Reliability Analysis of Suichatar Substation along with Cost Analysis

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Abstract: The basic function of an electric power system is to supply customers with electricity. Modem society demands that electrical energy should be as economical as possible with a reasonable degree of continuity and quality. This requires the investment in improving reliability of system to be compensated or oversubscribe by the benefit obtained from the improved reliability. This can be evaluated by reliability cost/worth analysis. This study attempts to analyze reliability of suichatar substation. Proposes a method to improve its reliability and presents a reliability and cost analysis for various of substation and finally gives an optimum solution point that gives improved reliability with minimum cost.

Failure mode and effect analysis have been used to evaluate the reliability of suichatar substation. Revenue loss to utility, customer damage cost in a present situation of substation have been computed. for improvement in reliability, this thesis has proposed two solution one is replacement of old and obsolete with new one and other is to make provision of spare unit. It is found that current transformer, potential transformer and disconnecting switch have been in use for very long and are old and gets faulted frequently. An attempt has been made to carry out liability and cost analysis of this substation for various scenario considering these old equipment. finally optimum configuration of these current transformer, potential transformer and disconnecting switch that improves reliability with minimum cost is found. A program has been written in matlab for all these computation and genetic algorithm has been used for cost minimization.

Keywords: Reliability, substation, reliability cost/worth analysis

DS=disconnecting switch

L=load point of substation

S=series block

1. Introduction

The basic function of an electric power system is to supply customers with electricity. Modem society demands that electrical energy should be as economical as possible with a reasonable degree of continuity and quality. To build an absolutely reliable power system is neither practically realizable nor economically justifiable. The continuity of energy supply can be increased by improved system structure, increased investment during the planning phase, operating phase or both. Over-investment can lead to excessive operating costs, which must be reflected in the tariff structure. Consequently, the economic constraint will be violated although the probability of the system being inadequate may become very small. On the other hand, under-investment leads to the opposite situation. It is evident therefore that the reliability and economic constraints can compete, and this can lead to difficult managerial decisions at both the planning and operating phase.

A power system can usually be divided into the subsystems of generation, transmission, and distribution facilities according to their functions. In a vertically integrated power system, one Company often owns all the subsystems. In this case, a power system planner can relatively easily access most of the required information and decide when and where to perform generation expansion, line and station reinforcement to meet future load growth and satisfy the corresponding reliability requirements. The balance between reliability and economic constraints is usually judged by the system planner.

1.1 Power System Reliability

Power system reliability evaluation can be used to provide a measure of the overall ability of a power system to perform its intended function. The concept of reliability can be subdivided into the two main aspects of system adequacy and system security. System security relates to the ability of the system to respond to disturbance arising within the system. System adequacy relates to the existence of sufficient facilities within the system to satisfy the customer demands within the system operating constraints. This includes the facilities necessary to generate sufficient energy and the associated transmission and distribution facilities to transport the energy to the actual customer load points. The three subsystems of generation, transmission and distribution are designated as power system functional zones. Reliability evaluation can be conducted in each of these functional zones or in the combinations that gives the hierarchical levels .

HL1=reliability evaluation of generation

HL2= composite reliability evaluation of generation and transmission

HL3= composite reliability evaluation of generation, transmission & distribution

1.2 System Adequacy

The reliability indices that have been evaluated are the three primary ones of average failure rate, average outage duration and average annual unavailability or average annual outage time. These are not deterministic values but are the expected or average values of an underlying probability distribution and hence represent only the long run average value.

2. Problem Statement

Generation and transmission system reliability has gained greater attention compared to distribution system and substation over decade A study showed that much of interruption of supply is because of problem in distribution system nevertheless the substation originated outage cannot be neglected as it also play a significant role in supply interruption for customer. This give rise to need to carry out reliability assessment of substation.

There is a rare practice of assessing reliability in nepal

Reliability of system can be improved by increasing the investment cost .but up to what degree of reliability to achieve and with what level of investment? And does the investment worth it? The answer to this question can be obtained by reliability cost verses reliability worth analysis.

