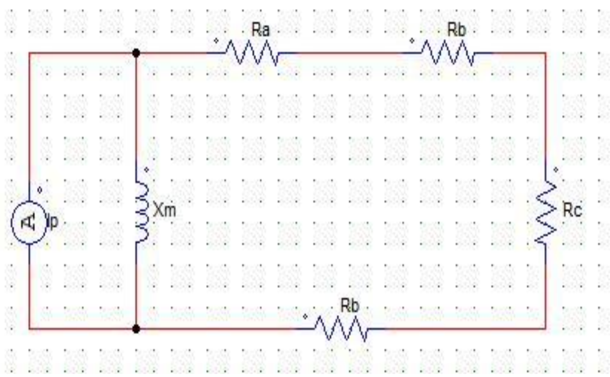
I. Introduction

A bus in a power system is the energy concentration and distribution point i.e. it is a connection point for many circuits like generation, transmission and load circuit etc. It is therefore the most important element in the power system. Although fault on a busbar is very rare, but if it occurs it may cause a damage equivalent to many simultaneous faults and results in complete shutdown of the system.
Due to fault on a busbar, system stability and supply services gets hindered. So in order to make the system operation more flexible and to improve the continuity of supply, complex bus arrangement is being used by some of the power system station which in turn requires highly sophisticated bus protection schemes.
Bus protection scheme should be fast and reliable. If the busbar protection relay fails to operate for an internal fault or if it mal-operates for an external fault then it can have disastrous effects on the power system stability.
With the advancement in digital signal processing some numerical protection techniques have been designed for busbar protection. By improving the measurement and computation using numerical technology it is possible to improve the reliability of bus protection by exploring more selective and dependable centralized solution.
Numerical techniques are thus providing a mean to enhance the system performance and its operation by providing new solutions for busbar protection.
due to external fault or through fault. When the external fault occurs then in that condition the current through all the circuits that are connected to that particular busbar contributes to this external fault. This then causes the higher current to flow through the circuit breaker of faulty circuit as compared to the current flowing through other healthy circuits. This high current when passes through CT the CT gets saturate. Due to this it is not possible to deliever appropriate current to the relay through this saturated CT. The degree of CT saturation can be lowered in case the current through other circuits becomes considerably lower. This makes difficult for the relay to distinguish between internal and external fault.[11]

It is the dc component of the fault current that saturates the CT more as compared to ac component. Thus while selecting the suitable bus protection relaying scheme it is important to select proper L/R ratio in order to decay the dc component of the fault current.[12] This L/R ratio is referred to as dc time constant and its value varies from 0.1sec for lines to about 0.3sec or more for generating plants.

A. Equivalent circuit for CT

An equivalent circuit for current transformer is shown in the figure below:-



X = magnetizing impedance

II. SATURATION OF CURRENT TRANSFORMER

The main protection problem in the field of busbar protection is the CT saturation. CT saturation mainly occurs

Ra = CT resistor

Rb = cable resistor

Rc = load resistor

The magnetizing impedance X and the secondary current of CT both becomes zero as soon as the CT gets saturate.

Ideally the primary as well as the secondary current of CT has identical waveshape but just after saturation the secondary current waveform gets distorted from its primary current. This causes mal-operation due to incorrect information delivered by the saturated CT to all the relays and measuring equipments.

Thus in protection relaying scheme CT is the most important component, so in order to avoid the CT saturation following numerical techniques play an important role.

B. Factors influencing CT saturation

Following factors influences CT saturation: -

- Current transformer saturation
- DC offset their direction and amount in the current.
- Cross-sectional area of the core.
- Presence of remnant flux and its amount.
- Consideration of core steel saturation flux density.
- Effect of load i.e. the total load connected and its magnitude.

III. NUMERICAL TECHNIQUES

A. Wavelet Packet Transform

A linear combination of wavelets is called a wavelet packet. These wavelet packets have the properties of their parent wavelet like they are orthogonal, smooth and also have location property. Recursive algorithm is used in order to compute the coefficient of linear combination. For signal analysis and processing wavelet packet transform is considered as the most significant tool also it is possible to carry out on line monitoring of the process through wavelet packet transform.[2]

During CT saturation it has the capability to detect and capture the important features of fault current signal that are very sensitive to CT saturation. The current signal can be decomposed into different components in different particular time windows and frequency bands through wavelet packet transform and thus the component reflects the features of original signal.

By applying differential relay principle, the coefficient of differential signal is given as:-

$S_{DC}(K)=$ (1)

Where, S_{DC} (K) — differential signal coefficient.

m — no of lines connected to the bus

K— fault sample just after fault occurrence.

To represent the energy level of SDC in the frequency band following equation must hold : -

$$\text{trip}(K) = \text{trip}(K-1) + S_{DC}(K) \quad (2)$$

Now the trip signal will be initiated by the protective relay only when trip(K) remains stay above a threshold level for a number of samples continuously (atleast for 3 samples after fault inception). So, in case of external faults or through faults, to maintain the stability of the relay it is necessary to maintain the threshold level to a value equal to 0.125, this value have been found by carrying out extensive series of studies. This set value of the threshold is greatly affected by the system environment.

Implementation of wavelet packet transform in real time is possible because it requires small amount of computation.

