THE STUDY OF THE RELIABILITY INDICES OF DISTRIBUTION NETWORKS WITH VIT SWITCHES ON THE MV FEEDERS AUTOMATION

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ABSTRACT

In this paper, VIT feeder automation switches are presented and its effects on improving electric distribution network reliability for a real MV feeder of North Khorasan Electric Distribution Company (Iran), are analyzed. This is done through numerical calculations and network reliability index calculation with Failure Effect Analysis method (FEA). Also, in this research, a real feeder in a distribution network on which VIT automation switches are installed and are operational is simulated in DIgSILENT PowerFactory software package.

The main advantages of this automatically operated equipment are: operate in loop rural network that are mountainous and impassable, fast network reconfiguration, reliability improving and no need for communication subtraction.

INTRODUCTION

Electrical energy distribution networks are the most extensive parts of power systems. These networks are the interface between consumers and producers and transmission systems and since they are close to the consumers, are of particular sensitivity. One of the ways to improve the reliability of distribution networks is to install intelligent equipment for rearrangement of faulty feeders and reducing outages [1].

Due to the radial structure of the feeders and the diversity of the equipment used, the largest share of reduction in reliability in power system belongs to distribution networks. According to the statistics and various studies, about 90% of customer outages are related to the distribution systems [1].

So far, many studies have been undertaken for improving the reliability of distributed systems [2-3]. But most of them are focused on finding the optimal location of protective equipment or the optimal positioning of switches [4].

After a fault occurs in a radial feeder, and supposing that all protective equipment are located optimally, if other system equipment such as transformers and conductors do not have sufficient capacity to supply the new sections added to them during restoration operations for areas without electric service, the areas under outage still have to stay off, and this reduces the distribution system reliability and increases losses associated with such outages, including damages to consumers. In case of a fault on a feeder, the first step is to identify the location of the fault. This, depending on the distance between the fault location and the repairing group, can take a long time.

Isolating the location of the fault and rearrangement of the network is done through opening and closing a number of switches, so that the faulty areas are separated from other sections of the feeder and the remaining areas are fed through adjacent feeders.

The total time from the beginning of the fault until the end of opening and closing the equipment, rearrangement and repair of faulted section, and bringing the faulty feeder back to service, is equal to:

$$T_{total} = T_{fl} + T_{sw1} + T_{rp} + T_{sw2} \tag{1}$$

where:

T_{fl} : Time needed to locate the fault,

T_{sw1}: Time required for rearrangement operations and restoration of parts of the load, before repairing the faulted section,

T_{rp} : Repair time,

T_{sw2} : Time required for opening and closing operations and rearrangement of the feeder, after the repair of the faulted section is finished.

It is obvious that the opening and closing times of switches for the rearrangement of the feeder, which is equal to $T_{sw1} + T_{sw2}$ plays a very important role in the total time of restoration, especially in long feeders.

In this paper, the field data of a distribution network feeder in North Khorasan Electric Distribution Company (Iran) and it's modelling in DIgSILENT software, the effects of VIT smart switches which minimize the rearrangement time of the remote points of long feeders, and the reliability indices - before and after the installation of the VIT smart switches on the feeder - will be studied.

VIT SMART SWITCHES

Due to the wide extension of distribution networks, when a line is faulted, finding the faulty point and isolating it by the operator needs a relatively long time, sometimes a few hours. This is one of the reasons for the increase in the rearrangement time. To reduce the outage time and to supply the electricity to customers in distribution networks rapidly, there are various techniques, the most important of which is the Distribution Automation System (DAS) [5]. In this system, a computerized control center, equipped with advanced computer software programs, exists. This center is connected to the equipment of the distribution network through communication lines.

