CURRENT BALANCING FOR DISTRIBUTED SINGLE PHASE LOADS BASED ON AUTOMATED PHASE TRACING

Mohammadreza NORUZI
Arak University of Technology–Iran
noruzi@arakut.ac.ir

Ali Akbar BASIRI
Markazi Prov. Electrical Distribution Co. - Iran
aligis1@yahoo.com

ABSTRACT

The information of a distributed single-phase loads was used to balance the currents in a three-phase system. The feeder phase and load profile of each single-phase load are used to reconfigure the network via an optimization process. A new developed 'phase tracer' equipment was used to determine the feeder phase of each load. By balancing the current of three phases, the current of Neutral Conductor in substation's transformer was reduced about 80%. This method also aimed to reduce the current in the other Neutral Conductors in network. The optimization process was performed by CYME software.

INTRODUCTION

Voltage quality and the power loss are the main concerns for the electrical engineers. These properties are resulted from different phenomena, but for a traditional urban LV network, the most affecting factor is asymmetry of the loads. This kind of problem has been noted from many years ago [1]. In many cases, the loads of an urban substation transformer are single-phase while these single-phase loads are connected asymmetrically to the secondary of transformer. The output configuration is Y shape, so besides the R, S and T conductors, there is a neutral conductor in center of Y, that any single-phase load must be connected from one side to this neutral conductor and from the other side to one of the three hot phases (R, S or T). Beside of asymmetry in the physical topology, another important factor is difference between the consumption values of the loads, because the consumption is retarded to the habits of customers. The unbalancing in network not only results power loss due to the current in neutral conductor but also makes the voltage profile poor especially at the end of power line.

In classic method, the balancing of network is performed manually by a workman; the approach shall be explained later in a separate section.

In a structural and automated method, for reducing the current in the neutral conductor, two steps should be concerned. First, the arrangement of distributed loads over the three phases should be known as an essential data. Second, an appropriate optimization method should be used to achieve the result.

In many researches, the arrangement of network was supposed as clear and determined parameter. These methods used different optimization methods to reach best result for reconfiguration of network to reduce the current of neutral conductor. If the power of loads is constant, it possible to zero the current of neutral conductor [2, 3, 4], but this assumption is not appropriate for an urban network.

A practical method for balancing is using the switching power supplies that enable to inject the active power in each phase selectively. This method is able to reduce the current of neutral conductor only in substation transformer. The considerable cost of device is another problem for this method [5, 6, 7].

Continuous measuring the output currents of the substation transformer and changing the connection of each single-phase load from high load phase to minimum load phase, is another approach for balancing the current in the network [8]. This technique compounded with intelligent decision of Neural Network was used in another research [9]. Related to previous method, in a simulation method, it was supposed that the instantaneous current of each load is measurable at the substation via Power Line Carrier. By this assumption and applying an optimization process, total balancing in the entire of network was performed [10]. It is notable that unbalancing in currents can increase the power loss and temperature of transformer [11].

Next, we introduce our method that uses the arrangement of single-phase loads in network and also statistical property of consumptions to minimize the current of neutral conductor in substation transformer and also in other part of network.

THE PROPOSED METHOD

As it mentioned before, the loads connection map is asymmetric, this means that the current of hot phases are different with each other which resulting a current in neutral conductor. It is obvious that if the loads are totally symmetric, the current amplitude of R, S and T phases will be equal to each other and the neutral conductor shall not carry any current, but practically it is not possible to happen for distributed single-phase loads. Another restriction is that each consumer uses the electrical energy with a special and different profile in 24 hours of a day. Although, consumption profiles are different with each other but it possible to classify the consumers to some distinct classes; for example household, public place, commercial office and small workhouse. By this

division, it is possible to define a general Load Profile for each class that the profile covers the behaviour of the most members in 24 hours of a day.
In this research, the information of loads is used to reconfigure the grid connection for decreasing the average current in neutral conductor inside and outside the substation simultaneously.
The steps of work are listed as follows:
A- Determining the hot phase that currently feeds each load.
B- Determining the type of load and assigning a load profile .
C- Optimizing the configuration.
In continue, each step shall be explained.

