ISSN: 2096-3246
Volume 54, Issue 03, October, 2022

Voltage SAG Mitigation for Grid Connected Hybrid PV-Wind Power System Using Battery and SMES Based Dynamic Voltage Restorer

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Keywords:
Voltage, Mitigation, Grid, PV-Wind.

ABSTRACT

"Green" power can only be produced by using renewable energy sources, which are plentiful and long lasting. Intermittent energy sources such as solar photovoltaic's and wind energy may experience fluctuations in power production due to the weather and the amount of sunlight they get respectively. To dampen distribution-side variations and shield mission-critical loads from power failures. To protect sensitive loads from being of affected by the distribution side protection and faults DVR is commonly used popular tool is the dynamic voltage Restorer,(DVR). The focus of this study is on strengthening the resilience of a hybrid PV-Wind power system to voltage fluctuations at the grid level. When there is a voltage drop, the power flow is corrected using a Dynamic voltage restorer (DVR) equipped with batteries and super magnetic energy storage (SMES). At the point of common coupling (pcc) the magnitude and angle of the three-phase voltage are typically locked by the pre sag compensation utilized. The ML-DVR circuit is shielded from interference thanks to the transformer, which isolates it from the mains. When building the ML-DVR, it is essential to consider the VSI capacity and the link filter values that connect the injection transformer and the inverter. The purpose of this study is to provide a novel design for a Dynamic Voltage Restorer (ML-DVR) Smaller link filter values and higher voltage source inverter (VSI) capacities increase the system's capacity to dampen voltage harmonics, swell, and sag in response to a wide range of fault circumstances. There is hope that the innovative RLC filter can do away with switching harmonics. A lower inductance requires less of a dc voltage supply. Furthermore, the modern ML-DVR architecture has the potential to enhance voltage quality by the battery and super magnetic energy storage (SMES) based DVR isused as a compensating device incase of voltage sag condition. It has been shown how the model's RLC filter parameters are organized generally. The new DVR, as recommended by ML, is a MATLAB-designed and -simulated Dynamic Voltage Restorer (DVR) with control over the voltage.

1. INTRODUCTION

Concerns about power quality have come to the force in recent years as the electricity system has become more vital to modern society. Has expanded & more sensitive cargo have some kind of link to it. Power quality is very bad when it causes voltage spikes, dips, harmonics, and flashes. The voltage drop might have resulted from anything on either the load or supply side, such as operating, starting an electrical motor or heater, etc. The ML-DVR is injecting the voltage in order to avoid power loss. The widespread use of non-linear loads like diode bridge rectifiers, ASDs, SMPSs, laser printers, etc., has led to deterioration in power quality. Voltage sags, which may last for a half cycle or more, cause RMS voltage dips of 0.1 V to 0.9 V. Problems occurred often in distribution systems if voltage fell to 40% - 50% of the specified level for less than 2 seconds. It is crucial to shield vulnerable loads from the harmful effects of the mentioned power quality issues are compensated by Battery and super magnetic energy storage.

Dynamic voltage restorer this kind of power source is preferred since it produces little greenhouse gas emissions and is in short supply. That is why it is so important to include in RES like wind and solar photovoltaic (PV) into plans for meeting future energy dynamic voltage restorer, Furthermore, state-of-the-art electrical power tools are now easily accessible. When the quality of the supply voltage rapidly degrades, DVR uses the combined skills of a distribution static compensator (D-STATCOM), unified power quality conditioner (UPQC), and dynamic voltage restorer (DVR) to restore the load voltage at the output terminals. To keep the rated load voltage above the grid voltage, ML-DVR injects the appropriate amount of voltage into the grid in series with the grid voltage. An ML-DVR system consists primarily of an inverter, an injection transformer,an super magnetic storage system (SMES) and a battery (BES). The purpose of each of these diverse inverter topologies is the same to prevent the load voltage from fluctuating by the injection of stable voltage at a precisely controlled amplitude and phase.

Multi-Level Dynamic voltage RestorerModeling the ML-DVR is a switching device for power electronics that introduces an adjustable voltage into the load voltage bus through a series connection. If this voltage is applied, the load will be unaffected by any disruptions in the voltage bus. When connected in series between a power supply and a load, a multilevel dynamic voltage regulator (ML-DVR) improves the voltage at the load or recovers lost voltage. To protect sensitive equipment from voltage drop, ML-DVRs may be wired in series with distribution systems. When there is a drop in voltage on a channel in the power grid, the ML-primary DVR is responsible for correcting for it by injecting additional voltage [2]. Here is the virtual circuit without the ML-DVR.

