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A Novel Approach for Mitigating Voltage Dips in Medium-Voltage and Low-Voltage Distribution Networks

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ABSTRACT

This paper examines voltage recovery in the event of a voltage decrease caused by a fault in the power network. Deficiencies in voltage are caused by these problems in the power network. At a particular location, power is brought back on, and the issue is seen as having been resolved. Within the scope of this research, a novel approach to lowering voltage losses in electrical circuits is proposed. In addition to other components, it is equipped with a solid-state switch and control electronics, as well as an energy storage unit. The decrease of voltage loss and the augmentation of voltage magnitude are two of the benefits that can be gained from the method that has been proposed. In conclusion, the purpose of this research is to provide an explanation of the fundamental operating principle of the approach and to demonstrate that Mat lab/Semolina possesses an exact representation of the technique.

Keywords: *Power Quality; Power Network; Voltage Dip and Control Electronics.*

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1. INTRODUCTION

Customers in residential, commercial, and industrial sectors supplied by electrical distribution networks receive reliable and high-quality electricity. Conversely, power quality challenges are increasingly imposed on contemporary power systems because to the swift rise in electricity demand, the integration of renewable energy sources, and the prevalent usage of sensitive technology devices. Voltage sag, commonly termed voltage dip, is one of the most prevalent and economically consequential issues related to power quality. The phrase "voltage sag" denotes a reduction in the root mean square (RMS) voltage that transpires over a duration of half a cycle to one minute, falling between 10 and 90 percent of the nominal value. In commercial establishments, hospitals, data centers, and manufacturing firms, brief voltage sags can disrupt industrial operations, damage sensitive electronic equipment, impair automation systems, and lead to significant financial losses. Consequently, the primary issues facing contemporary electric power systems are the improvement of voltage stability and the mitigation of voltage sags.

Voltage fluctuations can be ascribed to two fundamental sources. Transmission line faults, short circuits, lightning strikes, equipment malfunctions, transformer energization, switching operations, and unplanned outages exemplify the disruptions categorized as utility network disturbances. These disruptions result in a decreased supply voltage received by clients. These disruptions permeate the distribution network. Distribution feeders utilized by many consumers may induce secondary outages. Large industrial loads, including induction motors, electric arc furnaces, welding equipment, compressors, pumps, and heavy machinery, draw significant inrush currents during startup or quick loading. The elevated currents result in substantial voltage drops across the feeder impedance, thereby harming adjacent consumers linked to the same Point of Common Coupling (PCC). The impedance of the system, feeder length, transformer capacity, fault location, and load magnitude are all factors that affect the severity of a voltage dip.

For substantial electrical equipment, a beginning current typically ranging from five to eight times the rated running current is commonly necessary. Cables employed in installation and distribution systems can endure the standard currents utilized in operations. The abrupt increases in current are the primary cause of the substantial voltage losses that transpire across the network impedance. Neighboring customers report a voltage dip lasting from a few cycles to several seconds. The duration of the voltage drop is dictated by the operational parameters. Although they may endure for an extended duration, reductions in motor starting voltage are frequently less severe than declines in system failure. In industrial facilities with numerous continuously operating motors, frequent sags can diminish equipment efficiency, cause production downtime, escalate maintenance costs, and reduce the lifespan of electrical equipment. The extent of these voltage dips is directly affected by several factors, including the impedance of the utility supply network, the installation's cabling, and the point of common coupling to which the customer load is connected.

Voltage sag has been one of the most extensively investigated issues in the realm of power quality during the past decade. This is chiefly because to the substantial technological and economic ramifications it entails. Microprocessor-based technologies, including programmable logic controllers (PLCs), variable frequency drives (VFDs), robotic production systems, computers, and communication equipment, are particularly essential in contemporary organizations. These devices are very responsive to even minor variations in voltage. Transient voltage sags can lead to numerous adverse effects, such as process interruptions, equipment malfunctions, data loss, product issues, and expensive production downtime. Consequently, academics and engineers in the electrical domain have dedicated substantial effort to analyzing the features of voltage sag, identifying its contributing variables, and devising effective mitigation strategies. Various international standards, such as those set by the IEEE and the IEC, define voltage sags based on their duration and severity of damage. These guidelines aim to establish a standardized framework for assessing equipment performance and power quality in demanding operational conditions.

