ANALYSIS OF THE OFFLOADING CAPABILITY OF A PRIMARY SUBSTATION IN AN OPEN RADIAL DISTRIBUTION NETWORK.

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ABSTRACT

One of the challenges in an open loop radial distribution network is determining if a primary substations load can be offloaded to another primary substation in the event of a busbar or transformer fault by opening a Normally Closed (N.C.) point at the faulted end and closing a Normally Open (N.O.) point at the other end. This analysis may seem rudimentary from the surface but is vital as it determines if the load that a primary substation normally feeds can be fed from other primary substations to maintain customer supply in the event of such a fault. This paper deals with an automated approach to this problem with a focus on performing this analysis on large networks as manual methods can take an inordinate amount of time and can't be reproduced easily for different cases and years.

INTRODUCTION

In modern distribution systems, open or closed loop arrangements can be implemented in order to feed load throughout the network. A closed loop system will provide a greater degree of reliability; however its installation and maintenance costs would generally be more expensive than that of an open loop system. [1]

An open loop system being less reliable in nature can minimise its Customers Hours Lost (CHL) by knowing beforehand the correct feeding arrangements to implement if a fault occurred anywhere on the system. Obtaining the most efficient feeding arrangements to ensure that a primary end to end feeder can be back fed in both directions in the event of a fault can be a time consuming process. This paper will describe a manual approach of how to achieve this and furthermore explain how to make this process automated.

THE OFFLOADING PROCESS

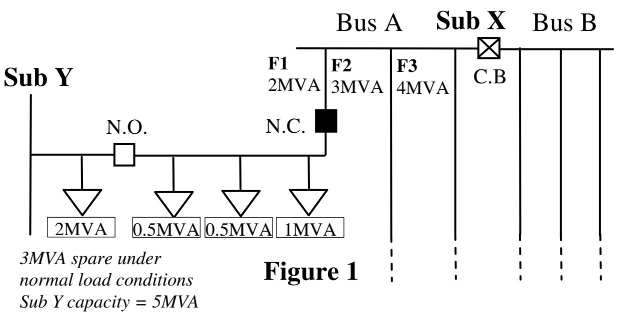

Figure 1

Figure 1 shows a sample substation with two busbar sections sectionalised by a circuit breaker. Bus A has three feeders F1, F2 and F3 with a combined load of 9MVA. Bus B has several feeders whose loads are not relevant for this particular example. If a fault occurs on Bus A the load that it supplies which totals 9MVA will have to be fed from neighbouring primary substations in order to maintain customer supply. For this 9MVA to be offloaded each feeder needs to be examined individually. Feeder 1 (F1) has a total load of 2MVA which is made up of three individual loads of 0.5MVA, 0.5MVA and 1MVA respectively. In order to restore supply to these three loads the N.C. point on F1 should be opened and the N.O. point should be closed. Sub Y will now feed the load that F1 was supplying in addition to the 2MVA it supplies under normal conditions. However in order for this to occur, Sub Y needs the spare capacity to do so and in this case it has 3MVA spare under normal load conditions. Once Sub Y takes on this extra load it will have 1MVA spare capacity to cater for other primary feeder offloads if required. [2]

The same analysis needs to be performed for Feeder 2 (F2) and Feeder 3 (F3) to ensure that all three feeders can be offloaded in the same manner. As can be observed this process may seem simplistic, however repeating this for an entire network can take a large amount of time. [3]

The above mentioned offloading process deals with busbar faults however, it is also essential to take into consideration transformer faults. The transformer fault analysis requires the use of the primary feeder offload information obtained from the busbar fault analysis which is indicated above.

Consider the sample substation as shown in Figure 2

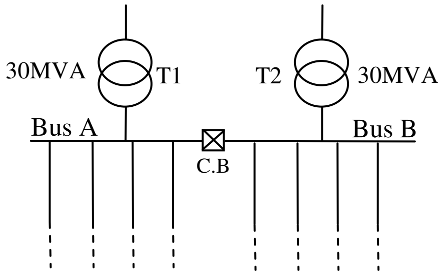

Figure 2

This substation has two 30MVA transformers operating in parallel. If one of the transformers is lost, either T1 or T2, the other transformer will have to feed all primary feeders.

If this occurs the firm capacity of the substation is 36MVA (one transformer operating at 20% overload), this percentage overload depends on the network operation policy of the system that the transformer is installed on.

We can divide this analysis into two tests, Test 1 and Test 2. Test 1 is a first stage test, if one transformer is lost say T1, the firm capacity of the station is now 36MVA. If the load of all the primary feeders does not exceed the firm capacity then the transformer passes Test 1. If the load does exceed the firm capacity then Test 2 needs to be undertaken; which involves summating all the primary feeder loads that can be offloaded and subtracting them from the substation load. This new substation load is then compared against the firm capacity.

