Cold Load Pickup and Second Harmonic Restraint features

Preface

Some types of electrical loads, as air conditioning/heaters after a long cooling time, motors and power transformers, for a period of time following energizing draw transient currents that may differ greatly from the normal load levels. Similarly a circuit breaker closing on large loads that will be detached before that an overload condition occur, cause a momentary overcurrent. Consequently, settings of feeders protective functions that have been applied to give short circuit and ground fault protection may not be suitable during this period and, without specific actions, unwanted protection tripping may occur slowing the service entry and creating extended outages.

The relays of Pro-N family that include overcurrent and ground faults protective functions are equipped with two features that may be useful to avoid unwanted tripping during the above mentioned transient overcurrents. One is the Cold Load Pickup (CLP) and is useful for the most load types, the other is the Second Harmonic Restraint (2NDH-Rest) that is specific and more reliable of CLP for power transformers.

Cold Load Pickup (CLP)

CLP feature allows selected thresholds of phase and ground overcurrent protections, both directional and not directional, to be changed or blocked for a set time in order to overcome transient overcurrents.

The trigger of the CLP feature is the logical condition of *circuit breaker closed*, that Pro-N relay detect by means of two digital inputs connected to the circuit breaker auxiliary contacts 52CA and 52CC; the two digital inputs must be also set to “52CA” and “52CC”.

In *Parameters* submenu of each threshold of the protective functions, the CLP feature can be set:

- disabled (setting *OFF*)
- enabled in order to block the threshold (blocking mode by setting *ON threshold block*)
- enabled in order to change the threshold (changing mode by setting *ON threshold change*)

When the *circuit breaker closed* condition is detected, the CLP timer set in the submenu of CLP function is initiated and, throughout the CLP set time:

- the threshold is blocked if CLP is set to *ON threshold block* or
- the threshold is changed to the value that is set if CLP is set to *ON threshold change*.

When CLP timer has elapsed, the threshold is unblocked if CLP is set to *ON threshold block* or the threshold is revert back to the original value if CLP is set to *ON threshold change*.

Note that when the circuit breaker is open, the threshold is already blocked if CLP is set to *ON threshold block* or the threshold is already changed to the value if CLP is set to *ON threshold change*: this is useful in order to avoid unwanted tripping due to unblocked threshold or threshold with his original value for cases where a delay of the circuit breaker closing happen, i.e. where the three poles of the CB do not close at the same time or during long CB closing time.

Typical applications where the CLP feature may be useful are for overcurrent protections, both directional and not directional, on feeders where the circuit breaker closing starts air conditioning/heating loads after a long cooling time, motors or more generally momentary large loads. Also to power transformers CLP should be applied, but for its we recommend the use of the most reliable Second Harmonic Restraint feature (see following paragraph).

The CLP may be also useful for instantaneous not directional ground fault overcurrent protections on motors starting, because it is likely that incorrect operation of the protection would occur on imbalance transient secondary current due to asymmetric line CTs saturation (sometimes, but not so likely, also ring type summation CT can saturate due to the asymmetrical line currents). Instead unwanted tripping of directional ground fault protections can not occur in these events because his residual voltage measurement not exceed the relevant threshold.

Depending upon the magnitude and duration of the starting current, it may be necessary to block operation of thresholds or raising his setting. Also a combination of both blocking some thresholds and raising others may be adopted.

Both for phase (directional and not directional) and ground faults (not directional) overcurrent thresholds, we recommend the use of the CLP feature in blocking mode only when strictly necessary, thus only in the cases where transient overcurrent have a short duration with his magnitude and transient imbalance of residual secondary current nearby to the fault current level. This is the case of direct starting large motors started without mechanical load, with small short circuit power of the supply and ungrounded neutral.

In this cases the CLP time must be set higher than the biggest duration of the starting phase current or imbalance current with a suitable safety margin.

When CLP blocking mode is applied, attention must be made because before CLP time has elapsed, the protection is disabled. Thus if a fault is present during this time two cases may occur:

- the fault will be removed by the protection only after the CLP timer has elapsed, thus thermal and dynamic limits of electrical components to the fault current during this time must be respected.
- the fault is removed by an upstream protection before the CLP time has elapsed, but in this last case the selectivity is loss.