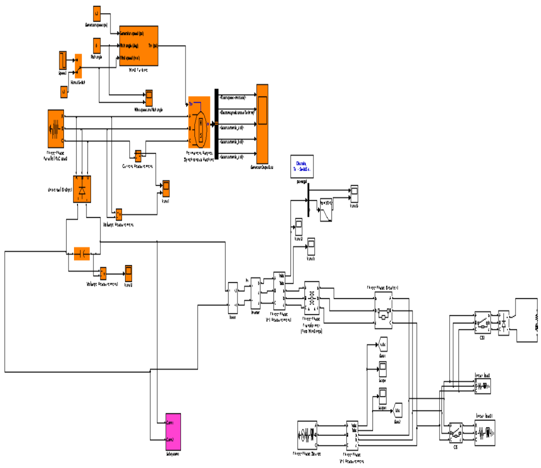

Fig 1 Circuit without ML-DVR

For this reason, the ML-DVR is installed in close proximity to the load that has to be protected. The ML-DVR may inject DC power from the energy storage unit or convert AC electricity from another source, depending on the nature of the interference or incident (VSI). Both the dq0 and Park transformations may be used to set up the ML-DVR controller. The dq0 method shows the phase shift at the beginning and end of the voltage drop in addition to its magnitude and direction.

Fig.1 shows the circuit configuration without DVR for the different loading cases. Two of the three linear loads and one nonlinear load were used to put the circuit through its places in both static and dynamic load testing.

ISSN: 2096-3246
Volume 54, Issue 03, October, 2022

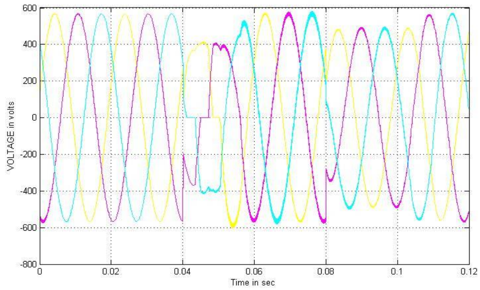

Fig 2 Voltage profile without ML-DVR

As can be seen in fig.2, the voltage profile is perturbed during loading periods, which is the primary problem that DVR attempts to solve.

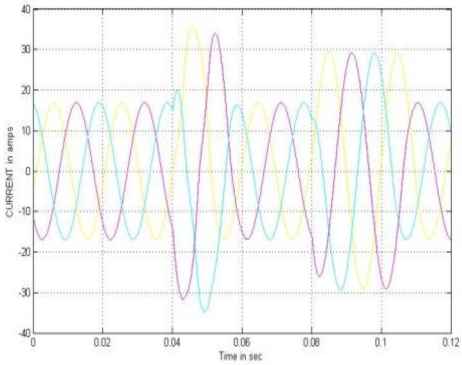

Fig 3 Current profile without ML-DVR

We can notice that the current profile is experiencing interruptions in the loading times, which is another problem that DVR may help fix indirectly by looking at fig.3.

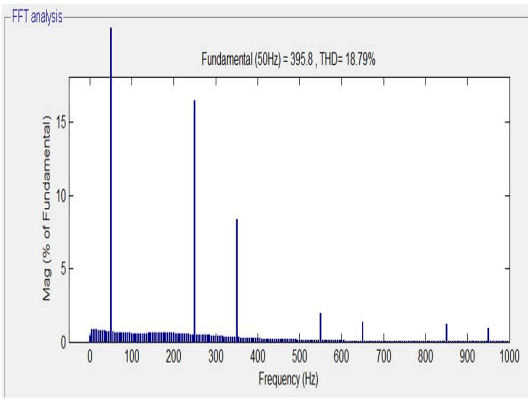

Fig 4 Total harmonic distortion

Figure 4 shows the total harmonic distortion (THD) as a function of frequency, and it is evident Caused by THD.