A-Determining the hot phase that currently feeds each load

In this preliminary step, a 'phase tracer' equipment was used to determine the feeding phase of each load. This equipment includes of two parts. The first part is a signal transmitter that is fixed in the substation and the other part is a portable device which is carried by electrical workman to the place of single-phase load. He/she connects the portable device into a plug in parallel of single-phase load. There are 3 color-LEDs over the portable device that one of them shall be lighten based on the hot phase (R, S or T) that feeds the single-phase load. This equipment is shown in figure 1. It has been designed and developed by first author after two years researching and testing different ideas. It has been tested in many old fashion 4 wires electrical network and the accuracy of results was over 99.5% when distance between load and substation is lower than 350m. In case of new electrical networks with Messenger conductor, the accuracy shall be 100%, regardless of measuring distance.

Fig1. Phase Tracer equipment. Fixed part is in right side and portable part in left side.

B- Determining the type of load and assigning a load profile

The type of loads could be easily determined in 'phase tracing' process. But, assigning the load profile need some ex-prepared curves. In this research, these curves have been computed previously based on long duration data gathering from different type of consumer. The long data of each type was averaged separately to produce the 'Load Profile' .

C- Optimizing the configuration

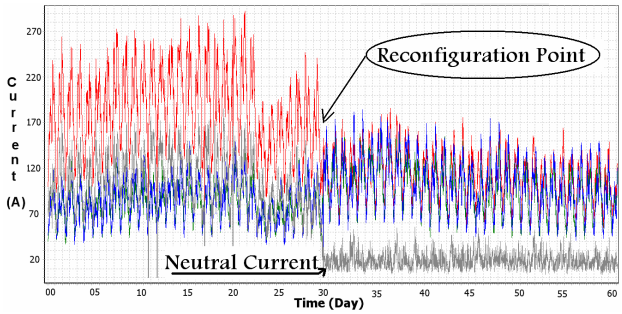
This step is a high dimensional optimization problem. This kind of problem are usually cannot be solved analytically; instead, random search based method are preferred to be used. In each optimization method, it needs defining a ‘target’ that iterative process aims to reach it. For this problem, the ‘target’ is zeroing the current of neutral conductor.
For optimizing the problem, the above preliminary logged data of our electrical system was recorded in a GIS (Geographical Information System) based structure in CYME software. All of data includes the substation specification, conductor type, position and type of distributed load, load consumption curve (load profile) were stored in database.
The CYME software has an internal optimization algorithm that its result is a new configuration for the network and proposing some changes in single-phase connections.

RESULTS

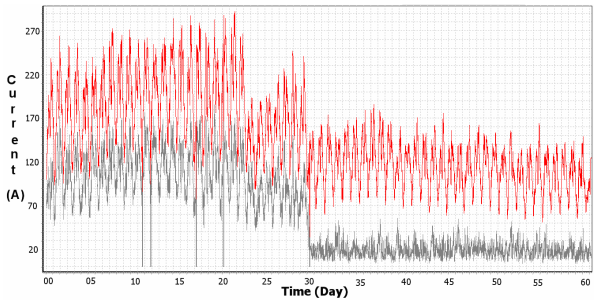
The output of CYME software was used to gain the optimum configuration for electrical network.
Problem was defined on a 20KV/380V, 315KVA transformer with 95 different type loads that were mostly of household type. The Result of CYME optimization was 12 changes in electrical network.
The current value for three phases and neutral conductor of transformer before and after reconfiguration are shown in figure 2.
The calculations show that the voltage profile of distribution electrical network was improved about 1.36% and the power loss in conductors was decreased about 8%.

COMPARING THE PROPOSED METHOD WITH CLASSIC MANUAL METHOD

In classic method for balancing a network, a professional workman measures the current of neutral conductor in the substation and main branches of network, and tries to balance the current by exchanging the branches from one phase to another. It is obvious that there is no guarantee about the zeroing the neutral current in the entire of network.



(a)



(b)

Fig 2. Current values of three phases and neutral conductor, before and after reconfiguration. Horizontal axis shows 30 days before reconfiguration and 30 days after reconfiguration. a) Gray color for Neutral Current and Red, Blue and Green for three hot phase's current. b) Gray color for Neutral Current and Red for the most deviated phase

Another and important difference is that in classic method, the balancing is performed in a short period of day. This means that by passing the time, the consumption of loads will changed in different manners. So, it is obvious that the network shall be unbalanced again. But, the proposed method tries to find an optimum solution that result the heist probability of balancing in all of the 24 hours of day. This is the main difference between our method and the classic method.

