A COMPREHENSIVE ANALYSIS AND SOLUTION FOR SYMPATHETIC TRIPPING IN DISTRIBUTION NETWORK

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ABSTRACT

The objective of this paper is to provide a comprehensive analysis and solution for sympathetic tripping in distribution network. Al Ain Distribution Company (AADC) is responsible to operate and maintain the power distribution from 0.415 kV up to and including 33 kV level in the eastern region of Abu Dhabi emirate. AADC is always keen to provide safe and secure power supply to its customers.

This paper analyses the sympathetic tripping problems and provides solution using an economical, safe, secure, and reliable scheme with utmost care, in order to minimize the damage to equipments and ensure continuity of power supply to customers as far as practicable in AADC network. The scheme is developed in combination of overcurrent, under voltage and negative sequence functions, which are readily available in numerical protection relays. The solution provided in this paper not only analyses modern relays/schemes, but also the possibility of improving existing protection scheme problems, where electro-mechanical relays are available with required modification without major cost impact.

INTRODUCTION

Al Ain Distribution Company (AADC) is one of the subsidiary companies in Abu Dhabi Electricity and Water Authority (ADWEA) in the United Arab Emirates (UAE). There are twenty (20) numbers of 220/33 kV Grid stations, two hundred (200) numbers of 33/11 kV primary stations, twenty (20) numbers of 11 kV switching stations and about five thousand (5000) 11/0.415 kV distribution stations available in AADC network. AADC obtains the power from TRANSCO, the transmission operator through 220/33 kV grid transformers and it is one of the subsidiary companies in ADWEA network.

Isolation of sympathetic tripping is a great challenge worldwide. Though the same had been discussed in several papers, there is no solution without affecting other characteristics in protection such as overcurrent sensitivity. Transmission network fault would affect the voltage imbalance in distribution network while there would be no impact on transmission, when fault is in distribution network. Sympathetic tripping would occur for the healthy distribution feeders due to delayed voltage recovery when the fault is in transmission or distribution network. There is a possibility to prepare a sophisticated scheme using IEC61850 protocol by exchanging the GOOSE message to all protection IEDs (PIEDs) within the substations, as all modern relays are compatible with 61850.IEC GOOSE messaging can be used in development and implementation of distribution protection schemes for improving the performance and reduction of overall fault clearing time. However, any sympathetic tripping would not be prevented, in case of communication failure between the IEDs. Hence, a comprehensive scheme should be prepared to prevent sympathetic tripping and it should trip only under real fault conditions, without initiating any false tripping of healthy feeders, when the fault occurs on either transmission or distribution network.

First section of this paper analyzes sympathetic tripping phenomena in general and various solutions offered previously in consideration with pros and cons in Transmission and Distribution network. Second section analyzes sympathetic tripping issues and implemented solution in Al Ain Distribution network. Final section of this paper discusses in detail for the new scheme, which is proposed to be implemented in Al Ain Distribution network. To overcome existing issues in such a way that the feeder should operate only for real fault conditions without initiating any false tripping of healthy feeders without compromising any of the protection settings (such as to decrease the sensitivity settings of overcurrent etc.), when fault occurs on transmission or distribution network.

SYMPATHETIC TRIPPING PHENOMENON

Sympathetic trips are undesirable relay operations for unbalanced or high load conditions, which occur during, or immediately, following out of section faults.

“Being constant power type of loads, the stalled motors characterized with reduction in impedance (Z_{load}) and lagging power factor draw excessive reactive power or current from the grid in the locked rotor condition in order to deliver same energy and the system voltage remain depressed viz., voltage recovery is delayed for several seconds even after the fault is cleared. As load current increases beyond the setting of protection relays, the undesired tripping of several distribution feeders occur. This phenomenon is universally termed as sympathetic tripping as tripping occurs on healthy feeders with high concentration of motor loads in sympathy with fault, happening elsewhere on the same or higher voltage network” [1].

Delayed voltage recovery conditions are commonly initiated by a fault on adjacent feeder of the distribution voltage level or on a higher transmission voltage level. The root cause of the sympathetic trip problem depends on the type of loads served by distribution feeders. There are two classifications of sympathetic trips. One which occurs due to delayed voltage recovery conditions ,and the other which occurs due to load unbalance during an out of section fault. The main causes of sympathetic trippings are the increased numbers of Air Conditioners, over loading of feeders and high fault currents near the substations close to transmission network or source. The delayed voltage recovery problem is as a result of the type of connected load.

