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DSMPI Controller Based Series Voltage Regulator for a Distribution Transformer to Compensate Voltage Sag/Swell

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Abstract: *In this paper a series voltage regulator is proposed which supports the output voltage during "sag and swell conditions" at the input. The input of the converter is single phase AC and the output is also single-phase AC with different voltage magnitude. The input voltage is modified with abnormalities like "sag and swell conditions". The output voltage is stabilized by closed loop controller which maintains the voltage at certain level. A comparative analysis is carried out with PI and DSM-PI controllers for the generation of output voltage. Magnitude and THD comparisons are taken between these two techniques using FFT analysis tool available in MATLAB Simulink software. All the graphs of the input and conversion voltages of the converter are shown with respect to time.*

Keywords: Single-phase AC; Sag and swell conditions; PI and DSM-PI controllers; Harmonics; THD; MATLAB Simulink software.

Introduction

Power quality problems, such as voltage sag and swell, primarily impact the distribution system. Voltage drops happen because of things like short circuits, lightning strikes, faults, and inrush currents. Voltage surges may be caused by a number of factors, including the starting and stopping of large loads, inadequately sized power supplies, poorly controlled transformers, and a single line to ground fault on the system. "Generation, transmission, and distribution are the three main components of the electric power system."[1]

Electric power is analysed to address PQ difficulties and establish the optimal compensating strategy in order to mitigate the repercussions of inadequate PQ and enhance the utility's performance.[2]

Voltage Sag

When the voltage drops by 10% to 90% for a half cycle or longer, this is known as voltage sag. Figure displays the voltage signal with a drop.

Voltage Swell

A voltage swell occurs when the voltage increases by 10% to 80% over the typical value for a half cycle or longer. Fig. displays the voltage signal during an increase.

1.1 OBJECTIVES

Following are the objectives of the present work:

•To investigate the techniques to mitigate voltage sag, swell

• To select a device that best suits the application
• To control the device such that desired performance is obtained
• To decrease the THD by mitigating the problem of distorted voltage due to sags, swell or, harmonics

A comparative analysis is carried out with PI and DSM-PI controllers for the generation of output voltage. Magnitude and THD comparisons are taken between these two techniques using FFT analysis tool available in MATLAB Simulink software.

II. LITERATURE REVIEW

(Carreno et al., 2021) [2] There is a lot of strain on distribution systems because of the wide range of possible operating circumstances, which puts distribution transformers and lines at risk and reduces the quality of service provided to customers. The quality of service may be impacted when fluctuating loads cause voltage profiles to go beyond the ranges specified by grid regulations. On the other hand, nonlinear loads like diode bridge rectifiers without power factor correction devices provide nonlinear currents that disrupt the distribution transformer's functioning and shorten its lifespan. The unpredictable use of household appliances is a major cause of variable loads at residential levels; nevertheless, electric car charging stations have lately contributed to this phenomenon as well. As a result, the distribution transformer cannot function reliably under such situations, necessitating the use of backup infrastructure. Hybrid transformers, which combine the functions of a traditional transformer with a power converter, are one promising approach to addressing a variety of power quality issues. For anyone interested in learning more about hybrid distribution transformers, this article serves as a literature overview.

(Qureshi, 2020) [3] The quality of the electricity supplied to them is a major factor influencing the performance of modern technological gadgets. Power quality issues, such as non-sinusoidal voltage and frequency of current, are common and occur often, causing failure of end-use equipment. Voltage fluctuations during drops and spikes are the primary issue. Custom power devices may be utilised to solve these problems. These issues are solvable, at least to some degree. Ideally, power grids provide consumers with a steady stream of energy that exhibits sinusoidal voltage of narrow magnitude and frequency. In comparison to small and medium enterprise systems and uninterruptible power supplies, DVRs have a greater capacity for power. When compared to the DSTATCOM and other bespoke power devices, the DVR is more compact and affordable. The DVR is quick, adaptable, and effective. DVR has the additional feature of correcting for harmonics in addition to compensating for power dips and surges. When abnormal conditions arise in the distribution system, voltage sag/swell and power quality issues are eliminated or at least lessened thanks to DVR.

(Tajne, 2020) [4] Most distribution systems' primary worry is a voltage issue related to power quality. Thus far, the under-voltage (voltage sag) situation brought on by a short circuit or fault has been the primary source of the voltage issue. Today, power quality in the distribution system is the most pressing concern for all types of modern infrastructure. Under-voltage (voltage sag) conditions induced by short circuits or faults in the distribution system are often thought to be the root of the voltage issue. In this study, a series voltage regulator for distribution transformers is introduced to address the problem of voltage drop/rise on the secondary side of the transformer. The secondary side of a transformer is connected to a series voltage regulator based on hysteresis. Gating signal production is handled by the hysteresis controller, whereas reference voltage generation is handled by the Phase lock loop. Every part of the system is created in MATLAB. In order to enhance power quality disturbances, the system is tested under a variety of conditions.

(Dandoussou&Kamta, 2020) [5] The study's goal is to analyse clearly by identifying and describing each disturbance. The primary goals are to examine the causes of unexpected faults on wires that provide loads and to conduct a survey of the adverse effects resulting from the load, in particular typical loads utilised in industrial settings. The effects of these disruptions on a Distribution Line network were analyzed through simulation, and the findings were given.

