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Understanding ROCOF Protection

Simplifying the concepts of Protection for Distributed Energy Resources

10 February 2020 – Large scale deployment of renewable and distributed energy resources are becoming the mainstay of the electrical network's transition to a sustainable energy future. Whilst progress in this area has been positive, there are significant technical challenges and departures from traditional protection methods to ensure the ongoing reliability and stability of the distribution grid. For the modern distribution grid with generation located throughout the medium voltage networks, new protection techniques are needed to identify Islanding scenarios, of which the primary passive protection technique today is Rate of Change of Frequency, or ROCOF. In this article we cover a brief of this functionality.

The Application Scenario

Gone are the days of the traditional centralized generation model of power systems. In Queensland Australia, roof-top photovoltaic (PV) generation exceeds 4GW (https://www.dnrme.qld.gov.au/energy/initiatives/solar-future), a total generation asset larger than any single conventional power plant in all of Australia. Grid-scale distributed energy resources are proliferating at a furious pace, as the marginal cost of generation is effectively zero once the capital has been deployed to create a wind farm or grid scale PV array.

Economics aside, the challenge of maintaining grid stability when generation is distributed poses a new challenge for protection engineers. Among key issues is the formation of an “island”; a scenario where a subsection of grid becomes disconnected from the remainder of the power grid, supported only by its local Distributed Energy Resource (DER).

From a technical standpoint, for this island to remain sustainable, the real and reactive Power consumed by the load must closely match the generation – a scenario once thought improbable but published field events in Brazil and Spain have shown islanded scenarios being sustained for significant time. (Dysko © 2013). The likelihood of injury/equipment damage under islanded conditions remains hotly debated, but current technical standards in most countries globally mandate that islands be detected, and the generation tripped for safety reasons.

To solve this challenge, a suite of protection functionality to detect the islanded condition from the perspective of the generator has evolved. ROCOF is the quintessential anti-islanding technique, alongside other passive techniques such as Voltage Vector Shift and Reverse VAR Protection. Active techniques also exist, typically driven by power electronics devices such as inverters, but for current switchgear and protection relay methods the passive techniques are by far most commonly used. Passive protection techniques also have their limitations, but with thorough understanding of the principles of operation protection engineers can optimise the performance of these features and make safe and prudent judgment in their application.

ROCOF Explained

Fundamentally, ROCOF protection examines the frequency of voltage at a point, comparing it over time to derive an estimate of the change in frequency over time. The conceptual principle of operation is that grid stability mandates a match between load and generation, and if this becomes imbalanced, the frequency will either rise or fall based on excess generation or generation shortfall respectively. In the scenario that a grid section with a DER becomes islanded, the likelihood of a load/generation mismatch is high, therefore frequency will adjust, and this movement can be detected by protection relays and the generator can be tripped to de-energise the island. Of course, this also highlights the biggest issue with ROCOF – if a grid island has matched load and generation, ROCOF will not see the scenario. Protection engineers should be aware of this non-detection zone and design schemes accordingly.

$$ROCOF = \frac{\Delta P \cdot f}{2 \cdot S_n \cdot H}$$

Where:

$ROCOF$ = Estimated Rate of Change of Frequency (Hz/s)
ΔP = Change in Active Output Power after Islanding Event (MW)
f = Generator Rated Frequency (Hz)
S_n = Nominal Generator Rating (MVA)
H = Inertial Constant of the Generator (s)

The bigger the mismatch between load and generation, the larger the estimated ROCOF during island inception. It is also important to note that momentary large voltage dips can occur during network operation, resulting in massive but temporary ROCOF, but these are not the intended operation. Therefore, a 500ms operating time is typically applied, as non-islanding related voltage dips should not persist for such a period of time.

As grid generation inertia reduces, ROCOF generally increases, leading to wider fluctuations of frequency under network disturbances. High ROCOF scenarios can be disastrous for conventional generation sources, as pole-slipping can occur around 1.5Hz/s to 2Hz/s, and in a leading power factor pole slips can occur at 1Hz/s (Palermo, 2016). Global standards for ROCOF settings vary, but examples for limits are include the Irish ROCOF Grid code limit of 0.5Hz/s, Northern Ireland's limit of 1Hz/s. UK national grid requirements are for all new generation sites commissioned after July 2016 to be limited to 1 Hz/s over 500ms. The Australian National Electricity Rules cites a minimum access standard of 1 Hz/s for 1 second, and 4Hz/s for 250ms. Distribution Network Service Providers themselves have their own limits, which are often more arduous than the Grid regulatory bodies. Examples from Australia are included in Table 1.

Table 1 – Examples of ROCOF Setting Standards for Australian DNSPs

DNSP	**ROCOF Setting***
Ausgrid	1 Hz/s 1 Sec (Delay time)
AusNet	0.5 to 4 Hz/Sec 1 Sec (Disconnection Time)
Endeavour Energy	0.4Hz/sec 0.5s trip time
Energy Qld	3 Hz/s 0 Sec (Delay time)
EvoEnergy	1.0 Hz / 1 sec 2 second definite time delay

**Subject to amendments to standards. For current values, confirm with local DNSP's.*

What does this mean for Engineering Projects integrating Renewable and Distributed Generation?

In Australia, connecting grid scale distributed generation mandates the inclusion of ROCOF protection. Whilst the prescribed operating quantity may be updated, all projects require the capability to detect and operate on these quantities.

With renewable energy sources typically showing lower maximum fault currents than synchronous generation, NOJA Power's OSM Recloser device has been increasingly applied as the point of connection circuit breaker for these installations. The NOJA Power RC20 controller has ROCOF included as standard, along with the RC10/15 platform ROCOF implementation road-mapped for release with the forthcoming 1.24 firmware release. With these features available in the core product, protection engineers can meet AEMO access standard requirements using a standard integrated product.

NOJA Power OSM Reclosers used to connect a 17 MW Solar Farm to the Medium Voltage Distribution Grid.

"ROCOF is available to all users of our RC10, RC15 and RC20 products," reports NOJA Power Group Managing Director Neil O'Sullivan. "Legacy equipment can have the ROCOF function added with a firmware upgrade at no cost. As ROCOF is quite often mandated by regulation our reclosers can be used to isolate islanded networks to comply with Regulator obligations."

To find out more about Renewable Generation connection projects or NOJA Power's suite of Medium Voltage Switchgear and protection systems, visit www.nojapower.com.au or contact your local NOJA Power Distributor.

References

Dysko, A. (2013), *Loss of Mains Protection,* University of Strathclyde Engineering presentation.

Palermo, J. (2016). *International review of frequency control adaptation*. 179.