ADVANCED FAULT MANAGEMENT AS A PART OF SMART GRID SOLUTION

Dragan S. Popovic
DMS Group – Serbia
dragan.popovic@dmsgroup.co.yu

Elena E. Boskov
DMS Group – Serbia
elena.boskov@dmsgroup.co.yu

ABSTRACT

Concept of advanced fault management as a part of the Smart Grid solution is based on full coordination of local automation, locally controlled switchgear and relay protection with maximum exploitation for minimizing fault duration and undelivered energy. Island operation is proposed as possible solution for energization of important consumers in order to maximally protect such consumers from outages. All considerations are elaborated trough examples. Also some ideas for further improvements are also suggested.

INTRODUCTION

This paper presents the concept of advanced fault management as a part of a Smart Grid solution. The proposed concept is based on an algorithm that provides a full coordination of equipment for local automation and remotely controlled switchgear in order to provide maximum exploitation of the existing equipment for minimization of fault duration and undelivered energy [1]. During analysis of network automation the following standard equipment is usually considered:

- Fault indicators: fault detectors (directional and unidirectional) with local and/or remote indication.
- Local automation: automatic reclosing, reclosers, autosectionalizers, changeovers as well as grounding breakers driven by grounding relay.
- Control centers with SCADA[1] and DMS[2] power applications.

Foundation for the proposed concept is off-line setting of the equipment of local automation and on line coordination of remotely controlled switchgear that superpose on such set spontaneous reactions of local automation. The paper devotes special attention to Fault management regarding operation of local automation and relay protection settings in presence of distributed generators (DG) in medium voltage network. Fault elimination is basic activity that is carried out by relay protection and local automation. Depending on automation level, localization and isolation of faulted element can be also done more ore less automatically. Application reclosers, sectionalizers and other local automation significantly improve functionality of fault management and decreases duration of undelivered energy to the consumers. Supply restoration which is the final part of the fault management is omitted from consideration in this paper. It considered that this mechanism will be applied through a standard procedure.

Fault management is the scope of the second part of the paper. Focus is made on elimination and isolation of fault. Standard solution is elaborated in this part. Advanced fault management is considered in the third part where one contemporary solution is suggested. The proposed concept is verified by simulations on one real distribution network. Obtained results have demonstrated that application of the proposed concept enables full coordination of effect of local automation and remotely controlled switchgear, which especially significantly increases the quality of supply for important consumers. Conclusion and literature are given in the last two parts of the paper.

FAULT MANAGEMENT – STANDARD SOLUTION

Aspect of supply reliability of consumers is considered in a frame of fault management that comprises fault elimination and location.

The considered part of a network is displayed in figure 1 where one HV/MV supply station with one noticed feeder is considered. The feeder has 4 MV/LV substations and one switching station where a DG is connected to the network. Normal low voltage consumers are denoted with C1 – C3, while important customer is denoted by IC. Also, every substation in supply bay is equipped with fault detectors (FD) which are used for localization of faulted section. Fault detectors are of directional ones.

Protection of feeder is organized by overcurrent J> relays. One relay marked by R is placed on feeder head, while other one is placed in DG bay and it is marked as DGR.

When fault occurs over current relay protection R on feeder head trips after 0.3 – 0.5 sec. Time setting of DGR depends on contribution of fault current from DG [2,3]. Generally, there are two possible cases. The first one encompasses DG which is directly coupled to distribution network. Such DG could cause relatively significant increasing short circuit current value. DG of greater power gives greater contribution to fault current. The second case becomes more and more usual where DG is coupled to distribution networks via power electronic device. Such device is used for DG control. Presence of such device limits contribution while DG with invertors this contribution is limited to the value of rated DG

[1] SCADA – Supervisory, Control and Data Acquisition
[2] DMS – Distribution Management System

current (in some cases short circuit current can have slightly higher value of 150% [4,5].

