DISTRIBUTION SYSTEM RELIABILITY IN SHWE SAR YAN PRIMARY SUBSTATION

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Abstract

This paper is intended to find the most reliable method in distribution by using protective devices because high reliability power system is urgently needed in Myanmar. Approximately 80% load interruptions are due to breakdown in distribution system and insufficient supply. Therefore, it is important to understand the impact of the outages on the customer's outage costs, system adequacy and security. In this research, the impacts of protective devices installation on distribution system reliability were analyzed using analytical method and evaluation techniques. Load data on the feeders were collected from Shwe Sar Yan primary distribution substation from December 2017 to December 2018 and system data were calculated on monthly basis for one year. In this research, fuses were used in every lateral line for lateral protection and it could be seen that the energy not supplied (ENS) in feeder 1 was decreased from 448.92 MWh/yr to 32.91 MWh/yr. By using fuses, total ENS were reduced from 17207.11 MWh/yr to 4451.65 MWh/yr in all feeders besides it was abated from 17207.11 MWh/yr to 4377.14 MWh/yr because of disconnecting switch and also depleted from 17207.11 MWh/yr to 4416.71 MWh/yr by 90% protection failure. In this research, reliability improvement scheme was tested as lateral protection with fuse, feeder protection with disconnecting switches and effect of protection failure rate and then the amount of total ENS were reduced too much during one year. In this research, using disconnecting switches method is the best. By studying this research, it could be chosen the most reliable method in distribution system.

Keywords: protection failure rate, Energy not supplied (ENS), impacts, distribution system, protective devices, disconnecting switch, fuses

Introduction

Electricity is one of the most important forms of energy in the world. The ability of an electric power network to provide an adequate supply of electrical energy is usually designated by the term power system reliability(Brown Richard E,2008). Reliability means the ability of a system to perform required function under state conditions for a given period of time. It is very important for power system to meet the required power demand and to be reliable as possible. This research is intended to analyze the distribution system reliability and describes the hierarchical levels in electrical power system and described reliability indices and calculation of power system reliability is Shwe Sar Yan substation. The system rating is 230/33/11 kV. In this research, the analysis of reliability improvement will be calculated by protection system.

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Analysis of Power System Reliability

Reliability refers to the continuity of power flow when power distribution network is considered. It supplies continuous power to the customers. It provides power in such manner that the system behavior carrying on without interruption. System adequacy and system security are basic concepts of power system reliability. Power system adequacy is the ability of the system to supply all energy demand requirements at all times. System adequacy is associated with system steady-state conditions and offers information on future system behavior that can be used in system planning. Security, on the other hand, is the ability of the system to avoid service interruption under sudden disturbances. System security is associated with the dynamic and transient real-time system operation, such as general and transmission line contingencies and generation uncertainties(Leonel de Megathacs ,2008).

2. 1. Basic Power System Planning

A power system can be divided into the subsystems of generation, transmission, and distribution facilities according to their functions. For the purpose of conduction power system reliability assessment, these systems are combined into different system hierarchical levels or functional zones (Lee Layton, 2004). In this research, only distribution system reliability is calculated. Customer-oriented indices and load-oriented indices are classifications of distribution system reliability. In this research, only customer- oriented indices as SAIFI, SAIDI, CARDI and ENS are calculated by using protection system and used formula e are as follows.

The system average interruption frequency index (SAIFI) is given in Equation (1)

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} \qquad (1)$$

System average interruption duration index (SAIDI) is followed in Equation (2)

$$\text{SAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customers Served}} \qquad (2)$$

Customer Average Interruption Duration Index (CAIDI)is shown in Equation(3)

$$\text{CAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customer Interruptions}}$$

$$\text{CAIDI} = \frac{\sum \gamma_i N_i}{N_T} = \frac{\text{SAIDI}}{\text{SAIFI}} \qquad (3)$$

Total energy not supplied by the system is estimated using Equation (4)

$$\text{ENS}=\sum L_{a(i)} U_i \qquad (4)$$

Where $L_{a(i)}$ and U_i respectively are the average connected load and the average annual outage time at load point i.

