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Building Principles of High Voltage Relay Protection

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Abstract

Main characteristic of relay protection (RP) is selectivity. The fullest realization of this characteristic is given on principle operation of differential protection. On the ground of this reason and analysis of the arc monitoring the short circuits, two principles of the building RP are formulated: usual metric (which is used for building all the types existing RP with measuring relays) and proposed logical principle (on which is built arc protection, on flash of the electric arc at short circuits (SC)). The differential metric principle RP is proved to be the most appropriate for building RP on logical scheme. There are compared factors existing RZ by the approximation to logical principle of the building RP. As special principle of the building RP is distinguished the distance protection. The advantage the logical scheme of the building RZ are discussed in contrast with existing metric.

Keywords*: Relay protection, differential protection, setting*

1. Introduction

The main mission of relay protection (RP) is a reaction on faults on equipment and line of electric network. This mission is realized with automatic operation: finding faults on protective or external objects and tripping faulty object with switching devices. To execute the given problem automatically it is necessary RP to have distinguished SC on protectable and external elements to network *i.e.,* possessed the selectivity characteristic. At present it is reached with blockage on the action RP under SC on external components. This is realized hard by restrictions of the RP operating zone (differential protection and their principle modification in the manner of protection with exchange by information between relay sets on the ends of the line or output terminals of the equipment, for example carrier-current protection), by breaking the range of meanings of the respond parameter on intervals under SC on protectable and external objects (stepped current and distance protections). At second event each interval of the respond parameter is provided private channel (the step) of protection.

2. Main Part

2.1. Selectivity Characteristic and Its Realization in Existing RP Built on Metric Principle

Protections with hard restrictions of the operating zone as well as channels stepped protections are realized on one and same scheme. The signal of the respond parameter is

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continuously come on relay measuring organ. On achievement meanings of the signal given level (the threshold or setting value) measuring organ gives the potential signal which directly or on given algorithm of the logic switches the tripping devices of the protected, allowing distinguish external SC from internal. Thereby for systems of the checking the type RP first selective characteristic or selectivity from hindrances is necessaryelement and it removes faulty element from network.

In both events is beforehand realized adjusting the measuring relay by setting its trip or threshold of the action from disturbances of the respond parameter acting in measuring organ. Due to this it is provided guaranteed superiority of the useful signal of the respond parameter on disturbances and reliable action of the relay measuring organ at achievement by meanings of the respond parameter the setting. The overbalancing under the hindrances and corresponding action of the measuring organ purposefully to name the first RP selectivity characteristic [1-5].

Such characteristic inheres all the checking, monitoring and signaling systems however it is not a characteristic understood in relay protection selective of the disconnection the faulty element. This is therefore that either of the RP checking systems must locate element or its part with galloping processes and accordingly high-speed unhooking the failure element to network. The meanings of the respond parameter on border protected and external elements differ very little. So together with the main channel RP it is required additional channel, producing quick analysis, but insufficient condition to provide high-speed eliminating the damage or indignations *i.e.,* selective withdrawal from network of the failure element. Hereupon in practical realization of the systems of the checking as a rule are developed additional automatic channels adding device or system of the checking characteristic distinguishing the damages and indignations on controlled and external object. In the case of RP these channels must be such high-speed as the main.

Designed at present actions in concrete entailment more varied and they can be grouped as design-circuital, information- exchanged, current-temporary and others. Use them at building allows the device or system RZ to distinguish internal and external SC. This the system measure, providing selectivity of the action RP, can be named the second characteristic .The function second selectivity characteristic RP also possible to express as blocking (the prohibition) of the action RP under SC on external entities. Blocking or prohibition of the action RP under SC on external for protectable object component to network is concretely realized in two modifications at present.

a) The Case of Differential RP and protection with Exchange Information

The current sensors of differential RP are placed on the terminals of the protectable power equipment and united between itself and measuring organ hard on differential scheme. In a like manner the current sensors of protections with exchange the information about response between kits on ends lines are placed on the ends of lines and connected through special (high-frequency or fiber-optic) channel of the exchange by information on response kit RP on removed ends of the protected line. For the purpose of blocking in these protections it is used direct or indirect checking the direction of the through current sensor under external SC comparatively this sensor and protectable object. In the event of differential RP this checking is indirect through differential scheme of the subtraction of the through current from amount current all other terminals under external SC. In the event of protection with exchange by information between kits on the ends lines checking the direction of the through current SC is realized by means of directed relay measuring organ of the resistance (protection with allowing signal of the exchange), relay of the direction to power (protection with blocking signal), indirect way by means of opposite polarity first half-wavelength of the sinusoidal industrial current on the ends or terminals, where exists the through current under external SC(phase-comparison protection).

