Analysis of 20 kV Power Distribution System Reliability using the Section Technique

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Abstract. Electrical power is one of the basic human needs in life. The development of electrical power, as time progresses, requires power systems to have a better level of reliability. This research aims to know the level of 20 kV power distribution system reliability at feeder. The feeder analyse is a PKW feeder from PLN Area Bandung Utara. The level of reliability is obtained from index SAIDI (System Average Interruption Duration Index) and index SAIFI (System Average Interruption Frequency Index). This research uses the method of Section Technique. From the addition on each section’s index, the value of SAIDI is 3.112934347 hour/year and SAIFI is 1.1152 times/year.

1. Introduction

Power distribution system has a role on well distribution of electricity. Electricity energy is very important necessity for human activity. Usually, reliability of distribution power can be defined as ability of a system to give enough supply of power with satisfying quality [1]. Therefore, power distribution system should have a good reliability so human need of electricity power won’t be disturbed.

The level of reliability can be disturbed by some obstacles like natural ecosystem, human activity, old instruments, even animals around the power distribution feeder [2]. If power distribution feeder often get a problem, the quality of power distribution will worsen [3]. There are known indexes to use for knowing the reliability of power distribution such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index).

There are some factor that should be known and counted before analyzing the level of reliability, which is frequency of failure and duration of the failure. In this research, author is using Section Technique method for process data which is obtained and produced a reliability level. This method is similar to FMEA (Failure Mode and Effect Analysis) method which counts reliability of a system based on effects of failure with the system and how it will affect the load point. Consequences from individual failure of an instrument will systematically identified with analysis on what happened when problem occurs [4]. But on the method used by author that the calculation will be separated on some sections. After that it will be compared with SPLN 59:1985.
2. Reliability on power distribution

2.1. Definition and basic theory of reliability
Reliability is defined as probability of an instrument of system to be able to function as it supposed to be, during some time and under some work conditions. So, reliability on distribution system is probability of distribution system for be able to work functionally under certain time range and under certain work conditions [5].

2.2. Reliability on distribution of power
Level of distribution system’s reliability can be measured from how far the power distribution continuously occurred to consumers without power outage. Along with time, there are growing numbers of power load which can be seen on growing numbers of industrial site, economic growth, also new housing that demanding a high reliability level over time [5].

2.3. Calculation on reliability index

2.3.1. Average failure rate ($\lambda_i$). Average failure rate is frequency of failure on each component that will affect load point [4].
\[
\lambda_s = \sum \lambda_i
\]

Where $\lambda_i$ is Failure Rate on load point $i$.

2.3.2. Average annual outage time ($U_s$). Average annual outage time is duration on power outage that happens on each component that will affect load point [4].
\[
U_s = \sum \lambda_i \cdot r_i
\]

Where $\lambda_i$ is Failure rate on load point $i$ and $r_i$ is Repair time or Switching.

2.3.3. System Average Interruption Duration Index (SAIDI). SAIDI is index that used to calculate level of reliability where the index counts the median on outage duration that inflicted on customer in certain period of time [6].
\[
SAIDI = \frac{\sum U_i N_i}{\sum N}
\]

Where:
- $N_i$ = Number of consumer on load point
- $U_i$ = Duration of instrument failure on load point
- $N$ = Number of consumer on feeder

2.3.4. System Average Interruption Frequency Index (SAIFI). SAIFI is index that used to calculate level of reliability where the index counts the median on outage frequency that inflicted on customer in certain period of time [6].
\[
SAIFI = \frac{\sum \lambda_i N_i}{\sum N}
\]

Where:
- $N_i$ = Number of consumer on load point
- $\lambda_i$ = frequency of failure rate on load point
- $N$ = Number of consumer on feeder

2.3.5. SPLN 59:1985. Standard that used for Failure rate and repair time on power distribution system instrument 20kV is SPLN 59:1985, listed at Table 1.
Table 1. SPLN 59:1985.

