RELIABILITY ANALYSIS AND MAINTENANCE PLANING OF MODERN 132 KV GRID SUB-STATION

Irshad Alam[1], Surya Deo Choudhary[2], Dr. Md. Fakhruddin Ansari[3], Rajeev Kumar [4]

[1, 3]Department of Electrical Engineering, BIT Sindri, Dhanbad, (India)

[2]Department of Electronics & Communication Engineering, DAVIET Daltonganj, (India)

[4]Department of Electronics & Communication Engineering, RIT Koderma, (India)

ABSTRACT

With the confirmed rapid development of electricity supply, grid sub-station play very important role in power transmission, interconnecting link between power station and consumer. It can be standardized of their voltage and KVA rating arrangement of switching factor. This paper includes the general introduction of grid sub-station, short description of different equipments in a grid sub-station, the fundamentals of failure prediction techniques derived from reliability engineering. It provides ground for treatment of field failure data for studying the various performances of the GSS equipment. Some well known failure distributions along with mathematical expression also include facilitating the study of equipment failure behavior. The failure curve may deviate from that of the mathematical model developed from a particular failure distribution curve due to varying nature of physical causes involved with the failure data, still efforts are made in the dissertation to predict the failure of GSS equipment. Feeder comprises of many clearly identifiable and independent sub-systems. Data on failure patterns of the feeders employed in 132 kV grid sub-station in Rajasthan has been collected for the three years and classified components wise. Simple graphical technique has been used for trend analysis. Exponential distribution has been used for the calculation of reliability analysis, as it is mostly suitable for electronics & electrical components. After calculating different reliability parameters in respect of varying working hours for each component of all three feeders, the feeder system reliability has been determined by using the rule of probability .Graph for failure distribution and reliability for the three feeders have been drawn showing the pinpoint critical subsystems/ faults. This part has been mentioned in this paper. In many cases break down hours are due to power failure and not from any fault in the sub-system of the feeders or in the feeders. A maintainability schedule for feeders as well as their sub-systems in the organization concerned has been maintained. In view of reliability of three feeders maintenance aspect can be improved. Includes conclusion and also shows the limitations of research. In this chapter suggestion has been given for future scope of research.

Keywords: KVA, GSS, Feeder, Grid, Sub-Station, Reliability, Break Down.

I. INTRODUCTION

Reliability is a relatively new field whose conception is primarily due to the complexity, Sophistication and automation in modern technology. It has acquired importance due to problems of Maintenance, repair and field failures. The reliability of device/component/system is defined as the probability that when operating under stated environmental conditions, the device/component/system will perform its intended function adequately for a specified interval of time.

General expression for reliability is:

$$R(t) = exp^{-\int_0^t \lambda dt} = exp^{-\lambda t} \qquad \text{where } \lambda \text{ failure rate.}$$

Failure density function: - The failure density function $f_d(t)$ is defined over the time interval $t_i<t<=t_i+\Delta t_i$ as the ratio of number of failures occurring in the interval to the size of original population divided by length of time interval.

$$f_d(t) = \frac{N(t_i) - N(t_i + \Delta t_i) / N_0}{\Delta t_i}$$

Hazard Rate: - The hazard rate over the interval $t_i<t<=t_i+\Delta t_i$ is defined as ratio of number of failures occurring in time interval to the number of survivors at the beginning of time interval, divided by length of the time interval.

$$Z_d(t) = \frac{N(t_i) - N(t_i + \Delta t_i) / N(t_i)}{\Delta t_i}$$

Failure distribution:-The time to failure behaviour of device or component is known as failure distribution. It shows the nature of failure behaviour and helps in quantitative analysis of reliability.The distribution which are in common use are:

- Normal distribution
- Lognormal distribution
- Binomial distribution
- Exponential distribution
- Weibull distribution
- Poisson distribution
- Gamma distribution

All the above distributions I have used Exponetional distribution which is define as, Exponetional distribution function is, $f(x) = \lambda\, e^{-kx}$ $0<X>-\infty$

In the present work we have analyzed the reliability of modern 132KV grid sub- station.