Reliability Indices Calculation

3.1 Reliability and Load Data

Shwe Sar Yan primary substation has two transformers, 100MVA and 60MVA transformer, 230 kV/ 132 kV line supplies to Tagontine and Pyin Oo Lwin. In 60MVA transformer (230 kV/ 33 kV), there are four feeders such as Shwelyanbo, Patheingyi, Chan Mya Tharsi and Pyi Kyi Tagon. Shwelyanbo is designated as load point A. Patheingyi is referred to load point B. Chan Mya Tharsi and Pyi Kyi Tagon are assumed as load point C and D. Figure (1) illustrates the load data in Shwe Sar Yan primary substation from December 2017 to December 2018. Figure (2) shows single line diagram of Shwe Sar Yan primary substation.

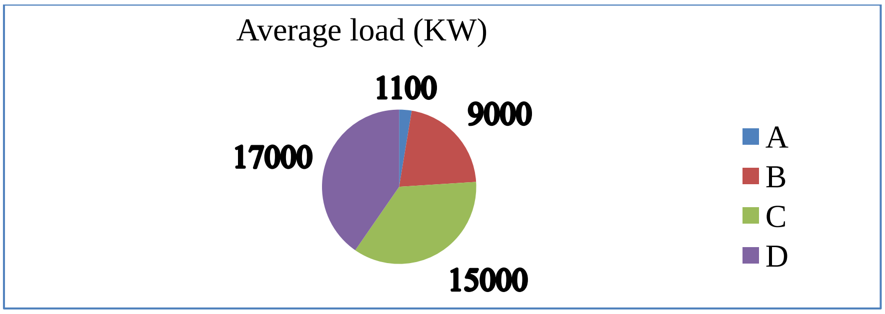

Figure 1 Average Load in Shwe Sar Yan Primary Substation during One Year

