POWER QUALITY ENHNACEMENT BY USING DVR

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Abstract: Consumers and utilities alike should be concerned about the current state of the power system's power quality. Numerous problems have arisen as a result of the integration of renewable energy sources, smart grid technology, and increasing use of power electronics equipment. Harmonics in current and voltage, voltage sag, and swell are all dangers to the sensitive electronics. Interference with other parts of the system can cause voltage variations in these devices. This is why power quality is so important now because of an increase in sensitive and expensive electronic equipment that requires reliable and safe functioning. In the distribution grid, the Dynamic Voltage Restorer (DVR) is a common D-FACTS (Distribution Flexible AC Transmission System) device for dealing with non-standard voltage, current or frequency. Stable voltage to the load is maintained by injecting voltages into the distribution line. A MATLAB/Simulink simulation of the suggested strategy's ability to smooth the distorted voltage caused by harmonics was carried out. The 3rd and 5th harmonics are included in a power system model with a specific power supply. For both DVR and non-DVR scenarios, the system's responsiveness to load voltage is evaluated. A smooth adjusted load voltage was achieved using the proposed DVR-based approach, which effectively regulated voltage distortion. With the addition of 3rd and 5th harmonics to the supply voltage, the load voltage THD percentage rose from 18 to 23 percent. In both cases, the deployment of the planned DVR reduced THD by less than 4%.

Key words: Power quality, FACTS, Dynamic voltage restorer

I.INTRODUCTION

Invisible and readily available in most of the world, electrical energy is today acknowledged as a consumer necessity [1]. As a supplement to solar, solar thermal, wind, and other renewable sources of energy (RES), RESs are utilized. [2] and [3] The intermittent nature of RESs, harmonic distortion, and reactive power causes the power system to become unstable, resulting in worse power system performance. For reactive power correction, voltage stability, and power quality in distribution networks, FACTS devices are frequently used [4] and [5]. FACT devices, on the other hand, affect a variety of system parameters [6]. It is the goal of this research to uncover the root causes of poor power quality and propose solutions to these issues. Sensitive equipment includes things like computers, laptops, relays, solid-state electronics, variable speed drives, and optical devices. When other portions of the system interfere with the power supply, these devices are vulnerable to voltage fluctuations. Generation, transmission, and distribution are all components of the power system, which is provided to a variety of loads on the distribution side by means of other transmission lines. When a variable amount of power is being delivered to the load, power quality is critical. As a result, clients with delicate loads, such as those in the home and the workplace, are affected. Even if there are a variety of loads on the distribution side, poor power quality has a greater impact on sensitive loads than on other types of loads. Sensitive loads are becoming increasingly important in a wide range of applications, from operating rooms in hospitals to semiconductor systems in processing plants to database systems to gadgets to monitor air pollution in populated regions. They may fail in the event of an unstable power supply that results in a substantial amount of money being wasted.

Therefore, power quality affects the distribution side. Controlled and unaffected electrical characteristics are specified by the power systems to ensure that their functions are not disrupted. We'll talk about voltage surges and distorted voltage with lots of high harmonic content. As a result of voltage disturbance caused by faults, there is sag, transient and a high distorted voltage with harmonic distortion and Total Harmonic Distortion (THD). Voltage sags and harmonics issues can be particularly damaging to sensitive instruments. Many issues can arise as a direct result of voltage sag, including motor torque disturbances, device overheating and burning, and device misfiring, to name a few. For power quality to be properly addressed, the harmonic must be addressed. [7] When considerable current is extracted from the power supply, a short duration reduction in RMS voltage appears, generally known as voltage dips [7]. When someone turns on an air conditioner or a large motor, for example, utility instruments are the primary cause of sag production during the initiation of the load and remote fault clearance. There is a six-fold increase in current when the motor is running compared to the actual current. Voltage sag will be introduced during the motor's startup due to a large amount of reactive power being absorbed.

