NEW SETTINGS INCLUDING RATE OF CHANGE OF FREQUENCY FOR INTERFACE PROTECTION RELAYS USED FOR GENERATORS CONNECTED TO MV GRID

Samuel EMELIN
Enedis – France
samuel.emelin@enedis.fr

Vincent GABRION
EDF – France
vincent.gabrion@edf.fr

ABSTRACT

On the French distribution grid, protection against faults in presence of distributed generators is mainly based on autonomous interface protection relays that take into account phase-to-phase voltages characteristics (RMS value and frequency) and zero sequence of phase-to-earth voltage (RMS value). Transfer trip is also used on a small proportion of production sites.

This paper brings details about the different settings used on the French grid, their advantages and drawbacks, and focuses on the benefits of the new setting which reduce the risk on the interconnected transmission grid stability while maintaining the distribution grid performance.

INTRODUCTION

On the French grid, protection against faults in presence of distributed generators is mainly based on autonomous interface protection relays that take into account phase-to-phase voltages characteristics (RMS value and frequency) and zero sequence of phase-to-earth voltage (RMS value). Transfer trip is also used on a small proportion of production sites.

Until now, four different settings had been used on the French grid on autonomous relays (excluding the ones with transfer trip). Those settings are chosen depending on the sensitivity of the generator to grid disconnection (often dependant on its size), and the characteristics of the grid to which the generator is connected (mainly because of the use of fast reclosing and connection through dedicated feeder).

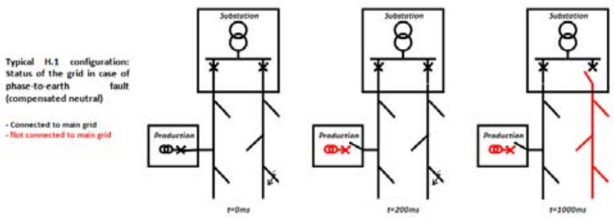
Historical settings are given in the table below:

	Setting H.1	Setting H.2	Setting H.3	Setting H.5
Max V_0	10% V_n Instantaneous tripping	10% V_n **Tripping delayed** by t_0 + 0.5s	10% V_n **Tripping delayed** by t_0 + 0.5s	10% V_n **Tripping delayed** by t_0 + 0.5s
Min U	85% U_n Instantaneous tripping	85% U_n Instantaneous tripping	85% U_n **Tripping delayed** by t_1 + 0.5s	80% U_n **Tripping delayed** by 1.2s
Max U	115% U_n Instantaneous tripping	115% U_n Instantaneous tripping	115% U_n Instantaneous tripping	115% U_n **Tripping delayed** by 0.2s
Min f	47.5 Hz Instantaneous tripping	47.5 Hz Instantaneous tripping	49.5 Hz Instantaneous tripping	47 Hz **Tripping delayed** by t_1 + 0.5s
Max f	51 Hz Instantaneous tripping	51 Hz Instantaneous tripping	50.5 Hz Instantaneous tripping	52 Hz **Tripping delayed** by t_1 + 0.5s

Where:
V_0 is the zero sequence of phase-to-earth voltages (almost 0 when there is no phase to earth fault)
V_n is the nominal value of phase-to-earth voltage (11.5 kV on a 20 kV grid)
U is one of the three phase-to-phase voltage
U_n is the nominal value of phase-to-phase voltage
f is the frequency of the grid
t_0 is the duration of the first "long" opening of the feeders circuit breakers in case of phase-to-earth fault
t_1 is the duration of the first "long" opening of the feeders circuit breakers in case of phase-to-phase fault (0,5s)

H.1 SETTINGS

The advantage of H.1 settings is that it is quite simple. But it has drawbacks: with these settings most of phase-to-earth faults and severe phase-to-phase faults cause a tripping of production, even if the fault is not on the feeder that supplies the producer.



