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ANALYSIS OF MODERN RAILWAY POWER QUALITY CONDITIONS WITH INSPECTION METHODS TO MITIGATE OPERATING SYSTEM FAILURES REFERRING TO REGULATIONS AND STANDARD REFERENCES

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KEYWORDS
Power quality conditions; overvoltage; risk mitigation; ETAP; and losses.

ABSTRACT

Elevated stations or commonly called elevated stations have an electric power system with a main power supply of 20KiloVolt with a nominal voltage of 750volt and a station operating facility voltage of 380volt laying station. This research uses the inspection method by making observations by work instructions and instruction manuals for railway infrastructure maintenance studies. The main objective of this study is to prevent overvoltage interference problems by recommending risk mitigation through investigative and simulation analysis methods using Electric Transient and Analysis Program (ETAP) software that can help evaluate and estimate strategic steps by paying attention to regulations and standard references and detecting losses in operating pattern disturbances due to disruption of power quality conditions caused by overvoltage surges in the station traction substation system by investigation and simulation methods using Electric Transient and Analysis Program (ETAP) software. This overvoltage is carried out in the context of research on maintaining services to the public and preventing system failures by using risk mitigation and investigation and simulation methods using Electric Transient and Analysis Program (ETAP) software that pays attention to environmental, safety, technical, and economic aspects with regulations and standard references. This research is in the form of mitigation analysis and describes the losses that have an impact by looking at a power quality condition and the follow-up provided to prevent overvoltage and components of modern railway electric facilities. The results of this study are in the form of recommendations, strategies for risk mitigation with risk analysis, and policies from voltage increase problems recorded by SCADA OCC logs and relays with a value of 893.88 Volt DC.

INTRODUCTION

Modern railway systems are used in rolling *stock* systems with the need for power supply from 750VDC traction substations. The modern railway system has a carrying capacity of more than 1000 people in one trip. Modern train specifications have a total of 8 *trainsets* consisting of 2 *cars* from each *trainset* with a third rail power source on the VVVF-IGBT propulsion system and SIV (*Auxillary Static Inverter)* system with a maximum design speed of 90km/h and a maximum operating speed of 80km/h. In this study (Josue & Worku, 2021), power quality conditions are very important for railway operations to run railway operation patterns, so prevention is needed so that there are no system disruptions that can *triple or sudden blackouts caused by electrical power disruptions in power quality conditions. Disturbances that occur can be of various kinds, including surges in electric voltage (over-voltage*) and instability of electric voltage (Alnuman et al., 2018). Based on IEEE standards, if the voltage deviation between 10% lasts for more than 60 seconds it is called *overvoltage* (Mariscotti & Sandrolini, 2021). The existence of disruptions in electricity supply can affect or even damage an electric power system (Perhubungan, 2011). Disturbances that occur can be of various kinds, including overvoltage surges *caused* by loss of traction power supply from stations that are interconnected on the *mainline* so that DC *switchgear* equipment *trips occur* with the condition of the 3rd rail (*third rail*) the downflow electricity does not show voltage and the station rectifier transformer is off. value *The overvoltage* for DC *switchgear* is more than 900 volts at all stations so the *protection relay* station works by disconnecting the voltage (Delfino et al., 2003). If this voltage fault is connected to electrical or electronic equipment and exceeds its nominal voltage tolerance limit, then it may interfere with the performance of those equipment or may even damage them. Overvoltage that occurs in the electrical system of the traction substation caused by loss of traction power supply on *the mainline* can cause operational disruption when the voltage exceeds the set limit, the busbar device equipment and DC *switchgear* will cause equipment system failure to occur to the detriment of the train operation pattern. working DC switchgear relay at the 59 relays protection regulatory point with a regulatory limit of 900VDC and controlling the 20kV fluctuations included in this study to ensure system reliability and obtain recommendations in the form of risk mitigation and losses from costs and internal and/or external modern railway systems. Internal overvoltage conditions can be caused by the *switching* of loads from the power source of the utility company, which are uneven or variable causing modern railway power systems to go out (Uher, 1976). This overvoltage is carried out in the framework of research on maintaining services to the public and preventing system failures by using risk mitigation and investigation and simulation methods using *Electric Transient and Analysis Program* (ETAP) software that pays attention to environmental, safety, technical, and economic aspects with regulations and standard references (Aatif et al., 2021). Detecting problems in power quality conditions using investigation and simulation methods using *Electric Transient and Analysis Program* (ETAP) software can analyze overvoltage at station traction substations.