3. Methodology

Reliability of substation and improvement in reliability of substation can be obtained by following proposed methodology

Governing equation:

Series equation

When two or more components are connected in series,their equivalent failure rate gets added and total unavailability also gets added which is shown below

$\Lambda=\lambda 1+\lambda 2+\lambda 3\ldots\ldots\ldots\lambda n$

U=U1+U2+U3...........Un

$R=U/\lambda$

Where n=no of components connected in series

Λ=equivalent failure rate of all series connected components

U=equivalent unavailability of series connected components

R =Equivalent outage duration of series connected components

Parallel equation:

When two or more components are connected in parallel their equivalent failure rate, outage duration and unavailability can be obtain as

equivalent failure rate(λpp)=

$\lambda 1*\lambda 2(r1+r2)/(1+\lambda 1*r1+\lambda 2*r2)$

rpp = (r1*r2)/(r1+r2)

Upp= $\lambda pp*rpp$

Expected energy not served (EENS) of load point is given by the product of load demand at that load point and unavailability of that load point.

Cost minimization:

In order to improve the reliability of Suichatar substation, two options are proposed in this thesis which is either making a provision of spare part or replacement of faulty component. Both of this option tends to improve the substation reliability but requires certain investment to be done.

Normally reliability increases with investment and customer damage cost decreases with improved reliability. Inadequate reliability of electric power supply ultimately costs the customers much more than good reliability. It is therefore important to determine the optimal reliability level at which the reliability investment achieves the best results in reducing the customer damage costs due to power supply interruptions. Therefore the cost expression to be minimized is as follows

Total cost=equipment cost + installation cost + interrupted energy assesment rate (Iear)* EENS

Where Iear=Interrupted energy assement rate

Solving strategy:

In order to compute reliability of Suichatar substation, failure rate and outage data were collected from substation along with single line diagram of substation .from single line diagram reliability block diagram was constructed by replacing component connected in series by their equivalent series block and parallel connected equipment by their equivalent parallel block which is as shown below:

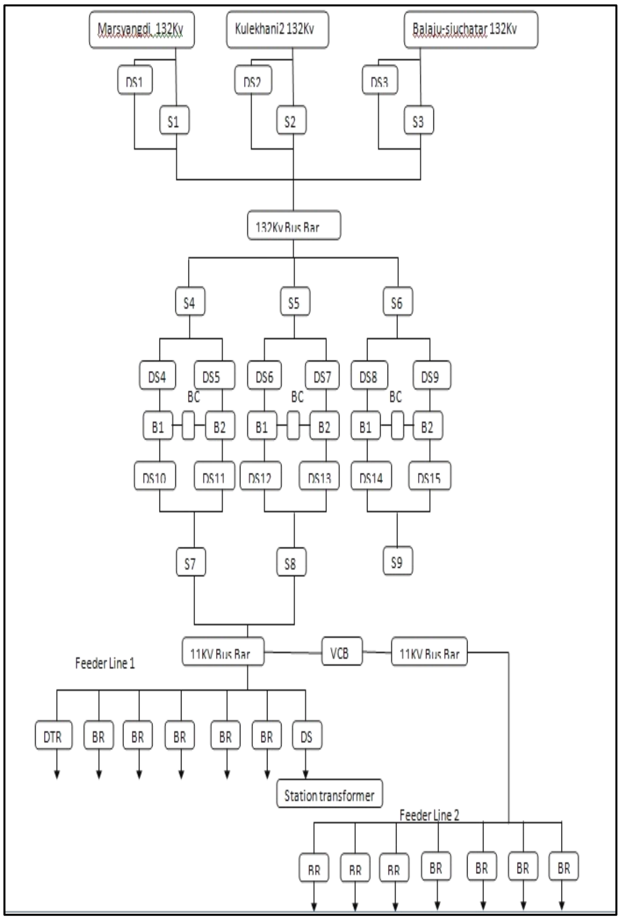

Figure 3.1.a: Reliability Block diagram of suichatar substation

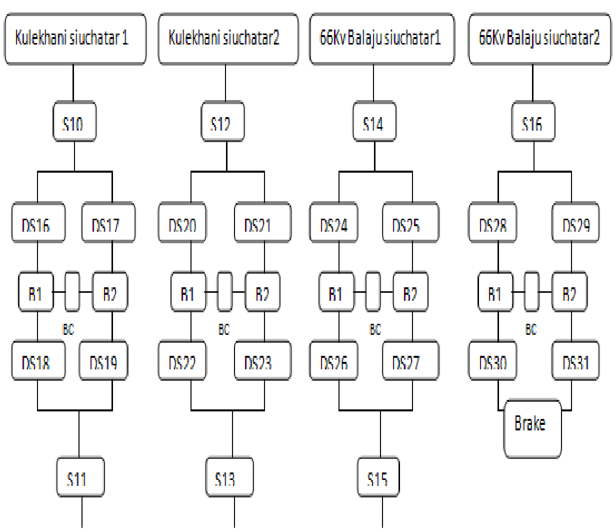

Figure 3.1.b: Reliability block diagram of suichatar substation

Where ds is disconnecting switch, s is equivalent series block, br is breaker, b is bus bar

1) Equivalent failure rate of sample series blocks is obtained using equation for series connection

2) load point of substation are identified For each of load point of substation, identify the failure of component or combination of component failure.ie overlapping failure of two or three component that cause outage of load point that are termed as failure modes of load point overlapping of four or more component is not considered because the value is negligible.

The failure modes of all the load point are computed as below:

load point 1 gets failed when any of the below mentioned condition appears which is also termed as failure modes of load point 1

I) Failure of series block S7 and S8

II) Failure of series block S7 and failure of DS12 and DS13

III) Failure of series block S8 and failure of DS10 and DS11

IV) Failure of bus bar 1 and failure of DS11 and DS13

V) Failure of busbar2 and failure of DS10 and DS12

VI) Failure of 11kv bus bar

VII) Failure of 132kv bus bar

VIII) Failure of series block S4 and S5

IX) Failure of series block S4 and S8breaker

X) Failure of series block s5 and s7

XI) Failure of series block s4,ds6 and ds7

XII) Failure of series block s5,ds4 and ds5

Similarly failure modes for all the other load point are identified

The failure modes that are identified in this way represent component outages that must overlap to cause a load point outage. The events are therefore defined as overlapping outages and the associated outage time is defined as the overlapping outage time. Each overlapping outage is effectively a set of parallel elements and its effect can be evaluated using the equations for parallel components. Also, since each of these overlapping outages will cause system failure, all the overlapping outages are effectively in series from a reliability point of view. The system indices can therefore be evaluated by applying the equations for series components in order to combine all the overlapping outages.

3) load demand on every load point was collected from substation expected energy not served(eens) of every load point was evaluated as

Eens(Mwhr/yr) of load point = unavailability of load point(hr/yr)*load in mw

Then old and aged, obselete component of substation are identified.

In this thesis two reliability improvement scheme are suggested

i. Making provision of spare parts for old and faulty component that will reduce the outage time.Outage time will be replacement time for no spare availability but if spare parts are available outage time will be equal to the time to replace the faulty unit by the spare unit.

ii. Replacement of faulty component with newer component .the newer component will have improved failure rate. The component tends to fail infrequently in long duration.

It is not economically justifiable to replace all the old equipment, or make provision of spare unit for all faulty component.

In an attempt to improve the system reliability ,this require increase in investment cost, but the question arise whether the cost is compensated by the benefit obtained from the improved reliability ,in order to solve this issue, GA tool in MATLAB have been used and develop fitness function in MATLAB. This code finds the optimum configuration of DS, CT PTie which DS/CT/PT to replace? Which DS/CT/PT should be given spare so that the reliability gets improved significantly with minimum cost. Cost is composed of the overall investment cost and the customer damage cost.overall investment cost is the total equipment cost and its installation cost. Customer damage cost is the product of Iear and Expected energy not supplied .Beside this ,reliability and cost analysis for various scenario are carried out using this program

The various scenario are:

1) Substation in its original state
2) Replacing all ct, pt and ds
3) Making provision of spare for all ct ,pt, ds in 1:1
4) Replace all ds only
5) Making provision for spare for ct only
6) Making provision for spare for pt only
7) Making provision for spare for ds only

4. Result and Discussion

Reliability indices for every load point of substation for recent three consecutive year is shown below