| Component               | λ (Failure Rate) | \(ri\) (Repair Time) | \(ri\) (Switching Time) |
|-------------------------|------------------|-----------------------|-------------------------|
| Distribution Trafo      | 0,005/unit/year  | 10                    | 0,15                    |
| Circuit Breaker         | 0,004/unit/year  | 10                    | 0,15                    |
| Recloser/Sectionalizer  | 0,003/unit/year  | 10                    | 0,15                    |
| Overhead line           | 0,2/km/year      | 3                     | 0,15                    |
| Underground Cable       | 0,07/km/year     | 10                    | 0,15                    |

3. Research methods

Research on Reliability of power distribution system 20 kV on PLN Area Bandung Utara PKW feeder using descriptive analysis method, which is research method that uses collective data directly and analyze to make a conclusion that can be used as base for consideration on good power distribution, and result of maintenance can be reference on fixing system performance on power distribution to consumer.

Analysis used is using section technique method which is a method that evaluate reliability by dividing system on smaller section to minimalize error on shorter time. This method on evaluating reliability is based on how failure of an instrument affects system operation. Effects or consequences from individual instrument’s failure will systematically identified with analysis on what happened if error happened. Then each of instrument failure will be analyzed on each load point using approach from bottom to top that considered on one failure at a time [1]. Figure 1 shows the SAIDI and SAIFI calculation steps using Section Technique Method.

![Figure 1. Steps of section technique method.](image-url)
4. Results and discussion

4.1. Single line diagram of feeder

On this Reliability level analysis the data used from one feeder from Bandung Utara that is PKW Feeder. This feeder supplied from Dago Bengkok Electric Power Substation. To analyses component at PKW feeder needs a single line feeder diagram as shown in Figure 2.

![Single line diagram PKW feeder.](image)

PKW feeder has 14 load points in form of distribution transformator and 2 sectionalizer. With 1,796 consumer, total length of feeder is 6,482 kms. This PKW feeder will be devided on 2 section. Total of consumer data on each analyzed feeder load point can be seen on Table 2 and Table 3.

| Load Point | Power Substation Distribution | Total Consumer |
|------------|-------------------------------|----------------|
| 1          | PKWG                          | 1              |
| 2          | PKWF                          | 330            |
| 3          | PKW                           | 330            |
| 4          | TKGW                          | 53             |
| 5          | PKWA                          | 54             |
| 6          | PKWB                          | 36             |
| 7          | PKWD                          | 67             |
| 8          | PKWE                          | 27             |
Table 3. Total consumer on load point PKW feeder section 2.

| No | Load Point | Power Substation Distribution | Total Consumer |
|----|------------|-------------------------------|----------------|
| 1  | 9          | PKWC                          | 28             |
| 2  | 10         | DCLC                          | 1              |
| 3  | 11         | DCL                           | 550            |
| 4  | 12         | DCLB                          | 120            |
| 5  | 13         | PDV                           | 26             |
| 6  | 14         | DCLA                          | 173            |

PKW feeder is a feeder that doesn’t have a lot of line. Total length of 6,482 kms feeder is divided into 21 lines. Data on length of each line on PKW feeder can be seen on Table 4.

Table 4. Channel length.

| Channel | Length (Kms) | Overhead Line | Underground Cable |
|---------|--------------|---------------|-------------------|
| Line 1  | 0.57         |               |                   |
| Line 2  | 0.375        |               |                   |
| Line 3  | 0.155        |               |                   |
| Line 4  | 0.153        |               |                   |
| Line 5  | 0.09         |               |                   |
| Line 6  | 0.095        |               |                   |
| Line 7  | 0.127        |               |                   |
| Line 8  | 0.253        |               |                   |
| Line 9  | 0.398        |               |                   |
| Line 10 | 0.253        |               |                   |
| Line 11 | 0.52         |               |                   |
| Line 12 | 0.214        |               |                   |
| Line 13 | 0.223        |               |                   |
| Line 14 | 0.253        |               |                   |
| Line 15 | 0.48         |               |                   |
| Line 16 | 0.132        |               |                   |
| Line 17 | 0.389        |               |                   |
| Line 18 | 0.41         |               |                   |
| Line 19 | 0.314        |               |                   |
| Line 20 | 0.285        |               |                   |
| Line 21 | 0.793        |               |                   |
| **Total** | **1.49**   | **4.992**     |                   |

4.2. Reliability system index analysis using section method technique

On reliability system index analysis in PKW feeder is divided on two section. This calculation is using failure rate and recovery time on 20kV distribution network standard based on SPLN 59:1985[1]. Calculation of reliability on each section is explained on below.