METHOD RESEARCH

Risk control is carried out if existing and running controls have not been able to reduce the level of risk from danger to the level of *As Low As Reasonably Practicable* (ALARP) acceptable to modern railway systems. In this case, the *risk level rating* is *medium* or *high.* If the results of the previous risk assessment, the level of risk already shows *low*, then additional risk control is not needed. Hazard control methods that *have been carried out in previous risk assessments can be grouped according to the control hierarchy below, namely:*

1. Elimination

2. Substitution
3. Engineering *controls*
4. Administrative *controls*
5. Personal *protective equipment*;

The above hierarchy of controls must be considered to eliminate hazards or lower *risk levels*. The Risk Assessment process must be re-established after additional control assumptions have been established to obtain the level of *residual risk*. Elimination is an effort to control hazards/impacts by eliminating work tools or ways of working that can cause danger. Substitution is control by replacing goods/tools/ways of working that can cause hazards with other goods/tools/ways of working that are not dangerous. Engineering control is an effort to control by engineering or re-modification, and *administrative control* is an effort to control administratively (Hermawan et al., 2021).

RESULT AND DISCUSSION

Chronology of events

On Monday, February 20, 2023, the train lost electrical power on the line (SOGO arch) to the depot station, causing KA 1201 to experience a 10-minute delay. The loss of traction power supply from stations where the system is interconnected with two is marked by a third rail that does not show voltage and the rectifier transformer is *shut down*. The DC Pro event log contained in the OCC room shows an overvoltage has occurred. The chronology of the incident is that it has reported to the OCC that the train lost electricity, it is known to the electrical system of all *trip* stations, on the alarm indicated *over-voltage*, the OCC asked the driver to announce the delay to the passengers who were on the train on, OCC reported to the team on duty regarding the incident and asked to go to Back *of House* (BOH), OCC informed the second holding station regarding the incident, the team checked at BOH, the electric power was turned on remotely after *being unlocked* by the team. DC Pro indicates that *trips* occur caused by overvoltage. Setting point for overvoltage for each inlet and *feeder,* i.e. setting point with a value of 900VDC within a specified time of 10 seconds. The input voltage of 20kilovolts increases, this causes the DC voltage rise to exceed the limit within its current limit when it is less than 900VDC. When it is close to 900VDC then the relay works to disconnect the voltage. When the voltage is 893.88Volt, the relay works as a form of protection. In this case, *the rectifier output* shows ± 860VDC just before the trip occurs. This means it only has a voltage margin of 40VDC to the trip state (59 sets of protection: 900VDC). The occurrence of voltage increase from the 20KV PLN source from the substation so that the DC *switchgear protection relay* and SCADA readings exceed the threshold. *The protection relay* disconnects (*open circuit breaker*) traction voltage on the *third rail* to protect DC Switchgear devices and trains that are in operation.

SCADA Log Analysis on Modern Railway System Systems

In this problem, it is obtained through SCADA log data from the results of relay 59 contained in the *switchgear.* When there is an overvoltage, relay 59 works effectively and reliably to prevent interference with power quality conditions. *Rectifiers* produce DC voltages depending on their input voltage, if the input voltage increases then the output of the DC voltage will increase and vice versa. Because our DC voltage has overvoltage protection (set: 900VDC), so if there is an increase of 20kV coming in it will have a great impact on the Output DC voltage. In this case, an increase of *Incoming* 20kV brings the DC Voltage beyond 900VDC and triggers *the Over Voltage Protection* (59 *Protection*) relay causing the DC system *to trip* to all stations on the *mainline third rail* train. The occurrence of unstable voltage from the 20KV PLN source causes the DC *switchgear protection relay* and SCADA readings to exceed the threshold. The *configured overvoltage* value for DC SWGR is 825 V at all stations. Reading the input voltage of PLN up to 21KV on the SCADA *workstation* and activating *the station relay protection*. *Protection relays* break the *tractive voltage on the* third rail *to protect DC* switchgear *devices and trains in operation.*

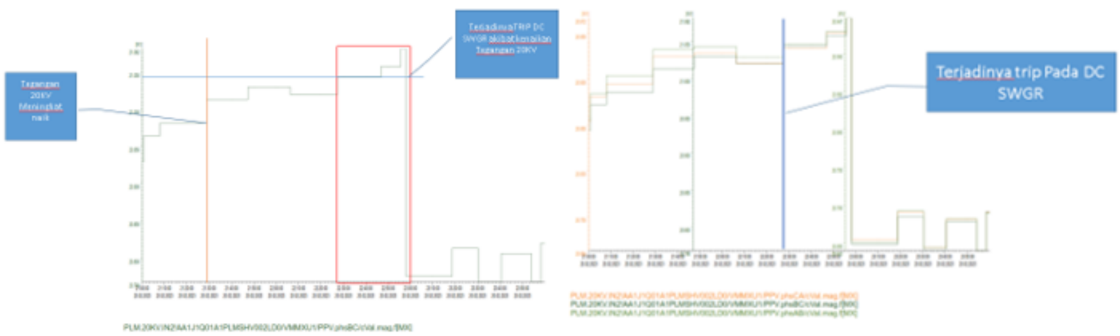


Figure 1
Power Incoming Data 2 Reciever Station.