Instead, when long and moderate load transient overcurrents occur, the CLP changing mode must be applied because during the long CLP time, the protection, although with reduced sensitivity, is always enabled. This is the case of air conditioning/heating loads, that have long and moderate increase of the load current magnitude during starting after a long cooling time. However the CLP changing mode can be also used when fault current levels are much higher than the motors starting currents (i.e. wound rotor type asynchronous motors started with resistor or motors with autotransformer or soft starter).

In all these applications the CLP time and the threshold in CLP changing mode must be set higher than the biggest duration and magnitude of the starting overcurrent with a suitable safety margin.

In CLP changing mode attention must be made in order to obtain selectivity with uprestream protections also during the CLP time, when the threshold of downstream protection is increased in CLP changing mode.

Moreover, renouncing to the time grading selectivity with downstream protections, in some feeder applications may be desirable to clear a fault condition in a quicker time after that a circuit breaker closing command is issued (manually or automatically), rather than to wait for the trip delay time elapse of the involved protections. I.e. some faults may not be cleared after some attemps of autoreclosing due to the fact that the conditions that has led to the fault have not been removed from the feeder, or due to grounding clamps left on after a maintenance visit. In these cases a fast tripping is required if a fault is still present on the feeder after the one or more attempts of circuit breaker closing (*SOTFFP - Switch On to Fault Fast Protection*). The CLP feature can be applied in changing mode in order to obtain this particular fast tripping by means of a instantaneous pickup decreasing (any threshold in CLP changing mode can be set less than his final threshold). Also directional ground fault thresholds can be set with CLP in this application. Obviously this application assume that on CB closing without fault, no transient overcurrents or starting/inrush currents occur, such as no unwanted tripping of SOTFFP occur. If is desired that SOTFFP is enabled after some attempts of automatic reclosing device, an output contact of this device (that is activated after the desired number of reclosing cycles) must be connected with CB auxiliary contacts in order to enable SOTFFP at the digital input of Pro-N relay.

Second Harmonic Restraint (2NDH-REST) feature

When a power transformer is energized, as well know an inrush current flow in the side that have been energized with an amount and duration that depend by many factors which:

- by the instantaneous value of the supply voltage at the time where the transformer is energized
- by the transformer design, magnetization characteristic and size
- by the residual flux

The maximum amount of the inrush current is produced by energizing the transformer at the zero point of the voltage wave, when it increase or decrease with the residual flux respectively positive or negative. Moreover the ratio between the maximum amount of the inrush current and the nominal current of the transformer decrease if the size of transformer increase, whereas the duration of the inrush current increase with the size of transformer. The following table shown typical values of the first peak and the time constant of the inrush current for some sizes of power transformers. These data can be requested to the transformer manufacturer.

Transformer size [kVA]	First peak value of the maximum inrush current	Time constant of the maximum inrush current [s]
50	15 In	0.1
100	14 In	0.15
160	12 In	0.20
250	12 In	0.22
400	12 In	0.25
630	11 In	0.30
1000	10 In	0.35
1600	9 In	0.40
2000	8 In	0.45

Some types of instantaneous protections as overcurrent, residually connected ground fault and differentials, are affected by this inrush current and their unwanted tripping can occur on transformer energizing.

Although usually considered only in conjunction with the energizing of a transformer, magnetizing inrush current can be caused by any sudden change of magnetizing voltage. This change include high overloads and their removal, the occurrence of a fault, the removal of the fault and out-of-phase synchronizing. Thus a desensitizing or blocking logic that is operative only when energizing transformer (i.e. Cold Load Pickup) is not adequate in order to avoid unwanted tripping of the above mentioned protections in these events.

The most reliable method in order to avoid operation of the protections is to detect the second harmonic content and, if it increase above a setting threshold, restraint (block) these protections.

This feature, that is traditionally applied to transformer differential protections, is also available to restraint any selected threshold of overcurrent and ground fault protective function of the Pro-N protection relay family. Moreover in Pro-N relay it is possible to set 2NDH-REST feature to one or more output contacts in order to block any external protection relays where second harmonic restraint is not available.

In Pro-N relays a Digital Signal Processor (DSP) perform 24 samples per cycle of the three line currents and extract his second harmonic content by using the DFT (Discrete Fourier Transform) algorithm and digital filtering.