CONCLUSION AND FUTURE OF THE WORK

It was shown that information about the feeding phase and load profile in a distributed single-phase network can be used for balancing the network and decreasing the current value in neutral conductor.

The classic method for zeroing the neutral current in substations, only is focused on the neutral node in the transformer of substation, but the proposed method not only reduces the current of neutral node in substation but also decrease the current of other neutral conductors in the other parts of LV network.

Beside of decreasing the current of neutral conductor, calculations show that the voltage profile of distribution electrical network has been improved about 1.36% and the power loss in conductors has been decreased about 8%.

In contrast with manual balancing method, the proposed method tries to find an optimum solution that maximizes probability of balancing for the entire of 24 hours of a day .

A new developed 'phase tracer' equipment was used as an essential tools for performing the balancing. For recent electrical networks with Messenger conductor, it is possible to install this low cost 'phase tracer' equipment inside the meters and measuring the data in substation or control room automatically. If the instantaneous consumption of each load is also transmitted to Center Room, then it is possible to compute the balancing results online; based on the temporary status of grid. And, if there is a selective switch for each load which lets changing the feeder phase, then the network balancing shall be done automatically.

It was seen that the neutral conductor current was not fully zero. This is result of two properties. First the used 'load profile' was a statistical average of different data. Second, for a certain problem, all of the optimization methods might not converge to absolute optimum point. For the first problem, extracting the voltage profile of each load individually, and for the second problem, comparing with another optimization method like Genetic Algorithm, are the solutions and future research subjects in this area.

REFERENCES

[1] G.F. Aroyan, and K.G. Lakey, 1951, "A three-phase balancing unit for single-phase variable loads", *Thesis (Nav. E.),* Massachusetts Institute of Technology. Dept. of Naval Architecture and Marine Engineering.

[2] K. Wang, S. Skiena, and T. Rolmrtazzi, 2012, "Phase balancing algorithms", *Technical Report,* STOAW' BROOK University, Report no. 837.

[3] A.B. Singh, 1999, "Generalized concepts for balancing single phase load fed from three phase supply", *Electric Machines & Power System*, vol. 27, issue 1, 63-78.

[4] H. Alamshahi, K. Zare, and Y. Naderi, 2013, "Dynamic load balancing of single-phase loads for reducing power losses", *European Journal of Scientific Research*, no. 116, 45-50.

[5] Z. Yongqiang, and L. Wenhua, 2004, "Balancing compensation of unbalanced load based on single phase STATCOM", *4th conf. IEEE-IPEMC*, vol.2, 425 – 429.

[6] C. Chen, and Y. Hsu, 2000, "A novel approach to the design of a shunt active filter for an unbalanced three-phase four-wire system under nonsinusoidal conditions", *IEEE Transactions on Power Delivery,* vol. 15, issue 4, 1258 – 1264.

[7] A. Hasanzadeh, M. Parniani, and S.M.R. Sadriyeh, 2005, "A comparative study on current control methods for load balancing and power factor correction using STATCOM", *IEEE Power Tech. conf.* , Russia, 1-7.

[8] Y. Zhen, L. Zou, J. He, Y. Su, and Z. Feng, 2013, "Fast unbalanced three-phase adjustment base on

single-phase load switching", *TELKOMNIKA*, vol. 11, no. 8, 4327-4334.

[9] U. Fei, and R. Wang, 2014, "Single phase swapping to solve load phase balancing by ADSCHNN in LV distribution network", *International Journal of Control and Automation*, vol.7, no.7, 1-14.

[10] A. Pasdara, and H.H. Mehne, 2011, "Intelligent three-phase current balancing technique for single-phase load based on smart metering", *International Journal of Electrical Power & Energy Systems*, vol. 33, issue 3, 693–698.

[11] Y. Wang, and M. Lee, 2012,"A method for balancing a single-phase loaded three-phase induction generator", *Energies*, no.5, issue 9, 3534-3549.