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The Role of Preventive Major Maintenance in the Costs of Electric Energy Distribution Companies

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Abstract

Objectives: The unwanted and unplanned outages due to faults occurred in electrical energy distribution systems are one of the main concerns of distribution companies. This paper examines this concerning. **Methods/Statistical Analysis:** This paper examines about ninety outages in related to the medium pressure power lines in second region of Bushehr over two-month period. **Findings:** It has identified faults caused by power outages, and the time of outage for each fault is extracted in all regions of the primary data obtained from the power events. Then, by determining the cost function with the purely economic factors, are obtained the costs of each fault individually. In the following, for each fault are provided a series of preventive overhauls or preventive recommendations. Until increasing the system's trustworthiness, the operating costs of unwanted faults are completely eliminated or minimized. **Application/Improvements:** The application of this paper is that examines the roles of preventive major maintenance in the costs of electric energy distribution companies.

Keywords: Cost Function, Electric Energy Distribution Companies, Energy Not Served (ENS), Preventive Maintenance, Unplanned Outage

1. Introduction

Maintenance performing on power distribution networks is one of the key processes in managing power distribution systems. The repairs performing carried out with the aim of outages reducing and improve the lifetime index of equipment. Although at first glance, maintenance performing seem to be obvious and every day, but by examining the constraints and objective functions, we face a complex problem called the maintenance planning to make maximum productivity. The most important constraint is its maintenance management is its finished price and Rial[1] share in the sale of electricity energy. Since investments in maintenance performing depending on the type of power outage is diverse and different. So planning to do the most effective and productive work will be challenging. The high number of equipment of distribution system and the investment constraints make it impossible to do all maintenance, so prioritizing will be a very important part in the planning of maintenance. On the other hand, the developmental backlogs and maintenance in power distribution networks, the culture of network use, urban social culture in dealing with urban facilities, and the planning way of all and all have a very serious impact on the planning of preventive maintenance.

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Also, one of the most important goals of power distribution companies is to provide uninterrupted and quality service to their customers[1]. In this regard, the electricity distribution companies try to select an optimum maintenance strategy in order to reduce the failure rate of network equipment and increase the reliability of the system. This objective was not accomplished as desired in traditional maintenance methods in which the repair of network components was performed at specific time intervals. The huge maintenance expenditures and the inefficiency of these methods in reducing the outages in the system made it necessary to develop a more effective and comprehensive maintenance strategy; a strategy based on the ability to monitor network reliability and to consider the interrelationship between reliability and maintenance costs. These necessities gradually caused the maintenance strategies to be inclined towards the reliability-centered strategies and away from the time-based strategies. The Reliability-Centered Maintenance (RCM) strategy attempts to present an organized framework for the improvement of network reliability and the reduction of maintenance expenses by relying on cost/benefit studies and the reliability analysis of networks[2–4]. In the RCM strategy, the corrective and preventive maintenance strategies are subjected to cost/benefit analysis, and the optimum strategy is selected[5–7] deal with preventive maintenance planning based on risk assessment. As the distribution system components continue to operate, their failure probability increases and therefore the resulting risk goes up. An optimal maintenance model reduces the risk of component failure[8]. The instant causes of failure in Tehran's electricity distribution system are classified and ranked, and the more important factors are selected for the implementation of preventive maintenance activities. In this reference, after finding the most prevalent causes of instantaneous failures, the variables with higher priorities are selected. In[9], the minimization of power outage cost and maintenance cost constitutes the objective function. Ultimately, the results of applying this method in the Birka system of Sweden are evaluated. In[10], the duration of consumer power outage is minimized through the optimal allocation of a maintenance budget.

Many systems need preventive maintenance to reduce the failure rate in the long time periods[11]. In[12], a method for maintenance policy is presented to provide optimal reliability using the Poisson process to display the system fault pattern. In this regard, this reference has helped optimize the type and time of maintenance by this method. Other researches in[13] addressees this issue for optimization of maintenance from the perspective of the new algorithm reliability, which has optimized the utilization of distribution transformers. The application of RCM in systems is to reduce the fault rate and thereby increase the reliability. One of the most important activities of RCM is the management of input information and how they are analyzed (monitoring and supervising using appropriate control tools on the network)[14] addresses how information is managed. Another aspect of maintenance managing issues is the implementation of investments with the cost of blackouts, which[15] has optimized and minimized adjusting of budgeting the by Particle Swarm Optimization (PSO) method[16]. Determining the optimal maintenance time to achieve the related goal is another topic that the reference[17] has examined. The reference[18] presented a practical model for budgeting and practical planning of distribution system maintenance to achieve this goal.