This type is the most commonly utilized for voltage sags. This method indicates that following a disturbance, the supply voltage rapidly decreases to a lower level and subsequently returns to its usual value once the fault is rectified. The globally known power quality standards are IEEE Standard 1159 and IEC 61000. The residual voltage magnitude and duration were the two primary metrics employed in measuring a voltage sag. These factors dictate the magnitude of the disruption and its impact on different types of electrical apparatus. Power quality monitoring systems continuously assess these events to evaluate system performance and ensure compliance with regulatory standards. Moreover, sophisticated monitoring technologies enable utilities to pinpoint network segments susceptible to errors, detect recurring issues, and implement corrective actions to enhance voltage stability.

A variety of compensatory mechanisms and specialized power devices have been devised to mitigate voltage sags. Examples of these include the Dynamic Voltage Restorer (DVR), Distribution Static Compensator (DSTATCOM), Unified Power Quality Conditioner (UPQC), Static Synchronous Compensator (STATCOM), and uninterruptible power supply (UPS) systems. Conversely, the Dynamic Voltage Restorer (DVR) has attracted significant attention owing to its rapid response time, excellent efficiency, and capability to inject the requisite compensatory voltage during a sag event without interrupting the load. To enhance the efficacy of the voltage compensation systems, sophisticated control algorithms, power electronic converters, and renewable energy sources were integrated. Consequently, effective voltage sag mitigation has emerged as an essential element of contemporary electrical distribution networks to guarantee a power supply that is consistently reliable, efficient, and of superior quality.

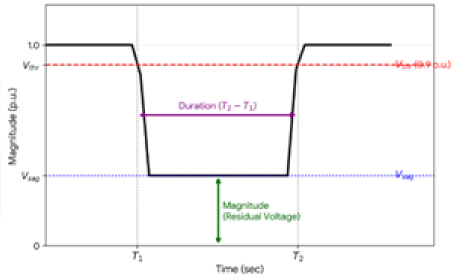

Fig1: Voltage drop is a genuine phenomenon.

The reduction of a voltage, on the other hand, may create a change in the geometric shape of a system even in the absence of mechanical components, as demonstrated by experimental evidence. In the event that there is a failure or a dip, the voltage will drop very quickly. Following the resolution of the problem or dip, the voltage will return to the level it was at before to the occurrence of the problem.

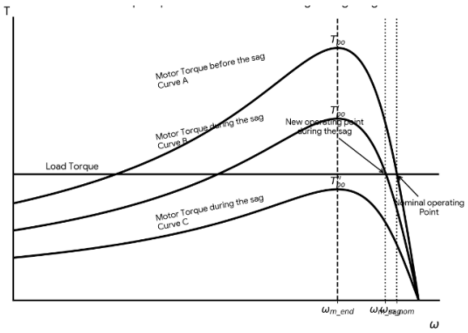

Fig2: The torques exerted by the motor and load before and during certain instances of voltage sags.

Spinning machine loads are regarded as an additional component that affects the system. It is not the case that the voltage will immediately drop to zero; rather, it will gradually decrease to zero throughout the course of the fault's duration, either until equilibrium is reached or until the fault is resolved. From this point forward, this will continue until the problem is fixed for the long term. In the event that these criteria are met, the voltage will gradually return to the value that it had when it was first measured.

Induction motors have the potential to have their protection selectivity and their ability to start reduced when they are subjected to currents that are higher than the rated value. In the case of power electrical systems that make use of converters that transform direct current into alternating current, this is the situation that occurs.The implementation of dynamic voltage restorers, which are more generally known as DVRs, was carried out with the purpose of enhancing the protection of distribution networks. This was done in order to increase the efficiency of the protective system. In the event that there is a problem with the distribution system, it is possible that load feeders in the nearby area will experience a rapid loss of power. This is a possibility. In order to simplify the monitoring of the power restoration process in a timely manner, digital video recorders, which are commonly referred to as DVRs, are strategically positioned at various locations along the power path. with the purpose of preventing harm to fragile tools, machinery, and other tools and equipment than would otherwise be possible.