(KARAMAN et al., 2020) [6] With each passing day, the issue of poor electricity quality becomes more pressing. The primary elements affecting power quality are harmonic current and reactive power. Harmonic current and reactive power are used by the induction motors from the mains supply. Transmission line efficiency and heat loss are both negatively impacted by reactive power and harmonic current. These issues have been addressed using passive and active filter applications. Passive filters have a few limitations. Examples of these limitations are the system's large physical size and its resonance with load. Since Active Power Filters (APFs) may be used in conjunction with harmonic and reactive power compensation as suitable control approaches, their potential application domains are expanding quickly. Using a three-phase Parallel Active Power Filter, this research suggests simulating the process of power factor correction and reactive power compensation for a three-phase induction motor in MATLAB/Simulink. The "Sine Multiplication Technique (SMT)" is used to produce the reference currents used by PAPF. We show simulation experiments to evaluate the motor's functionality in a variety of real-world circumstances. "Using a hysteresis controller-based PAPF filter, the reactive power of a three-phase induction motor may be compensated, bringing the power factor up to 1."

(Wang & Cao, 2019) [7] Power Line Communications (PLC) have a significant challenge from impedance mismatch, which reduces signal power transfer and may disrupt transmissions. Power line modems and power line networks have an inherent impedance mismatch; however, this may be efficiently compensated for by using impedance matching methods tailored to a particular frequency or frequency range. In this research, we explore the complexities involved in finding the right balance between competing goals in impedance-matching network design. We also present a helpful taxonomy of the many existing state-of-the-art PLC impedance matching approaches and conduct a thorough examination of their respective histories. We conclude with a discussion of key problems (concerns) and recommendations for future study that warrants more investigation. In order to develop an efficient impedance matching coupler for PLC applications, this paper offers a helpful reference for researchers and manufacturers to rapidly comprehend impedance matching concepts.

(Hren&Mihalič, 2018) [8] Total Harmonic Distortion (THD) and DC link usage are two important factors to keep in mind while designing a single-phase inverter system (grid-connected, UPS, or motor drive). When the DC voltage is lowered, the output voltage may be maintained within a specific range by using over-modulation. Higher-order harmonics (especially the third), which are connected to the fundamental frequency, have a negative impact on the inverter's output voltage. In this study, we conduct a comprehensive examination of a single-phase inverter in the over-modulation domain, dissecting its performance at each of its three possible output voltage levels. According to the results of a frequency spectrum analysis, the third harmonic component in the output voltage is almost cancelled out by the third harmonic component in the modulator.

(Sur et al., 2018) [9] The Reduction of Transmission-System Harmonics is the subject of this paper. Since harmonic frequencies are a common source of power quality issues, this study focuses on methods for removing harmonic content from the system using a variety of Active and passive Filter configurations, each of which is managed by an Active Damper Controller. The non-linear load is the primary generator of harmonics since it uses discontinuous current and injects harmonics, both of which result in transmission losses. The simulation work is also carried out in MATLAB to evaluate the outcome without or with hybrid filter, demonstrating that the active damper may become a potential solution to stabilize the future power electronics-based power systems.

(Naderi et al., 2018) [10] Due to the increasing sensitivity of loads and the proliferation of nonlinear loads in the electrical distribution network, it is obvious that power quality has become a crucial component of contemporary systems. The dispersed nature of harmonic loads makes distributed power quality improvement (PQI) a necessity when trying to manage them. Years of research have gone into developing various filters and devices to enhance power quality, but the nature of the distribution system has changed, making power electronic based DGs more important than ever. In this research, we analyse the supplementary services of flexible DGs and perform a thorough literature assessment of power quality enhancement devices. The literature on the concept of microgrids, testbeds, and associated control approaches is also reviewed. In spite of the fact that DGs were used in several PQI-related contexts, these usages did not constitute the defining characteristics of multi-functional DGs. Several strategies of control are examined and classified based on their treatment in the academic literature. Finally, a few detailed comparisons are made between the various methods, taking into account their nature, capabilities, benefits, and implementation costs.

(Senapati et al., 2018) [11] Power quality in a grid-connected PV-battery-fuel-cell hybrid energy system is improved in this research by exploring the usage of a shunt active filter. To control the shunt active filter, we use a variation on the Sinusoidal Current Control Strategy. A shunt active power filter is included to lessen the load imposed by the harmonic current component and compensate for the imaginary or reactive power produced by the precise and careless functioning of the hybrid system. Using a method of sinusoidal current management, the source of the current may be recovered. To evaluate the performance of a sinusoidal current control method for a shunt active power filter in a passive load situation with a non-linear load, we use MATLAB R2016a. Through MATLAB simulation, we confirmed the power filter system's capacity to mitigate harmonics, and we validated the control strategy. Total harmonic distortion (THD) of voltage and current proves whether or not a controller designed for ShAPF can successfully provide harmonic isolation of passive loads.

(Singh et al., 2018) [12] In recent years, shunt active power filters (SAPFs) have become an established cutting-edge technology for resolving issues associated with current harmonics and reactive power compensation. In this work, we provide a technical overview of several SAPF control techniques. Several control techniques, such as the construction of switching patterns for a voltage source inverter, the management of dc link voltage, and the formation of reference current in the time domain, frequency domain, and via soft computing, have been investigated. The purpose of this work is to offer a comprehensive introduction to SAPFs for use in a wide range of scientific and technical disciplines.