Consider Figure 3 below which indicates loadings on the primary feeders for the substation to provide a numerical example of how this transformer test works.

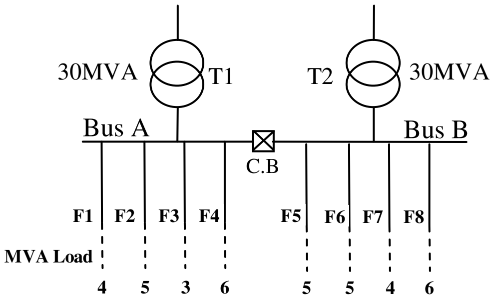

Figure 3

Bus A has a total load of 18MVA and Bus B has a total load of 20MVA. If T1 fails, T2 will now have to supply the station with T2 being overloaded by a maximum of 20% with a firm capacity of 36MVA for the substation. The total load of the substation is 38MVA so it will fail Test 1. F1 and F5 can actually be offloaded to neighbouring primary substations therefore bringing the load down to 29MVA (38MVA - 9MVA). The substation will now pass Test 2 as 29MVA is less than the firm capacity of 36MVA.

AUTOMATING THE PROCESS

The offloading process may seem to the experienced engineer as fundamental, however for large systems performing this analysis on many substations can prove to be time consuming work and if any of the source data changes (such as feeder loads) this can lead to unnecessary replication of work which has a further impact on the amount of unpredicted time the engineer has to spend on the analysis.

Automating this process can be undertaken using several programming languages. Visual Basic using Microsoft Excel was utilised to automate this procedure. One of the main reasons for this is that Excel is readily available to any engineer.

At this stage of the analysis, information about the system must be compiled, such as the location & reference number of all the N.O. and N.C. points on the system during normal feeding operations, individual primary feeder loads, transformer quantities per substation and their MVA ratings, number of busbar sections per substation and thermal MVA rating of all primary feeders. This information must not change throughout the entire process. The location of the N.O. and N.C. points shall provide the basis for all the normal and standby feeding arrangements.

A logical approach should be undertaken for naming busbars, feeders, N.O. and N.C. points. Whatever approach is selected it should be consistent throughout the network.

The load for every primary feeder on the system in MVA should be obtained. This can be achieved by taking a snapshot from SCADA for the entire network at a certain time or by taking an average loading for each feeder during a specific period. The sum of these primary feeder loads will make up the total load of the substation.

Once this information has been collated the actual process can be undertaken. Figure 4 below shows a flow chart of the process to offload a substation and to give a better overall visual representation. Sub X with two busbar sections is used an example.

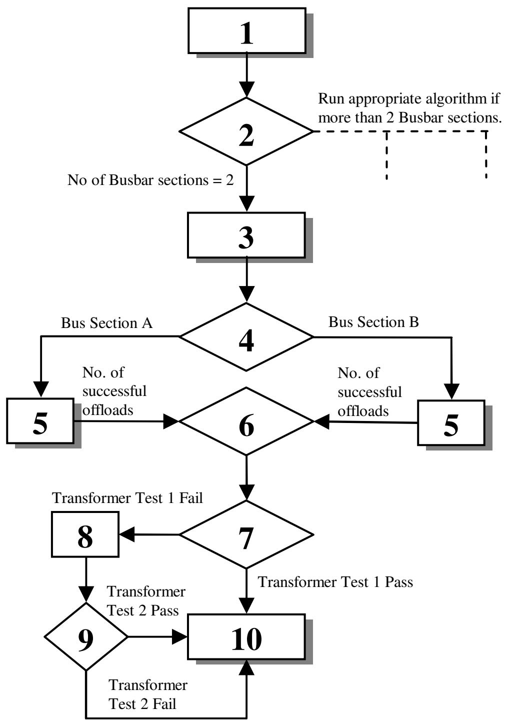

Figure 4

1	Calculate No. of Busbar Sections
2	Run appropriate algorithm.
3	Analyse primary feeders & N.O points in order of most spare capacity on the standby substation.

4	Run faulted Bus A & Bus B as two separate cases.
5	Note the amount of: **(a) Successful Offloads, (b) Offload with Load implication,** (c) **Offload Not Possible** and return this info to the algorithm.
6	Determine whether the substation is acceptable or unacceptable in the event of a busbar fault.
7	Transformer testing, if the transformer passes Test 1 jump straight to 10, if not undertake Test 2.
8	If the substation fails Test 1, run Test 2.
9	If Test 2 passes or fails, return relevant info to algorithm. If it fails flag this for further action.
10	Determine overall status of substation and output results.

Figure 5

The process illustrated in the flow chart (Figure 4) demonstrates a summarised overview of the procedure. The offloading process which is written in Visual Basic requires much more complex methods which are too detailed to be covered in the scope of this paper.