In this voltage increase, an increase is detected on the supply side of the voltage of 20 kV. The voltage increase obtained is detected through the SCADA system contained in the OCC.

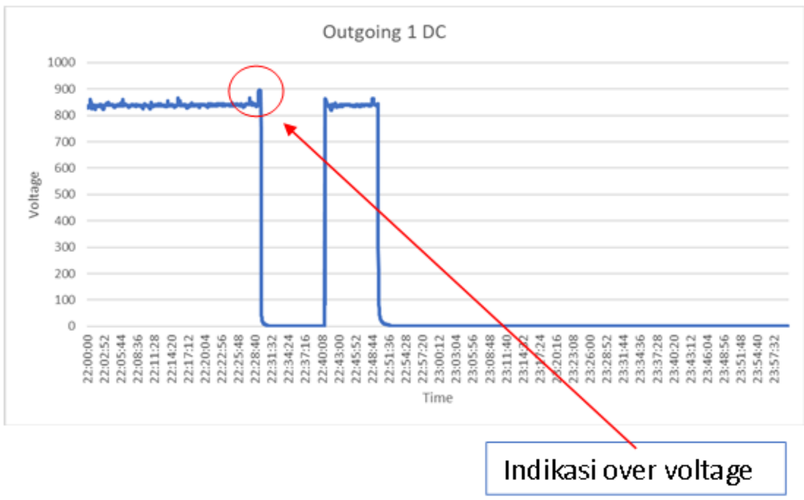


Figure 2
SCADA Outgoing Log Relay 1 Reciever Station

The condition before HSCB recovery is in the locked position, so the relay responds to indications of over voltage at peak voltage and gives an emergency open indication so that it cannot be closed/powered on. Essentials and non-essentials are systematically connected to SCADA so CBs can travel directly. The display on SCADA Power has an alarm stating overvoltage. The power supply system in protective tripping works when there is a rapid failure to isolate the fault, especially on the side of relay 59 contained in the DC switchgear of each station based on the design of the protection system under normal operating conditions and during train queues. The power grid is interconnected between two traction power supply substations or two distribution power supply substations. If there is a failure in the power supply supplied from the source, it can be supplied by another source using an interkinesis system. The risk of capacitor switching effects is determined by capacitor size and network impedance (Gharehpetian & Shahnia, 2006). The worst situation occurs when a capacitor bank is energized close to an already connected bank. To reduce transient overvoltages and inrush currents during capacitor switching, there are various techniques to reduce such negative effects (Plămădeală & Slobodeaniuc, 2019).

Inductors help limit the higher transient frequency components by effectively reducing the peak value of the inflow. This method contributes to reducing overvoltage by increasing the attenuation of the oscillating transient part of the capacitor-switching transient. The main applications of flexible power components In distribution networks can be described using load compensation. Individual loads connected to the distribution system away from the ideal component draw a balanced sinusoidal current. Characterized by having a poor power factor, being unbalanced, and introducing waveform distortion in the distribution system, degrading power quality in this case, the utility has a strictly coded network connection to limit interference that may occur at certain loads enter into the system and maintain high power quality standards. Power flow in an electric power system is generally a power event that flows in the form of active power (P) and reactive power (Q) from a generation system (sender side) through a line or transmission network to the load side (receiver side). Under ideal conditions, the power provided by the sender side will be equal to the power received by the load. But in real conditions, the power sent by the sender side will not be the same as that received by the load. This is influenced by several things, namely:

1. Impedance in transmission lines can occur due to various things and already includes the resultant between resistive, inductive, and capacitive resistance. This causes power losses because it is converted or wasted into other energy in energy transfer.
2. The types of load-connected paths are resistive, inductive, and capacitive. The resultant between capacitive and inductive resistance will affect P.F. so that it affects the ratio between the amount of power transferred and received.