(Tareen&Mekhielf, 2018) [13] Nonlinear loads, current harmonics, and power quality issues are all easily remedied by a shunt active power filter. There are drawbacks to using APF topologies for harmonic correction since they need a large number of components with a high power rating. With the use of low-power rating APFs and passive filters, hybrid topologies are used to reduce the voltage source inverter's power rating. Many passive components are packed inside the transformer in “hybrid APF topologies for high-power rated systems.” In this study, we suggest a new “VSI topology for a three-phase SAPF” with four switches and two legs, which may significantly cut down on both the system's price and its footprint. “A two-arm bridge structure, four switches, coupling inductors, and LC PF sets make up the suggested topology.” When the set of power switching devices is removed, the third leg of the three-phase VSI is also gone, and the phase is instead connected straight to the negative terminals of the dc-link capacitor. When compared to traditional APF topologies, the suggested topology improves the capacity of harmonic correction and enables full reactive power compensation. The new experimental prototype is subjected to extensive laboratory testing in line with the IEEE-519 standard to validate the results with respect to total harmonic distortion, balanced supply current, and harmonic compensation.

(Madhu et al., 2018) [14] Total harmonic distortion must be kept below the threshold for unacceptable levels in order to comply with power quality standards (IEEE-519). The shunt active power filter is the primary focus of this research because of its popularity in the field of harmonic removal. The load current has been continually monitored, and the active power filter has continuously adjusted to the shifting harmonics of the load. This study describes the operation and efficiency of a PI and Hysteresis current controller based on the instantaneous power theory applied to a three-phase shunt active power filter.

(K.V.PRADEEP KUMAR REDDY, 2018) [15] One of the most critical challenges facing the electricity grid is meeting the power quality (PQ) standard. Voltage dips and surges in low-voltage distribution systems, as well as transmission-side issues caused by power-hungry appliances, are among the most common issues with electrical current quality. When dealing with power quality issues in the electrical grid, one of the most prevalent methods for mitigating voltage sag and swell is the installation of a series voltage regulator on a distribution transformer. An automated secondary connection power electronic converter is attached to a line frequency transformer in the proposed configuration. Automation of this connection is achieved by the use of a high- or medium-frequency transformer.

(Devadasu, 2017) [16] Voltage fluctuations, power surges, and other types of poor power quality may have a negative impact on the efficiency of the power grid. Nowadays, power engineers handle voltage sag and swell to lessen power quality difficulties. Even a little shift in voltage may have a significant impact on the efficiency of the power grid and the performance of any associated loads. In this work, we show how to use FFT analysis to spot a voltage dip or spike. The study also includes the DVR-implemented solutions to the identified voltage sag and swell problems. DVR is controlled by the straightforward d-q theory, which generates the necessary reference signals and gate pulses for the DVR's switches. Through the use of MATLAB/SIMULINK, we were able to model the suggested idea and show the resulting findings for detection and prevention. It was shown how to use FFT analysis to detect voltage sags and swells throughout the power system network at various stages. In addition, the findings demonstrated that voltage sag and swell may be reduced using DVR.

(Biricik et al., 2016) [17] Low ratio “shunt active power filters (SAPFs)” may perform current harmonic cancellation and provide unity power factors in the presence of undistorted and balanced grid voltages. When source voltages are erratic and imbalanced, however, this is impossible. This research presents the “hybrid active power filter (HAPF)” topology, which is an efficient and low-cost method of meeting the needs of industries in terms of harmonic current suppression and non-active power compensation. The integration of power capacitors and LC filters with the shunt active power filter (APF) is studied using an efficient method. Using instantaneous reactive power theory and a self-tuning filter algorithm, a novel approach is given for mitigating the detrimental consequences of a less-than-ideal grid voltage. An FPGA architecture was created with the help of the OPAL-RT system to allow for real-time control of the investigated system. The tested and shown performance result of the proposed HAPF system.

(Ali et al., 2016) [18] Power electronic converters and the power electronic loads they connect to the distributed power plants are a source of harmonics and reactive power, which degrade the operation of the power system network. Activated filters, sometimes called active power line conditioners, are a novel kind of switching compensator that were developed to address the shortcomings of passive LC filters. These active filters can wipe out interference from a wide variety of harmonic orders, can withstand resonance between the filter and the network's impedance, and can be built to a small size. The focus of this research is on developing a shunt

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active filter with a controller based on many theories to compensate for harmonics and reactive power in unbalanced and distorted systems.

(Meenakshi et al., 2015) [19] Using a constant frequency variable speed wind turbine, this research implements the SVPWM switching mechanism. For a "doubly-fed induction generator," MATLAB/Simulink is used for modelling and simulation. We have measured the overall harmonic distortion of this wind electric generator at several settings of stator current, rotor speed, and electro-magnetic torque. When compared to other pulse width modulation methods, this one reduces distortion to a greater extent.

