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# Evaluating Performance of Medium High Electricity Distribution through FMECA Method

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**Abstract**

Major electricity distribution falls in medium-high power with 20 kV networks. They serve major industries and residential areas that serve entire customers. Due to its importance, however, these networks dealing with many potential unknown problems; and deliver severe impacts to company revenues. Operating and maintaining medium-high power system are not easy tasks since they involve with unknown and unpredictable disturbances. Any potential distribution may bring down entire networks. So it is important for every utility company to ensure the medium-high power networks properly managed and anticipated to any potential disturbances. The article applies FMECA method to identify and analyse any potential problems that may disturb the power networks. FMECA method has advantages to provide recommendation and systematic preventive steps for network operation and maintenance team. The outcome of the article is expected to be used as a reference for technicians to anticipate the potential problems far before it happens.

**Key words:** Medium-high power networks, range of 20 kV, collaboration team, FMECA method, potential disturbances, recommendation and anticipation.

## 1. INTRODUCTION

Indonesia has enjoyed consistent economic growth for more than 4-5% annually [1]. To maintain this consistent growth, it needs to be supplied with sufficient electricity investment and utilization. To maximize the electricity use, the energy company needs to manage the process of electricity production, delivery and distribution effectively.

One of the most challenges that commonly faced by energy company is to manage the reliability distribution of electricity in medium range power of 20 kV, to serve customer bases such as in industrial and residential areas. Serving these customer bases is not an easy task since there are many disruptions and unknown causes [2], [3]. The common interruptions can take place such as disturbances in electricity generation, transmission, and distribution process. As a result, the blackout is the output of any of those disturbances. The blackout can also happen due to poor plan and maintenance execution, natural disasters, and external factors around the networks.

Several efforts have been introduced as such reviewing and fixing the entire life cycle medium-range power assets such as: planning process, procurement, construction, assets operation, maintenance, repairment, replacement, and disposement of ineffective assets. The article examines the life cycle of medium power range of 20 kV which is the critical point that links source generators to end customers.

The preliminary study from the last 3 years shows the electricity utilization has reached optimal usage, so it needs to find appropriate method to manage it and avoid peak utilization. The article examines the efforts to improve the reliability of medium range power by using the indicator System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI), Index Energy Not Sale (ENS), and disturbance index per 100 km, or known as frequency interruption in medium voltage. Those indicators are vital to be used as reference to simulate the power performance and predict potential disturbances. Those indicators will be further used as an effective maintenance measure to improve overall performance of medium power range.

The article takes a case study of an electricity distribution company located in UP3 branch, North Sumatera, Indonesia, that serves major industrial and residential area. The article applies FMECA method to examine those important indicators above and make some important recommendations for planning and managing medium-high power system.

## 2. THEORETICAL FRAMEWORK

### 2.1. Electricity Maintenance and Failure

Electric power can be easily and efficiently transported to location far from production center and converted into desired forms. The electric power normally utilizes a three-phase alternating current (AC) system that operated by transformers at different voltage levels [2]. The operator system needs to ensure that the process of transmission enables to reduce voltage dips and power losses. The power transportation includes small networks of radial configuration and voltages stepped down to end-user levels [4].

The power transportation mechanism is complex tasks since it involves many internal and external disturbances.

Due to its complexity, the system failures are unavoidable condition whenever the maintenance task is not properly taken place. System failure may take other mean as the function of machines do not reach certain expectations [2]. So, it needs necessary maintenance efforts to increase the system performance and make prediction simulation before the failures take place.

To address those failure issues above, the maintenance tasks should cover comprehensive administrative and technical measures that involves supervision efforts in maintaining and recovering all systems into operation stage [5]. The British Standard Glossary Term defines the maintenance task as a collection of organized activities in maintaining equipment into optimal condition with minimum cost [6].