ETAP Design a Modern Railway System

The purpose of using ETAP is to view equipment, trigger thresholds, data storage, and analysis and interpretation of equipment. The use of ETAP in taking a proactive approach to power quality monitoring to understand the normal power quality performance of a system, identify problems quickly, and see reactive modes of power quality monitoring by identifying the causes of equipment incompatibility to obtain solutions. Load flow is an analysis performed to determine whether a system voltage is operating within specified voltage limits under normal operating conditions or faults. It is used to determine voltage losses at various points of the system, voltage readings on each bus, and real and reactive power losses through each branch and feeder. ETAP creates an alert if the supply bus is below the nominal voltage. Likewise, load flow is often performed to identify the need for additional generating units, and the addition or replacement of capacitors and/or reactors to maintain system voltage within specified limits. From the information gathered from the load flow test, the voltage profile of the system is very important. If there is a substantial variation in voltage over the system, a large reactive flow will occur. This can lead to increased real power loss, and in extreme scenarios, possible system damage. It is common practice to install capacitor banks when a particular bus exhibits low voltage, to provide reactive compensation to loads. The main cause of all major power system disturbances is due to voltage below. Load flow studies can also be performed to determine the optimal capacitor size and location. The simplest way to increase the power factor is to add a power factor correction capacitor to the electrical system. PF correction capacitors act as reactive current generators. They help compensate for the non-working power used by inductive loads, thereby increasing the power factor.

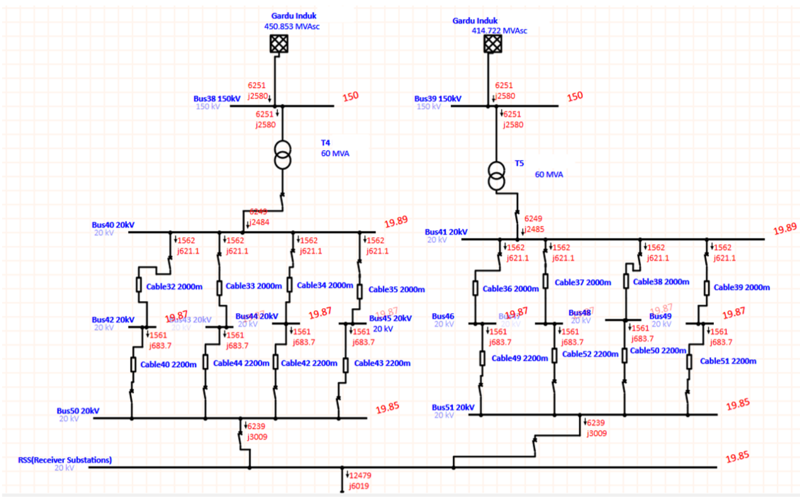
The voltage rise can be caused by a change in load-side impedance or a change in source-side impedance. Systems that are not spherical such as delta systems are prone to swelling due to a single line-to-ground error (SLG). When a single line-to-ground (SLG) fault occurs in one phase of the non-spherical delta the phase voltage drops, however; the other phase will swell until the fault is cleared. Voltage swells can also be caused by de-energizing large loads on the load side. The voltage will be equal to the time the inductance of the current changes over the changes in time. The greater the inductance or the more sudden the de-energization, the greater the voltage.

By checking the voltage and current, we can see, a large load is turned off suddenly, pushing the voltage. A rise in voltage can cause damage to the insulation. This can happen because of one large transient, but more generally because of a repeating small transient of magnitude. Transients can also cause small breakers to trip offline at regular intervals. This type of transient would be seen as a single-ended sub-cycle surge. Another common cause of transients is the activation of capacitor banks. When the capacitor bank turns it on, it creates a ringing transient of oscillations.

Transient voltages can result in degradation or immediate dielectric failure in all classes of equipment. The high magnitude and rapid rise time contribute to the isolation of damage to electrical equipment such as switchgear, transformers, and traction motors. Repeated low-magnitude transient applications to Equipment can lead to slow degradation and eventually isolation failure, decreasing equipment mean time between failures. Transients can damage insulation due to insulation, as wires have capacitive properties; both capacitors and wires have two conductors separated by insulators. Capacitance provides a pathway for a temporary pulse. If the transient pulse has enough energy it will damage that part of the insulation.

Waves can occur due to a line-to-ground fault in the system, which can also result in a temporary voltage rise in the non-faulty phase. This is especially true in non-spherical or floating ground delta systems, where a sudden change in ground reference results in a voltage rise in the unrounded phase. Close to the substation in the grounded system, there will be no voltage rise in the undamaged phase because the substation transformer is usually delta-wye connected.

