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The Study of Design and Development of Load Balancing Using Fuzzy Logic Tool of MATLAB: A Review Report

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Abstract:
The distribution system problems, such as planning, loss minimization, and energy restoration, usually involve the phase balancing. This paper proposes the study of design and development of load balancing using fuzzy logic tool of MATLAB. Input to the fuzzy step is the total load per phase of the feeders. Output of the fuzzy step is the load change values, negative value for load releasing and positive value for load receiving. The output of the fuzzy step is the input to the load changing system It also performs the inter-changing of the load points between the releasing and the receiving phases in an optimal fashion.

Keywords*: Distribution System, Phase Balancing, Using Fuzzy Logic Tool*

1. Introduction

Phase balancing is very important and usable operation to reduce distribution feeder losses and improve system security. There are a number of normally closed and normally opened switches in a distribution system. By changing the open/close status of the feeder switches, load currents can be transferred from feeder-to-feeder, i.e. from heavily loaded to less loaded feeders.
In distribuation system, to reduce the unbalance current in a feeder the connection phases of some feeders are changed manually after some field measurement and software analysis. Although in some cases this process can improve the phase current unbalance, this strategy is more time consuming and erroneous. In this paper, we propose the use of fuzzy logic-based load balancing system for load change implementation as novel procedures to perform the feeder load balancing.

2. State of Art

A simple search technique for service restoration and load balancing was proposed by Castro et al. **[1]** considering the data base and implementation requirements given by the operators for on-line distribution automation application.
In the method proposed by Aoki et al. *[2],* load transfer is carried out initially for a pair of transformers which have the highest and the least load indices (load to capacity ratio). By appropriate switching operations, the load indices of other transformers are equalised as closely as possible. Load balancing for feeders is also performed in a similar way, through open loop switches.
Baran and Wu [3] proposed a method, by which a gradual reduction of system load index is achieved through a search process.
A heuristic method for load balancing was proposed by Hsu et al.[4]. The method is applicable to bwh constant as well aswhanging load conditions.
Chen and Cho [5] evaluated the optimal switching operations based on the hourly load patterns.
The critical switches are identified by investigating the optimal switching patterns. Expert systems have also been used for load balancing [6-7].
Considering Feeder reconfiguration for loss minimization was first proposed by Merlin *et al*. [8] using a discrete branch and bound technique. In this method all the network switches are closed to form a meshed system, and then the switches are opened successively to restore to the radial configuration. However, this method involves approximations.
Shirmohammadi *et al*. [9] proposed an algorithm to overcome these approximations. In this method, the switches are opened one by one, based on an optimal flow pattern.
Peponis *et al.* [10] have developed a methodology for the optimal operation of distribution network. In this method loss minimization is obtained by installation of shunt capacitors and reconfiguration of the network.

Schmidt *et al*. [11] have formulated the problem as a mixed integer nonlinear optimization problem. The integer variables represent the status of the switches, and continuous variables represent the current flowing through the branches.
Broadwater *et al.*[12] have considered the time varying load demand, obtained through load estimation, to reduce the loss.
Morton *et al*. [13] have proposed a method based on an exhaustive search algorithm for obtaining a minimum loss radial configuration of a distribution system. The algorithm uses the graph-theoretic techniques involving semi-sparse transformations of a current sensitivity matrix.
M.W. Siti *et al.* [14] contribute such a technique at the low-voltage and medium-voltage levels of a distribution network simultaneously with reconfiguration at both levels. While the neural network is adopted for the network reconfiguration problem, this paper introduces a heuristic method for the phase balancing/loss minimization problem. A comparison of the heuristic algorithm with that of the neural network shows the former to be more robust.
K. Viswanadha Raju *et al.* [15] describes a new, two stages, and heuristic method, for determining a minimum loss configuration of a distribution network, based on real power loss sensitivities with respect to the impedances of the candidate branches.
S.K.Salam *et al.* discussed [16], the effects of distributed generation on voltage regulation and power losses in distribution systems C.L.T.
Borges *et al*. [17] have presented a technique to evaluate the impact of DG size and placement on losses, reliability and voltage profile of distribution networks.
Davidson *et al.* [18] have presented an optimization model for loss minimization in a distribution network with DG.