An energy storage element, control electronics, a solid-state switch, a harmonic filter, an isolation transformer, a voltage source converter, and a solid-state switch are the components that make up a Dynamic Voltage Restorer, which is also known as a DVR. In addition, a solid-state switch. One of the limitations of this digital video recorder (DVR) is its dynamic performance, which is something that ought to be taken into consideration. One of the most important aspects of the device is its speed capabilities, which allow it to deal with rapid voltage drops. These capabilities are among the most important components of the device. You need to take into consideration the magnitude, duration, and severity of voltage dips if you want to get the most out of the energy storage equipment that you have. Your equipment will be able to function at its most effective level as a result of this. A filter needs to be applied to the switching converter in order to cut down on the amount of harmonic elements that are included within the converter. This step is quite important. It is also necessary to take into account the issue of the dependability of the equipment, which is another factor that must be taken into consideration. This does not resolve the issues that were brought up earlier in the talk; it does not offer a solution to those issues. One of the detriments of the digital video recorder (DVR) is that it has a high power density, which represents a disadvantage. We can trace the comparatively high cost of home video recorder (DVR) components to the low power density of these components, which is the reason for the relatively high cost.

2.OPERATIONWITHDVR

The current method involves the utilization of an inverter in order to supply a sinusoidal voltage following a voltage drop and a catastrophic failure. Following this, the amplitude of this voltage is altered so that it can serve as the output voltage that will be utilized by the system. By utilizing the standard inverter voltage output regulation method, the essential apparatus is able to function in a dependable manner. It is seen in Figure 3 that the entire flowchart of the approach is shown. The initials ZL and CB stand for line impedance and circuit breaker, according to their respective meanings. Additionally, an inverter, a filter, an isolation transformer, and a power storage device are all essential components for any digital video recording system. Utilizing static triacs as a means of removing the requirement for a digital video recorder (DVR) during regular operation is a common technique. In the case that there is a problem with Load 1, the inverter will produce a sinusoidal voltage, which will then be linked to the Load 2 bus in a sequential manner.

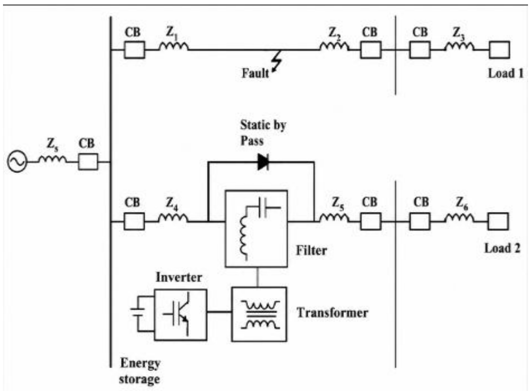

Fig3: The figure illustrates a standard digital video recorder (DVR).

According to the information presented in [10], transformers are frequently linked in series in order to isolate the inverter output voltage from the bus line. The high frequency carrier can be removed from the signal by utilizing pulse width modulation, which can be used to create a filter. As can be seen in Figure 4, a significant number of cycles are required in order to achieve the desired output and input voltages of the inverter.

The adjustments to the voltage are delayed as a result of the filter [9]. The need that the transformer must always keep the power frequency at 50Hz is one of the drawbacks of this method. It is also one of the reasons why this method is not recommended. As the capacity of the transformer increases, the magnetic fields that are produced by the core of the transformer decrease. This is because there is an inverse relationship between the magnetic field and the operating frequency. Therefore, the size of the transformer will expand, which will result in the system becoming larger and more expensive.

It is illustrated in Figure 4 that the DVR is responsible for bringing the source, inverter, and load voltages back to normal homeostasis following a voltage drop.

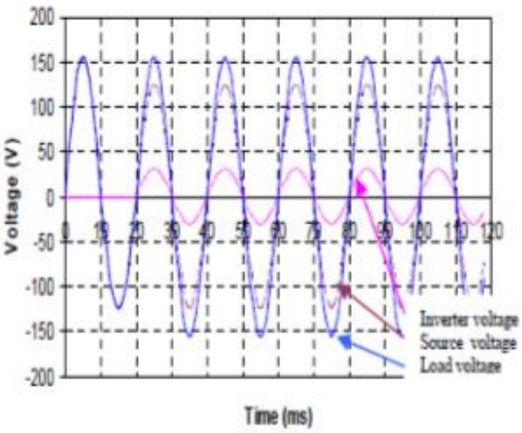

Fig 4. The DVR assumes the responsibility of reestablishing equilibrium among the voltages of the source, inverter, and load in the occurrence of a voltage drop.