The following section discusses the solutions offered previously and subsequent section analyzes pros and cons of sympathetic tripping.

One of the solutions discussed previously is that to block the sensitive over current setting and/or to reduce the sensitivity by increasing the pickup setting for the duration of inrush for a period of time that expected inrush condition by sending the signals from faulty feeder relay to healthy feeders relay once fault detected to avoid sympathetic tripping [3]. However, this solution can be applied within the station feeders itself and might not be possible to send the signals from one station relay to other stations, as the number of stations are away from the fault location. Any sympathetic tripping would not be prevented, in case of communication failure between the IEDs. Also, it is difficult to exchange the data between two or more substation IEDs, as the communication traffic would lead the scheme unreliable due to data size. Hence, it is always better to prepare the scheme within the feeder itself without depending on the data from adjacent feeders.

Another solution is to decrease the power system impedance to reduce line voltage drop in such a way that operating transformers in parallel, adding resistor/reactance earthing to transformers in order to reduce the fault levels and increasing conductor sizes thereby, decreasing the system impedance. Such measures would have a major impact on existing design/equipment especially on transmission network and may increase the complexity of setting earth fault protection relays.

One common sympathetic tripping solution offered previously is to permanently raise the phase and ground overcurrent element pickup thresholds. This solution would unnecessarily penalize fault detection sensitivity. Lowering individual feeder currents and balancing each feeder load as much as possible to reduce pre-fault unbalance current are some of the solutions suggested to mitigate sympathetic trip from network perspective. This proposal is difficult to implement due to network arrangement. Installing under voltage contactors for all motor loads in customer premises is one of the solutions for sympathetic tripping. However, customer arrangements are mostly not under direct control of power utility companies.

EXISTING SYMPATHETIC TRIPPING ISSUES AND IMPLEMENTED SOLUTION IN AADC NETWORK

In this section we analyse sympathetic tripping issues and implemented solution in Al Ain Distribution network. The problem has occurred in Al Ain of geographical nature (i.e. warm-dry climate), where a large percentage of the loads consists of air-conditioning motors. Single phase residential air conditioners are a common application for these motors. Two factors appear to predominate in influencing the voltage recovery problem. a) The number of air conditioners experiences a voltage dip during a fault and b) Reduced load impedance under stalled motor conditions.

There were several sympathetic trippings recorded in Al Ain Distribution network in the years 2003, 2009, 2010, 2011 and 2012. One of the major incidents was recorded in July 2009. Load losses of about 175 MW was reported when there was a 1Φ-G fault in 220/33kV, 140 MVA grid transformers at Zakher grid and were several trippings reported on the distribution feeders in several 33/11kV substations in various regions throughout Al Ain [1]. Therefore at the end of Year 2009, AADC initiated a project for analysis of protection settings in order to evaluate the impact of changing the settings to avoid sympathetic trips. Solution implemented in AADC network for sympathetic tripping was to raise phase overcurrent element pickup thresholds.

Another incident happened on July 2010 which took load loss of about 90 MW due to sympathetic tripping in various 33/11 kV feeders in AADC network when the fault happened on the 400 kV double circuit transmission lines on Taweela-Dahma and Sweihan - Dahma circuits. It should be noted that the load loss was minimised compared to 2009 and positive effect was felt in the year 2010 after successful completion of project for setting study analysis for sympathetic tripping.

This solution implemented in AADC didn’t prevent sympathetic tripping fully , as there were number of feeders tripped during the year 2011 and 2012 at various fault occurred at transmission and distribution network. Therefore, it is necessary to implement a permanent solution to prevent the sympathetic tripping.

PROPOSED SOLUTION FOR SYMPATHETIC TRIPPING IN DISTRIBUTION NETWORK

In this section, the solution proposed for sympathetic tripping without penalizing any of protection characteristics is analysed in detail.

As stated in the beginning, sympathetic trips are undesirable relay operations for unbalanced or high load conditions, which occur during, or immediately following out of section faults. All unbalanced faults produce negative sequence current and while balanced load and three phase faults does not produce negative sequence currents [5].

During sympathetic tripping incidents, mostly over current relays, voltage relays, capacitor bank and load shedding scheme are most likely to operate in view of low voltages and high currents associated with these incidents.

in consideration with voltage and current sample rate, as the modern relays have the facility to record the trend curve of load consumption. Any protection scheme reliability is in combination of both scheme logic and protection settings. Proper protection settings study ensuring adequate grading margin is also important. The relay logic is based on current and voltage measurement during pre and post voltage dip incidents and would control or block the operation by sensing the sympathetic tripping scenario based on these measurements, as modern relays having facility to record current and voltage signals.