3. Present Technology Used for Load Blancing

3.1. Circuit Breaker

A circuit breaker (CB) is a switching device for making and breaking the connections in an electric circuit. A circuit breaker is capable for carrying current under normal operating conditions as well as for a specified time, short circuit current for abnormal circuit conditions.

3.2. Contactor

A contactor is switching device operated manually (by hand) when necessary and has only one rest position. A contactor is capable of making, carrying and breaking currents under normal as well as overload conditions.

3.3. Disconnector

A disconnector is switching device capable for carrying rated current under normal operating conditions. Short circuit currents are carried for a specified time interval. A disconnector provides isolating distance and is used for opening /closing a circuit under negligible current conditions or during the period of normal voltage across the terminals of its poles.

3.4. Switches

- *Earthing switch:* An earthing switch is also a switching device for earthing different components of a circuit. It is capable of carrying short circuit current under abnormal condition for a specified time. Under abnormal condition, it can act as a fault thrower or perform inadvertent operation of a live circuit to earth.
- *Fuse switch:* A fuse-switch establishes moving contact with a fuse-link. Normally, it makes contacts during the fault condition.
- *Mechanical Switch:* A mechanical switch is a device capable of making, carrying and breaking current under normal operating conditions. During overload and short circuit, its operation is a well known function. Under these circumstances, it may be called a ‘fault-make, load break’ switch or isolator .

Although a switch is useful for switching different loads under normal/abnormal operating conditions but it is not suitable for frequent operation. Mechanical switches may be manual or motor operated, and have a fuse for interrupting short circuit current under fault condition. Figure 2.1 shows various combinations of switching devices.Operation of these switching devices makes it possible the safe and reliable operation of distribution system. When overload condition exists and voltage sag occurs due to excessive losses, these switches are operated to prevent the sensitive equipment from being damaged. Similarly, under fault conditions, these switching devices are operated and hence prevent the sensitive equipment from being damaged due to high fault current [19].

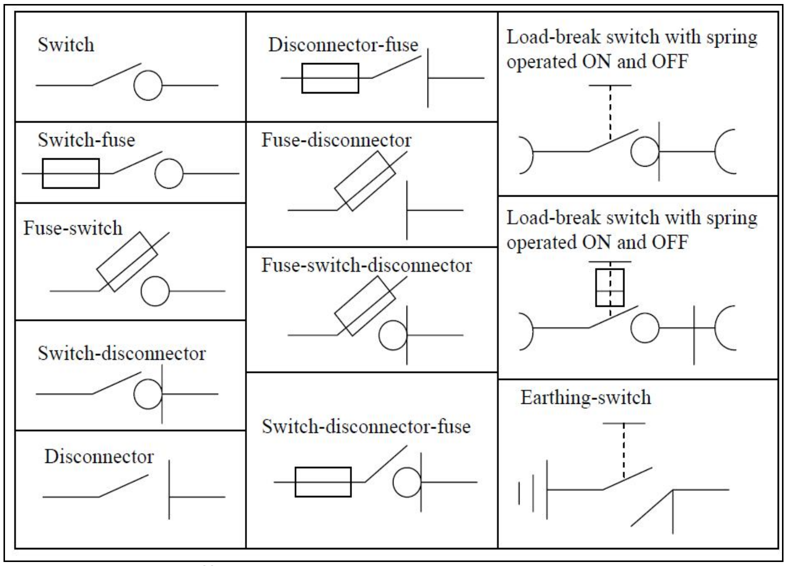

Figure 1: Different switching options used in distribution system

These switches can be used for different operations like disconnecting, grounding, as a selector, and transfer. Mainly, they are classified on the bases of their applications. In addition to the main switch blade, such types of switches must have an interrupter which is designed to eliminate the arc which may damage the blade when the circuit is opened [20]. Pole-mounted disconnector having rating up to 30kV is used for sectionalizing and isolating purpose in rural electrification as shown in Figure 2.2.