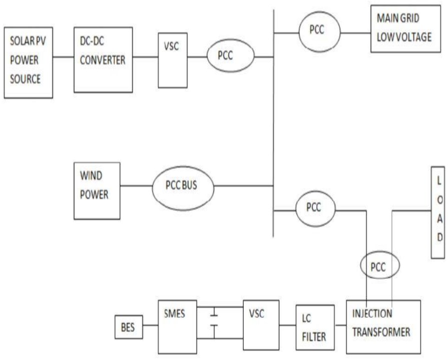

Fig 5 The BES- SMES based DVR

Above fig.5, is a block schematic of the BES-SMES-based DVR.

Existing Simulation Circuit with DVR for PV Wind Power System

The electricity by combining solar and wind power. It is possible that a hybrid system of wind turbines and solar panels will make for a highly appealing energy source. Combining two solar and wind systems has the potential to boost stability and reduce operating costs since one may offset the other's shortcomings. Incorporating solar and wind energy installations into the grid improves the economics and reliability with which renewable energy sources meet demand.
The quantity of energy storage required to deliver constant power is also decreased when a hybrid energy source (such as solar and wind) is used in an autonomous device. The two most common forms of solar energy generation are photovoltaic and concentrated solar power. Include examples from the technical, physical, and photovoltaic worlds. Concentrate cell activity has increased from 30% to 40% in the recent decade, and further increase to above 50% is expected, as stated by Kurtz [8].

Power output from PV modules is highly dependent on the quantity of sunshine reaching them. When more light is shined on an object, the photocurrent rises and the voltage-circuit falls [11]. If a solar cell is heated up, its efficiency will drop across the board, Solar power technology's potential to reduce energy consumption grows with its widespread use. The concentrated solar power plants' high energy costs suggest the market requires either considerable price reductions or governmental measures that promote or compel the use of these technologies.

Flywheels, lead-acid batteries, superconducting magnetic energy storage (SMES), and super-capacitors are only a few of the many energy storage systems now are used. While energy production takes most of the spotlight, useable power is provided via storage. For the purposes of compensation in a DVR system, an employee's power storage device is equivalent to the employee's own personal power generator. Mechanisms for quick charging and discharging are employed in place of lead batteries.

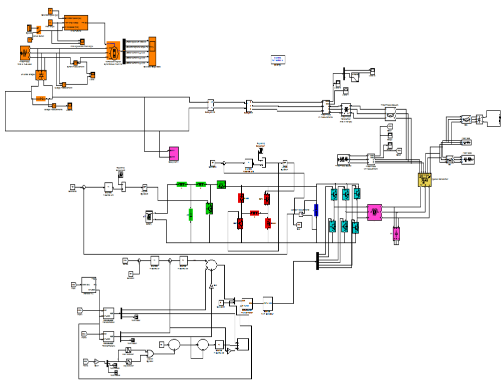

Fig 6 Total circuit configuration with existing controller

The accompanying schematic depicts a common DVR's circuit layout under varied loading conditions. Two of the loads in this circuit are linear, whereas the third is non linear. The dynamic voltage restorer modifies the voltage profile of the circuit using a conventional control mechanism, as illustrated in [5].To smooth out fluctuations on the distribution side and protects critical loads from outages. A popular tool is the dynamic voltage restorer (DVR) is used. The focus of this study is on strengthening the resilience of a hybrid PV-Wind power system to voltage fluctuations at the grid level.

When there is a voltage drop, the power flow is corrected using dynamic voltage restorer(DVR) equipped with batteries (BES) and super magnetic energy storage (SMES). At the point of common coupling the magnitude and angle of the three-phase voltage are typically locked by the pre sag correction utilized. An automatic DVR is used to prevent essential consumer loads from tripping and suffering losses due to voltage sag, swell interruptions, harmonics, and flashing [6]. It is usual for this drop to occur after a breakdown on a distant bus, while switching between large loads, starting motors, or turning on a transformer.

There is some evidence that a DVR, in combination with a BES and SMES, may enhance the reliability and safety of energy delivery in a conventional power system. The DVR runs swiftly, but only for a short period, while utilizing SMES alone as its energy storage in contrast, the DVR's response time and length of operation are both slower when using BES alone. That is why it is crucial to combine BES and SMES units to increase DVR's performance potential. Electrical generation from PV and wind power systems is inconsistent and unreliable. The quantity of sunshine and the velocity of the wind are two meteorological factors that greatly affect.