ANALYSING THE RESULTS

Once the procedure is completed, the output is very useful to the Engineer in terms of giving an immediate overview of the results and the spare capacity of neighbouring primary substations to standby feed load in the event of a busbar/feeder or transformer fault.

In addition to the procedure being able to analyse the spare capacity of neighbouring primary substations to feed standby load, the thermal MVA rating of the primary feeder at the standby feeding substation is analysed to see if it can accommodate this extra load. This primary feeder may be feeding load already under normal conditions so this new extra standby load that it now has to feed and its existing load is summated together and compared against the primary feeder's thermal rating in MVA to ensure that the conductor has sufficient capacity. At the end of the procedure a graphical result of this information is automatically represented for each substation and the Engineer can see at a glance which primary feeders won't be able to transfer their load as a result of this load implication.

This is shown in Figure 6. This sample substation has six primary feeders, Primary Feeder 1 is the feeder which has been faulted or the feeder whose busbar section has been faulted. Primary Feeder 2 is the feeder on the substation which is to standby feed the now unsupplied load. The graph is displayed in terms of the destination feeder rating in MVA. As can be observed F01 & F02 exceed the capacity of Primary Feeder 2 thermal MVA rating in each of their respective cases. One of the major benefits of this graphical representation is that it immediately highlights the problem to the Engineer and an alternative feeding arrangement can then be examined to rectify it.

Graph of Sample Substation (showing loading under standby feeding conditions)

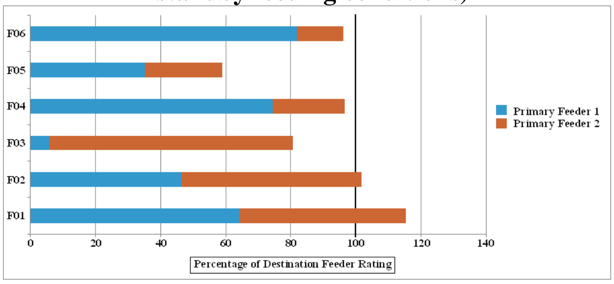

Figure 6

The procedure can also report this information differently which can be seen below in Figure 7 for the same sample substation.

Graph of Sample Substation (showing loading Transferable/Non-Transferable load MVA)

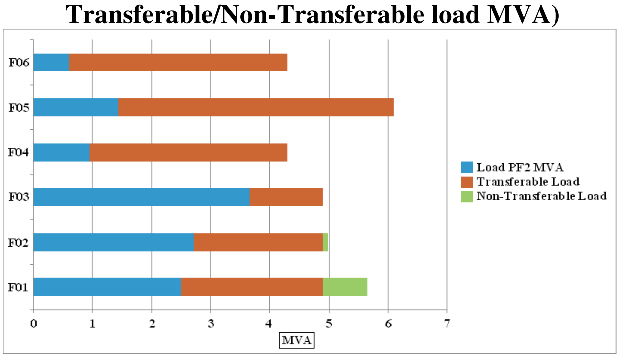

Figure 7

The graph in Figure 7 displays the information shown in Figure 6 a little differently. The load on PF2 is displayed and this is the base load that the feeder will have to feed under normal conditions. In this graph the extra standby load that PF2 will now have to feed which is usually fed from PF1 is divided up into the transferrable load and non-transferable load. As can be observed from the graph the transferable load will only be displayed up to the terminal rating in MVA of PF2. Any load above this point is non-transferable and can't be fed using PF2. This type of representation not only indicates which feeders can't be offloaded to other primary substations but also indicates how much load will be left unsupplied.

Dependent on the conductor type it may be necessary to consider a combination of MVA thermal rating and/or voltage drop calculations to determine how much load a conductor can accommodate, it is important to bear this in mind if the procedure is to be adopted for a network which has a combination of both conductor types.

DOCUMENTING THE RESULTS

In addition to presenting this information in a graphical format the procedure also outputs a summary page of all the substations on the network, the substations that can be successfully offloaded and the ones that can't. A log file is also generated which details all the offloading steps for the entire network, for a typical large network this can exceed 1000 pages and is very useful for reference purposes when analysing the results of the procedure. The procedure also has the capability of transferring and formatting all of this information into a Microsoft Word Document for the purposes of a report.

CONCLUSIONS

One of the main benefits of this procedure is to eliminate the time that would be required if this analysis was done by hand. In addition if the source data changed (which can occur commonly), halfway through a manual calculation the engineer would have to revert back and in some instances may have to start the analysis again.

The procedure which comprises over 2000 lines of code can produce results for an entire network very time efficiently. One of the useful features is that hypothetical feeders/substations can be analysed in addition to the entire existing network and the results will determine if installation of these components will have a beneficial effect on the network.

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