Dealing with Inrush Currents

Techniques to Solve Nuisance Tripping when Energising Distribution Feeders

28 May 2017 – Among the subtleties associated with distribution switchgear configuration, Inrush Current is a necessary evil which must be taken into consideration. It is the source of much frustration for field operators and SCADA control teams; when issuing a close command on an open breaker results in an immediate trip. Was it genuine fault? Is it risky to execute another close command? Is there something else at play? Protection engineering must take the concept of inrush into account, as it is omnipresent, potent, and is one of the realities of the distribution of electricity to consumers. Given the prevalence of this phenomena, it is certainly worth exploring the causes and techniques which can be used to mitigate this frustrating scenario.

Have you ever had your electricity supply to your residence cut off at the switchboard? You may be aware that your clothes iron is a bit faulty, and has a habit of tripping off the breakers in your house. Curiously, if you disconnect your iron but leave a lot of other loads on in the house, your breaker may immediately trip if you try turn on the power again. Is something else wrong? Was it your iron?

This is a very simple example of inrush at play. When you de-energise loads, particularly ones with transformers in them, they lose the energy in their magnetic cores. There is a finite amount of energy required to “energise” a core, that is, induce a magnetic field in it, but there is very little resistance offered.

This makes sense, since you would like to ensure that your transformer is losing as little energy as possible to the surrounding world, and rather transferring this energy through to the service on the other side – be it your laptop or your sound system. When you apply a voltage to a de-energised transformer, there is a surge of current as the magnetic core is powered up. When the core reaches its energisation, it begins energising the output core of the transformer. Now, the load on the load side of the transformer regulates the current draw, bringing the primary side current back to expected levels. When you try, and turn your house’s circuit breaker back on
after a trip and too many de-energised transformers are connected, the surge in current might be too much for the relay in your switchboard. Once the breaker is turned to the on position, and it promptly decides that it needs to interrupt this inrush current and trips again.

This problem is even greater at the medium voltage level, as almost every load for a utility is connected through a transformer. Unlike small household transformers, distribution transformers carry large capacities and accordingly, have larger inrush effects. It stands to reason that when a transformer is energised for the first time, there will be a flood of current into the transformer to energise it, before the secondary side puts up some impedance and regulates the current. However, transformers aren’t the only distribution switchgear to blame for this scenario.

Electricity distribution would be impossible today without the support of the powerlines that carry the energy to the end user. But de-energised powerlines also require energisation before they deliver power. When considered over a small distance, powerline impedance is considered almost exclusively resistive, but as the length grows the powerline begins to present greater and greater reactive components. For the sake of simplicity, a long powerline can often have an intrinsic capacitive component. When energising the line, the capacitor effect draws large currents as the lines charge up. This too can have a similar effect to transformer inrush, but is usually on a smaller scale. It is important to consider it, as the combined effects of transformer and line charging currents can cause spurious tripping – much to the frustration of the utility engineer and operator. So how do we address this phenomenon in the field?
Protection engineering design is about understanding what metrics of the system we have available to make a selective decision as to whether a fault is genuine or false. We also need to ensure that we have no false negatives at all, but minimise our false positives. Therefore, you wouldn’t want to risk not tripping, because you thought it was inrush but it turned out to be real. At the same time, you would prefer to not trip on inrush, because it is a “false positive”, and a loss of revenue and reliability for your customer. Inrush currents present some unique characteristics which allow engineers to address the phenomenon in isolation.

Firstly, when energising a transformer, the inrush current is large and fast. Typically, by the end of the 5th or 6th power cycle (around 100ms), most of the inrush would have tapered off. Therefore, if the current subsides within this time, it is reasonable to assume it is an inrush effect.

Secondly, when energising three phase equipment, the inrush is usually well balanced. All phases of three phase transformers will require energisation, and it is a reasonable assumption that they will require similar levels of energy to energise. If there is a residual current present, or an imbalance, then it’s a safe assumption that the cause is not inrush.

Finally, the surge must come after a time of “De-energisation”. If there is a surge whilst the transformer was already energised, then obviously, it is a fault, not inrush. Inrush currents will only appear after the supply has been disengaged for enough time to allow the transformers to deenergise. This is not necessarily a long period, by the time the 3rd or 4th power cycle after disconnection the transformer would dissipate most energy in its core.

Let’s examine the way that NOJA Power’s OSM Automatic Circuit Recloser system deals with this. As a piece of distribution switchgear, it is placed on medium voltage lines which will witness inrush of some form. It is an electronic controlled relay system with CT’s in the circuit breaker, so the configuration of the protection in the OSM’s Relay system (the RC10 Controller) must have a function to deal with this. In the NOJA Power RC10 system, it is called “Inrush Restraint”.

Inrush restraint is a technique which exploits the characteristics of inrush to gain selectivity. When the OSM Recloser system experiences a loss of primary voltage, the RC10 controller acknowledges that downstream devices will deenergise. Since the re-energisation current must be reasonably balanced, the RC10 applies an “Inrush Restraint” multiplier to the Overcurrent pickup level in the controller. Upon re-energisation, the multiplier will allow a greater balanced current through the recloser for a brief period of time. Typically, a multiplier of 5x current is applied, ramping down linearly to a multiplier of 1x after 200ms (effectively, no inrush restraint left). This technique exploits the transient nature of inrush, the requirement of prior de-
energisation, and selectivity to only allow balanced current.

To provide further selectivity, the NOJA Power RC10 controller’s inrush restraint capability does not apply to its High Set Current value. This value is typically the absolute maximum current the OSM Recloser should permit, so if your inrush level is dangerously high the device will still interrupt the current.

A rather simple capability in practice, but it is greatly effective in reducing the likelihood of nuisance trips due to inrush. It is also easily testable by protection technicians, as most injection sets are capable of simulating the inrush scenario. It should be mentioned that there are other techniques which can be applied to address inrush restraint, such as the asymmetric nature of inrush which causes harmonics. This approach attempts to provide further selectivity, but in practicality it is far harder to test and simulate for protection technicians in utilities, and offers very little benefit in comparison to the inrush restraint method.

With great experience in the application of distribution Reclosers, NOJA Power Group Managing Director Neil O’Sullivan commented “Inrush Restraint and Cold Load pickup are standard features in all our products and applied correctly will often eliminate all nuisance tripping when reenergising loads.” Inrush restraint is a frustrating phenomenon, but it is a simple enough concept to address with modern distribution switchgear and protection devices. By exploiting the three major characteristics of inrush restraint, the major effects of inrush can be easily mitigated. NOJA Power’s OSM Recloser system is certainly capable of this functionality, and with some study it can solve your energisation challenges on your network. For further information, please contact NOJA Power at https://www.nojapower.com.au