(Sandeep, 2014) [20] The increasing complexity of modern life has resulted in a corresponding rise in the need for electricity. Many common household appliances can't function without constant access to reliable electricity. There is a direct correlation between the power quality and the performance of the user's equipment. However, several internal and external variables influence the final product in terms of power quality. They include things like voltage and frequency fluctuations, malfunctions, outages, and so forth. Both the lifespan and performance of the apparatus are shortened by the poor power quality. As a result, these issues need to be addressed in order to improve the system's overall performance and the functionality of the consumer devices it supports. The existence of harmonics is the primary effect of these issues. Damage to the machinery occurs as a result of overheating, insulation breakdown, induction motors running too fast, etc. Filtering out these harmonics is the key to solving these issues. Numerous filter topologies exist in the literature for this function.

III. Transformers

Basics of Transformers

A transformer is an electrical tool used to transfer energy by electromagnetic induction from one circuit to another. There is no frequency shift during the power transmission because of the attendant. The state power transformer is used to symbolize transformers with an output power of 500 kilovolt amperes (KVA) or more in an electrical network and to show numerous AC supplies from the public electricity supply at varying voltages and ampere ratings.

This kind of transformer is used in distribution systems to convert between lower and higher voltages. Normal power transformers are fluid immersed devices with a 30-year lifespan. Based on their output voltage and current ratings, power transformers fall into one of three categories. There are three different sizes of power transformers: big, medium, and small.

- "The range of large power transformers can be from 100MVA and beyond
- The range of medium power transformers can be from -100MVA
- The range of low power transformers can be from 500-7500kVA"

These transformers are used for the transmission of electricity. The high-current, low-voltage circuit is maintained on one side of the transformer, while the low-voltage, high-current circuit is maintained on the other side. In order to generate electricity, a power transformer uses Faraday's induction law. It breaks out the electrical grid into zones, detailing how each component of the system was built to function at the rates determined by the power transformer.[25]

3.1 Types of transformers

Step up Transformer & Step-down Transformer - They are used in the transmission and distribution of electrical power to increase or decrease the voltage of the current.

Three Phase Transformer & Single-Phase Transformer - The former is often preferred in a three-phase power system because to its lower overall cost. However, a bank of three single-phase transformers is preferred than a single three-phase transformer when space is at a premium.

Electrical Power Transformer, Distribution Transformer – Power transformers are used to transmit electricity from one high-voltage system to another, such as from a power plant to the transmission and distribution networks. Their application in the transmission network extends to voltage boosting and lowering. It is most effective while running at or near full load, which is when it is used most often. In order to distribute electricity to homes and businesses, a distribution transformer reduces the voltage. It has excellent voltage control and can run at optimum efficiency for 24 hours a day, 50% of the time.

Indoor Transformer & Outdoor Transformer - Indoor transformers are those whose primary function is to be installed inside a building, whereas outdoor transformers are those whose primary function is to be installed outside.

Oil Cooled & Dry Type Transformer - Transformer oil is used as the cooling medium in oil-cooled transformers, whereas air is used in dry-type transformers.

Phase-Shifting Transformer- An important component of any sophisticated power transmission network is the phase-shifting transformer, which allows for fine-grained regulation of power distribution along individual circuits. Phase-shifting transformers' uses:

a) To regulate the transfer of energy between two huge, separate power grids;

b) To regulate the amount of usable active power in a transmission line by altering the effective phase displacement between the input voltage and the output voltage.

3.2 Distribution Transformers

The concept of a distribution transformer, a common kind of isolation transformer, is also presented. This transformer's primary use is in transforming very high voltage into more manageable levels, such as 240 or 120 volts, for use in power grids. Single-phase and three-phase transformers, pad-mounted transformers, underground transformers, and distribution transformers installed on poles are only some of the options in the distribution system.[27]

Service transformer is another name for a distribution equipment. The last voltage transformer in the electricity grid, it reduces the output used in the distribution lines to the users' rating.

Therefore, a constant supply of high-quality power is essential for a smart grid. The distribution transformer, seen in Figure, is an important component of the system for delivering clean power to the final user, whether it a business, factory, or home.

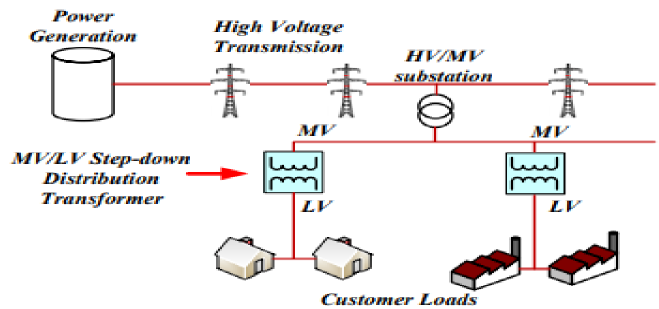

Figure 1: Concept of Functionality of Distribution Transformers in Electric Grid.

Distribution transformers may be found in a wide range of sizes and efficiencies to accommodate a wide variety of applications and end-user budgets. There are a number of different transformer types used in the distribution system, all of which include secondary terminals that provide electricity to the end user at a usage voltage level. One common kind of distribution transformer used in the USA to power single-phase appliances is the single-phase distribution transformer.