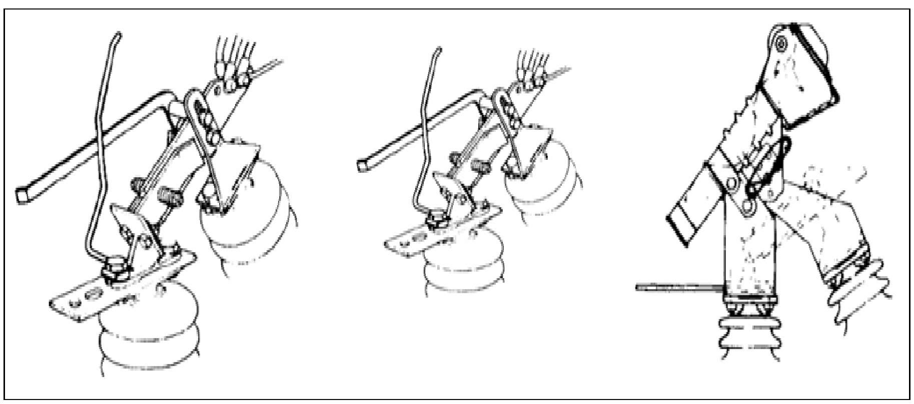

Figure 2: Pole-mounted distribution disconnector, (a) Fixed arc horn used to keep arching off main contact when making or breaking small charging currents, (b) Flicker arc horn, (c) Interrupter head

An interrupter switch combines the function of a switch and a circuit interrupter for interrupting currents not exceeding its continuous-current rating. Standard interrupter switches may be rated 600 or 1200 amp and 4.16, 13.8 and 34.5 kV . From operational point of view, they are gang-operated having all three blades open and close simultaneously. The interrupter has an auxiliary blade which opens in an arc chute after the main blade has opened. Energy-stored-operated switches (spring operated) are considered to be the best as their operation is independent of the operator speed. Switches having such principal of operation will always have full contact and can not be lifted with the main blade open and the arcing contact closed. The spring of the switch must be charged after the switch is closed before it can reopen. Switch operation is the method provided for its normal function. Hook operation of the switch is performed through a hook stick. Switches operated by mechanical operation are operated by means of a mechanism connected to the switch by insulated mechanical linkages. Mechanically switches may be operated manually, electrically, or by other suitable means.

- *Selector Switches*
  In order to increase the reliability of distribution system, sensitive loads are powered from either of two sources. This can be achieved by means of a two position disconnect type switch in series with a standard interrupter switch. To prevent the malfunctioning, these switches are interlocked so that the disconnect switch cannot be operated unless the interrupter switch is open. Duplex arrangement is used to select the desired source. In this arrangement, two load-break switches are used, each in its own cubicle. The incoming lines are connected to the jaw of a switch and the blades of the two switches are connected together and then to the load through a set of fuses mounted in one of the cubicles.
- *Disconnect Switches*
  In the substation, mostly live circuits, bus bars, etc are usually isolated by disconnect switches. They are also used conveniently during the feeder outage, repairs and maintenance, testing or any extension of the network.

The most common types of outdoor disconnecting switches are the rotating insulator and the tilting insulator type. The opening and closing travel of the blade of a rotating insulator switch is accomplished by the rotation of one or more of the insulators supporting the conducting parts. Similarly, in a tilting insulator type, the opening and closing travel of the blade is accomplished by a tilting movement of one or more of the insulators supporting the conducting parts of the switch .There are three classes of disconnect switches according to the function performed by these switches; station disconnect switches, transmission disconnect switches, and distribution disconnect switches .

- *Station Disconnect Switches*
  A disconnect switch is used to change connections within a circuit or isolate a circuit from its power source, and also provides isolation for maintenance of substation equipment. Usually a disconnect switch would be installed on both sides of an equipment to provide a visible isolation for personnel safety. Switches should be provided grounding blades for safety of the ground staff. These switches are designed for no load operation that is opening or closing of circuits when there is no significant voltage across their terminals. They are not suitable for arc interruption because of their low operating speed. Switches are also motor operated and are applied for remote switching. The blades of disconnect switch can be designed for vertical or horizontal operation. Many configurations are frequently used for switch applications, for example vertical break, double break switches, V-switches, center-break switches, hook stick switches, vertical reach switches, grounding switches[21] .
- *Transmission Diconnect Switches*
  Transmission disconnecting switches are generally used for load-management during "dead time" by switching the proper disconnects automatically. These switches are available up to 161 kV, 1200 A. The major objective of load management is to minimize outage time and allow for more efficient utilization of substation capacity at the distribution level.
- *Distribution Disconnect Switches*
  Because of increasing importance of the reliable operation of the power delivery system, it becomes necessary to eliminate longer outages during the fault conditions. These switches provide isolation as well as sectionalization of the faulty portion and the healthy portion. The utility must provide more sectionalizing or switching capability to avoid large and longer outages during faults. Figure shows a typical distribution load-break switch and Figure shows a typical hook-stick switch. Gang-operated switches with load break capability interrupt loads without ferroresonance problems. Three-phase switches can be installed in either horizontal or vertical configuration. During the installation, care must be exercised in proper alignment of blades and clips. Proper installations of theses witches provide smooth operation without overstressing porcelain insulators or distortion of contact surfaces and operational handles.