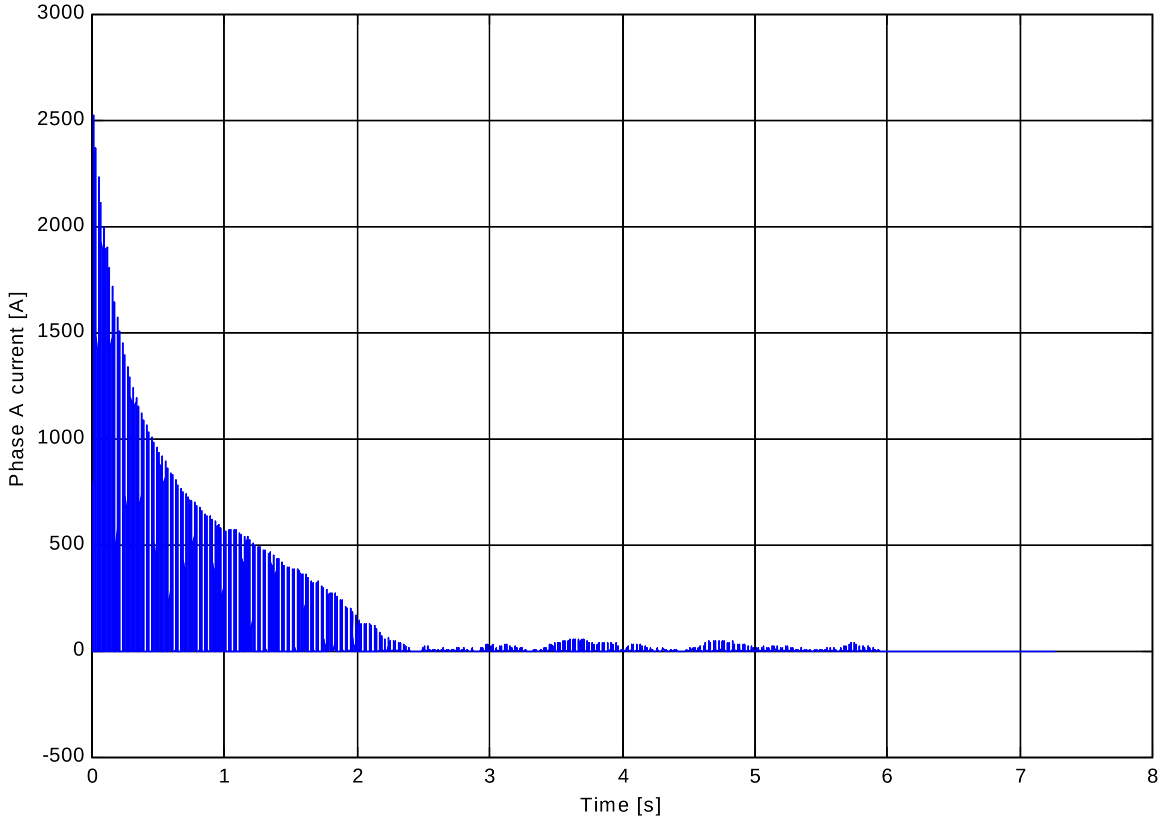
In *Parameters* submenu of each threshold of the protective functions, the second harmonic restraint can be associated (ON) or not associated (OFF) to this threshold. Moreover, in *2NDH-REST* submenu the user can set:

- if the second harmonic restraint is enabled (*ON*) or disabled (*OFF*),
- the second harmonic threshold that trigger the restraint of the selected protective function thresholds (*I2NDH>*),
- the time throughout the restraint is keep after the second harmonic content is decreased below *I2NDH>* threshold,
- one o more output contacts that are activated when restraint operate (this can be usefully used in order to restraint external protection relays where second harmonic restraint is not available),
- one o more leds in order to signalling the second harmonic restraint.

Is important to note that the second harmonic content is predominant in the magnetizing inrush current and it is always present. Some studies have show that under the most pessimistic conditions the minimum theoretical second harmonic component is in the order of 16%-17% of the fundamental, but several field tests have demonstrated that in a large number of measured waves the lowest second harmonic component found was 23% of the fundamental. Of course typical settings of *I2NDH>* can be around to 15% (12% in the most unfavourable cases). However exact second harmonic percentage measurements are available from power transformer manufacturers.