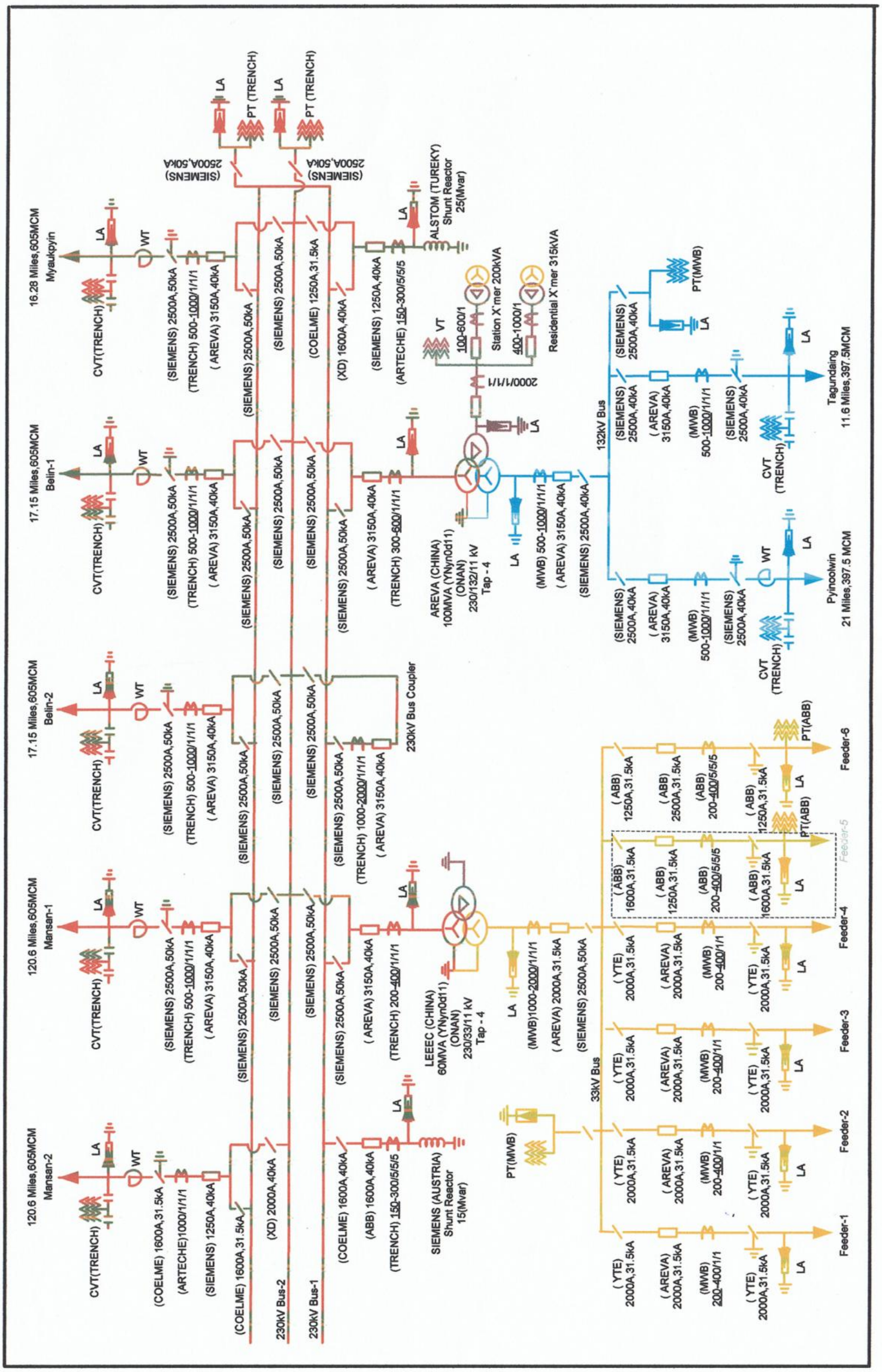

Figure 2 Single Line Diagram of Shwe Sar Yan Primary Substation

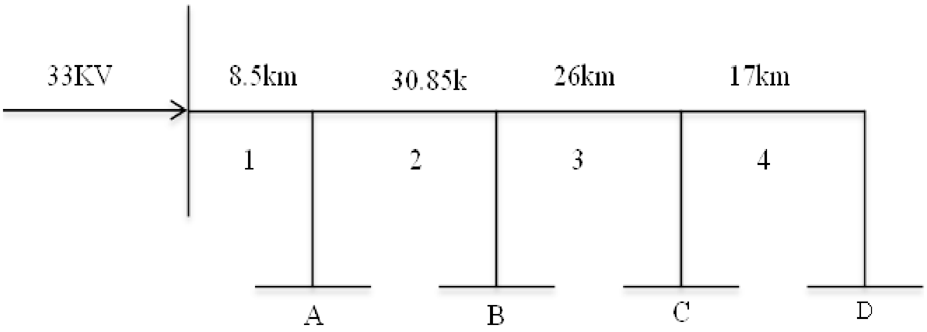

Figure 3 Radial Distribution Network of Shwe Sar Yan Primary Substation

Table 1 Basic System Data of Radial Distribution Network of Shwe Sar Yan Primary Substation

Component	λ (f/ yr)	r (hours)	Average load (KW)
Section			
1	0.13	4	1100
2	0.46	4	
3	0.39	4	9000
4	0.26	4	
Distributor			
A	4.16	6	15000
B	11.17	10	
C	10.75	11	17000
D	11.4	13	

3. 2. Reliability Indices without Protective Device

In this case, no protective device is used in the system. After that using the basic load point indices, system indices and energy-oriented indices can be calculated below:

Table 2 Basic Load Point Indices for Without Protective Device

	Load Point A			Load Point B			Load Point C			Load Point D		
Comp-onent	*λ* (f/yr)	*r* (h)	*U* (hr/yr)	*λ* (f/yr)	*r* (h)	*U* (h/yr)	*λ* (f/ yr)	*r* (h)	*U* (h/yr)	*λ* (f/yr)	*r* (h)	*U* (h/yr)
Section												
1	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52
2	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84
3	0.39	4	1.56	0.39	4	1.56	0.39	4	1.56	0.39	4	1.56
4	0.26	4	1.04	0.26	4	1.04	0.26	4	1.04	0.26	4	1.04
Distri-butor												
A	4.16	6	24.96	4.16	6	24.96	4.16	6	24.96	4.16	6	24.96
B	11.17	10	111.7	11.17	10	111.7	11.17	10	111.7	11.17	10	111.7
C	10.75	11	118.25	10.75	11	118.25	10.75	11	118.25	10.75	11	118.25
D	11.4	13	148.2	11.4	13	148.2	11.4	13	148.2	11.4	13	148.2
Total	**38.72**	**10.54**	**408.07**	**38.72**	**10.54**	**408.07**	**38.72**	**10.54**	**408.07**	**38.72**	**10.54**	**408.07**

Basic indices for each load point can be calculated using equation (1), (2), (3) and (4) . The results are shown in Table (3). In this case, no protective device is used in the system. With the obtained the basic load point indices, system indices and energy-oriented indices can be calculated as follow.

From equation (1) ,

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}}$$

$$\text{SAIFI} = \frac{38.72+38.72+38.72+38.72}{4}$$

$$= 38.72 \text{ interruption/ customer/ yr}$$

From equation (2),

$$\text{SAIDI} = \frac{408.07+408.07+408.07+408.07}{4}$$

$$= 408.07 \text{ hr/ customer/ yr}$$

From equation (3),

$$\text{CAIDI} = \frac{10.54+10.54+10.54+10.54}{4}$$

$$\text{CAIDI} = 10.54 \text{ hr/ customer interruption / yr}$$

From equation (4),

$$\text{ENS} = 408.07 \times 42.1 \text{ MW}$$

$$= 17207.11 \text{ MWh/ yr}$$

3. 3 Reliability Indices with Protective Devices

Using protective device on radial system has a great effect on reliability of the system. With the obtained the basic load point indices, system indices and energy-oriented indices can be calculated. By using protective devices, reliability improvement scheme is tested as follows :

(1) Lateral protection with fuse
(2) Feeder protection with disconnecting switches
(3) Effect of protection failure rate (Ohn Zin Lin, 2016)

3.3.1. Lateral Protection with Fuse

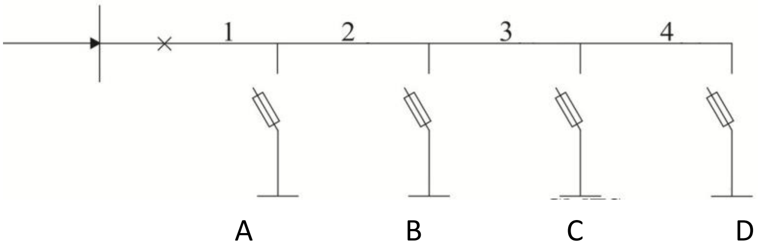

Figure 4 Schematic Diagram of Shwe Sar Yan Primary Substation by using Fuse

Table 3 Impact of Fuse on System Reliability Indices

	Load Point A			**Load Point B**			**Load Point C**			**Load Point D**		
Component	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**
Section												
1	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52
2	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84
3	0.39	4	1.56	0.39	4	1.56	0.39	4	1.56	0.39	4	1.56
4	0.26	4	1.04	0.26	4	1.04	0.26	4	1.04	0.26	4	1.04
Distri-butor												
A	4.16	6	24.96									
B				11.17	10	111.7						
C							10.75	11	118.25			
D										11.4	13	148.2
Total	**5.4**	**5.54**	**29.92**	**12.41**	**9.40**	**116.66**	**11.99**	**10.28**	**123.21**	**12.64**	**12.12**	**153.16**

The most unreliable load point is D because of the domain effect of the failures on its lateral distributor 11.4 f/yr compared with 4.16, 11.17 and 10.75 f/yr on other laterals. By using equations (1), (2), (3) and (4) . The calculated values of SAIFI is 10.61 interruption / customer / yr, SAIDI is 105.74 h /customer/ yr, CAIDI is 9.97 h /customer interruption / yr and ENS is 4451.65 MWh/yr.