However, the DAS, especially for a country like Iran, has a number of disadvantages, the most important of which are as

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the investment needed is very high, the use of a telecommunications system in it is inevitable, and in fact, the DAS's operation depends on it, also it needs an advanced software program which must be designed based on accurate network information and must be updated regularly and it has a low reliability, because if there is any problem or disruption in the software, in the communications system, or in the interface equipment, the whole system is disrupted [5].
Another method is a limited automation system confined in a small part of the network by using a recloser switch with two, or at most three, sectionalizers per recloser. This method has a number of drawbacks, the most important of which are as the performance limitations along with relative increase in costs, its application is restricted to radial networks and the impossibility of determining the faulty section [5].
Another method is the VT (Voltage-Time) method. Its application is in the networks where the zero points of transformers in the distribution network and the low voltage lines are not grounded. In these networks, the level of short circuit current is limited and the criterion for the switches to diagnose short circuits is the short circuit voltage. The disadvantages of this method are included to since the zero points of transformers in distribution networks and the low voltage lines in our country are grounded, it is not suitable for application in Iran, all switches will operate in the case of a short circuit, the number of operations in a fault increases, thus reduces the life-time of the switch and the increase in the rearrangement time of network [6].
VIT is a new feeder automation technique that it using the current and voltage information, VIT reserves the benefits of current controlled system (IT) and also voltage controlled system (VT).In terms of performance, there are two VIT Smart Switch types of [7]:

1. VIT Main Smart Switch, or briefly, VMSS,
2. VIT Smart Switch, or briefly, VSS.

The VMSS is usually placed at the start of the line and is somehow a control center for the system. At the same time, it performs as a recloser switch.
VIT Smart Switches are used in the on-off points of the network in the main line and branches as required. These switches have different performances, depending on whether they are used in radial or open ring feeders, or in main line or branches.
Different types of VSS according to the installation position in the network are as follows:

1. Normally Closed type used in the main lines of open ring feeders,
2. Normally Open type used between two lines of two different feeders in the open ring feeder,
3. Redial Mode in the radial feeders and the branches of open ring feeders.

The VIT Main Smart Switch performs like a recloser switch in the event of temporary faults (Figure 1), and no changes are made in the conditions of VSS's and the feeder [7].

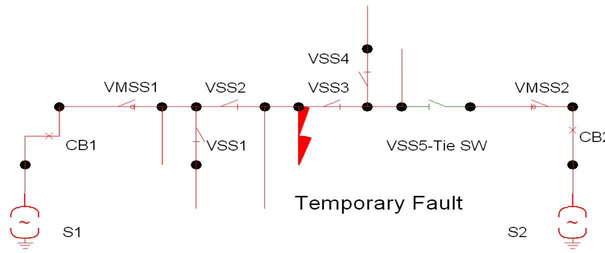

Fig. 1: Single-line diagram of switch conditions when a temporary fault happens in the ring feeder

In case of a permanent fault (Figure 2), every switch in the automation system performs intelligently and after several open and close operations of VMSS and VSS, the faulty part of the feeder is isolated, taking into account the source-side and load-side voltages and also based on the time setting of each VSS (Figure 3). The remaining sections, then, are fed via adjacent subtransmission substation.

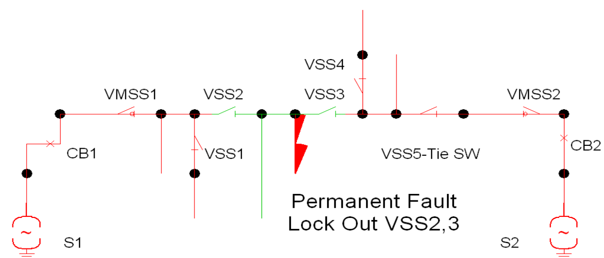

Fig. 2: Single-line diagram of switch conditions when a permanent fault happens in the ring feeder

The processor of VSS, similar to a sectionalizer, counts the number of shots of the VMSS. It then analyzes the situation of the switch at any given time and at previous times and the set number of shots, and gives the command to switch to close, to open, or to lock out (Figure 2).
In the case of permanent faults, the function of switches is different, depending on their location on the feeder (main line or branches), the method of employing these equipment in the radial or ring networks, and the method of isolating the faulty area. If VIT switches are installed on a radial feeder without the ring point, switch or switches are opened after the occurrence of the fault and the increase in the line's current to sense the current. After identifying the permanent fault, switches are closed respectively until the nearest switch to the location of the fault is locked and the rest of the feeder is energized. This method of isolation is applicable to the VSS's installed on the branches of ring feeders too.
The function of VIT switches and the isolation of the faulty area on the main line is slightly different in ring feeders. If a permanent fault happens and its current and voltage is sensed by one or more switches, all VSS's of the main line will open. Then, based on the time settings existing between VSS and VMSS, and after the VMSS is opened, the switches closest to VMSS are closed respectively to sense the fault current for the second time and the VMSS opens the whole feeder. At