3.PRAPOSINGCLASSICALCOMPENSATION

The power conversion technology has been upgraded in addition to the conventional digital video recorder in order to address the difficulties that were mentioned earlier. The presentation of switching electronics alternatives includes a discussion of the various topologies for power conversion and exclusive isolation. By utilizing high frequency inductors for the purpose of magnetic energy storage and isolation, this problem can be resolved in a very comprehensive manner. The paradigm of energy storage and switching power that is now in use is compatible with the ways that use switched capacitors. Power factor correction (PFC) is a technique that can be utilized to enhance power quality by reducing electromagnetic interference (EMI). Resonant switching is one implementation of PFC.An illustration of the system configuration can be found in Figure 5, and the appendix has ratings for the source, transformer, load, and line. One of the states of the system is the subject of the question. When the inductor is connected in series and the capacitor is connected in parallel, it is possible to achieve parallel resonance at the fundamental frequency. It is common practice to make use of the static Triac in order to postpone the activation of the compensatory arrangement until the control system is aware that another problem has occurred.

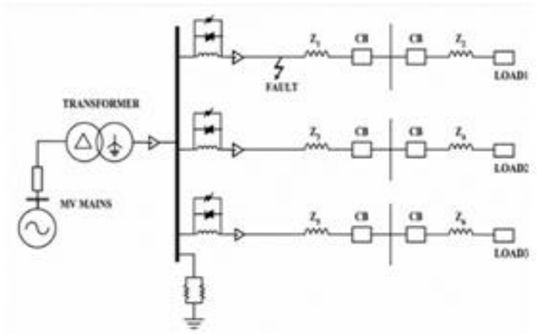

Fig 5. A visual depiction illustrating the standard salary range.

The network does not perceive the energy injection setting, It does not affect load performance. The bus receives electricity from a capacitor bank in the event that load1 ceases to function. In order to accomplish this objective, the static appliance that has been triggered should be connected in series with the energy storage component.

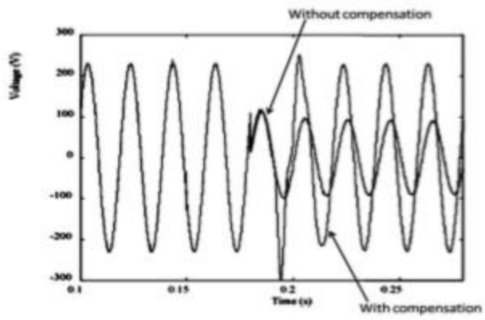

Fig 6. In the absence of remuneration, as well as in the presence of it,

The advantages are readily apparent. One of the primary objectives of this initiative is to cut down on expenses. There is also a reduction in the size of the apparatus.

In order to compensate for the voltage loss that occurs at the common connection point, it is possible to do so. The procedure is completed in a short amount of time. For the purpose of determining the optimal time to install devices, determining the impedance of the deficit, and identifying the occurrences of the problem, it is necessary to conduct a comprehensive examination of the methodology of investigation.

4.APPENDIX

Source rating:

The source has a voltage of 33 kilovolts between its phases.

One half of a hertz was the frequency that was recorded, along with the frequency.

Transformer rating:

Transformer ratio of 0.44 at 33 kilovolts per kilovolt.

The system is capable of producing a nominal output of 250 MVA. 50 hertz was the frequency that was recorded.

Load ratings:

Load	VAVG (VOLTS)	Freq (Hz)	P (KW)	Q (KVAR)
L_1	440	50	35	1
L_2	440	50	15	1
L_3	440	50	20	1

Lineratings:

Line Name	Length(Km)
TL1	**30**
TL2	**10**
TL3	**10**

5.CONCLUSION

Compensating devices improve the performance of passive networks by increasing the voltage at the Point of Common Coupling (PCC), thereby reducing voltage losses during suboptimal network operation. This paper demonstrates this method. This method reduces equipment dimensions and decreases operational expenses while effectively alleviating voltage fluctuations at the power control center. These advantages have been substantiated by computer analysis and preliminary prototype evaluation. The experiments demonstrate the practical potential of the suggested technique for improving the stability and efficiency of the system.

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