There must be a single kind of pole-mounted transformer for the single-phase residential load. There was a total of three secondary terminals on this pole-mounted distribution transformer design. There are three total terminals: two for the phases and one for ground. Voltage is 240 volts between phases when using two-wire systems, and 120 volts between phases and ground. Therefore, depending on their needs, consumers may get either 240 volts or 120 volts.

Some important properties of a distribution transformer are stated as:

• Minimal in size

• Used as a step-down transformer with input voltages as low as 33 kilovolts (kV).
• Consistently handles between 60% and 70% of its rated capacity throughout the day
• Requires only 3-5 volts and a standard wall outlet to charge

It is the kind of distribution transformer being used that determines how this instrument is wired. Single-phase transformers may have either one or two bushings, and are often configured in a wye. Only in the right configuration can these major sections be used with three-wire or four-wire wye connections.[28]

Additionally, these transformers may be connected to the overhead wires in two different ways, namely:

Wye: To do this, a transformer that converts phases to ground is used. The intersection between the two stages may be found at the top of the structure. Another part of the winding is grounded by its connection to the neutral line. Due to the possibility of ground-directed currents in the neutral section, a wye design is used when unstable powers must be connected. Unstable powers cause voltage changes on the three-phase wires when in the delta connection.

Delta: In this case, a transformer of the phase-to-phase kind is used. It features a two-phase connection between its two bushings. Another part of the winding is grounded by its connection to the neutral line. This setup has one major drawback: if one of the main phases goes into a de-energy condition, the other phase will cause current to flow in the other way, which might be dangerous for the workers and staff.

Some applications of the distribution transformer are as the following:[29]

This transformer is used in commercial and residential settings, and its output voltage ranges from high to low.

The major function of this is to provide isolation between two windings (primary and secondary) by reducing the input power.

Power plants generate electricity, and this transformer sends it to far-flung areas.

Electricity is often sent via a distribution transformer to businesses with use below 33KV and homes with usage between 440V and 220V.

IV. Research Methodology

Existing LFT is connected to an auto-connected PEs module on the secondary side to smooth out voltage dips and spikes; this is the suggested solution. As a result of this autoconnection, a compensator with a shunt input and series output may be constructed, with no capacitive energy storage required. Thus, the suggested system is distinct from the typical series compensator, such as a DVR, in both its structure and its operation.[3]

To produce the compensating voltage Vc, the suggested system takes use of the Vin at the input. Rather of relying on a battery to control the voltage, this is a tap changer transformer, which uses the source voltage to modify the turns ratio of the transformer, thereby regulating the load voltage. As a result of how the PEs module is built, we may use its partial power processing capacity to decrease the suggested system's rating. In addition, the system's overall efficiency may be improved when in bypass mode. The PEs module may regulate the voltage at the load's terminals by producing a compensating voltage that is vector-added to the grid voltage.[4]

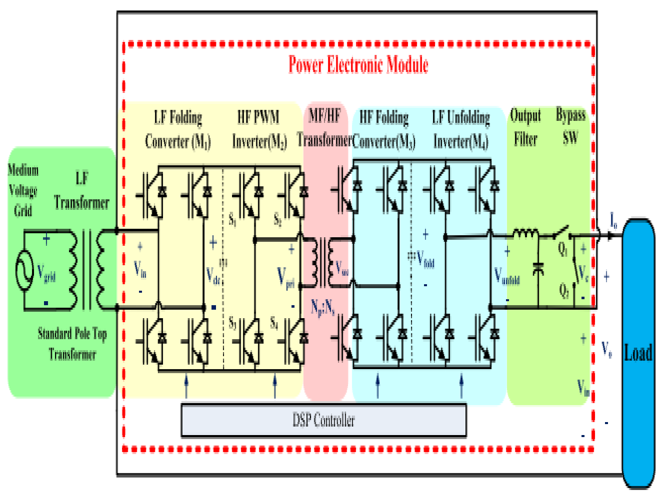

Figure 2: Detailed power electronics module in the proposed distribution transformer

DSM-PI Controller

The gains are locked to a certain value in a "conventional PI controller". Differently the value of the "DSM-PI controller" is continuously altered by mistake.

This "DSM-PI controller" monitors Kp and Ki's proportional and integrated gains and thus minimizes the reaction time. The primary benefit of this system is that the speed reaction time is decreased by reducing oscillations and perturbations. [5][6]

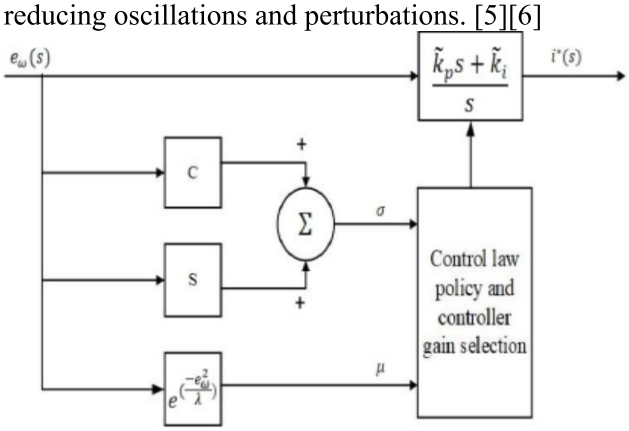

Figure 3: DSM-PI block diagram

Therefore, the "DSM-PI controller" accelerates the speed response and causes reduced oscillations and perturbations.[7]

"DSM-PI controller continually monitors Kp and Ki's gains of proportional and integral gains," therefore the reaction time is much decreased. Reduced oscillations and disturbances speed up the speed-time response, which is a major benefit of this design.