In some other studies, the strategy of maintenance and operation of transformers as one of the distribution system tools is tried and trying to minimize the costs that the reference[18] deals with. In[20] like reference[12] optimized the type and time of maintenance to ensure supply of the reliability. In a series of other studies has been addressed to optimization of preventive maintenance management with consideration of risks[21].

In this research, we have tried to define for planning of preventive maintenance with considering process of maintenance management of the cost. The cost function indicators are completely economic and there is no reliability index. Due to the very high quantity of equipment and equipment of the distribution system, the cost of renovating all of them and carrying out preventive maintenance of all equipment practically raises the cost price of the distributed system. Thus, with the determined cost from subscriber's electricity tariffs and energy consumption payments by them, the prioritization of programs and activities should be done in such a way that have improving the reliability indices, productivity and capital gain. The paper has been categorized as follows; the second section deals with the problem on paper and method. Description of the method, tables and related issues has been done in the third section. Finally, a conclusion has been presented in the fourth section.

2. Methodology

At the first, we have defined relation cost function and faults cost.

2.1 Defining the Cost Function and Obtaining the Faults Cost

The cost function equation described as follows:

$$f = \frac{ENS \times 823}{60} + \Delta T \times \frac{10000000}{\left(\frac{8760}{12}\right) \times 60} + fault\ elemination\ cost \quad (1)$$

In the Equation (1), ENS, 823/60, and ΔT are Energy Not Served (ENS), price per kilowatt of energy per minute, and outage time (minute) respectively.

In the two-month period reviewed in this article, there has been a premature loss of consciousness in electric district 2 of Bushehr[1]. After checking faults, about eighteen faults caused by the outages were detected. The number of occurrence of each fault and the total duration of the outage for each fault were determined. The burning of the cut out fuse, the faults in the jumper and the defect of the transient, had the highest number of faults. In Table 1, all eighteen faults with the highest priority are listed. As well, in the last row of this table, the energy not served is provided for each fault.

The faults occurred in electrification of the power grid for fixation and re-launch of the network includes fees. One of the most important costs is the purchase of newly replaced equipment in the distribution network instead of incident equipment, transportation and interconnections between the emobile events and the operator of the sub transmission substation and the dispatching operator that is required to be addressed. In Table 2, these costs are specified.

By using of the cost function and Tables 1 and 2, the included cost of each fault is calculated within the defined time frame. All the costs related to eighteen faults are given in Table 3.

2.2 Preventive Maintenance

In order to be able to resolve or decrease all the eighteen identified faults in the medium pressure lines, it should be a major overhaul of preventive measures or recommendations on the agenda. For this purpose, all the faults were

Table 1. Definition of the faults, the number of repetitions, the duration of the outage and ENS per fault

No.	Type of fault	Δt (Minute)	Number	ENS(MW)
1	Burning of the cut out fuse	25	1847	7.747
2	Fault in jumper	15	918	37.928
3	Transient	10	114	7.352
4	Firing of output cable connectors of transformer	9	850	1.569
5	Manpower error	6	251	6.051
6	Rupture of network wire	5	503	25.106
7	Burning of the cut out group	4	358	2.402
8	Entry of animals to the electricity system	3	197	0.148
9	Fault in the main key of the airing substation	2	159	0.213
10	Cable short-circuit of self-locking	2	578	3.169
11	Short circuit in low voltage network	2	469	0.412
12	Defective in an insulator	1	67	4.267
13	Defective in an arrester	1	15	0.838
14	Mistaken function of circuit breaker	1	143	0.28
15	Defective in transformer bushing	1	40	0.02
16	A firing on the airing substation board	1	178	0.342
17	Collision of vehicles with the network	1	158	0.57
18	Network equipment theft	1	120	0.003