4.2.1. Section 1. To know failure rate and recovery rate on system can be seen on failure mode list. Failure mode list for section 1 can be seen on Table 5.
Table 5. Failure mode list section 1.

| Instrument Data | Load Point Affected by Repair Time | Load Point Affected by Switching Time |
|-----------------|-----------------------------------|--------------------------------------|
| Number of failure | Instrument | Load Point | |
| 1 | CB | LP 1 – LP 14 | - |
| 2 | T1 | LP 1 | - |
| 3 | T2 | LP 2 | - |
| 4 | T3 | LP 3 | - |
| 5 | T4 | LP 4 | - |
| 6 | T5 | LP 5 | - |
| 7 | T6 | LP 6 | - |
| 8 | T7 | LP 7 | - |
| 9 | T8 | LP 8 | - |
| 10 | L1 | LP 1 – LP 14 | - |
| 11 | L2 | LP 1 – LP 14 | - |
| 12 | L3 | LP 1 – LP 14 | - |
| 13 | L4 | LP 1 – LP 14 | - |
| 14 | L5 | LP 1 – LP 14 | - |
| 15 | L6 | LP 1 – LP 14 | - |
| 16 | L7 | LP 1 – LP 14 | - |
| 17 | L8 | LP 1 – LP 14 | - |
| 18 | L9 | LP 1 – LP 14 | - |
| 19 | L10 | LP 1 – LP 14 | - |
| 20 | L11 | LP 1 – LP 14 | - |
| 21 | L12 | LP 1 – LP 14 | - |

Next to count frequency on failure and duration on failure in each load point. One sample case took from LP1. LP1 score gained from adding number of instrument failure by multiply failure rate of overhead line/underground cable with length of the line according to (1) formula. U LP1 score can also be gained by multiplying number of λ with repair time which can affect LP1 according to (2) formula. These can be seen on Table 6.

Table 6. Calculation of λ and U LP 1 section 1.

| Component | Failure rate of component | Length of cable | Failure rate (λ) | Repair time (hr) | Switching time (hr) | U (λ/hr) |
|-----------|---------------------------|-----------------|------------------|-----------------|---------------------|---------|
| CB        | 0.004                     | 0.004           | 10               | 0.04            |                     |         |
| T1        | 0.003                     | 0.001           | 10               | 0.02            |                     |         |
| L1        | 0.07                      | 0.057           | 10               | 0.09            |                     |         |
| L2        | 0.2                       | 0.375           | 10               | 0.25            |                     |         |
| L3        | 0.17                      | 0.155           | 10               | 0.15            |                     |         |
| L4        | 0.07                      | 0.153           | 10               | 0.17            |                     |         |
| L5        | 0.2                       | 0.09            | 10               | 0.15            |                     |         |
| L6        | 0.2                       | 0.065           | 10               | 0.15            |                     |         |
| L7        | 0.2                       | 0.127           | 10               | 0.15            |                     |         |
| L8        | 0.2                       | 0.253           | 10               | 0.15            |                     |         |
| L9        | 0.2                       | 0.098           | 10               | 0.15            |                     |         |
| L10       | 0.2                       | 0.253           | 10               | 0.15            |                     |         |
| L11       | 0.2                       | 0.098           | 10               | 0.15            |                     |         |
| L12       | 0.2                       | 0.214           | 10               | 0.15            |                     |         |

TOTAL 0.25346 TOTAL 2.096
On load point 1, condition occurred at all the instrument only repair time condition, which means no instrument on switching time condition. Therefore to seek value of U on table 6 only repair time condition only. After getting the number of λ and U on each load point, next is to count the value of SAIDI and SAIFI on section 1. Counting the value of SAIDI is using formula (3) and to count the value of SAIFI is using formula (4). The result of calculation of SAIDI and SAIFI value is can be seen on Table 7.