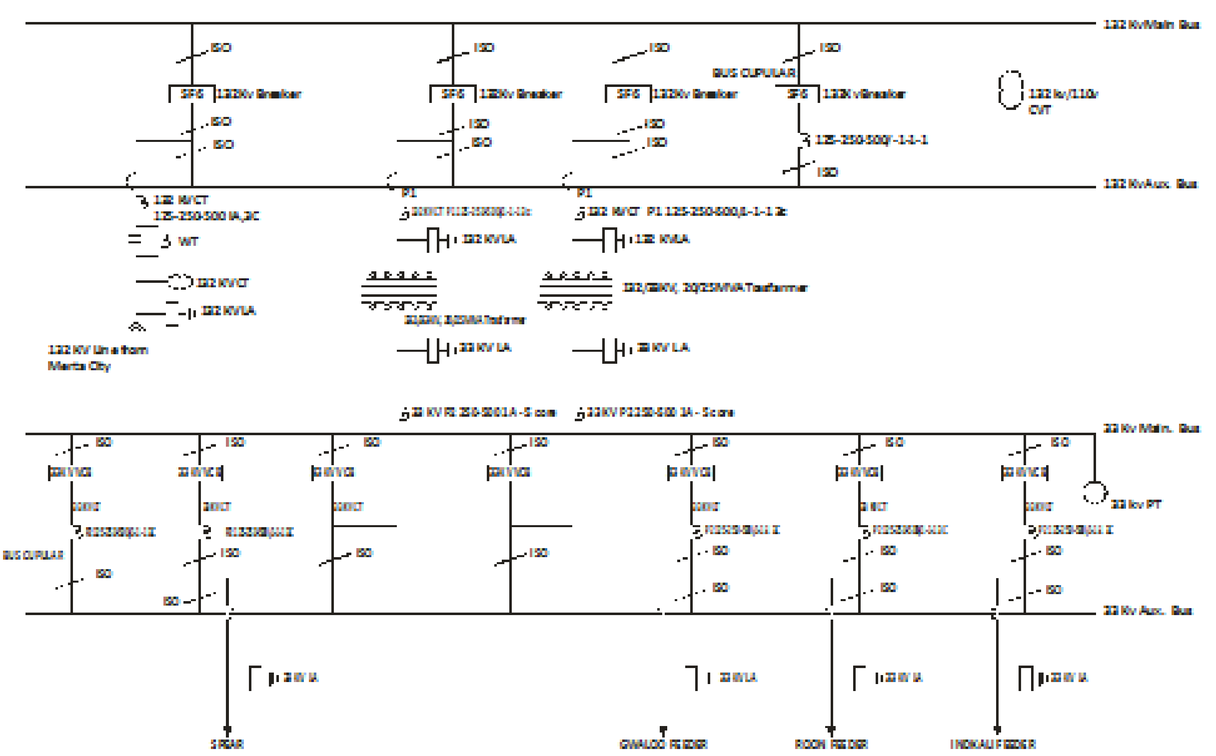
Grid sub-station:- With the confirmed rapid development of electricity supply, grid sub –station play very important role in power transmission. The sub-station is the interconnecting link between power station and consumer. Sub-Station transmit electric power over appreciable distance at high voltage where as it can be economically utilized at comparatively low voltage.

Data for reliability analysis has been collected from 132KV GSS (RVPNL), Roon Rajasthan.

Specifications of High Voltage Grid Sub-Station:-RVPNL is employing following specifications for grid sub-station.

1. Power received through double circuit 132 KV/line.
2. The station has two numbers of 25 MVA, 132/32 KV power Transformers.
3. The fault levels at receiving end are 5000 MV A.
4. Main and transfer bus-bar scheme is required.
5. Neutrals of power transformer are solidly grounded.