B. Comparative Analysis between PI and DSM-PI Controllers

In PI controller, the gains are fixed at a constant value which is a drawback when the system is in operation as the error generated is not a constant value. In order to overcome this limitation, a "Dual Sliding Mode with Proportional and Integral (DSM-PI) controller" is used for better time response.

Because of the DSM-PI controller's constant monitoring of gains of proportional and integral gains, the reaction time is greatly reduced. Reduced oscillations and disturbances speed up the speed-time response, which is a major benefit of this design.

V. Simulation Result

To validate the proposed power management scheme, MATLAB/Simulink software is used for complete simulation studies.

Table 1: Simulation parameters

Devices	**Values**
IGBT Devices (S1 – S4 to Q1 –Q4 of HF converters and switches of LF converters)	**250 V (1.5 p.u.)** **12 Arm s (1 p.u.)**
Output Filter Inductor Lf = (4 mH)	**12 Arm s (1 p.u.)**
Output Filter Capacitor Cf = (7.5 µF)	**85 V (0.5 p.u.)**
Small Coupling Capacitor Cd c = (0.8 µF)	**250 V (1.5 p.u.)**

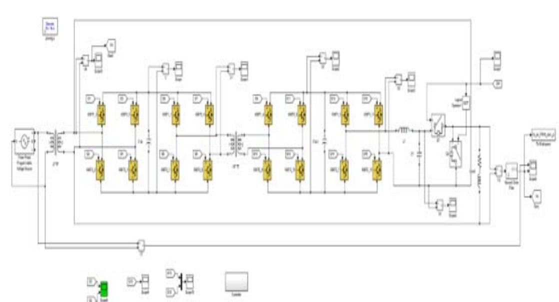

Figure 4: Power electronics module in the proposed distribution transformer using DSMPI Controller.

The above fig 4 is the Simulink modeling of the proposed voltage regulator circuit with input fed by three phase programmable source connected with only A phase. The A phase voltage amplitude is varied at different intervals of time creating sags and swells in the magnitude of the input voltage. The controller of the voltage regulator circuit can be seen

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below in figure 5 with feedback from the input side voltage and output side voltage.

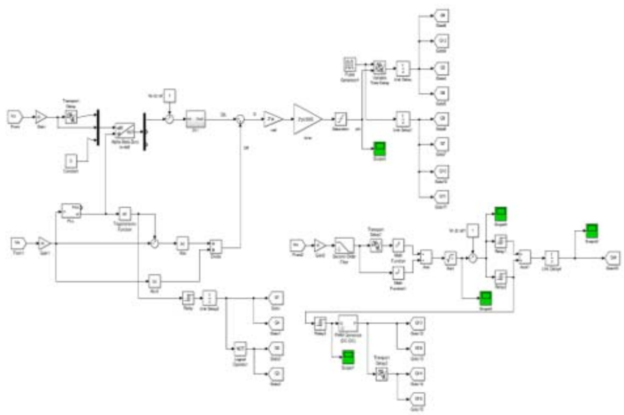

Figure 5: Control modeling of the proposed using DSMPI controller scheme.

The below figure 6 are the input and output voltage comparison of the proposed circuit.

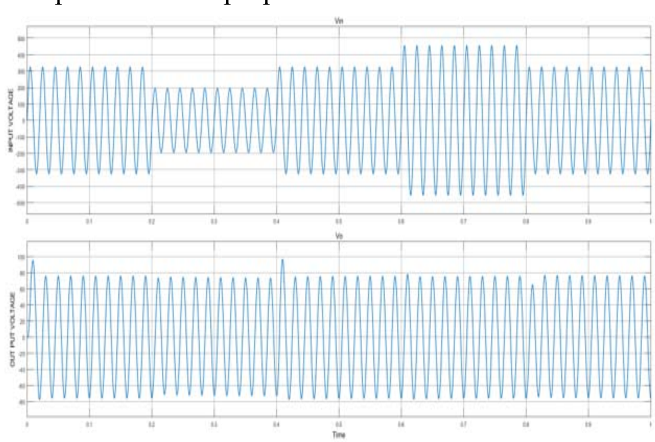

Figure 6: Input and output voltage comparison.

As seen the input voltage has sag from 0.2-0.4sec and swell from 0.6-0.8sec which is compensated in the output voltage by the proposed topology.

There are some sudden peak (0.4sec) and drop (0.8sec) voltages created at the change instances but however they are controlled later.

The below figure 9 is the secondary side low frequency (50Hz) transformer voltage which have very less harmonic content.

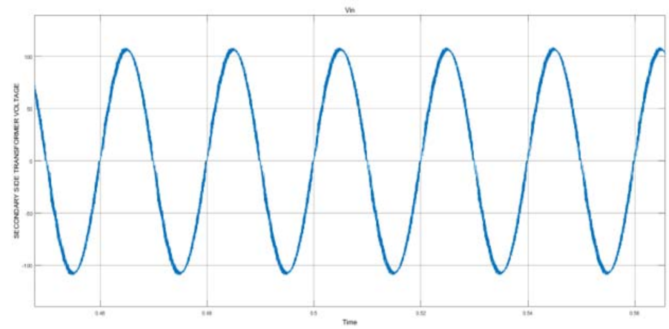

Figure 7: Voltage at secondary side of the transformer

The below figure 8 is the low frequency side controlled rectifier output which converts both positive and negative voltages of secondary voltage above to positive voltages.

