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Radial Distribution System Reliability Enhancement with Fault Passage Indicators in Rural Locations

S. Veerababu, Dr.P.V.V.Rama Rao

Assistant Professor, Dept. of EEE, Shri Vishnu Engineering College for Women, Vishnupur, Bhimavaram, India

Professor, Dept. of EEE, Shri Vishnu Engineering College for Women, Vishnupur, Bhimavaram, India

ABSTRACT: over a long back period of time , the Rural Electrical power distribution systems been vulnerable to extensive damage from various faults and surges which can cause power outages resulting in huge amount of economic losses and restoration costs. Most of the outages takes place because of result of failure of distribution support structures and surges caused by thunders. This paper presents the enhancement in Reliability analysis which plays a vital role in designing and planning of radial distribution systems that operate for minimal interruption of customer loads. After occurrence of a fault, the average restoration time of a load point depends on average fault location identification time and switching time. In order to achieve high degree of reliability mostly in radial distribution system Fault passage Indicators (FPI) are required by placing them at suitable location.

KEYWORDS: Radial distribution system (RDS), Fault Passage Indicator (FPI), Reliability Indices, Mat lab.

I. INTRODUCTION

The majority of Rudral distribution systems are designed to operate with a radial topology. Radial distribution systems have a set of series components between a substation and a load point, including breakers, lines, cables, transformers, switches, fuses and other equipment(9). A failure of any component in the series path results in the outage of a load point. Sectionalizing devices provide a means of isolating a faulted section. In some systems there is an alternative supply source for sections that become disconnected from their original source after the failure is isolated.

Reliability of a power system refers to the probability of its satisfactory operation over the long run. It denotes the ability to supply adequate electrical service on a nearly continuous basis, with few interruptions over an extended time period (3). Distribution reliability primarily relates to equipment outages and customer interruptions. In normal operating conditions, all equipments (except standby) are energized and all customers are energized. Scheduled and unscheduled events disrupt normal operating conditions and can lead to outages and interruptions (10). A reliability assessment model quantifies reliability characteristics based on system topology and component reliability data. Areas of inherently good or poor reliability can be identified. The model also identifies over-loaded and undersized equipment that degrades system reliability. Other useful results include the expected number of switch and protective device operations and the sensitivity of results to component reliability parameters.

The reliability of a distribution system may be increased by modifying failure rate and repair time of each section of the network. Such modifications can be acquired by considering the operation time and also restoration time that can be efficiently done by the Fault Passage Indicator.

II. PROBLEM FORMULATION

A radial distribution feeder of 11 kV, 2 MVA with a circuit breaker (CB), LP-1 to LP-16 and four switches with FPI locations (F1 to F9) is shown in Fig. 1. But for the operating conditions of the practical feeder should possesses :(I) Power supply, loads, protective devices and FPIs are 95% reliable (ii) Failure events are independent (iii) Weather conditions (iv) Fuses are placed at starting position of each lateral of the feeder. There are only permanent active faults which are considered. And in this paper the 24 load points with radial structure and three FPI s are considered.

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The network data and customer data required for the reliability analysis is the major important task to analyze. In this paper, the average time for identification of fault location without FPI, the average repair time of feeder sections, the average repair time of distribution transformers and the average switching time of protective devices for restoration of supply. The reliability indices of feeder without any FPI are taken as base case for comparison. The average fault identification time for of the feeder with one FPI for different locations, are calculated using the Eq. 1.

$$\mathbf{T_i = T_0(L_i / \sum_{j=1}^{n+1} L_j)} \qquad \boldsymbol{i = 1,2,\ldots\ldots.n+1} \qquad \ldots\ldots\ldots.1$$

Reliability evaluations with only three FPI at different locations and with multiple FPIs at best possible combination of locations are carried out for the present study and analysis.

A. Radial structure line diagram

The below figure shows the 11KV feeder with 16 load points and with 4 switches with fault passage indicator (FPI).

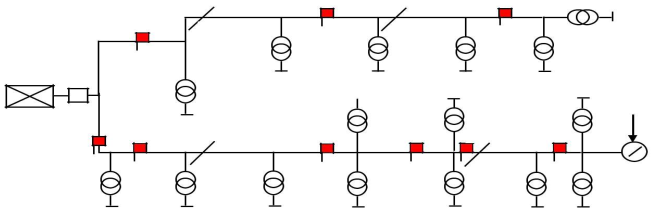

fig.1: Radial structure with FPIs

III. TIMING AND OPERATION & ALGORITHM STEP

In order to restore the power, in case of non-automated system a crew from the sub-station travel along the feeder to identify the location of fault and the time taken by the crew to find the location of fault is known as fault identification time. After finding the fault location, the protective device operates to restore the upstream and downstream loads and the total time taken is known as switching time. Finally, the faulted component is repaired to restore the loads under faulted section and this time is known as repair time. Reliability of a distribution system is measured by load point indices like

Failure rate ‘λ’,
Repair time ‘r’ and
Unavailability ‘U’

and the system reliability indices.

$$\mathbf{T_{rs} = T_{afl} + T_{sw}} \qquad \text{---------------} \ (2)$$

T_{rs} = restoration time
T_{afl} = average fault location
T_{sw} = switching time

There are two types of reliability indices, customer load point indices and system indices have been initiated to assess the reliability performance of distribution systems under different load conditions and also under fault conditions which may occur due to failure, maintenance and sudden lightnings. Load point indices measure the expected number of outages and their duration for individual customers. System indices such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) measure the overall reliability of the system [3]. These indices can be used to compare the effects of various design and maintenance strategies on system reliability.