The power supply system of modern railway systems uses technological equipment and materials that have reliability, but on the data side, the three winding inputs in using ETAP simulation cannot be entered because of limited data in order to analyze more deeply (Santiyanon et al., 2016). In the operating pattern of LRV traction load trains show time-varied and non-linear characteristic dynamics, which can cause power quality problems simultaneously such as negative sequence components with imbalance systems, power factors with reactive power, and harmonics with non-linear power. Reactive energy is an important concern in power systems when inductive loads such as traction motors. Systems that trip in field conditions can auto-switch off in abnormal conditions and auto-switch on back in safe conditions. Distribution systems that are not connected in the presence of nonlinear loads using ETAP are presented in this paper. Results (power loss, operating conditions, and annual benefits) are compared with those obtained from radial and loop networks. The radial model of loop distribution systems and interconnections is obtained by appropriate simplification of ordinary power grids. The computational results obtained show that component voltages affect the optimal placement of capacitors in all system configurations. When all loads are assumed to be linear, interconnected and loop system configurations offer the lowest power loss and best operating conditions than radial systems while radial system configurations offer the best annual benefits due to capacitor placement. In a distorted network, interconnected system configurations offer lower power loss, the best operating conditions, and the best yearly. Benefits due to capacitor placement can thus be used effectively for reactive power compensation which helps in increasing power factor, reducing system losses, increasing voltage, and increasing feeder capacity. The optimal value of the capacitor required can be determined. The algorithm finds the exact location of the capacitor. The results are encouraging with reference to the increase in power factor and voltage, thereby increasing the capacity of the feeder. Maximum benefit is obtained by selecting the optimal size of the capacitor and by placing the capacitor near the inductive reactance of the kVAR load. A limited number of standard kVAR sizes require that capacitors are clustered near the load center.



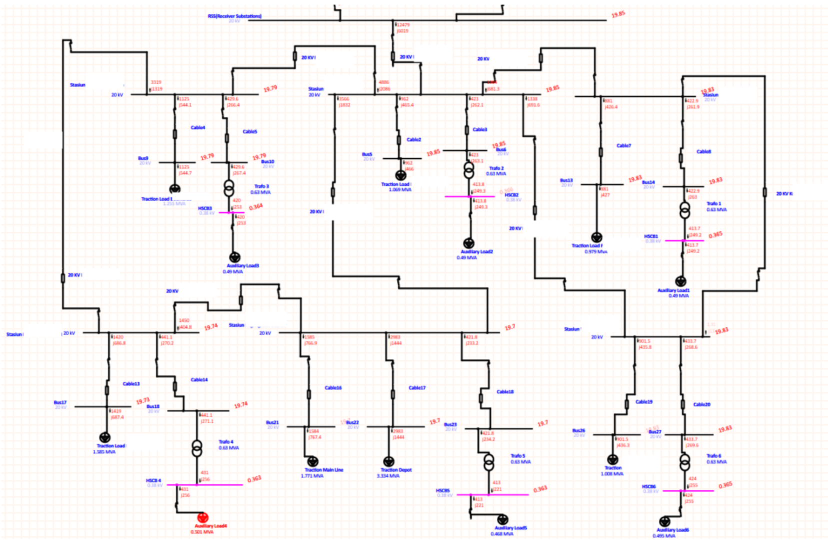


Figure 3
ETAP 150kV Modern Railway System

In the distribution system, there is often an unbalanced load on each phase (the distribution system is a three-phase system) or there is an overload due to the use of electronic devices by consumers of electrical energy. This situation if left unchecked will cause a decrease in the reliability of the electric power system and the quality of electrical energy distributed and cause damage to the equipment concerned. For this reason, action is needed that reduces unbalanced loading in phase and overload (overloading) in the electricity distribution network. In addition, radial distribution systems also have considerable power losses that cause reduced system reliability. Under normal operating conditions, network reconfiguration is carried out for two reasons, namely:

1. Reduce system power losses *(loss reduction);*
2. Get balanced loading to prevent network overloading (*load balancing*).