The grid and supply, which are connected to linear and nonlinear demand, provide time limits on the use of solar and wind power. However, techniques like SMES and BES allow for the storage of alternating current (AC) power by transforming it into a form that can be stored electromagnetically. In order to keep the load voltage constant, the SMES (super magnetic energy storage) device stores electric energy in its superconducting coil without resistive loss during voltage swell in system, and releases the stored energy during voltage sag. In the event of a power outage or other grid-related malfunction, the BES and SMES will discharge their stored energy by injecting voltage to the load using an appropriate injection transformer. A voltage injection is given to the transformer whenever it detects a dip in voltage, and a current injection is given whenever a rise in voltage is detected the voltage will continue to be supplied to the load regardless of the source of the fault or disruption.

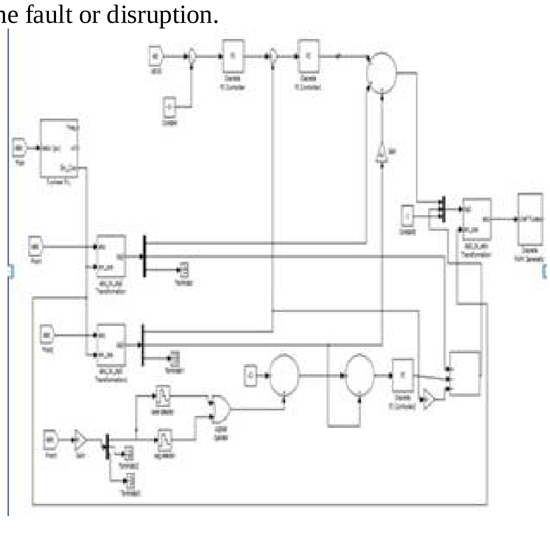

Fig 7 simulink diagram for existing controller

Pulse-width modulated VSIs are now the most used kind [4]. The energy storage device provided the required DC voltage. To convert DC current into AC current, one needs a voltage source inverter (VSI) (AC). There was a step-up voltage injection transformer in the DVR control circuit that was used to bring the voltage back up when it decreased. Therefore, the VSI voltage cutoff is enough.

iLA, iLb, iLcany discrepancies in the grid is three-phase voltage and current input to the abctransformation are recorded. P-Q theory is founded upon the phase-locked-loop (PLL) circuit for vector orientation and the proportional-integral (PI) controller for the dc-link capacitor voltage regulator method. After pulse signals are generated using the PWM (pulse width modulation) technique and sent to the inverter to switch ON, and after the three-phase load currents iLA,iLB,iLC in fixed coordinates are converted to the two-phase direct axis (d) and quadratic axis (q) rotating coordinates currents id-iq and vice versa, the injection transformer injects voltage[8]. If you have a three-phase system in the time domain and want to transform it into the direct, quadrature, and zero components of a rotating reference frame, the Park Transform is a useful building block. An invariant version of the Park transform maintains the active and reactive capabilities of the block and the system's powers in the ABC reference frame. The zero components of a stable system will always be equal to zero.

Battery viability for further charging, discharging, or maintenance as a stable energy storage medium are all determined by monitoring the battery's point of charge (POC) voltage and state of charge (SOC). The state of charge (SOC) may be determined by contrasting the battery's actual capacity with its rated capacity. Either initiate a charging cycle or a discharging cycle in the BES based on the setting of the insulated gate bipolar transistor (IGBT) switch. Essential to the field of power electronics are voltage source inverters (VSI). These kinds of devices are often used to provide voltage in three stages, with each stage having its own amplitude, phase, and frequency that may be independently adjusted. The introduction of pulse width modulation (PWM) methods and the development of quick, controlled, powerful, and resilient semi-conductors have contributed significantly to the advancement of VSI. Three-level VSIs are recommended over two-level VSIs in high-performance settings. When compared to its rivals, VSI's three-stage output voltage and current THD are much superior. Includes a toggle that may be used to reverse the flow of electricity via its three separate legs. These switches are achieved by using anti-parallel diodes and controlled switches (GTO or IGBT) to permit unrestricted current flow.