There are three common types of maintenance to address the performance of the system as follows [7]:

1. Corrective Maintenance (CM). CM relates with event-driven measures that take place with potential condition such as:
    a. Breakdowns. System needs to stop function and restarts whenever it readies.
    b. Emergency. System runs in emergency mode to minimize the risk of failures.
    c. Remedial. Part of system needs remedial action to fix and anticipate potential failures.
    d. Repairs. System needs repairment and
    e. Rebuilds. New system is needed to replace the old ones.
2. Preventive Maintenance (PM). PM can be differentiated into:
    a. Equipment-driven preventive Maintenance. It involves self-scheduled, machine-cued, setting up control limits, status of when system deficient, and requirement conditions.
    b. Predictive Maintenance. Predictive maintenance involves developing to the following activities such as: statistical analysis, trends of failures, vibration monitoring, thermography and ultrasonic observations, and other measures.
    c. Time-driven Maintenance. Time-driven maintenance addresses periodic, fixed intervals, hard time limits, and specific time of failures.
3. Improvement Maintenance (IM). Improvement maintenance applies reliability-driven method that covers the following activities such as: modifications, retrofits, redesign and change order.

2.2. Electricity Distribution

Electricity distribution is influenced by the reliability of several factors such as [8]:

1. Medium power voltage and supply.
2. Quality of transformer.
3. Distribution of high-power voltage, and supply from generator.

The power interruption can be caused by plan and inappropriate plan. The common interruptions are caused by poor design, improper operation, maintenance, and natural disasters. The poor design, operation and maintenance usually related to team coordination and understanding the hidden problems lie in the system [9].

These problems can be cause internally or externally. Many factors contribute to these internal causes such as: poor quality materials, improper technical skills, poor task execution, etc. External causes can be barriers around the networks such as animals passing around the networks and other unidentified objects. The common natural disasters such as: flooding, earthquake, and sudden electricity surge caused by lighting.

The article takes case study of stable area where natural disasters rarely take place. The common interruptions come from inappropriate plan and in frequent related to in appropriate maintenance plan and execution. Inappropriate maintenance plan has contributed to major problems in electricity distribution maintenance tasks and delivered severe impacts to medium-high range power networks [9].

**2.3. Disturbance Analysis Method.**

Electric power transmission networks are complex systems which experience major cascading disruptions. To analyze power performance relaying systems, high speed digital fault and disturbance recording devices need to be installed properly. Analysis of fault records will help in adapting operating and protection practices and assuring the reliability of a bulk power system [9][10].

The fault records will further to be used to simulate and predict the disturbance patterns. The article applies the Failure Mode and Effect, and Criticality Analysis (FMECA) method to address these issues. FMECA method enables to perform system analysis and disturbance evaluation, that deliver maximum benefits of assets utilization [11]. The article uses FMECA method to analyze the common disturbances in medium-high power distribution that occasionally occurs in certain area.

**2.3. Failure Mode and Effects and Criticality Analysis (FMECA) Method.**

The term Failure Mode and Effects Analysis (FMEA) was initiated by Lloyd Omdahl and American Society for Quality (ASQ) [12]. FMEA is an engineering technique that conducted to identify, analyse, reduce or eliminate certain unknown failure or potential system failure to the customers.

FMEA method enables to simulate effect analysis that enables to identify all potential failures with its impacts. It enables to study the potential hidden problem lies in “reliability” distribution system and suggest necessary measures to eliminate or reduce potential disturbance.

FMECA is an extension of FMEA with addition parameter such as: severity level and potential of failure parameters. The C in FMECA indicates the criticality (or severity) of the various failure effects are considered and ranked. Nowadays, the distinction between two terms has become blurred. FMECA was one the first systematic techniques for failure analysis. It was developed by U.S. military to analyse a failure mode, effect and criticality analysis in 1949 [13].

FMECA has advantages to assure that all potential failure modes have considered and proper provisions and enables to eliminate these failures. FMECA has several features such as [14]

- Assist in selecting design alternatives with high reliability and high safety potential in early stages.
- Ensure all conceivable failure modes and their effects on operational success of the system have been considered.
- List potential failures and identify severity of their effects.
- Develop early criteria for test planning and requirements for test equipment.
- Provide historical documentation for future reference to aid in analysis of field failures and consideration of design changes.
- Provide a basis for maintenance planning.
- Provide a basis for quantitative reliability and availability analyses.