Table 3: unavailability for all the load points of substation

		load in MW			
	notation	**2068 BS**	**2069BS**	**2070 BS**	**unavailability(hr/yr)**
load point l1	all 11kv	8.029	8.58	9.854	64.418
load point l2	Pat -1	6.705	6.954	7.188	3.2245
load point l3	Pat-2	6.7848	7.281	7.9018	2.7160
load point l4	teku	8.207	9.033	9.4514	2.8118
load point l5	k3	6.7452	8.083	8.622	4.1601
load point l7	bal 2-66	5.636	7.647	8.1848	3.621
load point l8	bal 1-66	7.27	8.24	8.619	3.919

Table 5: EENS for all the load points of substation

Notation	EENS (Mwhr/yr)		
	2068 BS	2069 BS	2070 BS
load point l1	517.032	552.9005	634.5541
load point12	21.6222	22.424	23.1777
load point l3	18.4275	19.776	21.4615
load point l4	23.079	25.401	26.575
load point l5	28.061	33.628	35.869
load point l7	20.41445	27.69936	29.6445
Load poinl8	28.496	32.312	33.783
Total EENS	657.132	714.144	805.0656

	2068BS	2069BS	2070BS
EENS (Mwhr/yr)	657.132	714.144	805.065
Revenue Loss/yr (Rs)	49,28,490	53,56,080	60,37,980
ECOST/yr (Rs)	3,28,56,600	3,57,07,200	4,02,53,250

All the above result shows that the system was unable to meet the expected energy accounting to the failure of different substation component. However , improving the performance of substation by either replacing the obselete component or making provision of spare part might reduce the volume of unserved energy. Cost of improving the substation performance must be compensated or oversubscribed by the energy lost cost to the utility as well as to the society otherwise, it will not be meaningful. For this we require reliability cost worth analysis which is under study.

Reliability and cost analysis for various scenario of improvement schemes are presented below. replacing all the ct of substation reduces the eens to 748.52 mwhr/yr .revenue loss to utility decreases to Rs 5613954.3 and ECOST reduces to Rs 39176387.9

Similarly for other cases ,it is presented below

Table 6: Reliability and cost analayis for various scenario are

	EENS	revenue loss to utility	ECOST	Equipment cost	total cost (equipment +ecost)
Replace all ct	748.52	5613954.36	37426362.46	5100000.0	38197456.15
Replace all pt	783.52	5876458.19	39176387.96	2200000.0	39509016.6
replace all ds	739.7	5548243.8	36988292.07	108000	38621196.38
spare all ct	746.4	5598314.45	37322096.39	5100000	38093190.09
spare all pt	784.97	5887347.41	39248982	2200000	39581611.45
spare all ds	696	5220083.45	34800556.36	108000	36433460.67
replace all ct and pt	725.68	5442648.18	36284321.26	7300000	37388043.62
replace all ct and ds	683.62	5127173.34	34181155.06	15900000	36585153.611
replace all pt and ds	673.17	5048777.27	33658515.16	13000000	35624048.13
spare all ct andpt	727.13	5453537.41	36356916.09	7300000	37460638.45
spare all ct and ds	638.6	4789822.4	31932149.3	15900000	3433614.3
spare all pt and ds	674.62	5059666.5	33731110.0	13000000	35696642.96
replace all pt and spare all ct	723.6	5427008.27	36180055.19	7300000	37283777.55
replace all ds and spare all ct	681.47	5111069.07	34073793.81	159000000	36477791.82
replace all ct and spare all ds	640.85	4806407.6	32042717.5	15900000	34446715.512

5. Conclusion

The eens for substation for year 2070 about 800 MWhr/yr. Revenue loss to utility was around Rs 60,00,000 and ECOST was about 400,00,000

EENS = 635.9270 Mwhr/yr

Revenue loss to utility = NRs 47,69,453.209

Annutised investment cost Rs 14,81,709.46

ECOST = NRs. 3,17,96,354.729

Equipment cost = NRs 98,00,000.000

TOTAL COST = NRs. 3,32,78,064.195

This result suggest that the existing reliability can be improved at an investment of around Rs 9800000.00 reducing the revenue loss to utility and expected customer interruption cost to society significantly.

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