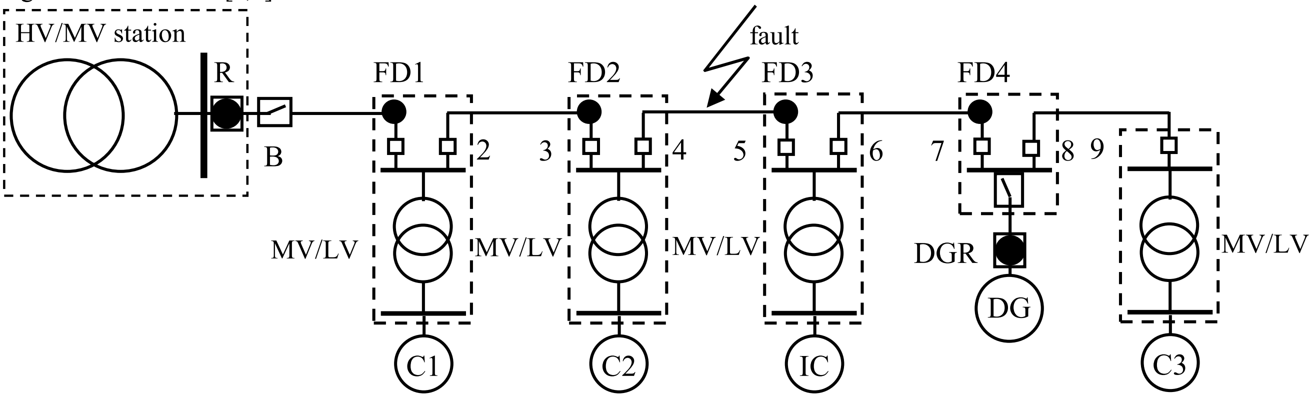

Figure 1 – Feeder with fault

Obviously, presence of DG in a distribution network introduces a new source in distribution network which causes changes in comparison with the situation without DG. Instead of radial operation, presence of DG introduces a situation typical for the transmission networks or loops where supply is provided from two sides.

Value of short circuit generated from DG is crucial for estimation of events which can happen in the network. It is interesting to consider what would occur in case the If value of DG current for fault on MV busbars in HV/MV station is smaller then current setting of protection R, time setting of DGR can be the same as time setting of protection R. Otherwise, time setting is raised for Δt regarding feeder protection. So, fault will be eliminated after opening the feeder breaker B and DG breaker. In the worst case, this elimination will happen after 0.3 – 0.5 sec + Δt.

After elimination of fault, automatic reclosing breaker B could be performed after 0.3 sec. Apparently the presence of DG has influence on time setting of local automation for automatic reclosing. Normally, outage of DG will happen, so energization of feeder will be carried out only from HV/MV station – this outage will cancel all effects of introducing presence of DG in distribution network. If fault is of temporary nature, it will be eliminated after previously described sequence, while one additional opening of breaker B is necessary for permanent fault.

Application of recloser instead of breaker B in combination with FD and appropriate local automation in each MV/LV substation opens possibility for further improvement fault procedure. This will be illustrated trough following example. Let consider the same fault as it is given on figure 1. Reclosers are typically designed to do 1 fast and 2 slow reclosing. Fast reclosing (0.3 sec) will eliminate temporary fault while permanent fault cause another (the second opening). Permanent fault will also trip fault detectors and they will initiate opening of appropriate switches. So if the considered fault is permanent, switches in substation with consumers C1, C2 and IC will be tripped and switches 1, 3, 5and 7 are opened (the last two fault detectors FD3 and FD4 will be tripped for opposite direction then others – for generators with power electronic coupling typical setting of 160% of line rated current will omit this tripping – this means that opening switches 5 and 7 can be suppressed). But anyway outage of DG happens and distribution feeder will operate as radial in events that will come after that.

In addition, recloser closes again and the FD1 will notice presence of voltage and switch 1 in substation with C1 is closed (typically after 5 sec). Then FD2 in substation with consumer C2 detects presence of voltage and switch 3 will be closed. This leads to re-supplying of the fault again and the recloser will open again. At the same time switch 3 will open once more but it will be blocked because opening happens immediately after its closing. New closing of the recloser and sequential closing of switch 1 will energize healthy part of the feeder. Faulted section is therefore identified. Its position is between open and blocked switch and next downstream FD/switch. If it is possible, the rest of the feeder downstream the faulted section could be re-supplied trough dispatcher action (this part is not of interest for this paper consideration).

<u>*Modified solution*</u>

In the networks which are grounded via low impedance, modified procedure could be applied. Having in mind that 70–95% of faults are line to ground faults and that 70–90% are temporary faults, it is very helpful to use the grounding breakers (three independent mono phase breakers connected to MV busbars in HV/MV station). The grounding breaker makes additional short circuit in HV/MV station exactly in phase where the fault occurs. The grounding breaker close contacts immediately after fault holds its closed for 150-200 msec typically, but it opens contacts about 100 msec before opening breaker B (or recloser). If fault is temporary, it will be eliminated in such a way, if not, feeder and DG protection operates normally after setting time. Obviously, automatic reclosing is omitted – temporary faults are eliminated without disturbance of consumers and without overvoltages caused by switching commutation.

It is interesting to notice that presence of DG has insignificant impact in the given example. This means that the presence of DG will not cause additional problems but it would not be helpful either. It is necessary to point out that the important customer will remain de-energized. The idea is to find a way to use the potential of DG presence for improving reliability of important customer supply. Possible solutions are elaborated in the next part of paper.

FAULT MANAGEMENT – DG APPLICATION IN ADVANCED SOLUTIONS

Standard procedure causes outage of DG and this is the main reason why capacity of DG can not be used during fault management.

Advanced solution means application of control actions which provides better solution for important consumers. Normally, it is assumed that network is grounded via low impedance. Elimination of temporary faults can be performed by a grounding breaker. Then application of DG resource is expected and normal segment in this solution.

In order to use DG as respectable factor that can improve reliability of operation especially for important consumers it is necessary to provide all preconditions for island operation. Thus, DG is considered as alternative source which can supply autonomously some of consumers in the island – especially attention will be paid on an important consumer. Normally, it is assumed that all prepositions for DG's island operation are fulfilled – normally, power of DG has to be sufficient for satisfying needs of important consumers and also the DG has to be equipped with appropriate power electronics and VAR resources which enable island operation as well as re-setting of DG protection for island operation (microprocessor relays have such capabilities).