The article applies the FMECA method to address the potential medium-high Power of Failures (PoF) through common agreed standards established in HQ. The common PoF are defined in the following questions:

1. How can each part of system in medium high power conceivable fail?
2. What kind of mechanism that might contribute to theses modes of failure?
3. What is (are) the effects whenever the failures take place?
4. Is the failure in the safe or unsafe direction according to initial plan?
5. What inherent provisions are provided in the design to compensate for the failure?

Those lists above cover the issue of failures mode, failures effect, failures cause that commonly applies in the range of medium-high power. The range is selected due to major disturbance that takes place.

The PoF list has acknowledged as national standard to analyse and evaluate the reliability of electricity supplies along with SAIDI-SAIFI parameters.

### 2.4. Types of FMECA.

The FMECA method can be differentiated in several types as follows [15]:

- Design FMECA is carried out to eliminate failures during equipment design, taking into account all types of failures during the whole life span of the equipment.
- Process FMECA is focused on problems stemming in manufacturing, maintenance or operation.
- System FMECA examines potential problems and bottlenecks in large processes.

The article applies all type of FMECA in examining entire maintenance plan and execution.

## 3. RESEARCH METHOD

### 3.1. FMECA Method.

The FMECA method has 5 main steps as follows [16]:

1. FMECA prerequisites.
2. System structure analysis.
3. Failure analysis and preparation of FMECA worksheets.
4. Team review.
5. Corrective actions.

#### 3.1.1. FMECA prerequisites.

The FMECA prerequisites stage examines the current situation through following steps:

1. System definition to be analysed. The article restricts the medium-high power system of 20 kV to be analyzed.
2. Collect available information that describes the system to be analysed. The information relates with: construction sites, disturbance events, design plan, type of quality materials, operation and maintenance errors, and external causes.
3. Collect information related to previous and similar design from internal and external sources. The article takes case study of disturbance events that took place in 2021, where major events have received HQ attention.

#### 3.1.2. System Structure Analysis.

The article applies the system structure analysis into internal and external causes. The case study is taken in one of remote area that common experiences disturbances, UP3 location, Medan Area (North Sumatera).

#### 3.1.3. Failure analysis and preparation of FMECA worksheets.

The article applies the suitable FMECA worksheet for maintenance power management system comprises of:

- Description of unit.
- Description of failures.
- Effect of failure.
- Failure rate.
- Risk reducing measures.
- Comments.

#### 3.1.4. Team Review and Correction Action.

The HQ addresses the SAIDI-SAIFI reports based on the blackout activity. The workflow of FMEA method comprises of roles of each department such as:

1. HQ Engineering Office.
   HQ Engineering Office prepares the PoF list that has agreed by HQ management. The POF list addresses the characteristics of medium-high power range area such as:
   a. Disaster management plan.
   b. Planned interruption and unplanned interruption.
   c. Unplanned interruption defines list potential facilities and sub-facilities that will be impacted, and potential disturbances on certain equipment.
2. Network Operation and Maintenance (NOM).
   NOM follows up the SAIDI and SAIFI report comprises of: type of disturbance events, climate situation during the event, and causes of blackout event.
3. Local Engineering Office (LEO).
   LEO analyses and evaluates the NOM findings and prepare several measures such as:
   a. Prepare cause group during blackout events (done by field engineers).
   b. Prepare summary of causes.
   c. Prepare follow-up tasks to conduct these measures: warning, mitigation, or prevent failure.

d. Propose further recommendation.

4. Taskforce in Asset Distribution and Maintenance. Taskforce is formed to prepare priority activity. This taskforce is known as Failure Defense Task (FDT). The initiative of FDT is to avoid or minimize potential risk of failures. The FDT team manages comprehensive range of tasks such as: design, procurement, development, operation, and maintenance. The FDT also has further task to ensure continuous improvement needs to be taken properly according to schedule and recommendation.