The voltage stability analysis of the power system is carried out by calculating the complex voltage on all buses and then calculating the power flow on the network buses. Computational analysis is called load flow analysis. Load flow analysis is used in the continuous planning of current power system performance and analyzing the effectiveness of system expansion needs in meeting increasing load demands. Load flow analysis provides an overview of the operating conditions of the entire power system, from generator networks, transmission lines, and distribution lines, to loads in an area. By using load flow analysis, it can find out the voltage at locations throughout the transmission system, for alternating current (AC) consisting of active and reactive power, phase angle or element magnitude, and time and follow on each line. Load flow analysis is critical in planning and implementation in designing future power system expansions and in determining the best operation of existing systems. Many researchers have proposed methods of numerical analysis in solving non-linear algebraic equations of load flow problems such as the basis of Newton's Raphson method in solving power flow is the Taylor series for a function with two more variables. Newton Raphson's method solved the power flow problem by using a nonlinear equation to calculate the magnitude of the voltage and phase angle of each bus. Using load flow analysis, we can find out the voltage at locations throughout the transmission system, for alternating current (AC) consisting of active and reactive power, phase angle or element magnitude, and time and follow on each line. Load flow analysis is critical in planning and implementation in designing future power system expansions and in determining the best operation of existing systems. Many researchers have proposed methods of numerical analysis in solving non-linear algebraic equations of load flow problems. AC load flow is performed on a reduced system that has all study areas represented. The load-duration curve, which is a function of reliability, is expressed as a continuous function of the load demand of the study area. This function is used to obtain the probability of the load demand density function of the study area. The expected annual value of the difference in study area loss between the two alternatives is evaluated using probability densities over the function and the derivative loss function. The calculated value shows excellent agreement with the value obtained by the load flow study. The results obtained from the load flow study are used to make relevant adjustments to improve system performance. Different approaches to power factor correction are examined, and considerations to keep in mind before additions or modifications to the system are discussed. It is important to highlight that the results of the ETAP simulation confirm that the introduction of shunt capacitors is strategically sized and positioned in the distribution system, helping to counteract losses due to inductive elements and improving the network voltage profile. It can be argued that investing in fixed and switched capacitors comes with many technical and financial benefits. These benefits include reduced power loss, increased voltage stability, reduced equipment loading, and costly grid upgrade delays. Overall, load flow analysis is essential to ensure optimal system performance and to prevent power outages. Reactive power (Vars) cannot be transmitted very far especially under heavy load conditions so it must be generated close to the point of consumption. This is because the difference in voltage causes reactive power (Vars) to flow and The voltage in the power system is only +/- 5 percent of the nominal and this small voltage difference does not cause substantial reactive power (Vars) to flow over long distances. So if that reactive power (Vars) is not available at the load center, the voltage level drops. Critical under voltage can cause excessive wear on certain devices such as motors as they will tend to overheat if the voltage is low. Its reactive effect on tissues is permanent. Fixed capacitors provide a constant amount of reactive correction (kVAR). In other words, a fixed capacitor is a type of capacitor that stores a fixed amount of electric charge that cannot be adjusted. Now, it is very important to consider what happens when the system is not operating at peak load and the power factor is close to 1. When the power factor at the load approaches 1, reactive compensation from the capacitor bank is not required at that time. Higher voltages create increased power demand, which is undesirable and can translate into reduced energy efficiency (too low voltages will also result in inefficiencies). The purpose of line drop compensators is to level the voltage profile so as to provide the required voltage boost at peak loads yet keep the voltage closer to nominal at lower loads.

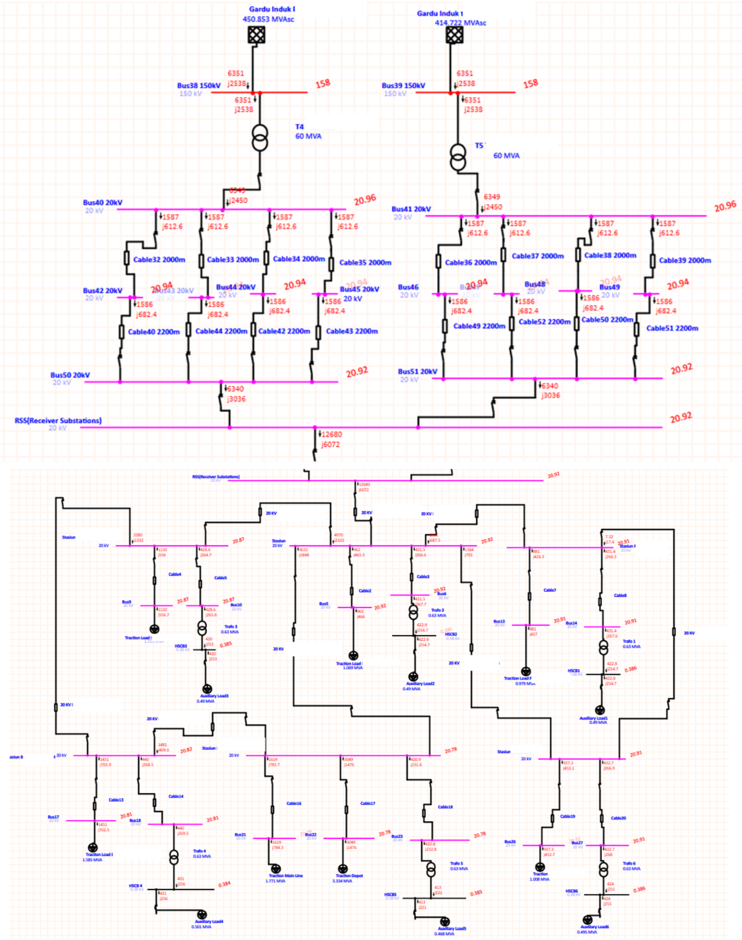


Figure 4
Design ETAP 158kV Overvoltage Modern Railway System

Conditions in this problem include the type of interference, the system undergoes changes in the status and function of equipment due to the influence of interference from outside the external electrical system of the modern railway system which results in improper conditions. The problem is that the reliability system of electric power modern railway systems under normal conditions still provides sufficient capacity to provide power supply to loads with different voltage variations, but if it exceeds the threshold limit set in this problem close to 900VDC then the system can identify system disturbances so that the load cannot serve due to trips on the system when the overvoltage relay works. In this problem, the relative equipment system experiences more work intensity.