3. 3. 2. Feeder Protection with Disconnecting Switches

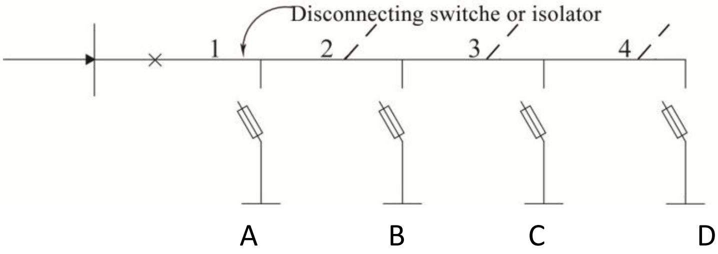

Figure 5 Schematic Diagram of Shwe Sar Yan Primary Substation by using Disconnecting Switches

Table 4 Impact of Disconnecting Switches on System Reliability Indices

	Load Point A			Load Point B			Load Point C			Load Point D		
Component	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**	**λ (f/yr)**	**r (hr)**	**U (hr/yr)**
Section												
1	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52
2	0.46	0.5	0.23	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84
3	0.39	0.5	0.2	0.39	0.5	0.2	0.39	4	1.56	0.39	4	1.56
4	0.26	0.5	0.13	0.26	0.5	0.13	0.26	0.5	0.13	0.26	4	1.04
Distri-butor												
A	4.16	6	24.96									
B				11.17	10	111.7						
C							10.75	11	118.25			
D										11.4	13	148.2
Total	**5.4**	**4.82**	**26.04**	**12.41**	**9.22**	**114.39**	**11.99**	**10.2**	**122.3**	**12.64**	**12.12**	**153.16**

By using equation (1), (2), (3) and (4) , the values of SAIFI, SAIDI, CAIDI and ENS are 10.61 interruption/customer/yr, 103.97 h/customer/yr, 9.79 h/customer interruption/yr and 4377.14 MWh/yr.

3 . 3. 2 Effect of Protection Failure Rate

Failure rate = (failure rate/fuse operates) x P (fuse operates) + (failure rate/ fuse fails) x P (fuse fails) (5)

Table 5 Impacts of 90% Protection Failure Rate

Component	Load Point A			Load Point B			Load Point C			Load Point D		
	λ (f/yr)	r (hr)	U (hr/yr)	λ (f/yr)	r (hr)	U (hr/yr)	λ (f/yr)	r (hr)	U (hr/yr)	λ (f/yr)	r (hr)	U (hr/yr)
Section												
1	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52	0.13	4	0.52
2	0.46	0.5	0.23	0.46	4	1.84	0.46	4	1.84	0.46	4	1.84
3	0.39	0.5	0.2	0.39	0.5	0.2	0.39	4	1.56	0.39	4	1.56
4	0.26	0.5	0.13	0.26	0.5	0.13	0.26	0.5	0.13	0.26	4	1.04
Distributor												
A	4.16	6	24.96	0.42	0.5	0.21	0.42	0.5	0.21	0.42	0.5	0.21
B	1.12	0.5	0.56	11.17	10	111.7	1.12	0.5	0.56	1.12	0.5	0.56
C	1.08	0.5	0.54	1.08	0.5	0.54	10.75	11	118.25	1.08	0.5	0.54
D	1.14	0.5	0.57	1.14	0.5	0.57	1.14	0.5	0.57	11.4	13	148.2
Total	**8.74**	**3.17**	**27.71**	**15.05**	**7.69**	**115.71**	**14.67**	**8.43**	**123.64**	**15.26**	**9.99**	**152.56**

The values of SAIFI,SAIDI, CAIDI, and ENS are calculated by using equation (1) (2), (3) and (4). And result are 13.43 interruption/customer/yr, 104.91 h/customer/ yr, 7.81 h/customer interruption/ yr and 4416.71 MWh/yr.