Table 7. SAIDI and SAIFI score section 1.

| Load point | λLP | ULP | Total of customer | SAIDI | SAIFI |
|------------|-----|-----|------------------|-------|-------|
| 1          | 0.5546 | 2.0996 | 1          | 0.001169 | 0.000298 |
| 2          | 0.5546 | 2.0996 | 330        | 0.385784 | 0.0983863 |
| 3          | 0.5546 | 2.0996 | 330        | 0.385784 | 0.0983863 |
| 4          | 0.5546 | 2.0996 | 53         | 0.061992 | 0.019014 |
| 5          | 0.5546 | 2.0996 | 54         | 0.0651283 | 0.0168996 |
| 6          | 0.5546 | 2.0006 | 36         | 0.020855 | 0.017831 |
| 7          | 0.5546 | 2.0996 | 67         | 0.0783258 | 0.019754 |
| 8          | 0.5546 | 2.0996 | 27         | 0.011561 | 0.008493 |
| 9          | 0.5046 | 2.0456 | 28         | 0.0319537 | 0.00827 |
| 10         | 0.5046 | 2.0456 | 1          | 0.0011412 | 0.0002954 |
| 11         | 0.5046 | 2.0406 | 550        | 0.6276613 | 0.162446 |
| 12         | 0.5046 | 2.0496 | 120        | 0.1369443 | 0.0354428 |
| 13         | 0.5046 | 2.0496 | 26         | 0.0298713 | 0.0078793 |
| 14         | 0.5046 | 2.0456 | 173        | 0.1074291 | 0.0510956 |
| TOTAL      |       |       | 1796      | 2.0746  | 0.5326 |

From calculation result, the scores of SAIDI and SAIFI on section 1 are respectively 2.0746 hour/year and 0.5326 times/year.

4.2.2. Section 2. List of failure mode on section 2 can be seen on Table 8.

Table 8. Mode failure list section 2.

| Instrument Data | Load Point Affected by Repair Time | Load Point Affected by Switching Time |
|-----------------|-----------------------------------|--------------------------------------|
| Number of failures | Instrument | LP 9 | LP 10 | LP 11 | LP 12 | LP 13 | LP 14 | LP 9 – LP 14 | LP 1 | LP 2 | LP 14 | LP 1 – LP 13 | LP 9 – LP 14 | LP 1 | LP 1 – LP 8 | LP 9 – LP 14 | LP 1 | LP 1 – LP 8 |
| 1               | T9         | LP 9 | -     | -     | -     | -     | -     | LP 9 – LP 14 | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 2               | T10        | LP 10 | -     | -     | -     | -     | -     | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 3               | T11        | LP 11 | -     | -     | -     | -     | -     | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 4               | T12        | LP 12 | -     | -     | -     | -     | -     | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 5               | T13        | LP 13 | -     | -     | -     | -     | -     | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 6               | T14        | LP 14 | -     | -     | -     | -     | -     | - | - | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 7               | S1         | LP 9 – LP 14 | - | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 8               | S2         | LP 14 | -     | -     | -     | -     | -     | LP 9 – LP 14 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 9               | L13        | LP 9 – LP 14 | - | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 10              | L14        | LP 9 – LP 14 | - | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 11              | L15        | LP 9 – LP 14 | - | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
| 12              | L16        | LP 9 – LP 14 | - | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 | LP 9 – LP 14 | LP 1 | LP 1 |
Table 8. Cont.

| Number of failures | Instrument | Load Point Affected by Repair Time | Load Point Affected by Switching Time |
|--------------------|------------|-----------------------------------|---------------------------------------|
| 13                 | L17        | LP 9 – LP 14                      | LP1-LP8                               |
| 14                 | L18        | LP 9 – LP 14                      | LP1-LP8                               |
| 15                 | L19        | LP 9 – LP 14                      | LP1-LP8                               |
| 16                 | L20        | LP 9 – LP 14                      | LP1-LP8                               |
| 17                 | L21        | LP 14                             | LP1-LP13                              |

Next is to calculate failure frequency value and duration of failure on each load point. This can be seen on Table 9.