For example, during a half-cycle to one-minute time span, a shift in voltage of 10 to 80 percent can be classified as a voltage swell. When voltage sags, and the voltage profile continues to rise, this results in overvoltage. Temporary, momentary, and instantaneous surges in voltage are three of the many forms of surges that can occur in electrical systems. Voltage swell occurs when the connection of big loads is disrupted. An increase in the voltage of the phase and natural wires that are faulty.

Single Line to Ground Faults is caused by a loose connection (SLG). Voltage swells can lead to electrical equipment failure due to overheating and damage, as well as insulation collapse. Figure 1 illustrates the voltage swell. Voltage harmonic distortion occurs when fundamental frequencies, like as 50 Hz, are multiplied by three, resulting in a result of 3 50 = 150 Hz. As seen in Figure 2, this is the third harmonic of the fundamental frequency. Harmonics are created by switching in power electronics because of the function of switching. Overheating and breakdown of circuits without proper management based on clear sine wave activation at zero crossover point are signs of harmonic issues [3], [8].

The following are the study's most important takeaways: lower than 5% of total harmonic distortion (THD) can be achieved by mitigating the problem of voltage distortion owing to harmonic distortion. Use MATLAB / SIMULINK and DVR to access and assess the performance of the provided model. 3. and 5. harmonic voltage profiles into the input voltage profile in order to better understand the power system. compare the DVR-based power system's performance to that of a system not using a DVR by inserting the identical third and fifth harmonics.

II. LITERATURE SURVEY

[1] N. Khan, S. Dilshad, R. Khalid, A. R. Kalair, and N. Abas, ‘‘Review of energy storage and transportation of energy,’’ Energy Storage, vol. 1, no. 3, Jun. 2019, doi: 10.1002/est2.49.

Continuity of supply to the client is ensured in large part by energy storage and transportation. Greenhouse gases (GHG) created by fossil fuels are causing a drastic shift in the generation of electricity around the world. It is possible to reduce GHG emissions in the environment by using energy storage systems (ESSs) to deal with unpredictable daily and seasonal fluctuations in demand for electrical energy. Mechanical, electrochemical, chemical, and thermal energy storage methods exist. Pumped storage and stored fuel for thermal power plants are the most commonly used methods of storing energy. In this work, the taxonomy of ESSs, their current state, shortcomings, and current tendencies are discussed. The current condition of fossil fuel reserves, their production, consumption, and CO2 emissions are also examined in this report. Coal, oil, and natural gas are not evenly dispersed around the globe, making them difficult to obtain. Transportation and distribution of these vital resources is constantly required because of the long distances involved in delivering these energy carriers. This study also discusses the many techniques of transporting energy from the supply to the demand. The current state and future prospects for energy storage and transportation in Pakistan are examined, as are the pros and cons of various storage systems. The copyright for this item has been taken care of. It's yours to keep.

[2] M. A. Basit, S. Dilshad, R. Badar, and S. M. S. ur Rehman, ''Limitations, challenges, and solution approaches in grid-connected renewable energy systems,'' Int. J. Energy Res., vol. 44, no. 6, pp. 4132–4162, May 2020, doi: 10.1002/er.5033.

Traditional energy sources are no longer able to meet the world's rising energy demands. A technological revolution is built on the foundation of electricity. At the current rate, most of our electrical needs are fulfilled by burning fossil fuels that have a negative effect on our ecosystem. Non-conventional and environmentally friendly methods of generating energy are being examined as a way to bridge the gap between demand and supply. The problems caused by greenhouse gases can be alleviated effectively with the deployment of renewable energy systems (RESs) (GHG). However, their power generation is highly variable and requires specialized site conditions. Power quality, dependability, power system stability, harmonics, sub synchronous oscillations (SSOs), reactive power compensation (RPC), and other issues may arise from the grid integration of renewable energy sources (RES). The intermittent nature of RESs can be alleviated by integrating energy storage systems (ESSs). Renewable energy sources have been thoroughly examined in this work. The use of ESSs in RESs as well as the stages of RES development have been examined. The role of ESSs in boosting the power system's life expectancy, efficiency, and energy density has been examined. And in addition, a variety of solutions have been given to address the essential challenges of PV systems such as low efficiency, harmonics, and inertial reduction. In contrast to typical review studies, this work examines the influence of FACTS technology in RESs-based power systems employing multitype flexible AC transmission system (FACTS) controllers. In MATLAB/Simulink, three models have been created. In the end, the results reveal that FACTS devices help to stabilize the RESs integrated power system. This review study is expected to help researchers from both industry and academia better grasp the difficulties and solutions for REs-based power systems and the future research dimensions in this field.