Advanced solution – restart of DG

Normally as one possibility it can be considered restart of DG after elimination of a fault. DG will operate in island (as it was mentioned, it is assumed that DG has all necessary capabilities for this supply). Size of island has to be adjusted according capabilities of the DG. In such a way, presence of DG, for sure, can be used for increasing reliability of important consumer supply. It is necessary to point out that short break in consumer supply will happen and it could be acceptable for most of consumers.

However this solution sometimes could not be simply applied in reality because the network and DG belong to different owners and coordination is not always possible. Sometimes important consumers will be disturbed during period of restart. Therefore better solutions are suggested in addition.

Advanced solution – Smart Grid solution

In order to provide permanent operation of DG after permanent fault herby is introduced a procedure for intelligent opening breaker/recloser accompanied with opening some of the switches[3] on the feeder. This solution means opening not only switches initiated by fault detectors but switches that determine the island as well.

Basic idea is very simple – to isolate island with DG and important consumer immediately after permanent fault occurrence. Which switches will be opened depends on the DG power, actual consumption, network state as well as available switches and protections. The scenario for islanding has to be prepared in advance and triggered by critical event. E.g. for feeder on figure 1, it means that opening breaker B/recloser will accompanied with opening switches 5 and 8. Critical event can be fault occurrence which will be detected by relay R and voltage relays with same time setting as protection R can be used for this purpose). This means that an island consisting of DG and MV/LV with IC is established. This operation will be successful for all cases when faulted section is not on trajectory between DG and IC i.e. on island. Appropriate fault detector setting can filter situation when fault occurs on the island. It is necessary to introduce fault detectors on border points of the island in regards to the rest of the feeder. On example shown in figure 1 fault detectors FD3 and FD4 can be used in this purpose. If both detectors are tripped, a fault is downstream of the island or if both ones are not tripped a fault is upperstream from the island. Finally, if only FD3 tripped and FD4 did not, this would mean that the fault is in the island and that islanding is not possible. Switch 8 has to be replaced by breaker in order to provide islanding in cases when fault is downstream of the island. Switch 5 has to open more slowly contacts of the breaker B and breaker 8 (ex switch 8) to avoid breaking short circuit current[4].

Coordination among breaker B, switch 5 and breaker 8 is adjusted by appropriate time setting. Mandatory prerequisite is that the DG is able to continue operation until island operation is established (this is for sure possible because contemporary DGs are able to operate at least 500-600 msec in the state of fault. This is quite enough time for establishing an island.

Role of the Smart Grid software component described here is

[3] It will be shown in addition that this switch has to be a breaker.

[4] If we directly coupled DG on the network, we should replace switch 5 with a breaker because of significant fault current from the DG side. This situation is not expected in real practise because most of the DGs are coupled by power electronic coupler where anticipated current is limited to the rated current. As it is already mentioned power electronic is mandatory for control in island operation and this automatically exclude needs for transforming switch 5 into the breaker.

to provide support for advance checking of all possible scenarios as well as calculation of appropriate settings and performing all simulations necessary for its realization.

Quality of the proposed solution can be significantly improved if coordination is result from the real time calculation and possibility to constitute island dynamically with respect to the current state of network. Remote controlled switchgear as well as microprocessor relays are unavoidable items in such realisation. Such solution will be the matter of some of next solutions.

CONCLUSION

In order to prepare and adjust the distribution network for its new active and dynamic role as well as to meet new requirements which are oriented towards improving reliability and security of consumer supply, the concept of smart grids solution is introduced. This paper focuses on a particularly important aspect – introduction of DGs in distribution network regarding the fault currents, relay protection and fault management especially with respect to the important customer presence. Standard solution was the basis on which the advanced solution based on the Smart Grid concept is elaborated. This solution demonstrates how the modest investments and know/how coordination can provide necessary autonomy and reliability of supply for the important consumers. At the same time this solution presents the next foundation for further improvements based on the real time solutions.

LITERATURE

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Dragan S. Popovic (1959) received his B.Sc. degree from the University of Novi Sad, Yugoslavia, in 1985, and the M.Sc. and Ph.D. degrees from the University of Belgrade, Yugoslavia, in 1990 and 1995. He is currently engaged as professor at the Faculty of technical sciences, University of Novi Sad. He has worked for a long time in researching fields of bulk power system analysis, control and stability. Presently he is engaged in researching and developing application software for distribution management systems with the DMS Group company from Novi Sad. He has also been the project manager on several projects in the field of distribution automation and distribution management system.

Elena Boskov (1979) has received her power engineering education at the Faculty of technical sciences, University of Novi Sad. Presently she is engaged in researching and developing application software for distribution management systems in the company DMS Group from Novi Sad. She has also been the project manager on the projects in the field of renewable energy sources, distributed generation and distribution management systems.