Comparison of Energy Not Supply (Ens) Value for Without Protective Devices and Fuse

Table 6 Energy Not Supply (ENS) for Normal State

Feeder	Failure Rate (f/ yr)	Outage Time (hr/ yr)	ENS (MWhr/ yr)
1	38.72	10.54	448.92
2	38.72	10.54	3672.98
3	38.72	10.54	6121.63
4	38.72	10.54	6937.85

Table 7 Energy Not Supply (ENS) Improvement with Fuse

Feeder	Failure Rate (f/ yr)	Outage Time (h/ yr)	ENS (MWh/ yr)
1	5.4	5.54	32.91
2	12.41	9.4	1049.89
3	11.99	10.28	1848.86
4	12.64	12.12	2604.35

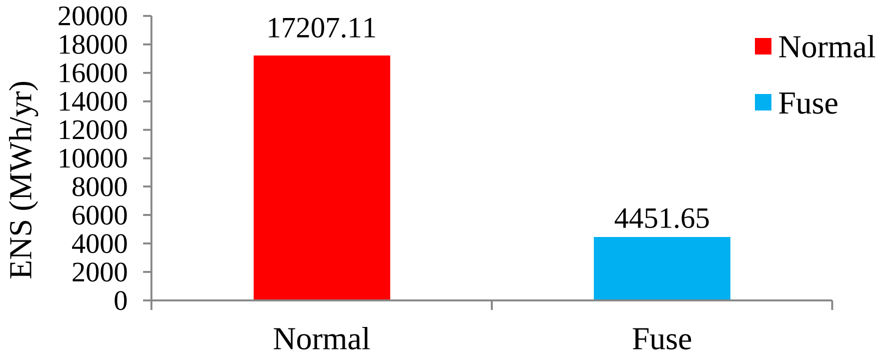

Figure 6 Comparison of ENS between Normal and Fuse

Comparison of Ens Value For Without Protective Devices and Disconnecting Switches

Table 8 Energy Not Supply (ENS) Improvement with Disconnecting Switches

Feeder	**Failure Rate (f/ yr)**	**Outage Time (h/ yr)**	**ENS (MWh/ yr)**
1	5.4	4.82	28.63
2	12.41	9.22	1029.78
3	11.99	10.2	1834.47
4	12.64	12.12	2609.35