[3] A. Kalair, N. Abas, A. R. Kalair, Z. Saleem, and N. Khan, ''Review of harmonic analysis, modeling and mitigation techniques,'' Renew. Sustain. Energy Rev., vol. 78, pp. 1152–1187, Oct. 2017, doi: 10.1016/j.rser.2017.04.121.

The malfunction of sensitive equipment is caused by voltage, current, or frequency abnormalities in the power supply. Nonlinear loads and the integration of inverter-connected PV and wind power plants have led to a harmonic problem in the power grid. Linear and nonlinear loads and switches, whether powered by sinusoidal or no sinusoidal sources, generate harmonics in the distribution network. For the purpose of integrating devices into harmonic analysis software, academics who study harmonic analysis model nonlinear loads and construct Norton and Thevenin equivalent circuits of devices. An experimental researcher may utilize harmonic analyzers to assess the harmonics in real systems to determine the most effective mitigation options. Because of the distorted power losses, utilities must boost apparent power to ensure a consistent and reliable power supply. For on-site measurements, harmonic analyzers use data acquisition hardware and built-in software algorithms. True power factor, total harmonic distortions, reactive and distortive power losses can be found with harmonic analyzers. When shunt capacitance is used at unity power factor, the situation gets worse rather than better. Further research into active power factor correction systems, which use clever algorithms to cancel out distortion, has been undertaken. Harmonic nonlinear physics is described to delve deeper into its applications. By creating a harmonic filter, we were able to compare and contrast various methods of reducing harmonics. Single and three-phase electronic loads are tested for conformity with harmonic standards by measuring harmonics, waveform distortions, and the true power factor (TPF). Harmonics in distribution networks must be reduced in order to achieve energy conservation. Due to the extensive use of nonlinear loads, this study indicated a 60–10 percent reduction in power factor and an increase in line losses of more than 2%. Consumers' accidental violations of IEC Standard 61000-3-2 and IEEE Standard 519–1992 lead to an increase in utility perceived power consumption.

[4] F. H. Gandoman, A. Ahmadi, A. M. Sharaf, P. Siano, J. Pou, B. Hredzak, and V. G. Agelidis, ‘‘Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems,’’ Renew. Sustain. Energy Rev., vol. 82, pp. 502–514, Feb. 2018, doi: 10.1016/j.rser.2017.09.062

It has become increasingly difficult for utilities to maintain power quality, voltage stability, and efficient energy use in the last two decades, due to the increasing use of renewable and distributed energy sources. Electronic converters are used extensively to connect new energy systems (with and without storage) and smart buildings to transmission and distribution networks. In order to improve the power quality, flexible ac transmission systems (FACTSs) and voltage-source converters, with sophisticated dynamic controllers, are developed. FACTSs also play a vital role in improving the power factor, enhancing the quality of power, and assuring effective energy consumption and management in smart grids with renewable energy sources. Power quality and renewable energy system usage can be improved by using FACTS technology tools and applications.

III.PROPOSED SYSTEM

The quality of the power supply can be determined by the frequency of the supplied voltage, which is an important sign of power quality. IEEE defines voltage sag as an RMS voltage drop of 0.9 per unit (p.u) 0.1 p.u of a nominal p.u, with a depth of the fall ranging from 10 ms to 60 seconds, as a drop in root mean square (RMS). Due to a variety of factors, voltage sags at the distribution level are frequently checked for the load. High-tech industries are particularly sensitive to voltage sags. While distortion and oscillation occurred, the load voltage requirements could be met with a specified frequency and an exact value of voltage drop. Voltage sag is the most common cause of the destruction of the manufacturing sector and its downtime, which is expensive and causes harsh problems for customers. Electric devices, also known as consumer power devices, are used to supply the distribution system with a certain amount of energy and voltage. The complicated issue could be solved. As opposed to the usual techniques of dealing with voltage sags, the DVR is expected to be a more effective solution. A DVR at the distribution level is used to remove voltage sag in order to assess the system's performance.