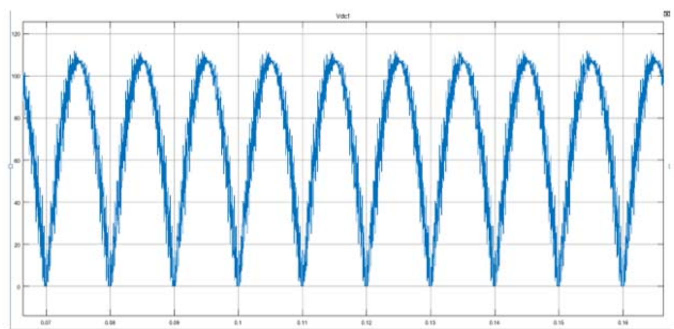

Figure 8: Low frequency rectifier output voltage

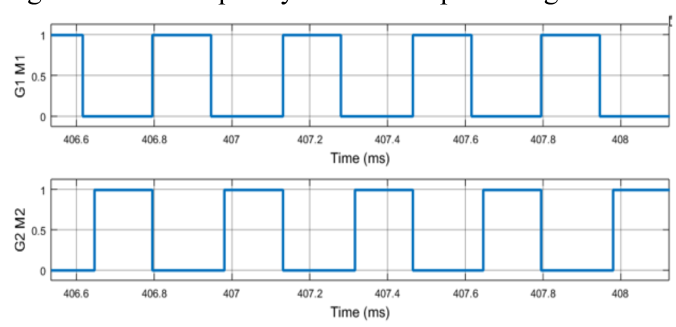

Figure 9: Pulse inputs to the power electronics devices G1 M1 and G2 M2.

The pulses to G1 M1 and G2 M2 switches are fed as shown above in figure 9 with 50% phase delay maintained always. In no state of operation these switches will turn ON simultaneously to avoid short circuit. The pulse inputs to G23 and M3 are shown below figure 10 followed by pulse inputs to G1-G4 and M4.

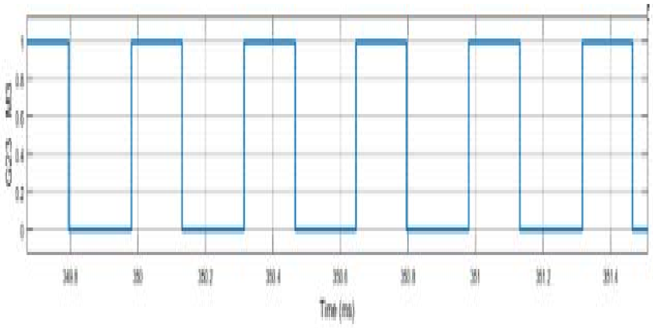

Figure 10: Pulse inputs to the power electronics devices G23 and M3

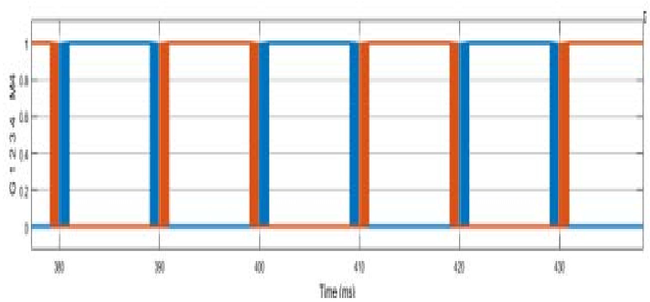

Figure 11: Pulse inputs to the power electronics devices G1 G2 G3 G4 and M4

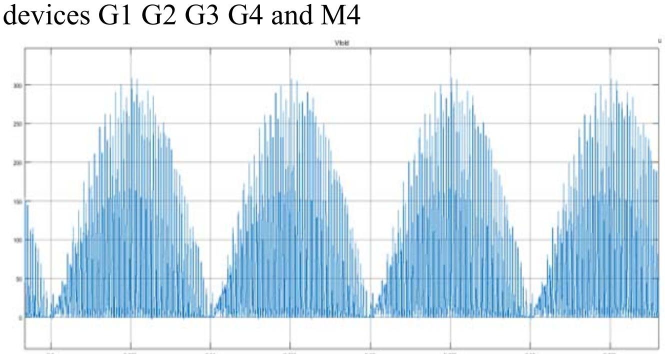

Figure 12: Output voltage of the high frequency rectifier

Rectifier voltage at high frequency (20kHz) secondary of high frequency transformer is shown in fig.12 and 13 displays the main side of the high frequency transformer voltage from the high frequency inverter.