3.5. Distribution Ring Main Unit

Three phase 400 volt line-to-line for domestic consumers is obtained from distribution transformers (100 to 1000-kVA rating) which have voltage range of 11 to 33 kV. The high voltage side of this distribution transformer must be provided with adequate protection to cater for normal operational switching. It should also have some means to isolate faulty parts of the circuit and to allow normal maintenance, extensions, and testing.

In order to fulfil the above criteria, usually switches are fitted at each transformer point on the medium voltage ring. The utilization of ring main switches is less costly than circuit breakers. Depending upon the protection philosophy adopted by the electric utility, transformer can be protected by a switch fuse, circuit breaker or contactor. The basic requirements of the ring main unit are mentioned below:

- *Ring main switches:*It should be able to carry full load ring current continuously, and full system fault current for 1second. It should sustain breaking or making of circuit at full load ring current.
- *Tee-off switches:* It should be able to carry full load ring current continuously, and full system fault current for one second. It should sustain breaking or making of circuit at full load ring current including starting inrush currents, momentary overloads, etc.
- *Environment:*Any equipment intended to be used on ring main units should be designed to meet the EPA pollution prevention standard. The disposal of faulty units should not pose an environmental hazard.
- *Impulse levels:*An impulse level of 2.7 to 3 per unit of system voltage is sufficient. So for a 33kV line and impulse level of 2.7 per unit or 75 kV is sufficient. When using an overhead line distribution circuits an impulse level of 95 kV can be specified depending upon insulation coordination criteria
- *Insulation and earthing:*Air, oil, SF6 or vacuum insulation can be used for clearance insulation, however in open environment only air is used as clearance around equipment. In sealed environment like inside a breaker, oil or gases are used. It is first of all necessary to place the breakers, fuses and switches in such a place which has sufficient air clearance from all busbars and transformers. Also the casings of these fuses, breakers or switches must be earthed, close to their vicinity to remove any static charge which may accumulate on them. Replacement of uses should be easy, quick and possible under all weather condition in case of outdoor station.
- *Test facilities and interlocks:*Test points should be available at each ring main terminations to check voltages etc. at these points.
- *Maintenance:* The facility to shut down the whole unit in one goes should be there for maintenance. A circuit breaker switchboard may have its individual breakers that cut only a part of circuit depending upon the requirements.

4. Objective

Main purposes of this paper are to understand the concept of load balancing, need of it in real world and design and development of it using fuzzy logic tool of MATLAB. This paper also gives good understanding of overall power system like power generation, transmission, distribution of power, automatic generation control and load profile. MATLAB covers very wide range of toolboxes, but this paper gives better understanding and hands-on experience of fuzzy logic toolbox.

5. Methodology

The following methodology will be adopted for the ongoing thesis work for load balancing:

- Tool used for Load Balancing
  In this paper, I have used fuzzy logic toolbox provided by MATLAB. MATLAB is an abbreviation of matrix laboratory. It was developed in late 1970s by the MathWorks Incorporation and provided to users[22]. MATLAB covers different areas of real time implementation like matrix manipulation, data algorithms, user interfaces with languages like C and C++, data analysis and graphical implementations. MATLAB provides separate tools for applications. For example, it provides toolboxes for signal processing, fuzzy logic, neural networks and many other real time applications.
- Fuzzy Logic Toolbox
  MATLAB provides inbuilt fuzzy logic toolbox that provides Graphical User Interface (GUI) based implementation of fuzzy systems. In this paper, this inbuilt function of MATLAB is used for load balancing[23].

6. Proposed Technique

In this paper, a fuzzy logic-based load balancing technique system for implementing the load change decision. The architecture of the proposed system is shown in Figure3.