b) The Case of Overcurrent and Distance Protection

In the event of stepped RP connected to sensors of the current on one of the ends or terminals of the protectable object the blocking or prohibition of the action RP under SC on external for protectable object to network is realized by means of post triggering delays. For instance second step channel to protectable line in contrast with time of the action of the first steps and other high-speed protection previous objects (the elements) toward action of the second step channel. The delay is executed on preset time (time setting). Blocking second step under SC on previous external entities stops on outflow of this time and second step the channel becomes nonselective. In row of the events under discussion delay depends on meanings of the respond parameter. It is necessary to notice that described blocking can be efficient only at co-ordination of sensitivity second step and the first steps previous elements to network so that the last were more sensitive to SC on external entities of the network. In row of the events stepped RP channels act not toward protectable equipment, but under SC on component of the network in opposite direction or protected elements, for instance, and autotransformer with many-sided power supply [1-3].

Similarly also third step to line is blocked on time with the second steps previous elements and *etc.*, It is possible also the other variants of blocking on time for instance the second step with more sensitive second step previous components to network. The most sensitive reserving step can also be blocked on time with rougher step previous elements. However because of need required sensitivity at standby of protection previous or adjacent elements reserving step are built on respond parameter from operating duty only and then co-ordination on time with more rough step previous (adjacent) elements becomes meaningless. So blocking on time formally execute with sensitive reserving steps of previous (adjacent) elements. Under such tuning reserving step usually turned out to be nonselective. In some cases (under radial topology of the network) no selectivity is turned out to correct by co-ordinations sensitivity reserving step with reserving steps of previous (adjacent) elements. Thereby the building RP both in fixing failures and blocking under external SC is completely predestined by scheme with using relay measuring organ basically current and resistances. This scheme of the building RP more conservative and hardly can be changed radically.

2.2. Building RP on Logical Principle

Operation and building of arc protection in principal other. The event SC without some measuring converters in the manner of signal of the arc flash is sent on airwaves, fiber or transparent insulation covering wire of each phase on optical sensitive elements of drive commutation devices perceiving pulses of the radiation and switching ends (terminals) protected object. This scheme of the building RP is unlike metric scheme. It is characterized two principle distinguishers. The first is the absence of the measuring converters: sensor and relay measuring organ of the response parameter. The measurement remained only at arrival of the arc flash on perceiving terminal of the drive of the breaker to act under mean not smaller certain values. The second factor consists in that due to optoelectronic system of the transmission of the signal insulating uncoupling with high-tension signal of arc flash turned out to be automatically executed *i.e.*, are not required high-priced high-tension measuring transformers being additionally source of the primary signal and secondary hindrance garbling, which require desensitization the sittings relay measuring organ.

Thereby logical scheme of the building RP has an essential advantage in contrast with metric. In this connection the possibility is reasonable to consider the association of these schemes for the reason use advantage both principles of the building RP. The building of such facilities RP possible on base metric RP with hard separation of the operating zone (area of the action) [1-9].

In existing protection with hard separation of the area of the action factor use measuring organ in respect to the greater distortion and hindrances contributed under SC single-type measuring current transformer is unessential. Really, in the event of current differential protection in measuring organ under external SC the small current imbalance (the hindrance) runs but under internal SC big amount current with all ends or terminals (the useful signal) is flowing. Consequently already on correlation of the useful signal and hindrances differential principle practically in clean type realizes the logical scheme of the building RP. Given correlation can be used as initial logical signal on unhooking the failure element from network. But if from composition of differential protection to exclude the nonlinear sensors (the transformers) of the current being source of the hindrances on miscellaneous reasons (design-technological deflections,, remanence and saturation ferromagnetic coils, breaches of the differential principle by putting into zone of the action of differential protection power transformers and autotransformers the rushes magnetizing current and others) that correlation useful signal-hindrances will else greatly more since imbalance under external SC will tend to zero importance. Differential protection not burdened imbalance of current transformers of the current had ideal correlation useful signal-hindrances for building of protection on logical principle.