## 4. FINDINGS

### 4.1. FMECA prerequisites.

Based on the SAIDI-SAIFI report on several months from October to December 2021. The common factors contribute in medium-high range power comes from internal factors are 47 events (33%) and external factors 94 events (37%). There are also 37 events (26%) recurring disturbances with unknown cause.

### 4.2. System Structure Analysis.

The system structure analysis addresses the internal cause factors as follows:

- Construction failures (8 events).
- Improper design (12 events).
- Poor quality materials (5 events).
- Operation mistakes (1 event).
- Maintenance mistakes (40 events).

While the external causes that recorded at the same period such as:

- Unidentified object interruptions (28 events).
- Natural disasters (8 events).
- Maintenance mistakes (37 events).
- Improper design (10 events).
- Third party involvement (11 events).

### 4.3. Failure Analysis and Preparation of FMECA.

**Table 1.** Unplanned Blackout Causes in Medium-High Power with Internal Factor.

| Sub-Facili-ty | Equipme nt | Event Damage | Cause Factor | Cause Group | Fre q |
|---|---|---|---|---|---|
| HUTM | Conduc-tor | broken | Improper construc-tion | Construc-tion error | 2 |
| HUTM | Conduc-tor | sticky | Improper contruction | Construc-tion error | 1 |
| HUTM | Junction | broken | Isolation media failure | Construc-tion error | 12 |
| HUTM | Conduc-tor | broken | Improper construc-tion | Construc-tion error | 1 |
| HUTM | Conduc-tor | open | Improper construc-tion | Construc-tion error | 3 |
| SKTM | Conduc-tor | switch | Junction loss | Poor material quality | 1 |
| SKTM | Termi-nation | fire | Junction loose | Operation errors | 2 |
| Protec-tion | FCO tube | fire | flashover | Mainte-nance error | 2 |
| Cubi-cle | Relay | switch | Fuse-link cut-off | Mainte-nance error | 33 |
| Cubi-cle | Relay | Switch | Trafo contact | Mainte-nance error | 3 |
| Cubi-cle | PMT | Broken | Life-time | Mainte-nance error | 1 |
| Cubi-cle | Inco-ming DS | Over-head cut-off | Improper construc-tion | Mainte-nance error | 1 |
| Cubi-cle | Circuit braker | Opera-tion failed | Isolation media failure/leak | Mainte-nance error | 1 |
| Cubi-cle | Isolator | Broken | Life-time | Mainte-nance error | 1 |

**Table 1.** Unplanned Blackout Causes in Medium-High Power with Internal Factor (continued).

| Sub-Facili-ty | Equipme nt | Event Damage | Cause Factor | Cause Group | Fre q |
|---|---|---|---|---|---|
| HUTM | Conduc-tor | broken | Improper construc-tion | Construc-tion error | 2 |
| HUTM | Conduc-tor | sticky | Improper contruction | Construc-tion error | 1 |
| HUTM | Junction | broken | Isolation media failure | Construc-tion error | 12 |
| HUTM | Conduc-tor | broken | Improper construc-tion | Construc-tion error | 1 |
| HUTM | Conduc-tor | open | Improper construc-tion | Construc-tion error | 3 |
| SKTM | Conduc-tor | switch | Junction loss | Poor material quality | 1 |

The application of FMECA method will be used as input to next investment preparation that involves design, procurement and planning, assets construction and operation, assets maintenance, repairment, and replacement.

The SAIDI-SAIFI report for October, November and December 2021 show that repeating disturbances causes by major internal factors (33%) and external (37%), and the rest is unknown causes. The events are recorded during shinny whether with minimum external disturbance. It is shown the following Table 1 above.