SINGLE LINE DIAGRAM OF 132 KV GSS SUB STATION ROON



Incoming Power:-At normal condition, the 132KV GSS RVPNL ROON receive its power from 400KV RVPNL Merta grid sub-station (Rajasthan), at 132KV, 3 phases, 50Hz from Merta to Roon grid sub-station, transmission tower consists of two way of 3-phase conductor (Zebra) from which only one is energized and other is kept as stand by.

Equipments in a Sub-Station:-Following equipments are installed at grid sub-station:

- Transformers
- Isolators
- Bus-bar
- Circuit Breaker
- Current Transformers
- Capacitive Voltage Transformer
- Potential Transformer
- Surge Diverter
- Wave trapper
- Earthing

II. CALCULATION OF FAILURE DENSITY F_D (T), HAZARD RATE (T), FAILURE DISTRIBUTION Z_D (T) AND RELIABILITY (T)

The GSS failure data obtained as mentioned below were used to find out the failure density, hazard rate, failure distribution and reliability of over current, earth fault, shutdown, and load shedding for Gowaloo, Indokli and Roon feeder. The results have been shown in table 3.1 to 3.12.

Comparison of reliability of feeders have been shown in graph

Data for reliability analysis has been taken from 132KV GSS, Roon Rajasthan from July 2008 to July2011and has been tabulated as given below:

Sample calculation- During first 90 days from July 2008 to September2008, Over current fault of Gwaloo feeder, the no of failure is 652.Using reliability models calculation of failure density $F_d(t)$, hazard rate $Z_d(t)$, failure distribution (t), and the reliability is done as shown below using failure data from table 3.1 to 3.4

For first 90 days

$f_d(t)$ = 47/(652*90) = 0.080*10^-3 f/days

$Z_d(t)$ =47/(652*90) = 0.080*10^-3 f/days

$F_d(t)$ = 0.087*90=0.072

$R_d(t)$ =1-0.072=0.927

For next 90 days

$f_d(t) = 35/(652*90) = 0.059*10$^-3 f/days

$Z_d(t) = 35/(652*90) = 0.064*10$^-3 f/days

$F_d(t) = 0.057 + 0.072 = 0.129$

$R_d(t) = 1 - 0.129 = 0.870$

The results obtained in this manner have been tabulated in table 3.1to3.12 for O/C, E/F, S/D and L/S for Gwaloo, Indokli and Roon feeders.

III. TABLES AND GRAPHS

Table 3.1
Gwaloo feeder (over current fault)

Time Interval (In Day)	No. of Failures	Failure Density (10^{-3}F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	47	0.080	0.080	0.072	0.927
90-180	35	0.059	0.064	0.129	0.870
180-270	47	0.080	0.091	0.205	0.794
270-360	90	0.153	1.912	0.353	0.646
360-450	55	0.093	1.411	0.450	0.543
450-540	23	0.039	0.060	0.488	0.511
540-630	32	0.054	1.000	0.538	0.461
630-720	34	0.057	1.160	0.592	0.407
720-810	58	0.098	2.220	0.685	0.314
810-900	70	1.119	3.360	0.802	0.197

Table 3.2
Gwaloo feeder (Earth fault)