In the event of protection with exchange by information on action kits on the ends (terminals) of the protectable object in each kit it occurs acting measuring organ under enough small importance of the response parameter. This provides on the one hand action of the kit in linear mode current transformer *i.e.*, without garbling the primary signal, but on the other hand, transition to logical signal, which herein after presents operating the kit RZ on corresponding to end of the protectable object. The hindrances and settings measuring organ kit of protection fall and correlation useful signal-hindrances will increase. And though signal-hindrances is a lesser extent in contrast with differential protection but noticeably approach the condition for building RP on logical scheme. However minimum limit of the hindrances in under discussion event will be an electric values of the operating duty which will also remain and at exception sensor current and presenting on measuring organs directly primary signal. Thereby, logical scheme of the building RP with exchange by information between kits on the ends (terminals) of the protectable object will be less efficient in contrast with differential protection since it does not allow boundless to reduce the hindrances below values operating duty.

Same, but in more negative sense it will be about possibility of the realignment current stepped protection on logical scheme. This group of protection logical scheme RP in several greater degrees correspond to the most sensitive reserving steps. Their settings are also built from operating regimes. However correlation useful signal-hindrances for these steps is far less since they are intended for protection not only automated object but also standbys of protection previous or adjacent element. The Last reduces the factor useful signal-hindrances in consequence of to the reduction of the accounting useful signal. The more rough steps has a correlation useful signal-hindrances else below since accounting useful signal is a minimum current SC on protectable object, but offset of setting is executed from maximum current under SC on removed (comparatively end or terminal, where is installed kit of protection) borders of the operating zone the step area action. The required correlation useful signal-hindrances is in this instance reached due to the difference of the places SC on neighboring border of the area action and space or distant border of the protectable object. Quantitative this difference can be a denominated difference between impedances of the protectable object before the place the accommodation of the equipment step and before of the most remote borders of the area action of the considered channel RP toward action of the kit. In row of the events this difference turns out to be small and accordingly small correlation useful signal-hindrance. The channels of such steps RP turn out to be not enough or in general non-sensitive so impossible building RP on metric scheme.

The analysis shows that work of current protection greatly depends on state of working sources, switching in network, type SC, many casual factors defining values SC current. As a whole current stepped protections in the most degree do not meet the requirements RP. This degree increases on measure of increasing of the voltage to network. In determined degree the quality of current protections increases due to use symmetrical forming current and voltages (inverse and zero sequence) However defect characteristic current protections are saved and also increase with increasing of the voltage to network.

Though stepped current protections in Russia wide-spread for all voltage levels of the networks, however using remote protections which respond on resistances from place of the installing the relay equipment on protectable object before places SC have an essential advantages in contrast with current. So under SC on protectable object without infeed on the part of intermediate ends (terminals) of the protectable object measured impedances do not depend on current, containing greater inexact nesses and hindrances,. The residual voltage defined this current and measured by impedance from equipment before point SC referred to current does not contain the current and in accordance to this all inexact nesses and hindrances in current. Less advantageous but close enough results possible might get under SC on previous and adjacent elements.

2.3. Remote Principles of the Building RP

Remote protection unlike current built on metric scheme RP by measuring under SC response parameter in the manner of relation of the residual voltage to current (the impedance) in an ideal event under linear measuring transformer in broad range current and voltage are exact or close to exact metering of the impedance from place of the installing the relay equipment before place SC and do not demand on state of working sources, volumes three-phase switching in network. It depends on type multiphase or monophasic SC. The conservation to linearity ferromagnetic measuring transformers current and voltages is possible in comparatively small range values in operating regimes. However in realities under SC transformers of the current are magnetic saturated and secondary currents are powerfully distorted, but transformers of the voltage in consequence of reduction of the remaining voltage on the contrary move over to more linear mode. So long metering of the impedances under greater and transient SC current will be of big inaccuracy. Also accuracy of metering of the impedances depends on forming resistances in place SC connecting. Hereupon expedient and exist the action miscellaneous eliminating at least partly named defects. So right after metering the resistances in connecting process remote protection in modern remote complex somewhat translate from metric scheme of the building RP in logical (for instance, memory functioning of first step measuring relay for time of the operated condition second step measuring relay impedances). Such way is greatly excluded influence growing in transient process of the connecting resistance contact under SC on main area of the lines. Due to this is saved initial accuracy metering remote protection (without connecting resistances) and reliability of the logic of the discrete signal of the unhooking. Besides high-speed measurement of the resistance allows more effectively use the linearity of the features measuring transformer.