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The FPIs can reduce the average fault location identification time and consequently decrease the duration of existence of fault in such a way that the interruption duration may reduces and can get achieve better degree of Reliability.

A. ALGORITHM STEPS

(i) Consider each load point on the system. (ii) Consider each component failure mode of the load points. (iii) Calculate average fault location time For each failure mode, if service is restored by repair of a faulted component, choose the restoration time as the sum of average fault location time and repair time. Otherwise, choose the summation of average fault location time and switching time as restoration time.. (v) Assess overall system indices by appropriately combining reliability indices of the load points.

B. FAILURE RATE (Λ):

Since every piece of equipment in a system will eventually fail if it is in service for a long period, there is a failure rate associated with each one. For some items, the failure rate is quite significant while for others it could be extremely low. Failure rate is defined as the number of expected failures per unit in a given time interval. It is just an expected value.

Failure rate (λ / year) = No. of Failures per year / operating time of total No of units per year

In this paper the failure rate is considered for one year as up on to the load points and customers. The table -I shows the failure rate under without Fault passage Indicator and with Fault passage Indictor.

Table-I: failure rate of load points and customers

S. No	Name of the equipment	Without FPI	With FPI
1	Failure rate of load points	0.000140	0.000108
2	Failure rate of customers	0.002154	0.000137

IV. FAULT PASSAGE INDICATOR

The main function of fault passage indicating system which is shown in below fig.2 is to identify faults occurring in the downstream section from the point of its installation in the medium voltage system. This is achieved by continuous monitoring of voltage presence and current flow in medium voltage line. Placing multiple FPIs on a radial feeder will decrease the average fault identification time. When multiple FPIs are placed, it is necessary to choose the best combination of FPIs to achieve high reliability.

Table-II: Details of Fault Passage Indicator:

S.No	Operating Quantity	Limits
1	Operating Voltage	11-66(KV)
2	Maximum voltage	12-72.5(KV)
3	Maximum current	25-0.17(KA)
4	Conductor Diameter	4-35(mm)
5	Communication Protocol	IEC-60870
6	Environment Test	IEEE-495

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Fault condition is indicated by flashing lights or through siren in FPI. This information is sent using radio signals to the communication gateway installed nearby for onward transmission to SCADA system at the control centre through a suitable communication channel.

Using this system, the utility acquires information regarding the section of the line having fault. This identification helps to eliminate the patrolling of the entire line for finding the fault, ultimately which reduces restoration time. Detection of current running in the phase it is clipped on Detection of transient / permanent phase -to-phase and phase-to-earth faults Communication of information to communication gateway using license free short range radio frequency To provide a local light indication on occurrence of fault, which in turn is a useful information for fault finding and maintenance activity.

fig.2: Fault Passage Indicator

V. RELIABILITY STUDY AND EVALUATION WITH 3-FPI

In this case the data shows in table III is the total number of load points are taken as 24 and the cases which are taken are 4 and failure load points 11,19,13,18 . due to those the remaining load points which are connected to failured load points get interrupted as given below , and interrupted duration(hours) under cases is different as shown in in the table III.

Practical data sheet which is considered is based on 1) overload capacity 2) enhancement and shifting of Distribution transformer 3) Internal faults and maintenance.

Some specifications are given for distribution feeder section

Total number of buses = 24

Feeder voltage = 11kv

Total number of customers = 6552

Total Average load connected = 6.972 kw

Table-III Practical data sheet of radial 24-bus structure:

S.No	Case	LP failure No	ILP	ID
1	1	11	11 12 13 14 22	3
2	2	19	19 20 21	2.5
3	3	13	13, 14, 22	3.5
4	4	18	18	1.5

ILP :Interrupted Load Points

ID :interrupted Duration

The results of reliability indices with and without FPI's for the above data sheet are shown in the table IV

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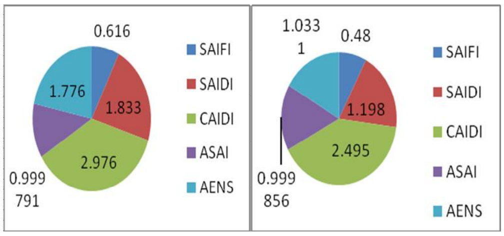
Table-IV: Results of Reliability Indices

S.no	Reliability Indices	without FPI	With FPI
1	SAIFI	0.616	0.48
2	SAIDI	1.833	1.198
3	CAIDI	2.976	2.495
4	ASAI	0.999791	0.999856
5	ASUI	0.000209	0.000144
6	AENS	1.776	1.0331



(3.a) (3.b)

fig.3: Comparison Pie-chart

From fig.3i.e, from both (3.a and 3.b) shows the comparison and improvement in all the Indices of the system due to reduction fault identification time in such a way that the restoration time is reduces due to Fault Passage Indicator(FPI).

VI. CONCLUSION

The rural utility radial feeder is considered without and with FPIs at different locations to evaluate the reliability indices for different configurations. The reliability improvement is important in emerging active distribution networks. Reliability is measured by reliability indices SAIDI, ASAI, CAIDI, SAIFI, ASUI and AENS. Electrical power distribution reliability can be improved in different aspects, from planning to operation and maintenance. First, for a single FPI placed at different locations one at a time, the order of priority of locations are identified in each configuration based on reliability indices which are again evaluated. Using these indices, the extra duration of supply, the extra energy that can be supplied and the percentage reduction of unavailability with respect to base case are evaluated.

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