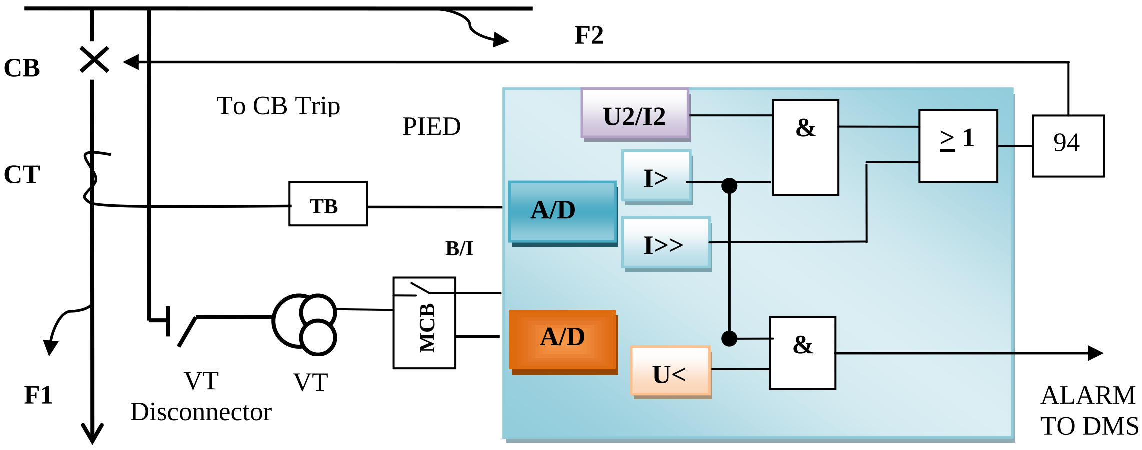

Figure-1: Protection Logic Diagram

Achieving grading margin in AADC network is not simple due to network arrangement and protection operation time is limited by constraints imposed by transmission (TRANSCO) operator by the maximum allowed operating time for grid transformer. In view of above, the scheme is developed in combination of overcurrent, under voltage and negative sequence functions, which are readily available in numerical protection relays with compatibility of IEC61850 for all feeders in the substations, viz., one relay with all functions for each feeder. The scheme is designed in such a way that the feeder should operate only for real fault conditions without initiating any false tripping of healthy feeders, when fault occurs on transmission or distribution network.

There is a possibility to prepare a sophisticated scheme using IEC61850 to exchange the GOOSE message to all protection IEDs within the substations, as all modern relays are compatible with 61850. However, any sympathetic tripping would not be prevented, in case of communication failure between the IEDs. Also, it is difficult to exchange the data between two or more substation IEDs, as the communication traffic would affect the reliability of the scheme due to data size. Hence, it is always better to prepare the scheme within the feeder itself without depending on the data from adjacent feeders. Voltage transformer supervision is also considered in the scheme, as the fuse or VT MCB failure would initiate false tripping of the circuit breaker by relay. The scheme is also developed

Figure-1 illustrates the protection logic diagram (PLD) for solution to prevent sympathetic tripping and to trip the faulty feeder only for real fault condition. In case of fault occurs in transmission / distribution network, the faulty zone will be isolated from the system without interrupting the healthy feeder.

The solution to overcome the sympathetic tripping is, to use two groups of settings used in combination with directional negative sequence functions, phase overcurrent and time delayed under voltage function, which are readily available as conventional protection scheme for all feeders in the substations. Group-1 setting is used as graded overcurrent with directional negative sequence function in order to eliminate only for particular feeder fault and prevent the sympathetic tripping. Assume that, there is a fault at F1 in the feeder, the fault current and negative sequence current will be detected and tripped by PIED. The relay will initiate the tripping signal to breaker, if both over current and directional negative sequence elements are operated by group-1 settings. During a sympathetic tripping, negative sequence current is following into the bus, therefore the negative sequence current direction can be used to block sympathetic tripping, if fault occurs at F2. Group 2 settings are used as graded overcurrent system with under voltage function to initiate disturbance/waveform recorder to analyse the fault and also, alarm signal shall be connected to distribution management system (DMS) control centre to isolate the feeder manually as necessary.