A. DYNAMIC VOLTAGE RESTORER PRINCIPLE

There is a GTO or IGBT based Voltage Source Inverter (VSI), a capacitor bank, and an injection transformer in the DVR. Solid-state power electronic switching device is another name for the DVR. Figure 3 shows a DVR connected to a distribution bus. Using an injecting transformer and a forced-commutation converter, the DVR creates a control voltage that matches the bus voltage and is injected into the system. Droop-controlled converter control topologies are described. Figure 1 shows how a DC voltage source functions like a device for storing energy provided by a DC capacitor

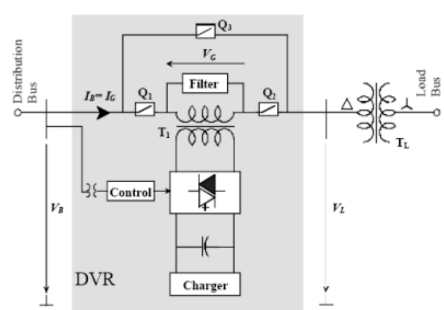

Fig. 1 Circuit of Dynamic Voltage Restorer

B. OPERATION OF THE DVR

Its main goals are to maximize the feeder capacity utilization (by minimizing the rms values of line currents for a specific power demand), reduce losses, and improve power quality at the load bus. For the most part, the main assumption was to ignore any variances The voltages at the source. In other words, the dynamics of the source voltage are much more sluggish than the dynamics of the load. harmonics can be caused by uncompensated nonlinear loads on the distribution system. Series-connected compensators are used to alleviate the effects of a subpar power supply. To compensate for voltage dips and surges, they're known as Dynamic Voltage Restorer (DVR) devices in the literature.

DVRs have now been implemented in microprocessor fabrication plants, paper mills, and other industrial facilities to monitor their operations. DVRs are typically modular in architecture, with modules ranging from 2 MVA to 5 MVA in capacity. From 11kV to 69kV, they have been installed in substations. During voltage sags, a DVR must power the load. There are many advantages to using a shunt converter to supply DC power to an active DVR for long periods of time. Here, we'll see about how DVR can be used to measure fundamental frequency voltage.

Each converter in the series is connected in order to give the needed voltage rating for the voltage source converter. Using the DVR, each phase can be supplied with a voltage of the required magnitude and phase. The DVR can be used in two ways:

I)To put it another way, the voltage delivered into the system in standby (also known as "short circuit operation" or "SCO") mode is zero.

ii)Boost (when the DVR injects a required voltage of appropriate magnitude and phase to restore the pre-fault load bus voltage).

Figure 2 shows the DVR's power circuit, which includes the following five components:

i) Voltage source inverter

An increasingly common method for generating VSI (PWM) is Pulse-Width Modulation (PWM). An energy storage device has been used to generate a DC voltage as discussed previously. DC to AC voltage conversion is done by a VSI, which is the source of this conversion. It has been used in the DVR power circuit to increase the voltage magnitude at the time of the sag event. For now, it suffices to keep the VSI voltage at the minimum.