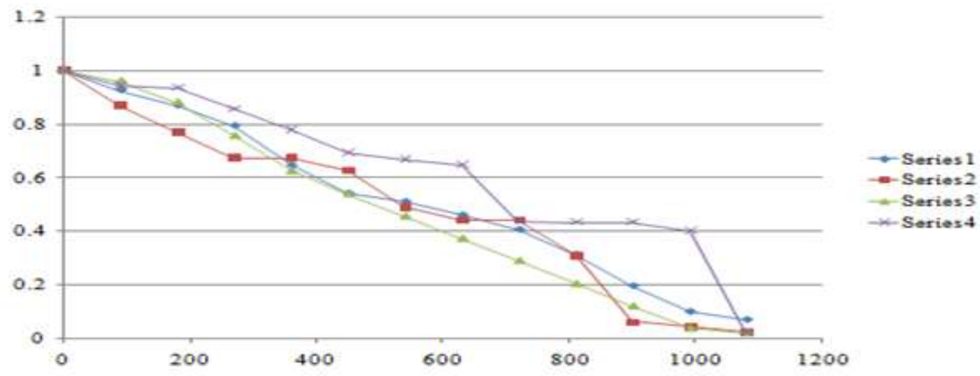
Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	0	0	0	0	1
90-180	3	1.440	1.440	0.130	0.869
180-270	2	0.096	1.110	0.230	0.770
270-360	2	0.096	1.230	0.325	0.674
360-450	1	0.480	0.069	0.372	0.627
450-540	3	1.440	2.222	0.508	0.491
540-630	1	0.048	0.092	0.558	0.442
630-720	0	0	0	0.558	0.442
720-810	3	1.440	2.720	0.688	0.311
810-900	5	0.024	6.140	0.938	0.062
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3.3
Gwaloo feeder (Shudown)

Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	1	0.042	0.042	0.038	0.961
90-180	2	0.085	0.088	0.118	0.882
180-270	3	1.280	1.449	0.243	0.757
270-360	3	1.280	1.666	0.373	0.626
360-450	2	0.085	1.307	0.459	0.540
450-540	2	0.085	1.481	0.542	0.457
540-630	2	0.085	1.700	0.625	0.374
630-720	3	1.280	3.030	0.708	0.291
720-810	2	0.085	2.770	0.794	0.205
810-900	2	0.085	3.703	0.877	0.122
900-990	2	0.085	5.550	0.960	0.039
990-1080	2	0.085	11.111	0.978	0.021

Table 3.4
Gwaloo feeder (Load sheding)

Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Density	Reliability
0-90	13	0.060	0.060	0.054	0.945
90-180	2	0.009	0.099	0.062	0.937
180-270	19	0.080	0.950	0.142	0.857
270-360	17	0.070	0.930	0.219	0.780
360-450	19	0.080	1.135	0.305	0.694
450-540	6	0.020	0.399	0.332	0.667
540-630	4	0.018	0.270	0.349	0.650
630-720	49	2.290	3.460	0.559	0.440
720-810	1	0.004	0.010	0.564	0.435
810-900	0	0.000	0.000	0.564	0.435
900-990	8	0.030	0.830	0.597	0.402
990-1080	99	4.640	11.111	0.978	0.021



Comparison of reliability of gwaloo feeder

Table 3.5
Indokli feeder (over current fault)

Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	41	0.080	0.080	0.079	0.920
90-180	19	0.040	0.046	0.119	0.880
180-270	40	0.080	0.097	0.199	0.800
270-360	60	1.290	1.610	0.325	0.674
360-450	45	0.090	1.412	0.424	0.575
450-540	29	0.060	1.042	0.485	0.514
540-630	31	0.070	1.230	0.548	0.451
630-720	54	1.160	2.409	0.659	0.340
720-810	72	1.550	4.102	0.815	0.185
810-900	54	1.160	4.870	0.937	0.062
900-990	29	0.060	4.669	0.956	0.043

Table 3.6
Indokli feeder (Earth fault)