By Shorting the dc link voltage supply would occur if switches T1 and T4, T2 and T5, or T3 and T6 of any inverter leg were turned on at the same time. It is also impossible to turn off both legs of the inverter at once, since this would cause the ac output line voltages to vary depending on the polarity of the line current. Here, PWM employees performing filters to convert the cardiac pulse form to a sinusoidal waveform, which is more intuitive for humans to process. In order to do the DC-AC conversion, the VSI must first be emptied of valuables, after which the output power will be recalculated. Electrical power inverters cannot function without an idle filter. This is accomplished, as shown in Figure 6, by connecting the high power side of the injector transformer to the load. The load on the injection transformer is therefore reduced. If a filter is connected to the input of an inverter, the resulting phase shift and power interruptions will be flipped. A filter connected to the load side of the circuit might be the answer here.

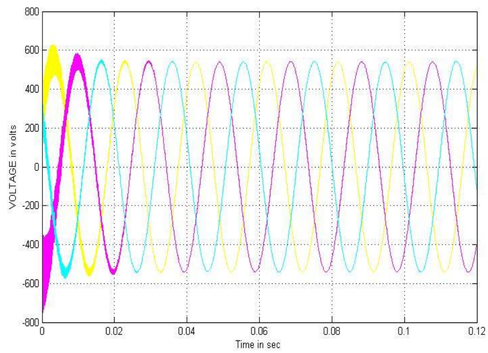

Fig 8 Voltage profile with existing controller

In the diagram above, we see how the voltage profile changes over time and how the dynamic voltage restorer adjusts for this using a more traditional control technique.

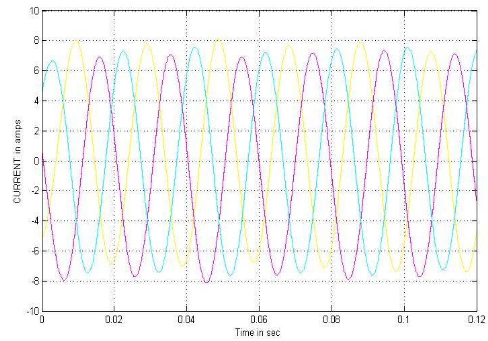

Fig 9 Current protile with existing controller

ISSN: 2096-3246
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A conventional control mechanism is used by the dynamic voltage restorer to correct the current profile, as illustrated in the figure above for the current profile as a function of time.

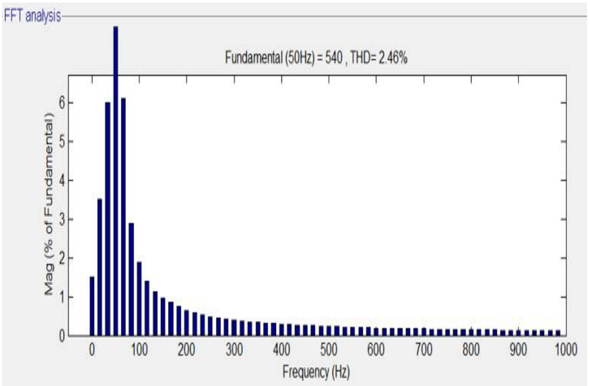

Fig 10 Total harmonic distortion existing controller

From the plot of total harmonic distortion (THD) vs. frequency above, it is clear that DVR, acting as a series active power filter, solves voltage problems caused by THD at peak loading times.

Proposed simulation diagram with multilevel inverter

Multi level inverters provide several advantages over their simpler, two-level counterparts, including reduced voltage stress, improved waveform spectral quality, slower voltage change rates, and less waveform distortion. That is why it is so common in electric power conversion and transmission applications including inverter systems, low-voltage motor drives, and wind power generation. Due to the complexity of their design and the large number of switches they use, multilevel inverters tend to malfunction often. The circuit's reliability would plummet if this happened. Because of the capacitor neutral-point voltages fluctuating in reaction to the open fault, the voltage stress on certain switches may increase if the issue is not resolved quickly. In the worst case, the whole circuit stops working, as it should, which might result in disastrous consequences in certain cases, it is expected that a circuit will continue to operate for some time even if some of its components fail, and hence greater circuit reliability is required. Thus, academics have shown a lot of interest in fault-tolerant control for multilevel inverter in recent years.