By the other side, if a fault occur during power transformer service or it is present at the instant of power transformer energizing, saturation of protection current transformers not produce second harmonic in the secondary measurement of the line currents so the protections are not restrained.

As example, the following figures show the waveform and harmonic analysis of maximum inrush current in one phase of 19 MVA 30/10.6 kV power transformer.



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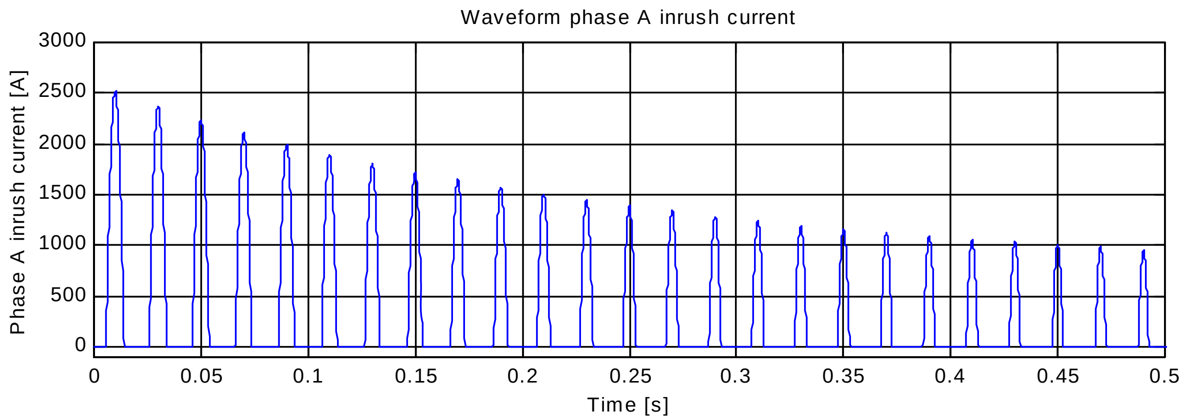

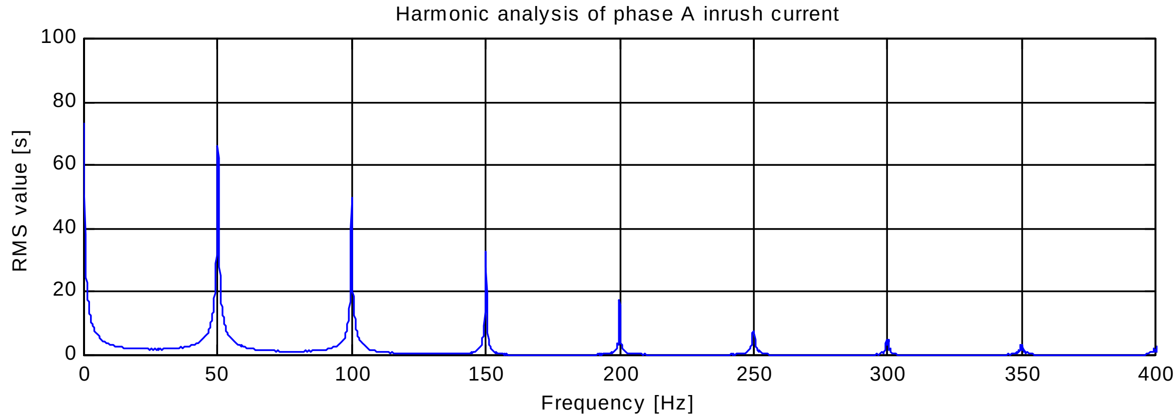

2NDH-REST vs. CLP

By the above description of 2NDH-REST and CLP features, rising that 2NDH-REST is a more specific and reliable method to avoid protection unwanted tripping in power transformer application and the main advantages are:

- 2NDH-REST also operate if magnetizing inrush currents are not due to the circuit breaker closing for transformer energizing (instead CLP operate only at the CB closing), so the protections can be restrained for the overall events that leading to the inrush currents.
- If CB closing is operated on to fault, the second harmonic restraint not operate and leave the protection free of tripping with own sensitivity and time. Thus fast fault clearing and selectivity with upstream protections are preserved. Instead CLP block or reduce the sensitivity protections during CLP time.

However CLP is the only feature that may be applied to the others load types other than power transformers, because no second harmonic is produced by the starting currents of these load types.