Table 9. $\lambda$ and $U$ LP 1 calculation section 1.

| Component | Failures of component | Length (meter) | $\lambda$ (failure) | Repair time (hr) | Switching time (hr) | $U$ (hour) |
|-----------|-----------------------|----------------|---------------------|------------------|---------------------|------------|
| I1        | 0.003                 | 0.033          | 0.001               | 0.05             | 0.0045              |
| I2        | 0.003                 | 0.033          | 0.001               | 0.05             | 0.0045              |
| L13       | 0.2                   | 0.233          | 0.046               | 3                | 0.0069              |
| L14       | 0.2                   | 0.233          | 0.046               | 3                | 0.0069              |
| L15       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L16       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L17       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L18       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L19       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L20       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |
| L21       | 0.07                  | 0.073          | 0.016               | 10               | 0.0079              |

After the value of $\lambda$ and $U$ on each load point, next is to calculate value of SAIDI and SAIFI on section 2. The result of SAIDI and SAIFI calculation on section 2 can be seen on Table 10.

Table 10. SAIDI and SAIFI score section 2.

| Load point | $\lambda_P$ | $U_P$ | Total of customer | SAIDI | SAIFI |
|------------|-------------|-------|-------------------|-------|-------|
| 1          | 0.58224     | 0.087336 | 1                 | 4.86281E-03 | 0.000524187 |
| 2          | 0.58224     | 0.087336 | 330               | 0.016049261 | 0.106981737 |
| 3          | 0.58224     | 0.087336 | 23                | 0.002577287 | 0.017181915 |
| 4          | 0.58224     | 0.087336 | 34                | 0.002653935 | 0.017506781 |
| 5          | 0.58224     | 0.087336 | 53                | 0.00323008   | 0.021726035 |
| 6          | 0.58224     | 0.087336 | 67                | 0.00323008   | 0.021726035 |
| 7          | 0.58224     | 0.087336 | 84                | 0.00323008   | 0.021726035 |
| 8          | 0.58224     | 0.087336 | 100               | 0.00323008   | 0.021726035 |
| 9          | 0.58224     | 1.00956   | 100               | 0.00323008   | 0.021726035 |
| 10         | 0.58224     | 1.00956   | 100               | 0.00323008   | 0.021726035 |
| 11         | 0.58224     | 1.00956   | 100               | 0.00323008   | 0.021726035 |
| 12         | 0.58224     | 1.00956   | 100               | 0.00323008   | 0.021726035 |
| 13         | 0.58224     | 1.00956   | 100               | 0.00323008   | 0.021726035 |
| 14         | 0.58224     | 2.37812   | 173               | 0.259072806   | 0.055084365 |

TOTAL 1796 1.033834857 0.58224
From the calculation above, the value on SAIDI and SAIFI are 1.038334347 hour/year and 0.58224 times/year respectively. After gained value on reliability index for each section, the reliability index can be gained by adding each value from each section as can be seen on Table 11.

Table 11. Analysed feeder reliability index.

| Section | SAIDI     | SAIFI     |
|---------|-----------|-----------|
| 1       | 2.0746    | 0.53296   |
| 2       | 1.038334347 | 0.58224  |
| TOTAL   | 3.112934347 | 1.1152    |

From the addition on each section’s index, the value of SAIDI and SAIFI are 3.112934347 hour/year and 1.1152 times/year respectively. This result will be maximum limit on reliability.

SAIDI and SAIFI value can be compared with other SAIDI and SAIFI value from PT. PLN rayon Bandung Utara on year 2017, where SAIDI value is 0.0567 hour/year and SAIFI value is 0.0875 times/year. It can be seen from SAIDI and SAIFI value on PKW feeder is reliable because it has value below the maximum reliability limit.

5. Conclusions
From the result of calculation on this research, can be concluded that good value for PKW feeder’s reliability index are 3.112934347 hour/year for SAIDI and 1.1152 times/year for SAIFI. After being compared to PT. PLN Rayon Bandung Utara on 2017 it can be concluded that PKW feeder is reliable.

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