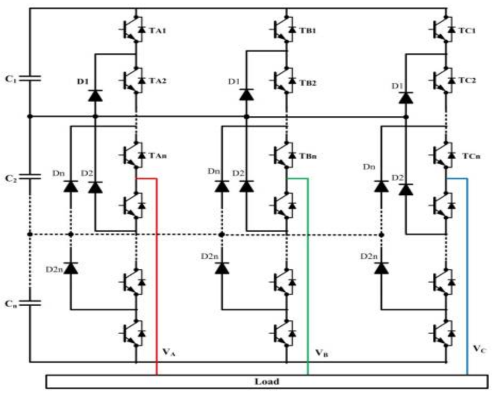

Figure 11 Three-phase n-level neutral point clamped inverter.

Figure.11 shows the first neutral point diode-clamped (NPC) multilevel inverter design, which was presented by Novae, Takahashi, and Akagi (1981). Diodes are used instead of capacitors in NPC inverters, and the neutral of the DC link capacitor is connected to the inverter's common points. For an n-level NPC inverter, the minimum of capacitors is (n-1). Because of this, we can use a lot less capacitors and free up more room by reducing the size of our passive components. This reduces size and weight as an extra bonus. Comparing the size, mass, complexity, and number of passive components, NPC's three-legged design with current reversible switches, controlled for the open and close, comes out on top. To accomplish these switches, anti-parallel diodes and regulated switches (GTO or IGBT) are employed to allow current to flow freely.

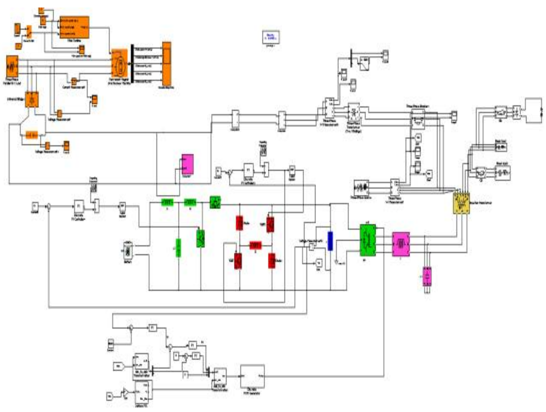

Fig 12 Proposed simulation diagram with multilevel DVR

Connected to one terminal of the voltage injection transformer is the series distribution line the other end has a plug for connecting to the DVR's power supply. DVR prevents key consumer loads from tripping and incurring losses due to PQ issues such voltage sag, swell, interruptions, harmonics, and flashing. Most voltage disturbances take the form of dips, or sags may be brought on by anything from a breakdown on a distant bus to the activation of a transformer to the beginning of large motors or the switching of several loads at once.

When there is a voltage drop, the power flow is corrected using a dynamic voltage restorer (DVR) equipped with batteries and super magnetic energy storage (SMES). Typically, pre sag correction is used to fix the current magnitude and phase angle of the three-phase voltage at the point of common coupling.

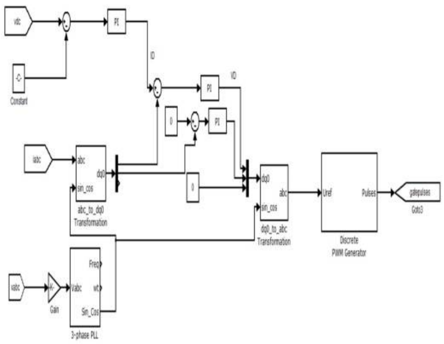

Fig 13 Simulink diagram for proposed controller

Phase-locked loop (PLL) circuit for vector orientation and proportional-integral (PI) controller for dc-link capacitor voltage regulator method [14] are the cornerstones of P-Q theory. Two-phase direct axis (d) and quadratic axis (q) rotational coordinates are derived from the three-phase load currents (ila, iLb, and iLc) in fixed coordinates (id-iq). A linear electrical load will draw a sinusoidal current with the same frequency as the voltage, but the current will be out of phase with the voltage most of the time. Most current harmonics originate from non-linear loads. A rectifier/inverter is an example of a non-linear load that extracts a non-sinusoidal current from the system. The load and its interactions with the rest of the system might cause the current waveform to become more inaccurate. Total Harmonic Distortion is a common metric for quantifying the degree of harmonic distortion (THD)were able to reduce the system's harmonics by using a multilevel inverter rather than a conventional two-level inverter. In the following diagram, we see the relationships between current, voltage, and total harmonic distortion. The multilevel inverter in the new design compared to the old one decreases total harmonic distortion.