Table 2. The costs imposed by the explained faults

No.	Fault	Descriptions of costs	Price in per unit (Rial[1])
1	Fuse link	Buying Fuse + Transportation	250000
2	Fault in jumper	Buying wire shipping and special fastener	1000000
3	Transient	Coordination	100000
4	Firing of output cable connectors of transformer	Buyingcable shoe, Electrical Adhesive andthe connectors	1000000
5	Manpower error	Coordination	100000
6	Rupture of network wire	Buying wire shipping and special fastener	1500000
7	Burning of the cut out group	Buying cut out Equipment + the waste Shipment	4000000
8	Entry of animals to the electricity system	Replacement of dismantled equipment	1000000
9	Fault in the main key of the airing substation	Buying the key	10000000
10	cable short-circuit of self-locking	Buyingelectrical adhesive, connectors and Fuse link	1000000
11	Short circuit in low voltage network	Buyingwire, the connectors and Fuse link	1000000
12	Defective in an insulator	Buyingisolators and wire + the waste shipment	1000000
13	Defective in an arrester	Buying arrester and wire+ Waste the waste shipment	4000000
14	Mistaken function of circuit breaker	Going and coordination	200000
15	Defective in transformer bushing	Buyingbushing, cable shoeand the connectors	1000000
16	A firing on the airing substation board	Buying safe board + Waste the waste shipment	60000000
17	Collision of vehicles with the network	Buying new base + carry and run new base + waste the waste shipment	20000000
18	Network equipment theft (3*12+240)	Buying cable and the new connectors	2500000

Table 3. Total costs of every fault

No.	Type of faults	F (Rial)
1	Burning of fuse of cut out	6777977
2	Fault in jumper	15729960
3	Transient	1126896
4	Firing of output cable connectors of transformer	9215590
5	Manpower error	740325
6	Rupture of network wire	7959294
7	Burning of the cut out group	16114690
8	Entry of animals to the electricity system	3047007
9	Fault in the main key of the airing substation	20039223
10	Cable short-circuit of self-locking	2175441
11	Short circuit in low voltage network	2112730
12	Defective in an insulator	1073840
13	Defective in an arrester	4014922
14	Mistaken function of circuit breaker	236490
15	Defective in transformer bushing	1009406
16	A firing on the airing substation board	60045331
17	Collision of vehicles with the network	20043893
18	Network equipment theft	25027438

made and the reasons for their occurrence were identified and identified. Then, to overcome those faults, the maintenance of the precursors set out in Table 4 is presented.

3. Related Issues on Problem

In Azadiline, pumping of the short-circuit of a self-contained cable has happened twice in a row with two hours of time difference. Therefore, with one-time investment (the training of workers and the correct implementation under strict supervision) the fault can be eliminated.

In Bahmani line two transient faults occurred in a short time interval in the line. Therefore, with one-time investment (correction of arrangement, distances and observance of network privacy in suspect locations) the network could be corrected.

Table 4. The preventive major overhauls

No.	Type of faults	Description of proposed preventive maintenance	Fault occurrence (load)	INV per unit (Rial)	Total INV (Rial)
1	Fuse link	Coordination between Protective equipment of substation and division of phases and technical and cleaning service of cut out	25	1000000	23000000*
2	Fault in jumper	Worker training and correct execution under strict supervision	15	300000	3600000*
3	Transient	Correction of makeup, distances and network privacy in suspected locations	10	2000000	16000000*
4	Firing of output cable connectors of transformer	Correction of connections and their technical service and cleaning	9	1000000	9000000
5	Manpower error	Worker training and correct execution under strict supervision	6	1000000	6000000
6	Rupture of network wire	Pruning the trees around the net and correcting, tightening the connections of the span wires	5	5000000	10000000*
7	Burning of the cut out group	Technical service, Cut out cleaning, phase division and coordination	4	2000000	4000000*
8	Entry of animals to the electricity system	Repair the door, lock and block the animal arrivals to the substation	3	500000	1500000
9	fault in the main key of the airing substation	Coordination between protective equipment, division of phases and technical and cleaning service of key	2	3000000	3000000*
10	cable short-circuit of self-locking	Worker training and correct execution under strict supervision	2	1000000	1000000*
11	Short circuit in low voltage network	Coordination between protective equipment of the substation and low voltage network	2	2000000	4000000
12	Defective in an insulator	Technical and cleaning service of insulator	1	100000	100000
13	Defective in an arrester	Technical and cleaning service of arrester	1	100000	100000
14	Mistaken function of circuit breaker	Principle setting of regulating circuit breaker relays and technical and cleaning service	1	1000000	100000
15	Defective in transformer bushing	Technical and cleaning service	1	500000	500000
16	A firing on the airing substation board	Technical service and periodic cleaning service of substation tableau	1	500000	500000
17	Collision of vehicles with the network	Proper design and correct selection of bases place	1	100000	100000
18	Network equipment theft	To close and locking the door and controlling the places log in posts	1	200000	200000