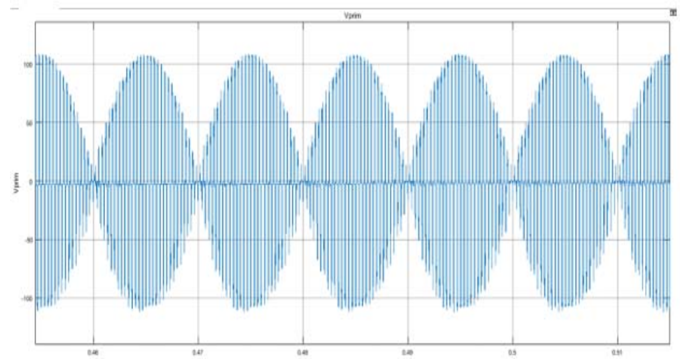

Figure 13: Output voltage of high frequency inverter

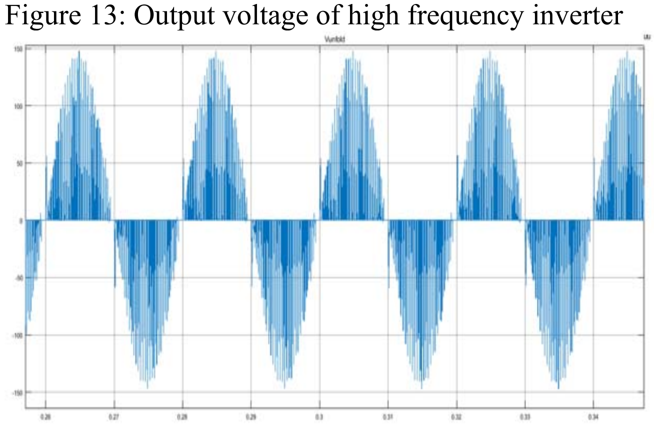

Figure 14: Output voltage of low frequency inverter

The final output voltage of the final low frequency (50Hz) inverter is shown in the above figure 14 which converts the DC voltage of the high frequency rectifier to low frequency AC voltage.

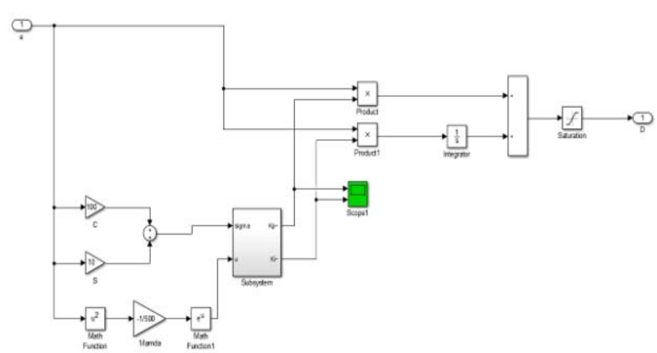

Figure 15: DSM-PI controller internal modeling

The above figure 15 is the modeling of the DSM-PI control replacing Sinusoidal PWM control for better improvement in THD.

A THD comparative analysis with SPWM and DSM-PI is shown in figures 16 below.

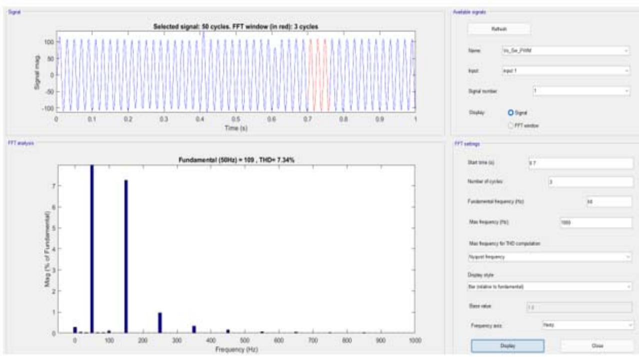

Figure 16: THD of output voltage of the converter with sinusoidal PWM technique

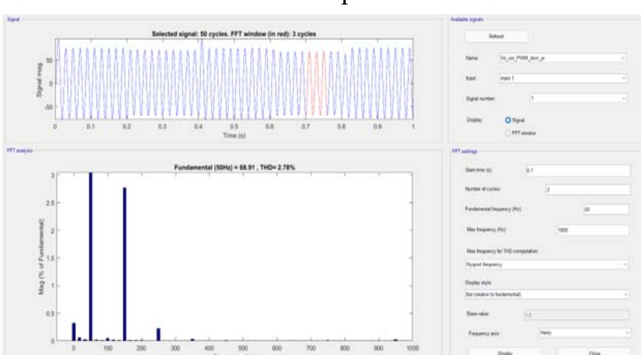

Figure 17: THD of output voltage of the converter with DSM-PI controller.

IV. Conclusion

The need for reliable electricity has grown in importance in the industrial sector and among consumers. Among them, voltage imbalance is regarded as the most significant impacting factor that causes electrical equipment to function poorly. As it can be seen in the results comparison of the input voltage and output voltages of the inverter, the input voltage has sags and swells at different time intervals. Sag from 0.2sec to 0.4sec and swell from 0.6sec to 0.8sec. The output voltage is however maintained at constant voltage magnitude even during input voltage fluctuation. The extra voltage compensation is given by the voltage regulator circuit using PI and DSM-PI controller. The THD comparisons of both the controllers are taken using FFT analysis recorded at 7.34% and 2.78% respectively. With the comparison of THDs the DSM-PI controller has very less harmonic content as compared to PI controller.

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