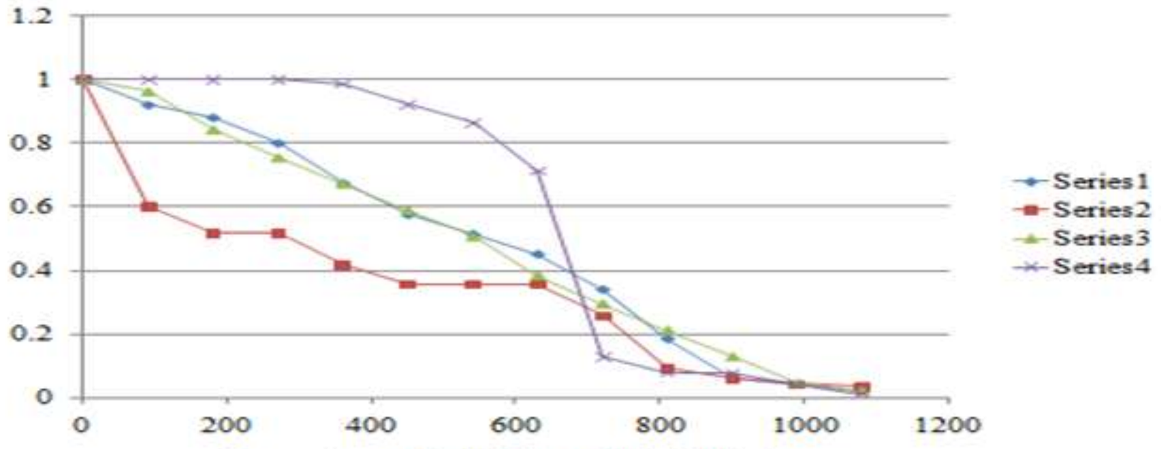
Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	8	3.864	3.864	0.347	0.652
90-180	1	0.483	0.740	0.413	0.586
180-270	0	0	0	0.413	0.586
270-360	2	0.966	1.587	0.518	0.481
360-450	1	0.480	0.925	0.565	0.434
450-540	0	0	0	0.565	0.434
540-630	0	0	0	0.565	0.434
630-720	2	0.966	2.020	0.660	0.339
720-810	3	1.440	3.303	0.802	0.197
810-900	2	0.966	3.703	0.902	0.098

Table 3.7
Indokli feeder (shudown)

Time Interval (In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Density	Reliability
0-90	1	0.040	0.040	0.038	0.962
90-180	3	1.280	1.330	0.158	0.842
180-270	2	0.080	1.010	0.244	0.755
270-360	2	0.080	1.111	0.327	0.672
360-450	2	0.080	1.234	0.410	0.589
450-540	2	0.080	1.380	0.493	0.506
540-630	2	0.080	1.587	0.618	0.384
630-720	3	1.280	2.777	0.704	0.295
720-810	2	0.080	2.469	0.787	0.212
810-900	2	0.080	3.174	0.870	0.129
900-990	2	0.080	4.444	0.953	0.046
990-1080	3	1.280	11.111	0.978	0.021

Table 3.8
Indokli feeder (Load Sheding)

Time Interval(In Day)	No. of Failures	Failure Density (10^{-3} F/D)	Hazard Rate (10^{-3} F/D)	Failure Distribution	Reliability
0-90	0	0	0	0	1
90-180	0	0	0	0	1
180-270	0	0	0	0	1
270-360	1	0.010	0.010	0.130	0.986
360-450	5	0.070	0.070	0.079	0.920
450-540	4	0.050	0.060	0.135	0.864
540-630	11	1.600	1.851	0.287	0.712
630-720	38	5.550	7.676	0.871	0.128
720-810	2	0.020	1.307	0.923	0.076
810-900	0	0	0	0.923	0.076
900-990	11	1.600	8.148	0.954	0.040
990-1080	4	0.050	11.111	0.984	0.010



Comparison of reliability of indokli feeder

In comparisons graph Series 1, series 2, series 3and series 4 represent curve of reliability of over current fault, Earth fault, shudown and load sheding respectively.

Calculation of GSS Reliability:

From the above table

Average Reliability of over current fault of Gwaloo feeder R_1=0.486

Average Reliability of Earth fault of Gwaloo feeder R_2=0.479

Average Reliability of shudown of Gwaloo feeder R_3=0 .439

Average Reliability of load sheding of Gwaloo feeder R_4=0.605

From the series theory of system Reliability, reliability of Gwaloo feeder

$R_G = R_1 R_2 R_3 R_4$

R_G =0.486*0.479*0.439*0.605=0.061 .... (1)