**Table 2.** Unplanned Blackout Causes in Medium-High Power with External Factor.

| Sub-Facili -ty | Equip -ment | Event Damage | Wea-ther condi-tion | Cause Factor | Cause Group | Freq |
|---|---|---|---|---|---|---|
| Cubi-cle | Relay | Circuit | Cloudy | Fallen tree | Uniden-tified object | 17 |
| Cubi-cle | Relay | Circuit | Shinny | animal | Uniden-tified object | 6 |
| Cubi-cle | Relay | Circuit | Rainy | Un-known | Natural disaster | 8 |
| Cubi-cle | Relay | Circuit | Shinny | Un-known | Mainten ance errors | 37 |
| Cubi-cle | Relay | Circuit | Light-ning | flash over | Poor design | 10 |
| SUT M | Con-ductor | Damage | Shin-ny | third party | Public | 6 |
| SUT M | Con-ductor | damage | Shin-ny | third party | Public | 5 |

### 4.4. Team Review.

The coordination team has conducted comprehensive reviews and produced the reports for internal factors are shown below:

- inappropriate maintenance tasks (21 events or 45%).
- constructor errors (8 events or 17%).
- poor material quality (5 events or 11%).
- operation errors (1 event or 2%).

While the reports for external factors are:

- maintenance errors (37 events or 39%).
- interrupted by unidentified objects (28 events or 30%).
- third party involvement (11 events or 12%).
- design errors (10 events or 11%).
- natural disasters (8 events or 9%).

### 4.5. Correction Actions.

Based on the reviews above, the coordination team made recommendation to the management as below.

**Table 3.** Recommendation for Internal Factor Improvements.

| Blackout Causes | Recommendation for improvements |
|---|---|
| Maintenance errors | (1). Resetting protection coordination, adjusting rating fuse cut-off, so whenever fuse-link cut-off takes place, it will not cause repetition impact; (2). Conduct proper inspection to medium-high power equipments with termo-vision devices and ultra-sound detectors. |
| Design error | Planning task should involve in examining junction components. Avoid using bolt-type junction since they cause many problems; instead of using join-sleeve type junction. |
| Construction error | Construction supervision should put special attention to the conductor bonding in isolators, height of pillars, distance between conductors, and up-skilling construction workers in pulling conductor shafts. |
| Procurement mistakes | Supervision to the vendor and quality of materials to acquire high quality materials. |
| Operation errors | Review all SOP related to cubicle operation to avoid inappropriate operation. |

**Table 3.** Recommendation for External Factor Improvements.

| Blackout Causes | Recommendation for improvements |
|---|---|
| Maintenance errors | Comprehensive inspection and maintenance tasks need to be conducted to external objects such as tree (at least 2.5 m from networks). |
| | Eliminate all barriers near networks, secure conductors from any animal and adding isolation to conductors that frequently passed by animal. |
| | Sosialise to people around about the danger of flying kites around the networks. Make sure the transmission line far from unidentified objects. |
| Design Failures | Install danger sign around transmission network assets to avoid unauthorized person come close. |
| | Planning task should pay attention to path or location that frequently get lightning. Secure and take preventive tasks to eliminate and minimize impact of lightning. |
| Operation errors | Create SOP for operating networks to anticipate natural disasters and make sure recover process can be conducted immediately and safe. |

## 5. CONCLUSION

FMECA method delivers many benefits to identify and analyse hidden problems related to medium-high power networks. The article takes a case study of range power of 20 kV in UP3 are in North Sumatera. The case study is selected to its importance strategic location that serves major industry area. The FMECA method requires establishing collaboration team across multiple departments to address the hidden problems related to medium-high power networks, such as design, procurement, construction, operation and maintenance. FMECA method provides advantages in addressing the priority lists to be followed up by the team. As a result, the Failure Defense Taskforce (FDT) is formed to follow up the FMECA reports. FMECA reports enable to classify the disturbances into several categories such as: manage, eliminate and minimize potential failures. FMECA method enables to produce some recommendation related to SAIDI-SAIFI technical reports, and highlights to examining the quality of materials (equipments). Tracking vendor and materials needs to be carried out to ensure the system can be properly operated and maintained.

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