In Sabz Abad-Bandargah line, there were three cases of rupture of wire with near-time occurrences with one-time investment (pruning the trees around the net and correcting, tightening the connections of the span wires). The reliability factor of the line could be increased due to this fault.

In Sabz Abad-Daryadelan line, there were two cases of rupture of wire with near-time occurrences with one-time investment (pruning the trees around the net and correcting, tightening the connections of the span wires) the network could be corrected.

In Sabz Abad-Daryadelan line, in Mehr-22 substation, burning fuse link once occurred and then two breakdowns of the cut out which all three of cases occurred in one day with a one-time investment (Coordination between protective equipment, division of phases and technical and cleaning service of key) the network could be corrected.

In Sabz Abad-Daryadelan line, in Mehr-88 substation, burning 25 Amperes (AM) fuse link once occurred on 6th August 2012 and then on 20th August 2012 one of the main jacks of the main key is 800 AM of the same substation has been defective. It concludes that, with a one-time investment (coordination between protective equipment and division of phases) can prevent the main key being damaged.

In Sabz Abad- Sabz Abad, three cases of faults have occurred in the interconnection of the overhead cable which with a one-time investment (worker training and correct execution under strict supervision) in this case, this fault was eliminated.

In Sabz Abad- Sharak Emam, there was a transient fault, and then with a short timeframe, faults occurred in the overhead communication jumper, which with a one-time investment of jumper improvements (worker training and correct execution under strict supervision) in this case, the transient faults caused by jumper problems were eliminated.

In Sabz Abad-Nakhoda line, three case of burning of elemental fuse occurred in the airing substation of southern Sartel which can be done with a one-time investment (coordination between the security equipment of substation and the phases load division and technical and cleaning service of the cut out) the fault can be eliminated.

In Sabz Abad-Nakhoda line, two case of burning of elemental fuse occurred in the airing substation of southern of the health house in between two days which can be done with a one-time investment (coordination between the security equipment of substation and the phases load division and technical and cleaning service of the cut out) the fault can be eliminated.

In Sabz Abad-Nakhoda line, there are two faults related to faults in the jumpers along the line that occurred immediately and in succession. Therefore, with one-time investment (the training of workers and the correct implementation under strict supervision) the fault can be eliminated.

All of the above issues in the investments are included, and marked with the star "*" in Table 4.

In above tables, f is total costs that are equal to 174040025, and INV is total investment that is equal to 83600000.

Due to the elimination of continuous outages and the continued energy supply to subscribers and the lack of the need to buy new equipment and added costs of 90440025 Rial will be reduced from the cost of unplanned outages.

4. Conclusion

The unplanned outages in distribution networks cause heavy costs. The reducing and or eliminating unwanted faults is one of the main concerns of distribution companies. The preventative maintenance is a good way to do this issue. By checking the outages of July and August in year 2012, were detected eighteen types of faults that causing an unplanned outage during this period. Accordingly, preventative maintenance has been proposed to reduce or cut the faults. The result of this preventive maintenance is up to 48 percent of the return on investment of the distribution company, which can be used to develop the network.

Initial investment for preventive maintenance of 11 faults was far less than their outage costs, and one case was equal and 6 cases were higher. With precision in Table 4 it seen that these six cases of repetitive errors in that area. So their elimination is irrefutable to boost network reliability. Another important point is that the study period in this paper is two months and the returning capital is calculated for these two months. While the pre-emptive maintenance intervals in power distribution networks have been around for several years. So, with a long-term vision, the cost of reimbursement would be much greater than 90440025 Rial.

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