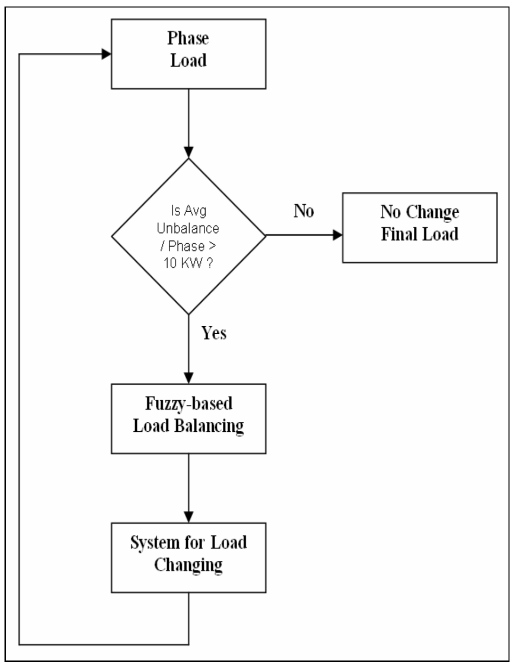

Figure 3: Architecture for the proposed load balancing system

$$\text{Avearge Unblanced} = \frac{\left[\text{Load}_{\text{Ph1}} - Load_{Ph2}\right] + \left[Load_{Ph2} - Load_{Ph3}\right] + \left[Load_{Ph3} - Load_{Ph1}\right]}{3} \qquad \text{Equation 1}$$

In Figure 3, the input is the total phase load (for each of the three phases). The average unbalance per phase, calculated according to (1), is checked against a threshold of 10 kW. If the average unbalance per phase is below 10 kW, we can assume that the system is more or less balanced and discard any further load balancing. Otherwise, we go for the fuzzy logic-based load balancing. The output from the fuzzy-based load balancing step is the load change values for each phase [4].A *negative* value indicates that the specific phase has surplus load and should *release* that amount of load, while a *positive* value indicates that the specific phase is less loaded and should *receive* that amount of load. This load change configuration is the input to the implementation system which tries to optimally shift the specific number of load points. However, sometimes the implementation system may not be able to execute the exact amount of load change as directed by the fuzzy step [5]. This is because the actual load points for any phase might not result in an optimum combination which sums up to the exact change value indicated by the fuzzy step. So, we implement the best possible change from the implementation system and iteratively check the system unbalance until we achieve the average unbalance below 10 kW, if achievable.

In general, distribution loads show different characteristics according to their corresponding distribution lines and line sections. Therefore, at the load levels, each time period can be regarded as non-identical. In the case of a distribution system, with some overloaded and some lightly loaded branches, there is the need to reconfigure the system such that loads are transferred from heavily loaded to less loaded feeders.. Nonetheless, the transfer of load must be such that a certain predefined objective is satisfied. In this case, the objective is for the ensuing network to have minimum real power loss. Consequently, phase balancing may be redefined as the rearrangement of the network such as to minimize the total real power losses arising from line branches. Mathematically, the total power loss may be expressed as

$$\boxed{\sum r_i \frac{P_i^2 + Q_i^2}{|V_i|^2}} \quad \text{Equation 2}$$

Where ri, Pi, Qi, Vi are respectively the resistance, real power, reactive power and voltage of the branch i, and n is the total number of branches in the system.

7. Discussion and Conculation

Load balancing is a critical requirement of the power system to ensure that entire system works without overloading. Fuzzy logic toolbox provided by MATLAB is used in this reviewt for design and development of load balancing. MATLAB is provided by MathWorks Incorporation and it covers areas of applications like data algorithm, matrix manipulation and data manipulation. Fuzzy logic is a toolbox that provides graphical user interface based implementation of fuzzy system.

Before consumer usage of power, it has to be properly generated, transmitted and distributed. Power stations generate the power by converting one form of energy into electrical energy. Once power is generated, it should be transmitted to the subsystems near consumers. So proper power transmission network is required to reduce transmission losses. Transmission can be overhead or underground depending upon requirements. The critical stage is power distribution. Depending upon the consumer usage, the distribution should be such that it can avoid over loading situation. Load profile gives the graphical representation of the customer power usage.

Fuzzy logic is the easy way to design load balancing. Using basic fuzzy rules and fuzzy blocks like normalized, Fuzzification, Defuzzification and Denormalized, we can design a load balancing system.

8. Referances

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