this stage, the last VSS after closing of which the short circuit current is established and the next VSS are locked out. In this situation, the switches on both sides of the faulty area are opened and locked and the faulty area is separated from the feeder. The remaining switches of the feeder, according to the time settings, are then closed and the remaining parts of the feeder are energized. The operation of the network in this state is radial from two directions.

THE RELIABILITY OF THE DISTRIBUTION NETWORK

Several methods of modeling and evaluating the reliability of distribution networks have been introduced and the research in this field still continues [8-9].

In general, the distribution network reliability assessment methods can be divided into two major categories of: analytical and simulation. In analytical methods, which are used frequently in reliability studies of distributed systems, feeders and related equipment are mathematically modeled in the form of series or parallel components and relevant indices are calculated in a relatively short time. Various methods of reliability assessment based on simulation methods have been proposed which are more or less related to the Monte Carlo simulation. This is done through numerical calculations and network reliability index calculation with Failure Effect Analysis method (FEA). Because of the wide extension of distribution networks and since load points are dispersed and because of the large number of equipment used, this method of calculation is not applicable in large network cases, needs long calculation times, high costs and even making mistakes in calculations is inevitable. Hence, in this research, a real feeder in a distribution network on which VIT automation switches are installed and are operational is simulated in DIgSILENT PowerFactory software package.

The indicators which show the feeder behavior include: SAIFI[1], SAIDI[2], CAIDI[3] and ENS[4].

SIMULATION OF THE MV FEEDER

VIT smart switches have recently been installed on three rural MV feeders of North Khorasan Electric Distribution Company (Iran).The Khanlaq feeder, coming from the 132/20 KV Shirvan city's substation, has been selected for the study of reliability indices because it is relatively long and has a high number of blackouts and unwanted hits. It is modeled in DIgSILENT software package. The rated load of this feeder is 2.5 MW, its length is 288 Km and the number of customers it supplies is 6150.

According to the statistics recorded by the Dispatching Unit of North Khorasan Electric Distribution Company (Iran) regarding the blackouts of the feeder in 2009 (before installation) and 2010 (after installation), the average failure rate and average outage time for each section is considered in the modeling.

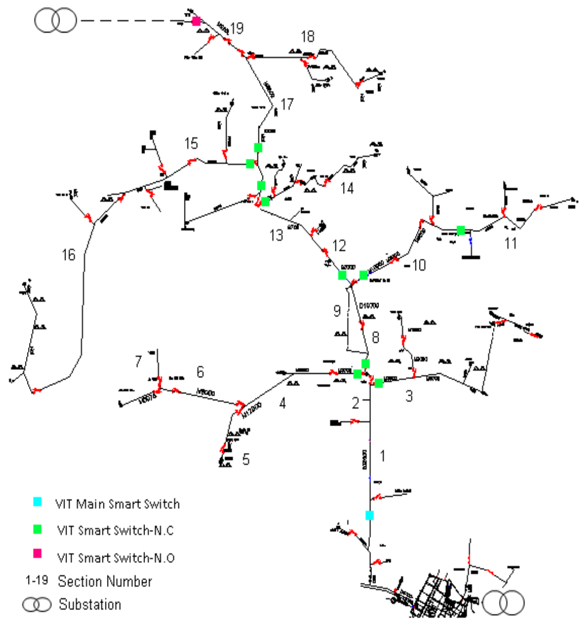

Fig. 3: VIT Smart Switches on Khanlaq rural MV feeder

The specifications of load points and the length of each section is shown in Table 1.