Overvoltage disturbances occur when there is suspected switching and there is a sudden increase in voltage and decrease in active power from electric power providers resulting in electrical imbalances in the electric power system of modern railway systems. This overvoltage-caused Power quality disturbance in a balanced power grid is a three-phase power system characterized by a sinusoidal waveform, where three phases have the same base frequency (equal to face value), the same voltage magnitude, and a phase shift of 120◦ . If any of these conditions are not met, the power grid is considered to be experiencing power quality impairment. Power quality interruption is defined as any problem that causes voltage or frequency deviations in the power supply and can result in equipment failure or power grid malfunction, which can cause problems at the load end. These power quality disturbances can be broadly classified into two categories, namely variations and power quality events. The variation in power quality is considered a steady-state perturbation and corresponds to a small deviation of frequency and amplitude from its face value. In contrast, power quality events are associated with major deviations such as blackouts, sags, and swells. These disruptions can have a major effect on grid stability, safety (protective relay malfunction), equipment useful life, and power system measurement performance and generate electromagnetic noise. Power quality analysis moving towards smart grids requires advanced control strategies, energy management systems, modern protective devices, and power quality monitoring to deal with power quality issues.

Overvoltage due to internal causes is generated due to the internal operating atmosphere of the system and fault conditions in the power system. Inter over voltage can produce at power frequencies, resonant frequencies, and high frequencies as transient overvoltage. Switching overvoltage is generally observed on long transmission lines, due to high ground capacitance on long transmission lines, overvoltage is observed on transmission lines. A line reactor is installed in the transmission line to control the switching voltage over. Transient overvoltage occurs During the opening of a circuit breaker under load or fault conditions, transient overvoltages are found throughout the CB contacts. This will greatly affect the circuit breaker and due to voltage, the circuit breaker may be damaged. by changes in the condition of the internal power system of modern railways caused by the possibilities obtained based on events at the time, namely (Policy, 2007):

1. The energy of the line through the low voltage side of the *three winding* transformers experiencing voltage instability must be analyzed directly and can also be used by the injection method using ETAP software so that it can see transformers, rectifiers, *capacitor banks*;
2. *Circuit breakers in high-speed* recloser relays on equipment components affected by voltage rises;
3. This increase in overvoltage occurs continuously which is the impact of the voltage difference from each time in a longer period of time so that there is a surge in the form of rising waves;
4. In braking, there is an increase in power consumption from the facility, but within the voltage limit operated when increasing by the amount of 900VDC, it includes the threshold limit of voltage increase when LRV brakes, or called a *regenerative brake event*.
5. In the absence of lightning, this is supported by voltage increases that are not impulsive.
6. In field conditions there has been no evidence for fault findings in power distribution systems such as *line-to-ground contacts*.

In this overvoltage problem based on IEC 60364, this problem is included in categories 3 and 4. Category 3 relates to wiring installations and control of electrical installation of equipment and Category 4 relates to protection on the electrical systems of modern railway systems. This does not include the voltage swell because the RMS value increases the voltage by more than one minute with an RMS value of 10-80%. Overvoltage has a duration of more than minutes with an increase in RMS up to 10 to 20% based on IEEE standard 1159-2019. When not protected by relays, the high-voltage electric power system of modern railway systems in the control and operation component system can cause failures in connections, cannot send current and voltage inputs to the control system, components in LRVs such as VVVF can experience overvoltage so that it can damage caused by overheating on the main converter or sudden failure of the operating system. When the relay works, the circuit breaker will trip, so that the power breaks the interconnection of the electricity system of the modern railway system. At the overvoltage experienced, we can see the risk of failure through.

Technical Recommendations

When the STATCOM proposal can be implemented, reactive compensators can reduce the effects of unbalanced loading using a thyristor that connects to the load and bus. STATCOM has very little active power capability because the voltage source is a DC capacitor. However, the active power capability of a DC capacitor can be enhanced by connecting a suitable energy storage device to it. Reactive power at the STATCOM terminals is proportional to the amplitude voltage of the source. For example, if the VSC terminal voltage is greater than the alternating current voltage at the connection point, STATCOM generates a reactive current (appears as a capacitor); Conversely, if the amplitude of the voltage source is less than the alternating current voltage, it absorbs reactive power (appears as an inductor). STATCOM is not cost-effective compared to *shunt reactors*, also, the inductance value is not below the control range. However, STATCOM is naturally increasing.