Grid access quality is low for production with H.1 settings. It can be sufficient for small production where a high number of tripping is not a problem. The situation may however be improved using delays in the settings.

H.2 SETTINGS

H.2 settings allow to improve quality of access to the grid, because the producer trips after that the feeders circuit breaker has opened. As a consequence, the producer does not trip when there is a phase-to-earth fault on a feeder different from the one to which the producer is connected. This has a strong impact on the number of tripping, as 80% of faults are phase-to-earth ones.

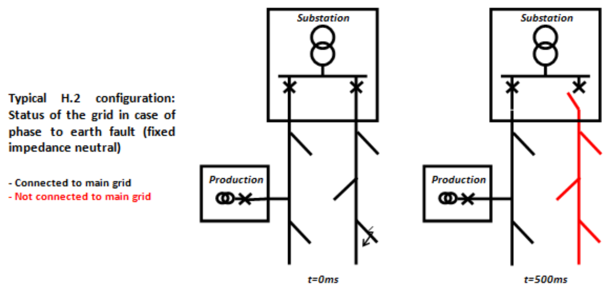
H.2 settings can only be used on feeders on which reclosers are not used. In France reclosers are widely used in primary substations (mostly 225kV/90kV/63kV to 20kV). They are used on feeders with a significant proportion of overhead lines, those types of feeders cover the main part of the country. Only the feeders in the core of cities are fully buried.

Mainly two types of MV earthing systems are used in France: compensated neutral (target for feeders with a significant proportion of overhead lines) and fixed impedance neutral (historical for the whole country – still widely used, and target for feeders made of cables only).

Outside of the cities, special circuit breakers are used to connect faulted phase to the earth in association with fixed impedance neutral. With these two earthing systems reclosers are used, with variations in the tripping delays.

Reclosers make a fast open-close cycle which duration is short (typically 300ms), and then one or two slow open-close cycles (typically 15 to 30s). A lot of electrical installations connected to MV or LV public distribution grid are designed to be immune to a fast open close cycle, so it is important that fast reclosing of circuit breakers remains operational.

H.2 settings cannot be used on a feeder on which a recloser is used, because on a single phase fault voltage and frequency can vary quite slowly on the islanded feeder disconnected from the mains. As a consequence, there is a strong risk of reclosing when voltages of the islanded feeder and the MV busbar in the substation are out of phase. As a consequence, H.2 settings are usable only on a fraction of feeders (urban mostly).



If a severe phase to phase short circuit happens (for example three phase fault not far from producer location), the voltage dips causes the tripping of the H.2 relay (same as H.1).

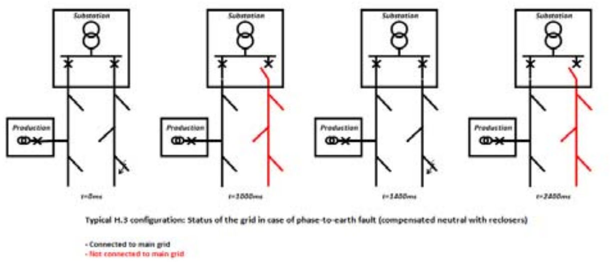
H.5 SETTINGS

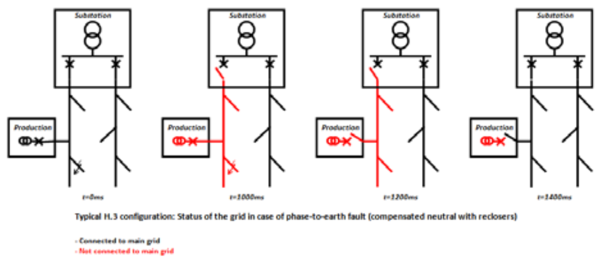
Another configuration, with H.5 settings, is used when a feeder is dedicated to production. This kind of connection is widely used due to the development of wind farms and large scale PV projects located in low human density areas. The amount of generated power is typically 10MW, when preexistent consumption is typically 2MW or 3MW per feeder. In those areas, electrical constraints including grid losses are so high that the best solution is to build new feeders to adapt the grid to the new flow of power. Those feeders are short, made of cables, and operated without recloser. In a lower number of cases, transfer trip is used in order to connect large power plant (5 to 8 MW) to strong enough already existing feeders.