ISSN: 2096-3246
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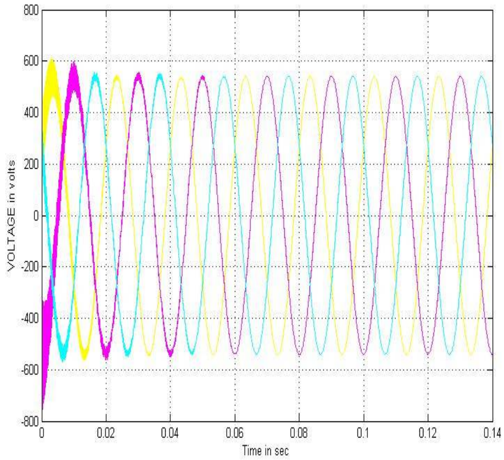

Fig 14 Voltage profile with proposed controller

The above a figure shows the voltage profile as a function of time, demonstrating that the multilevel dynamic voltage restorer has effectively compensated for the voltage profile using the proposed control technique

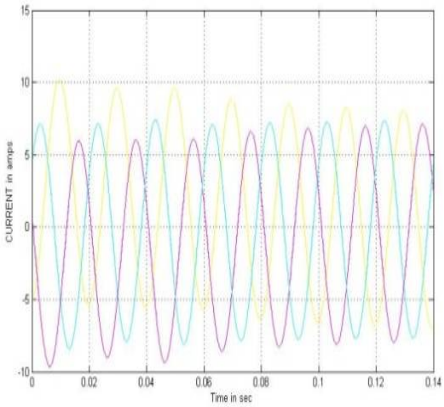

Fig 15 Current profile with proposed controller

As can be seen in the graph of the current profile vs. time above, the current profile has been effectively rectified by the multilevel dynamic voltage restorer using the proposed control scheme.

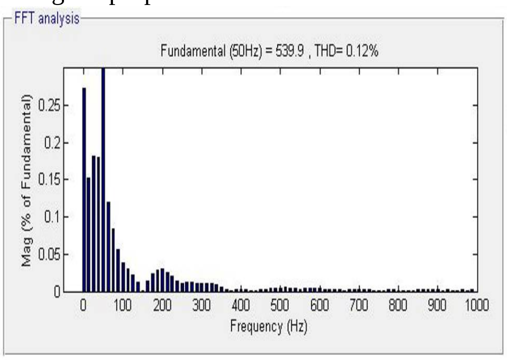

Fig 16 Total harmonic distortion with proposed controller

The power factor adjustment applied to the total harmonic distortion results in a lower voltage profile THD at peak loads as seen in the figure its active power filter in series mode, ML-DVR was able to resolve the issue.

CONCLUSION

The simulation results verify that the suggested ML-DVR is successful in addressing power quality interference. when the PV-Wind system's power production is intermittent or unstable, and the DVR's control block will detect the disturbance in voltage that occurred and compensates the required voltage injecting by DVR and protect the sensitive loads from being affected by voltage fluctuations or either by Fault conditionsor power outages.The DVR acts as a compensator when a three-phase transformer is used in addition to the primary supply using an injection transformer, the filtered VSI output voltage may be brought down to a more workable level. When building the ML-DVR, it is essential to consider the VSI capacity and the link filter values that connect the injection transformer and the inverter. The purpose of this study is to provide a novel design for a Dynamic Voltage Restorer (DVR),Smaller link filter values and higher voltage source inverter (VSI) capacities increase the system's capacity to dampen voltage harmonics, swell, and sag in response to a wide range of fault circumstances.

Multilevel inverter are found to be prime choice among the three distinct designs for multilevel inverters, each having its own topological benefits , drawbacks ,nevertheless, only one of these designs has demonstrated to be effective at completely removing harmonics. There is hope that the innovative RLC filter can do away with switching harmonics. A lower inductance requires less of a dc voltage supply. Furthermore, the modern ML-DVR architecture has the potential to enhance voltage quality. It has been shown how the model's RLC filter parameters are organized generally. The new DVR, as recommended by MATLAB-designed and simulated Dynamic Voltage Restorer (DVR) with control over the voltage. Transient current overshoot is mineralized by the control scheme's high-quality control dynamics. The simulation's final transient reaction met the expectations which will eliminate the harmonics.

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