A nonlinear, AC-based power flow model is used to accurately represent system load-limiting corrective actions. A quantitative measure for the amount of reactive power required for compensation in the electrical subsystem is Provided. The techniques compared are, synchronous condenser, SVC, STATCOM, and inverter in wind-PV farms. The integration of different compensation technologies will increase the flexibility of power generation and transmission system operators (TSO) in providing reactive power. The system is designed for conventional power plants. Future work is to extend the Strategy to accommodate other additional Services. DSTATCOM is able to quickly and accurately compensate reactive forces, thereby improving the power quality of the system It should be noted that D-STATCOM is able to quickly and accurately compensate for reactive power, thereby increasing the quality strength of the system There is a lot research on detecting links, but there are still definite limitations in actual engineering, so widespread implementation is still a long way off. DSTATCOM is more advantageous than capacitors because capacitors do not perform well on low loads and are very slow (Pham et al., 2003). DSTATCOM is very fast and absorbs and delivers reactive power very quickly in all load conditions [7-8] and can also reduce voltage imbalances. When heavy current flows into the network then the losses in the system are more. By adding DG and DSTATCOM losses can easily reduce due to increased voltage. After an increase in voltage, the acceptable current flows into the distribution network, so a reduction in losses is carried out after injecting this device. The study of load flow is the determination of voltage, current, and power at any point in the electrical network under normal or irregular conditions. Load studies are very important in planning the future development of power systems. This is due to the fact that satisfactory operation of the system depends on knowing the effects of interconnection with other power systems, the introduction of new loads, new generating stations, and new transmission lines before they are built and installed in the real world. The main information obtained from the load flow Study is the magnitude and angle of the voltage phase on each of the buses in the system under consideration. In addition, the flow of active and reactive power in each line is calculated. System power loss, voltage drop, and line loading percentage are also determined.

Modern *railway system power supply systems should see* the failure of PLN's single incoming *20kV supply affecting the* power *supply* of each substation and train while in operation, and the failure of *busbar switchgear* while still operating. Failure *of the single* DC *circuit breaker* normal operation in all *sections* and ensuring the train continues to operate as well as degradation of requirements in the *power supply* system. The electrical system of modern railway systems can be interconnected and has protection and there is a need for a load flow analysis method that is in accordance with the train operation pattern implemented using E-Trax. Requires power quality analysis through a *Unified power quality conditioner* (UPQC) in the e-Trax program so that it can see the movement of train operating patterns that are more comprehensive.

In the field that reliability, scheduling, and maintenance planning need to be focused primarily on maintaining reliability and stock-taking of spare parts, in failure prediction and evaluation, training is needed in accordance with the results of the evaluation with a predictive and preventive approach that is appropriate in a fast and appropriate maintenance and maintenance risk management strategy. Power providers when disruptions occur need to be coordinated with modern railway systems before action. No later than 25 minutes by providing information to the modern railway system on the same day of the disruption. Predicting opportunities outlines in detail the positive potential that may be developed by considering existing controls through technological opportunities, and financial aspects (Shipunova et al., 2022). There is a need for inspection of the interrelation of overvoltage and impedance on the third rail side and the electrical system of modern railway systems. Overvoltage protection should monitor at least two detected phase voltages so that overvoltage operating characteristics should be selectable for a specific time or inverse time characteristics in electrical systems of 20kV, 900V, and 380V facilities and infrastructure. Embraced identifying high-voltage substations related to the capacity to provide power for modern railway systems, it is necessary to design cable routes and their technical specifications with conductor adjustments so that there is an ideal balance on the side of resistance, especially in the inductance and reactance of busbars and cables.

CONCLUSION

Modern electric railway system systems can be interconnected which has protection and requires a load current analysis method according to the railway operating model implemented with E-Trax. Assessment should be carried out without a compensation device installed and the addition of STATCOM/VAR to power quality problem situations with a focus on estimating the magnitude of the power quality problem taking into account line station differences. Requires non-linear loading filters with active, passive, channel, and electronic feedback harmonic types. When problems arise in areas where reliability is required, maintenance planning and planning primarily focuses on maintaining reliability and parts stock, failure prediction and evaluation require training based on evaluation results with appropriate proactive and preventive measurement approaches. Risk management strategies for prompt and reasonable maintenance and maintenance. Additional joints and impedance on the third rail side and electrical systems of modern railway systems should be checked. Overvoltage protection must monitor at least two detected phase voltages, so overvoltage operating characteristics must be selectable for a specific time or inverted time curves in 20 kV, 900 V, and 380 V building and infrastructure electrical systems.

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