The development of the ways of the measurement of the resistance in transient process in combination with expansion mode's range to linarites measuring transformer together allow to obtain the more exact measurement of the impedance for the whole time of the work of all steps. The execution these though desirable but difficulty unlikely and demands big cost. So practically directed measuring relay of the resistance are not used in its metric but in logical function to define the direction of the action similarly power relay. The variant of the building RP is used in exactly such structure action with exchange by information by means of allowing signal between kits relay impedances on the ends (the terminals) of the protectable object. Under acting measuring impedance relay of the sensitive second and the third steps it is used not metering impedances before

place SC but potential logical signal of the action relay resistances which is used as permitting signal and is sent on all kits RP opposite ends (terminals) accelerating actions these kits under SC on object. As a result exactly, surely, selectively and quickly all switching units of the protectable object are unplugged. The metrology impedance relay herewith practically needs in that degree only in which necessary action relay as organ of the direction SC on protectable object or outside of it.

In other words, metrological quality impedance relay under SC in consequence saturation of current transformers more mediocre. So it is used only directivity acting of the feature that wholly it is enough for building of protection with exchange information *i.e.,* on logical scheme RP. In the event of usual stepped remote protection good metrological quality of impedance relay is very necessary. However under greater currents (SC is located close from the place the relay equipment is distributed) metrological quality of impedance relay can be not reached because different directivity inaccuracies of current and voltage transformers. Considering said it is reasonable using of remote protection for metering impedances under SC on distant ends (terminals) about locations of the relay equipment of kit (for instance in zone of the standby) under which current small and current protection can be not built. Herewith measuring transformers both current, and voltages work in condition of the linear communicating features. So very exactly and with it is enough good offset from hindrances remote measuring organs measure the impedances before place SC. However specified achievable if measures of the reception of the sufficient current of the exact work relay impedances is designed [5-7].

Thereby remote RP can be used with standpoint considered in article principle buildings RP both as in logical scheme of the measurement of the direction of the current in complex plane of the impedances and in metric scheme. In the first event accuracy is reached to account several factors: transformation of the metric signal in logical under small measuring current about current of saturation the ferromagnetic coils as well as to account of the absence to current inaccuracy in measured response parameter impedance. In second event accuracy can be reached only to account of the linarites of the current transformer features in all range primary current SC. When ensuring the linear communicating feature current and voltage transformers in all range of the electric values it may be select the special remote principle of the building, in natural fullness realizing metric scheme RP. The reason for such statement are a following facts:

1) unlike current response parameter resistance metering by remote measuring organ is not mode-operating but circuital-design response parameter (in spite of it is formed through regime parameters current and voltage) and this impedance practically does not depend on mode of the electric values under SC;

2) a resistance circuit from accommodation of the relay equipment of remote protection on protectable object before place SC is a single response parameter value which is uniquely connected with failure (SC) on protectable element, an influence of injection from stranger of the sources to network falling into area of the action remote measuring organ is greatly less in contrast with current stepped current protection.

3. Conclusion

The analysis presented principle of the building RP shows that each of them lawful with standpoint of obligatory need to automations of the protectable object to electric network but logical principle alternative metric and special remote or distant principle at present practically are not used in ditto time logical principle has technical and economic advantages due to possibility to exclude the high-tension sensors of the current. Due to this economic resource logical principle of RP building can be marketed on each interesting area of lines and windings of the power equipment with transmission signal about action RP of each intermediate area on main area or the end (the terminal). The

transmission of information on SC on intermediate area can be realized as on wire of the lines or windings of the power equipment, so and on fiber-optic lines. Hereunder can be marketed desirable but not brought earlier logical scheme of the building RP without measuring transformers. The traditional principle of the building stepped remote RP due to good metrological quality relay resistances certainly is perspective if develop and use the linear current transformers in broad range current also synthesize the procedure of the exact measurement of the greater impedances under small current.

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