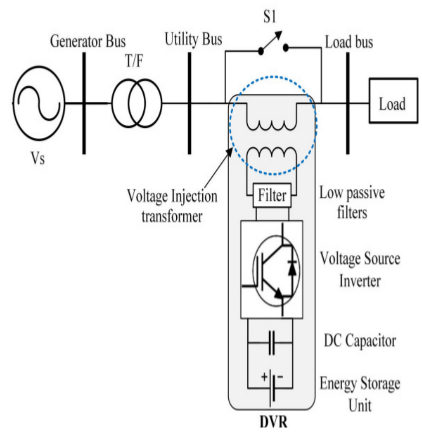

Fig.2 Dynamic Voltage Restorer

ii)Injecting transformer

In order to connect the VSC to the higher distribution voltage level, three single-phase transformers are connected in series with the distribution feeder. Star/open star winding or delta/open star winding can be used to connect the three transformers in the same way. Zero sequence voltage cannot be injected in this manner. Step-down transformer connections determine which winding of injection transformer is best suited for feeding the load.

iii)Passive filters

Both the high voltage side and the converter side of the boost transformers can use passive filters. Higher order harmonic currents due to the VSC do not °own via the transformer windings because of the converter side filters' lower voltage rating. The filter inductor's drawbacks include voltage drop and phase (angle) shift in the injected voltage (basic component). This can be expected from the DVR's control method. High-frequency currents can flow through the transformer winding due to a location of the filter on the high-voltage side, which removes downsides but increases the transformer's rating because of the high leakage reactance.

iv)Energy storage

Flywheels, Lead-acid batteries, Superconducting Magnetic energy storage (SMES), and Super-Capacitors [28] are all examples of energy storage systems. The major role of the storage unit is to provide real power during voltage sags. The active power produced by the energy storage device defines the DVR's compensating capabilities. Lead batteries are being employed instead of alternative storage systems because of their rapid charging and discharging response times. Internal space is determined by the rate of discharge, which is determined by a chemical process that takes place inside the device.

v)Pass-through switch

A DVR is part of a series. Fault currents can be caused by currents passing through the inverter if a fault exists in the downstream. The By-pass switch is being used to protect the inverter. A crowbar switch is commonly used to bypass the inverter circuit. Crowbar would deactivate when the current is within the inverter's range. On the other hand, if the current is too high, it will allow the inverter components to be bypassed.

IV.CONTROL STRATEGY

The following are the three most common methods of control.

Compensation for pre-sag

When the pre-sag condition occurs, the supply voltage is constantly monitored, and the load voltage is corrected accordingly. A higher DVR rating is often required for this method to work, as the load voltage is almost unaffected. Vo is equal to VS before sags develop. The magnitude of the supply voltage drops to VS1 due to the voltage sag. The supply's phase angle may also change (see Fig.2.2). The load voltage (VL = VS1 + VC1) is maintained at Vo by injecting a voltage VC1 from the DVR (both in magnitude and phase). According to some sources, it's required to correct for both phase jumps and voltage sags since some loads are more sensitive to phase changes than other loads.

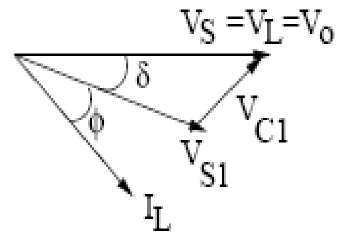

Fig.3 pre sag phaser diagram

Compensation for Delay

Regardless of load current or pre-sag voltage, the DVR injects a voltage that is always in phase with the supply voltage (Vo). Using this method, the injected voltage is kept at a minimum (magnitude). However, the load voltage phase is out of whack. To maximize the voltage rating of the DVR, this control method is used for loads that aren't sensitive to phase jumps. For these solutions, the DVR's power consumption is not zero.

V. PROPOSED CONTROL SYSTEM FOR DVR

The SRF theory is employed to estimate the reference signal in the DVR control block shown in Fig.4. To determine the IGBTs' gate signals, sensors measure the voltages at the supply and load terminals (vS and vL, respectively). The generated unit vector [23] is used to extract the reference load voltage V*L. A phase-locked loop is used to obtain unit vectors (sin,, cos,) from the load voltages (VLa, VB, VC) and then convert these to the rotating reference frame using the abcdqo conversion.

$$\begin{bmatrix} v_{Lq} \\ v_{Ld} \\ v_{L0} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} v_{Laref} \\ v_{Lbref} \\ v_{Lcref} \end{bmatrix}. \quad 1)$$

Similarly, reference load voltages

vDd =vSd – vLd (2)

vDq =vSq – vLq . (3)

PCC vS voltages are also transformed to the rotating frame. A rotating reference frame is used to acquire the DVR voltages.