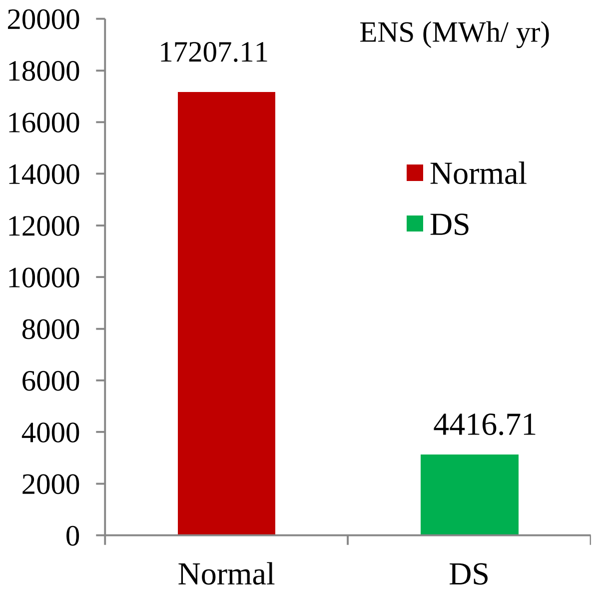

Figure 7 Comparison of ENS between Normal and Disconnecting Switches

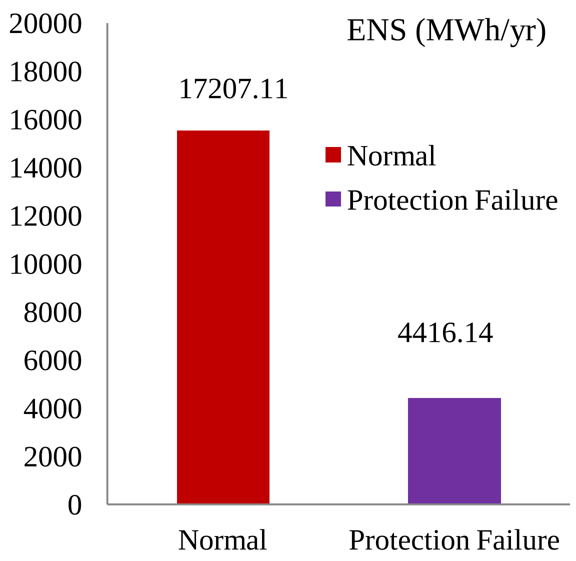

Figure 8 Comparison of ENS between Normal and Protection Failure

Comparison of Ens Value For Without Protective Devices and 90% Protection Failure Rate

Table 9 Energy Not Supply (ENS) Improvement with 90% Protection Failure Rate

Feeder	Failure Rate (f / yr)	Outage Time (h / yr)	ENS (MWh / yr)
1	8.74	3.17	30.48
2	15.05	7.69	1041.61
3	14.67	8.43	1855.02
4	15.26	9.99	2591.61

As above calculation, using protective devices, e.g. disconnecting switches and fuse decrease ENS (Energy not supplied) than calculation without using protective devices