Table 1: Feeder reliability parameters & line lengths

Section	λ	r (h)	line lengths (Km)
1	1.4	0.5	15
2	1.4	0.5	7
3	1.02	0.5	10
4	3.9	0.6	13
5	3	0.7	10
6	3.9	0.7	8
7	3.9	0.75	7
8	0.19	0.45	4
9	0.19	0.55	12
10	1.1	0.65	23
11	1.3	1.2	36
12	2.2	0.6	16
13	2.2	0.55	7
14	1	0.9	17
15	3.3	1.25	41
16	3	1.75	7
17	0.05	0.45	8
18	3.3	1.45	36
19	4	1.55	9

Simulation results

In this paper, study of the reliability indices on the real MV feeder automation-Khanlaq rural MV feeder-are presented to 4 states of this feeder. These states are as follow:

State 1: Before installation VIT switches.

State 2: Installation VIT switches just on the high load

1 System Average Interruption Frequency Index
2 System Average Interruption Duration Index
3 Customer Average Interruption Duration Index
4 Energy Not Supplied

branches.
State 3: Installation VIT switches just on the main line.
State 4: Installation VIT switches on the MV feeder automation completely.
Results of simulation Khanlaq MV feeder by DIgSILENT PowerFactory software package and change the reliability indices are shown in figure 4.

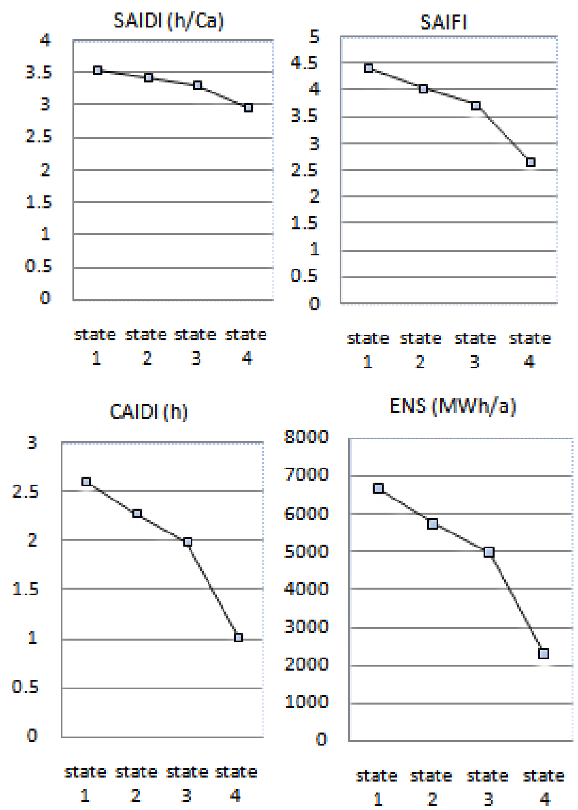

Fig. 4: Result of the reliability indices in 4 states

Table 3: Comparison percentage of reliability indices

Indices	SAIFI	SAIDI	CAIDI	ENS
State 2 to 1(%)	9.2	3.7	14.6	16
State 3 to 1(%)	18	77.4	31	34.4
State 4 to 1(%)	66.7	178	156	190

CONCLUSION

Currently, the VIT Smart Switches are the newest and the most automated switches in ring lines of the distribution networks. Training the personnel, proper operation and safety considerations regarding these switches have important roles with regard to increasing the efficiency and reducing outage times and Energy Not Supplied (ENS) indices on distribution feeders.

In this paper, intelligent VIT Smart Switches have been introduced and their functions in network rearrangement was described and modeled.

System reliability before and after the installation of this switches on one of the rural feeders owned by North Khorasan Electric Distribution Company was modelled and simulated in 4 states by DIgSILENT software package and the indices were compared with each other.

The main advantages of this automatically operated equipment are: operate in loop rural network that are mountainous and impassable, fast network reconfiguration, reliability improving and no need for communication subtraction. Calculations and modelling results showed that the studied indices have significantly improved through the proper installation and operation of VIT Smart Switches. The most important indicator of the distribution network's reliability, the Energy Not Supplied index, shows a 34% improvement.

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