Similarly, Average Reliability of over current fault of Indokli feeder R_5=0.455

Average Reliability of Earth fault of Indokli feeder R_6=0.362

Average Reliability of shudown of Indokli feeder R_7=0.451

Average Reliability of load sheding of Indokli feeder R_8=0.561

From the series theory of system Reliability, reliability of Indokli feeder

$R_I = R_5 R_6 R_7 R_8$

R_I = 0.455*0.362*0.451*0.561=0.041 .... (2)

Similarly, Average Reliability of over current fault of Roon feeder R_9=0.536

Average Reliability of Earth fault of Roon feeder R_{10}=0.547

Average Reliability of shudown of Roon feeder R_{11}=0. 418

Average Reliability of load sheding of Roon feeder R_{12}=0.507

From the series theory of system Reliability, reliability of Roon feeder

$$R_R = R_9\, R_{10}\, R_{11}\, R_{12}$$

$$R_R = 0.536*0.547*0.418*0.507=0.062 \quad .... (3)$$

According to parallel theory of system Reliability,

Reliability of GSS=1-[(1- R_G)* (1- R_I)* (1- R_R)]

Reliability of GSS=1-[(1- 0.061)* (1- 0.041)* (1- 0.062)]

Reliability of GSS=1-0.844=0.156

From above calculation it is observed that Reliability of indokli feeder is lower in respect of reliability Roon and Gwaloo feeder. The overall reliability of grid sub-station is much lower.

There for it required to improve the reliability of GSS.

The reliability of GSS can be improved by maintenance of grid equipment and line.

Maintenance that is performed can be dividing in two parts:

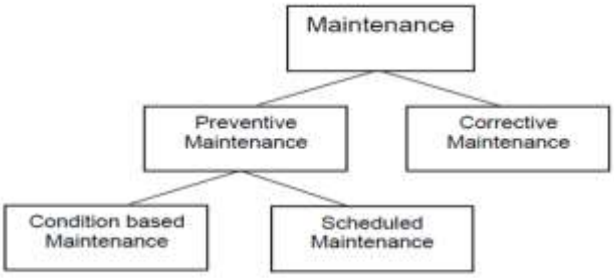
Corrective maintenance: - Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function. This type of maintenance is often called repair and is carried out after the failure of a component.

Preventive maintenance: - Maintenance is carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of functioning of an item. The preventive maintenance is performed regularly to postpone failures or to prevent failures from occurring.

Further preventive maintenance is also divided in two categories:

Scheduled maintenance: - Preventive maintenance carried out in accordance with an established time schedule or established number of units of use .Scheduled maintenance means that preventive maintenance is carried out in accordance with an established time schedule.

Condition based maintenance:- Preventive maintenance based on performance and/or parameter monitoring and the subsequent actions. Performance and parameter monitoring may be scheduled on request or continuous.



IV. FUTURE WORKS

- Reliability study of feeders were carried out by analysis of sub systems wise to failures and time .It can be further extended to predict the failure pattern of sub systems from data collected on component wise by rigorously examine the logical manner in which they are connected .This may lead to more accurate conclusions.
- Data were collected for three feeders .The study may be extended for data collection from other few grids. This will reflect more accurate failure pattern as data may depend upon working conditions and maintenance schedules.
- In this dissertation, only maintenance schedules for different feeders and their sub systems have been mentioned. It is further suggested to analyze the maintainability pattern by taking different models.
- In the dissertation, only exponationl distribution has been taken. Work may be extended for other distributions and different types of test may be done.

V. CONCLUSION

Several conclusions have been drowning from the study carried out on feeders in following way:

- Several identifiable system different feeders are arranged in series configuration while three feeders seem to be arranged in parallel configuration.
- During data arrangement, some of failures requiring comparatively very large time to repair have been considered as a major repair power failure. This is not taken into consideration while studying the reliability. However in this thesis, the time length has been increased for calculation of reliability.
- Through many distributions are used for reliability calculation, probability of approximating the exponential is more suitable.
- For three feeders Indokli feeder has poor reliability in comparison with Roon and Gwaloo feeders.
- In four types of faults, shutdown plays vital role in decreasing reliability of feeders.

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