Result Data for Reliability Indices

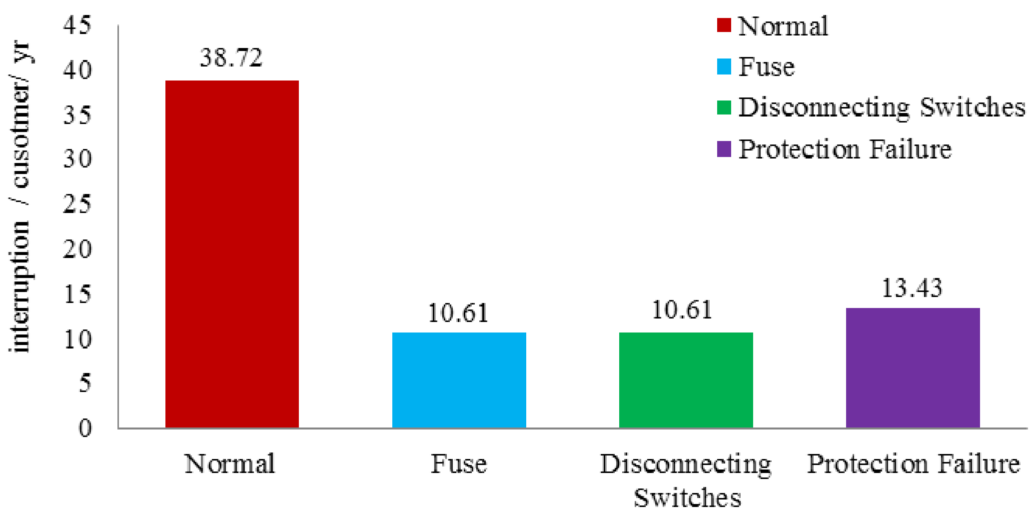

Figure 9 Result Comparisons for SAIFI

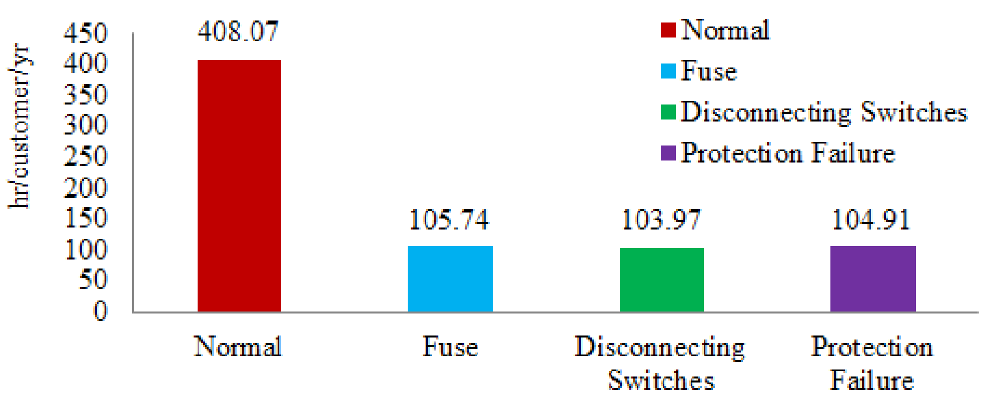

Figure 10 Result Comparisons for SAIDI

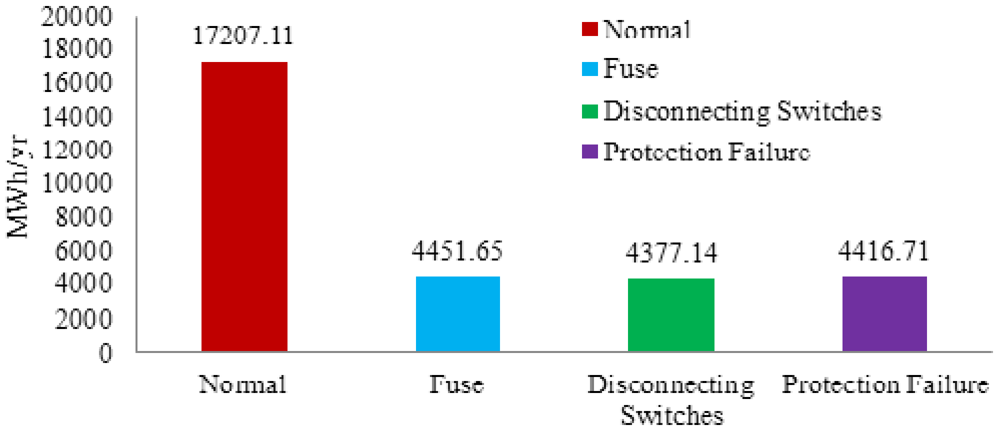

Figure 11 Result Comparisons for ENS

Discussion

In this research, the impact of protective devices installation, e.g, disconnecting switch and fuse on distribution system reliability is analyzed using hand calculations and hence fully understand reliability models and evaluation techniques. The reliability index of ENS, energy not supply is mainly evaluated and shown the comparison of ENS values with and without protective device. And then, the method that is the least value of ENS is chosen to improve the distribution using analytical method.

Conclusion

The reliability level of the system is computed after analyzing the real condition of the Shwe Sar Yan primary substation from December 2017 to December 2018. According to results, the values of ENS are as different as the protective devices which are used for reliability improvement and it is focused to check the condition of system reliability. Therefore, it can be found to get the most reliable method in distribution system. Shwe Sar Yan substation supplies the electricity to Tagontine, Pyin Oo Lwin, Shwelyanbo, Patheingyi, Chan Mya Tharsi and Pyi Kyi Tagon which are the large regions of Mandalay. There are many industrial zones and customers in it. So, the more outage, much indirect costs the customers impose. If the distribution networks will not be fully protected, interruptions will be occurred frequently.

Acknowledgement

The author would like to express her profound gratitude to the Department of Higher Education , Ministry of Education, Myanmar , for provision of opportunity to do this research and Myanmar Academy of Arts and Science for allowing to present this paper.

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