B. Cos-Sin Technique

Thus technique is explained as follows:-

For a given busbar the voltage signal at any instant is given by [4]:-

$$Va(t) = Vmax \cos(\omega t+\ ) \quad (3)$$

The complement of the above voltage signal can be represented as:-

$$Vg(t) = Vmax \sin(\omega t+\ ) \quad (4)$$

Now a discriminating signal M(t) can be obtained from above two equations by first squaring and then adding and finally normalizing the above two equations. So the discriminating signal obtained is as follows:-

$M(t) = V^2_a(t)/V^2_{max} + V^2_g(t)/V^2_{max}$

Or

$M(t) = Cos^2(\omega t+\ \ ) + Sin^2(\omega t+\ \ )$ (5)

If the effective value of Vmax do not changes and also if there is no extraordinary condition taking place then the result of equation remains unity. But if fault occurs then this unity relation is distorted. The peak value of the voltage is updated after every one complete cycle (say 20ms for frequency of 50 Hz).

To detect a fault the deviation 'δ' in M (t) is calculated for one complete cycle starting from the instant when the fault occurs. To calculate this deviation following formula is used:-

$\delta(t) = |\ 1 - 1/n \sum M(i)\ |$ (6)

where i = 1, 2, 3………n and n represents the number of samples of one complete cycle of system power frequency.

C. Travelling Wave Technique

The technique works on the following principle:

If a fault occurs on a busbar then in that case the direction detected for all the travelling waves is positive for all the lines connected to that particular busbar. [1]

However if a fault occurs on any one of the lines then in this condition the direction of the travelling waves detected for the healthy lines is positive whereas the travelling wave direction for the faulty lines is detected as negative.

To identify a fault the amplitude integral relationship between positive and negative travelling waves is used just after the short time when fault occurs.

The transient voltage and current are thus given as :-

$\Delta u = u^+(t - x/v) + u^-(t + x/v)$ (7)

$\Delta i = 1/Z_C\ [u^+(t - x/v) - u^-(t + x/v)$ (8)

Where $v = 1/\sqrt{LC}$ is called wave propagation speed

$Z_C = \sqrt{L/C}$ is called wave impedance.

L and C represents inductance and capacitance if the line

u^+ represents forward travelling wave along positive direction and u^- represents backward travelling wave in negative direction.

Thus u^+ and u^- can be obtained by solving equation (7) and (8) and is given as:-

$u^+ = (\Delta u + Z_C\ \Delta\ i) / 2$ (9)

$u^- = (\Delta u - Z_C\ \Delta\ i) / 2$ (10)

D. Intelligent Techniques

Recently for protecting the busbar various soft computing intelligent techniques have been proposed which are based upon human knowledge features. These are as follows :-

(a) ANN: - It is defined as Artificial Neural Network. Through thus number of specific problems is solved by using mathematical algorithm. It has got the learning capability due to which, at the output, simply by adjusting the weights it is possible to compensate the error.
(b) FIS: - It is defined as fuzzy interface system. It represents a mapping between inputs and outputs which is basically non-linear in nature. In this FIS system IF-THEN rules are used to obtain a solution to a problem. These IF-THEN rules are easily understood by the human operator and are therefore helpful to design a controller system which adds to its advantages. These rules are also useful to perform the tasks that have been already performed by the human. FIS has a limitation that it depends on fixed membership function and also it is not possible to compensate the error at the output of the FIS controller.
(c) ANFIS: - It has been found that it is very complex to model a differential protection using FIS and ANN. Since the transient period during power system operation is greatly affected by unknown parameters so it is not easy to describe the transient period by artificial explicit knowledge. These limitations faced by ANN and FIS have been overcome by Adaptive Neuro Fuzzy Interface System which provides integration between Fuzzy Interface System and Artificial Neural Network System. This ANFIS provides further integration to ANN technology and logic concepts of fuzzy becomes much more embedded due to this new intelligent technique [5]. Both linguistic information and numerical information can be combined together through a natural frame work provided by ANFIS. Linguistic information consists of IF-THEN rules while numerical information consists of input- output pairs.

Thus these Intelligent Soft Computing Techniques are becoming an important mean for enhancing the busbar protection.

IV. IMPACT OF ABOVE NUMERICAL TECHNIQUES ON BUSBAR PROTECTION

These techniques have already been implemented for busbar protection and after going through various studies following aspects have been examined: -

1) Discrimination between internal fault and external fault can be done by above techniques.
2) Techniques are stable during CT saturation and ratio mismatch which is major protection problem for busbar.
3) These techniques are also stable during different faults and fault inception angle and are sensitive to high fault resistance that usually occurs on busbar.
4) Through wavelet packet technique it is possible to successfully detect and discriminate severe CT saturation.
5) Phasor concept used by artificial intelligent techniques is very useful to overcome CT saturation and mismatch.
6) These numerical techniques are found to be fast, accurate and easily implementable.

V. CONCLUSION

There are numerous of busbar protection systems that have been implemented till now. The common factor in all the protection techniques is that they all demand for full confidence in normal operation of the power system both during normal operating condition of the power system as well as during the condition of a fault.

There are some conventional protection systems which depend upon constraints that are mostly imposed by significant design and operation which often makes this type of protection not to deploy busbar protection. Thus it becomes difficult for the primary plant design to sustain during long fault duration and also the protection system is not able to discriminate between different types of faults and hence it becomes difficult to isolate the fault with minimum disruption in power system.

Thus the implementation of numerical techniques enables the protection manufacturer to design the most reliable and safety system. A great freedom for the network operator to operate the system is provided by the real time simulation of the substation, which is one of the great advantages of the numerical techniques. No doubt these numerical techniques have a bright future in the field of busbar protection because of their high speed response, accuracy and reliability.

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