Rate of Change of Frequency protection changes to deal with increasing system Rate of Change of Frequency due to reduced system inertia and larger maximum loss of infeed (1800MW from 1320MW).

In 2012 NGET recognised that the development of large amounts of generation, and interconnectors to other networks with out inertia were reducing the GB system inertia. Reduced inertia results in increased system Rates of Change of Frequency (RoCoF) during large system disturbances such as the loss of a DC interconnector carrying large amounts of power, or the loss of a major generation in feed from a power station within GB. In turn these larger system RoCoF events were potentially sufficient to operate the RoCoF protection systems defined in G59. This would to result in unwanted tripping of embedded generation within GB.

In order to deal with the issue a joint Grid code and Distribution code working group was set up to consider altering the RoCoF protection settings required in G59. Prior to the working groups first meeting two cross channel interconnector trips resulted in the loss of additional generation within GB on the 28th and 30th September 2012. The working group decided that initially they would target generators of 5MW or more and commissioned studies by the University of Strathclyde to determine the effects of altering the RoCoF protection on generators of 5MW or more to a range of RoCoF events.

This work showed that while the risk of an islanding event increased by a factor of about 100 if the RoCoF setting was moved to 1Hz per second measured over a 500ms window that this risk would still fall in to the acceptable range of risks that DNOs currently operate with. Following public consultation it was agreed that for existing synchronous generating units and those connected for a short period after G59 was updated would be allowed to change the settings to 0.5Hz per second but that all non synchronous machines and synchronous machines connected after the end of July 2016 would have a setting of 1Hz per second measured over 500ms.

The working group struggled to agree a clear definition of what was required with some members wanting to define relay settings and others wanting to define an event which could be measured and tested against. In the end as different relays used different ways to define RoCoF protection settings, a compromise was reached and published in G59/3-1 in August 2014.

The published setting was 1Hz/s with a time delay of 0.5s (or 0.5Hz/s for synchronous machines connected up to the 31st July 2016)

This was then augmented with a note which says.

“The required protection requirement is expressed in Hertz per second (Hz/s). The time delay should begin when the measured RoCof exceeds the threshold expressed in Hz/s. The time delay should be reset if measured RoCoF falls below that threshold. The relay must not trip unless the measured rate remains above the threshold expressed in Hz/s continuously for 500ms. Setting the number of cycles on the relay used to calculate the RoCoF is not an acceptable implementation of the time delay since the relay would trip in less than 500ms if the system RoCoF was significantly higher than the threshold.”

From August 2014 to July 2016 the changes required to be made were implemented at power stations of 5MW and larger across GB and no issues were raised with any relay. Since August 2016 a number of instances have come to light of DNO witnessing engineers being concerned about the setting methodology of two relays supplied by ComAp. The affected relays are InteliPro and MainsPro. Both use a similar algorithm to detect RoCoF. They have a RoCoF setting in Hz/s and a measurement window setting in number of cycles. By adjusting these two settings the relays response to network changes can be modified.

The initial concern was about the relay using cycles to determine time which was a method described as un-acceptable in G59/3-1. Initial thoughts were that for the critical event of a falling frequency using cycles would result in longer times to trip and that perhaps it was not a big issue. However we did not know how the relay worked.

Martin Lee over the course of several meetings with ComAp in late January 2017 determined how the relay worked and has established that for a pure RoCoF event with the relay set to 1Hz/s and with a 25 cycle measurement window, with an applied RoCoF of 1.0Hz/s that the relay will trip in 0.98 second. The RoCoF needs to be raised to 2.0Hz/s to trip in 0.5 second and a trip in less than 0.5 seconds requires the RoCoF to be raised to 2.09Hz/s.

However pure RoCoF events where the RoCoF is constant from inception to the point it starts to decay, are only likely to take place at locations a long way away from the fault. At locations closer to the fault there will be a combination of a voltage dip, a rapid change in frequency over one cycle which is regarded as a vector shift (VS) followed by a steady RoCoF during the fault, at fault clearance there will be a restoration of voltage, another rapid change in frequency over one cycle and then a further steady RoCoF which will be sustained until generator control actions either reduce or increase the output of generating units. It was found that using the minimum number of cycles (5) and setting the relay to 1Hz/s would result in a trip for a system VS of only 2 degrees. At the old G59 suggested setting of 0.125Hz/s, setting the measurement window to 15 cycles results in a trip for a system VS of just over 2 degrees.

Because of these issues RoCoF very quickly gained a reputation of being “unstable” and VS was chosen as the preferred loss of mains technique provided by this relay. The ComAp relays have been very successfully marketed and appear to comprise at least 60% of the installed base of loss of mains protection relays in GB. At least in the south of England (survey data from Southern Electric Power Distribution and Western Power) it appears that RoCoF is no longer used for new jobs.

Using an excel spread sheet model created from information supplied by ComAp a RoCoF setting of 1Hz/s was tested with various levels of initial VS. At a RoCoF of just under 1Hz/s with no VS then the relay is stable and does not trip. As increasing levels of VS are applied at the beginning of the fault to replicate the changes caused by reactive power flowing into a fault the RoCoF stability level fell to 0.35Hz/s for a 70 degree VS. For a 72 degree VS the relay trips straight away. This boundary may move up or down a little as the pre fault frequency may not be constant or at 50Hz. However it is clear that the relay when set to 1.0Hz/s and with a 25 cycle measurement window, will remain stable for faults with initial VS of up to 60 degrees and with subsequent RoCoF events of 0.3Hz/s.

NG have recently indicated that they would not now expect the system to be run in such a way that RoCoF for a planned loss will exceed 0.3Hz/s. As such it would appear that the ComAp relay ought to be stable for both RoCoF and accompanying VS events which the WG have been looking at providing stability for.

Following a fault in the south west of England in May 2016 a large amount of embedded generation was lost. It was apparent that this was not due to RoCoF protection as the system RoCoF did not come close to 0.125Hz/s nor was it due directly to low voltage as the dip in voltage was not long enough to cause an under voltage trip. Investigations showed that a number of the sites had tripped due to operation of VS protection. Further work carried out by NG to date suggest that VS of up to 60 degrees might be seen for three phase short circuit faults on 400kV transmission circuits and that in some circumstances these VS events are replicated on lower voltage networks with substantially the same magnitude of VS.

As such it is recommended that until G59 is revised to deal with smaller than 5MW generating units and suitable RoCoF and VS immunity criteria are defined, that a D code Guidance note is issued as follows which allows the ComAp Relays to be used for RoCoF protection for above 5MW generating units.

Suggested text.

Following the issue of G59/3-1 in August 2014 it has become apparent that relays manufactured by ComAp (MainsPro and InteliPro) do not strictly comply with text introduced in G59/3-1 which prohibits the setting of the time delay in cycles rather than as a definite time delay for the RoCoF protection (section 10.5.7.1). On investigation of the relays operating method it is apparent that when RoCoF protection is set to 1.0Hz/s with a measurement period of 25 cycles that the relay is stable for all the manifestations of expected RoCoF (and its accompanying VS) events that are expected on the GB system and that therefore the relay can continue to be used on the GB network. It is expected that a revised definition of the requirements for stability during system RoCoF and VS events will replace the current note within G59/3-1 and G59/3-2 in due course.

End suggested text.

I suspect that in the mean time smaller than 5MW generators will continue to select VS as their preferred means of loss of mains protection and that this may continue to present NG and WPD with a challenge in this area until G59 is updated.