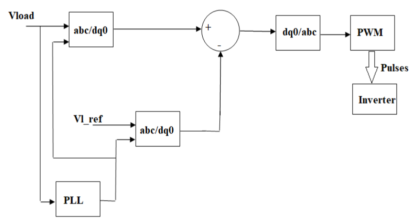

Fig. 4. Control block of the DVR that uses the SRF method of control.

VI.SIMULATION RESULTS

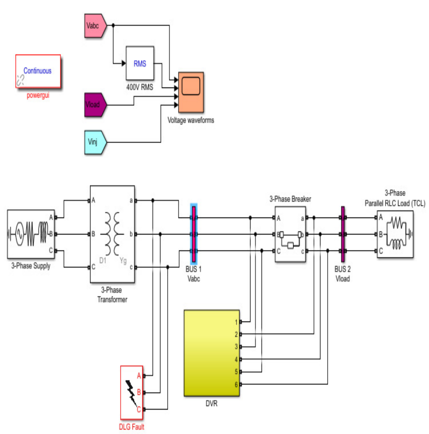

Fig .5 MATLAB/SIMULINK diagram of proposed DVR system

TABLE .1. Parameters and values of test system

Parameters	Values
Supply Voltage	415 kV
Frequency	50 Hz
Load Power Factor	0.74
Converter	IGBT (3arm-6 pulses)
Load active power	7.5 kW
Load reactive power	6.6 kVA

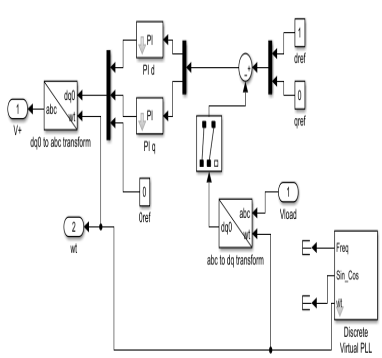

Fig 6 Controller system

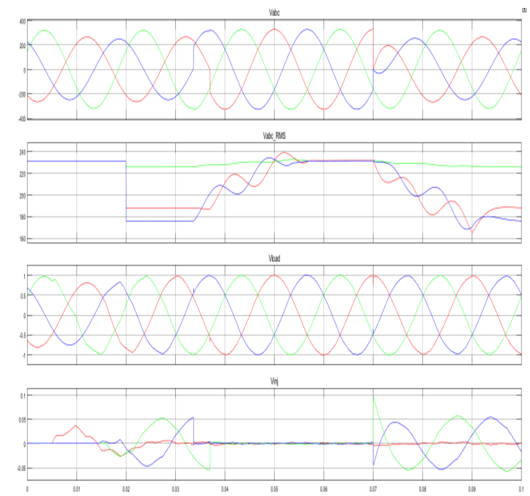

Fig.7 (a)Source voltage under sag condition (b) RMS voltage (c) Load Volatge d) DVR injected voltage

CONCLUSION

To improve the quality of power, DVR has been recommended as the most important gadget and has shown to be a beneficial and effective device. The control circuit and power system with a sensitive load are modelled and constructed using the MATLAB/Simulink platform to simulate a DVR with a power circuit. With and without the DVR, the test system's DVR is tested and compared to see how it performs. Programmable voltage sources are used to deliver distorted voltages with initially 3rd harmonic content, then 5th harmonic insertion in the supplied voltage. To compensate for the distortion of the load voltage, the proposed DVR-based control method was successful and maintained a more stable and smooth voltage profile with very little harmonic content. When the DVR injects the appropriate voltage component into the voltage supply, it is possible to remedy any voltage supply problem and keep the load voltage normal and stable in the optimal range. Future study in this field could benefit from the use of adaptive Neuro Fuzzy controllers for power quality improvement, for example. To improve the reliability of the power system, authors have already included Type-2 Neuro Fuzzy controls.

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