AADC is always keen to provide the quality supply to its customer as recommended by Regulation Supervision Bureau (RSB) within the allowable limit in order to avoid customer equipment damages. In many of sympathetic tripping, the voltage dip was approximately 60% of system voltage for about 6 seconds. Also, instantaneous function is used as backup of overcurrent settings with time delay.

With negative sequence quantities, it is possible to design reliable directional elements for all type of unbalanced faults. The negative sequence components are present in all unbalanced faults and there will not be any negative sequence components for three phase faults. If the fault is in front of the relay, the reactive impedance measured by relay is U2/I2= - Z1s. If the fault is behind the relay, the reactive impedance measured by relay is U2/I2= + (Z1L+Z1r) and accordingly fault can be detected by relay as forward or reverse fault [4].

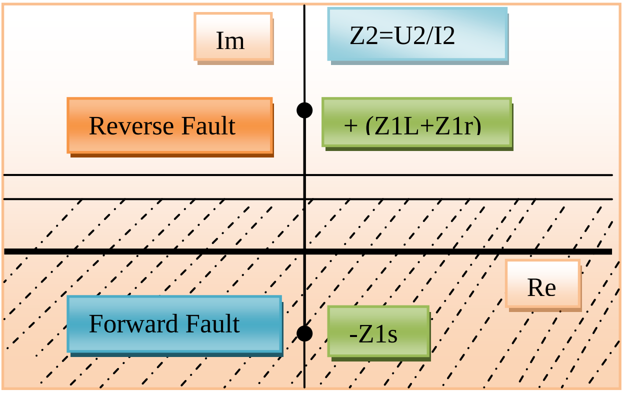

Figure-2: Directional Element operating Zone in Negative Sequence Impedance

The negative sequence directional element, as with other function in protective relay, does not operate alone [4]. Hence the scheme is developed in such a way that, the relay should operate only for real fault and should prevent the sympathetic tripping during the fault at transmission or distribution voltage level. The negative sequence directional element reliably determines the direction of all fault types in power system, except three-phase fault. Providing directional relay logic based on negative and zero sequence current detection as the direction of the sequence currents is reversed for the out of section feeders/relays on the radial circuits during motor stalling conditions. These currents flow as in the case of a reverse direction fault. Positive sequence quantities have been correctly associated with load and balanced conditions. Zero sequence quantities are easy to measure and quantify. Negative sequence quantities, on other hand have not been readily measurable in electro-mechanical relays, but can be measurable by numerical relays.

Figure-3 illustrates scheme proposal for the existing protection arrangement. To achieve the above stated scheme logic, negative sequence relay with under voltage function shall be installed as all the existing feeders have overcurrent relays. The scheme logic shall be prepared externally, as logic cannot be built inside the relay due to relay generation (i.e. from electro-mechanical relays to static relays).

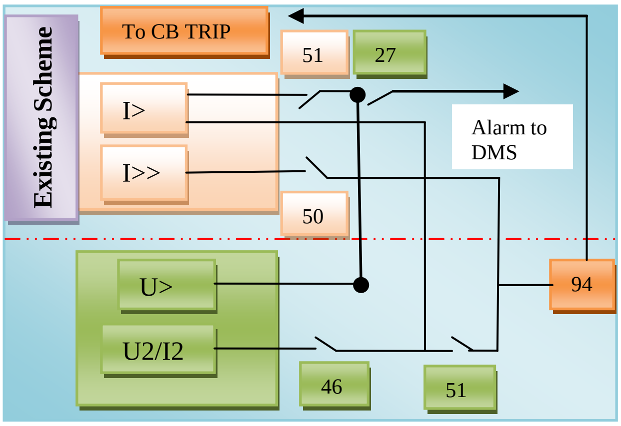

Figure-3: Scheme Proposal for Existing arrangement

CONCLUSION

Sympathetic tripping is an undesirable relay operation due to unbalance or overload conditions which occur during or with time delay following out of zone fault. It should be prevented in order to avoid supply interruption to customers while at the same time, equipments should be prevented from the damage, where faults occur on the feeder. The proposed scheme discussed in this paper is possible to implement in all new distribution feeders, as modern relays have the facility to implement. In the existing feeders also, it is possible to implement with required changes as discussed in previous section. However, utility company has to decide the importance of scheme requirement for sympathetic tripping prior to implementation in consideration of cost and time impact.

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