In H.5 configuration, as frequency and voltage varies quickly because production and consumption are separated, the voltage and frequency windows in which MV producers can feed the grid are widened, and tripping are delayed. H.5 settings is compatible with mandatory rules for production greater than 5MW, which have to remain connected to the grid on normalized voltage dips and frequency variations (interconnected power system stability). The number of disconnections is very low.

H.3 SETTINGS

The last configuration used in France is the one using H.3 setting. This configuration is used when production (below 5MW) is connected to a feeder which supplies also MV and/or LV customers, and when reclosers are used. In this case, a system is added in the substation: voltage presence is detected on the feeder and forbids the circuit breaker to close when the islanded feeder is still energized by local production. This event, which weakens the quality for consumers due to late operation of the reclosing cycle, is rare thanks to the narrow frequency window. A slight deviation in frequency makes the producers trip. This trip has to be quick as fast reclosing cycles usually last 300ms.

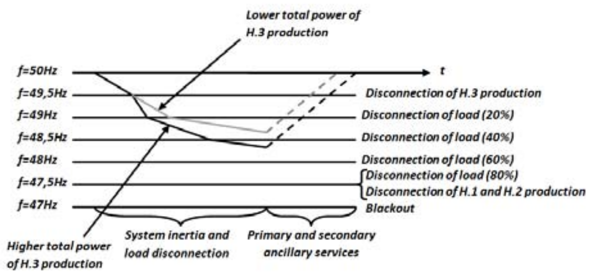




Note that this behavior is not certain if the situation on the islanded feeder is close to equilibrium when the fault appears. This combination of H.3 protection and fast reclosers works in most cases, and thus allows a minimum impact of faults on the quality of supply.

SYSTEM STABILITY ISSUE

H.3 settings are historically based on a narrow range of permitted frequency (49,5Hz – 50,5Hz) with the aim of ensuring a fast disconnection of production so that the feeder recloser (open-close in 300ms) works properly. As more and more distributed generators are connected to the MV grid, the narrow range of frequency has become an issue with regard to the stability of the interconnected power system. In case of severe transmission events (loss of large generating plant, loss of critical international lines), the drop or rise in frequency can be outside of the narrow range of frequency, causing the disconnection of decentralized generators, and as a consequence reducing the stability of the power system.



Frequency variation on the interconnected power system after the loss of generation

As a consequence, Enedis changes the narrow settings to wider settings (47.5Hz/51.5Hz) when the rate of change of frequency (ROCOF) is below 0,5 Hz/s (the frequency drop/rise is slow, which means the generator is likely to be connected to the main power system). When the frequency drop/rise is higher than 0,5 Hz/s, the generator is supposed to be connected to a feeder which is disconnected from the transmission grid, and disconnection occurs when frequency is outside the narrow settings (49.5Hz/50.5Hz).

CONCLUSION

Those new settings maintain a quick disconnection when ROCOF is greater than 0.5 Hz/s, which means that frequency has reached 49.5 in less than 1 second. In the rare cases where the islanded feeder is close to equilibrium and the frequency has not reached 50,5 or 49,5 Hz within 1 s, the previous settings would not have disconnected the production in less than one second either. The H.3.1 settings reduce the risk on the interconnected transmission grid stability while maintaining the distribution grid performance.

REFERENCES

Technical reference documents available on www.enedis.fr:

- Enedis-NOI-RES_13E: protection of production installations connected to public distribution grid

- Enedis-PRO-RES_10E: choice of interface protection relays for MV connected generators

ENTSO-E Position Paper: Dispersed generation impact on continental Europe region security, 15 November 2014