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PROTOTYPE DESIGN OF ARDUINO BASED VOLTAGE STABILITY IN MARINE POWER SYSTEMS

K.NANDHINI #1 and Prof. R.KALPANA *2

#*Final year, M.E, Power Electronics and Drives, P.S.V College of Engineering and Technology, Krishnagiri (D.T), India*

**Associate Professor, Electrical and Electronics Engineering, P.S.V College of Engineering and Technology, Krishnagiri (D.T) , India*

Abstract*— This project aims to design and modeling of Dynamic Voltage Restorer (VOLTAGE INJECTOR) for maintaining the Power quality of the system. Power quality problem is an occurrence manifested as an on standard voltage, current or frequency that results in a failure of end use equipment. One of the major problems dealt here is the power sag and swell. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (VOLTAGE INJECTOR), which is the most efficient and effective modern custom power device used in power distribution networks. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. This projects presents modeling, analysis and simulation of a Dynamic Voltage Restorer (VOLTAGE INJECTOR) using MATLAB. A new control technique is proposed to control the capacitor-supported VOLTAGE INJECTOR. The control of a VOLTAGE INJECTOR is demonstrated with a reduced-rating VSC. The reference load voltage is estimated using the unit vectors. The proposed hybrid system can effectively suppress the voltage fluctuation. The simulation of proposed work is carried out using MATLAB. Hardware implementation has been done with a ARDUINO-UNO based ATMEGA controller, whose 'c' programming had been done with software and flashed using Arduino ISP software and downloaded the hex files using a flash programmer connected to a personal computer via USB port. Both simulation and hardware implementation shows the compensation well.

***Index Terms*— Dynamic Voltage Restorer, reduced rating VSC, ARDUINO-UNO, ATMEGA controller.**

I. INTRODUCTION

Marine power systems have experienced a rapid evolution in the last decades, starting from the simple lights and radio electric supply systems adopted in the mechanical propelled ships from the early nineteen century. The adoption of electric propulsion, together with the electrification of most of the onboard loads, has led to a revolution in both design and use of modern vessels. The drivers for this evolution process were efficiency, performance, reliability, quality of service and safety. Nowadays, the will to achieve ever-higher performance levels for the stated drivers is causing further changes in marine electrical systems, pushing towards a pervasive presence of power electronic converters. Indeed, marine Integrated Electric Power Systems (IEPSs) are rapidly evolving to the Integrated Electric and Electronic Power System (IEEPS) concept. The replacement of mechanical driven equipment (such as pumps, compressors, etc.) with electrical driven ones is not sufficient anymore to achieve the high standards expected by the owners, so a step forward is ongoing: the introduction of high rates of electronic power converters to feed the loads. The adoption of variable frequency drives allows removing the complex and inefficient mechanical flow regulation equipment, thus allowing a more reliable, efficient and performing operation. Moreover, the increasing interest into artificial lift systems, which are becoming more and more common in both onshore and offshore oil and gas installations, promotes an important rise into the total electric power to be installed onboard, causing, at the same time, a growth in the rate of loads supplied by electronic power converters. Indeed, these are necessary to regulate the production flow rate, achieved by changing the speed of electric pumps installed in the well. Besides from the flow regulation application, electronic power converters are increasingly being adopted in marine power systems, whether they are integrated in UPS systems, or necessary for the new automation systems. Their utilization makes it possible to: achieve higher performance, increase redundancy, increase reconfiguration options, and raise overall efficiency. However, a drawback may arise, which is Constant Power Load (CPL) voltage instability. In fact, a CPL tends to absorb a constant electric power in spite of the disturbances on supply network, behaving like a nonlinear load with a peculiar characteristic: when system's voltage drops, it increases the absorbed current. This behavior, which is the opposite of a conventional linear load (such as an induction motor), could cause instability in system voltage. CPL instability has been extensively analyzed in DC and AC distribution systems. The analysis in AC is more difficult, due to the increase in system's variables. In this paper, two models to assess stability in AC power systems in presence of CPL loads will be presented, trying to give also a simplified approach dedicated to early design stage assessment. The CPL behavior of electronic power converters is the downside of one of the main advantages of electronic power conversion: the ability to decouple the loads from the power supply, keeping constant voltages and/or currents supplied in spite of input variations.

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipment. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly. Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (VOLTAGE INJECTOR). VOLTAGE INJECTORs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The VOLTAGE INJECTOR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

The term harmonics referred to Power quality in ideal world would mean how pure the voltage is, how pure the current waveform is in its sinusoidal form. Power quality is very important to commercial and industrial power system designs. Ideally, the electrical supply should be a perfect sinusoidal waveform without any kind of distortion. If the current or voltage waveforms are distorted from its ideal form it will be termed as harmonic distortion. This harmonic distortion could result because of many reasons. In today's world, prime importance is given by the engineers to derive a method to reduce the harmonic distortion. Harmonic distortion was very less in the past when the designs of power systems were very simple and conservative. But, nowadays with the use of complex designs in the industry harmonic distortion has increased as well. This project explains the effects of Harmonics in the Power System and steps to reduce the effects of Harmonics. This project will also explain how Harmonic distortion is one of the most important problems associated with power quality and creates several disturbances to the Power System. It includes the Harmonic reduction techniques to improve the power quality and it will also include the simulation for the same. This project also explains different types of inverters that are used in the Power System. During the transformation from DC to AC, harmonics affect the power quality a lot. How harmonic reduction will improve the power quality will be explained in detail.

II. Strategic Modeling

A. *Cause Of Power Quality Variation*

As always, the main objective of the power system would be generation of electrical energy to the end user. Also, associated with power system generation is the term power quality. So much emphasis has been given to power quality that it is considered as a separate area of power engineering. There are many reasons for the importance given to the power quality. One of the main reason is, the consumers are well informed about the power quality issues like interruptions, sagging and switching transients. Also, many power systems are internally connected into a network. Due to this integration if a failure exists in any one of the internal network it would result into unfavorable consequences to the whole power system. In addition to all this, with the microprocessor based controls, protective devices become more sensitive towards power quality variation than were the past generation protective devices. Following are some of the disturbances which are common in affecting the power system.

i. Transients:

In terms of power system, the transients can be defined as an action or a situation in power system with variations in power system and which is not desirable in nature. A general understanding of transient is considered to be an oscillatory transient which is damped due to the RLC network. A person who is new to the power system also uses the term "surge" to define transient. A surge may be analyzed as a transient which is resulting from the stroke of lightening where protection is done by using a surge arrester. A person who is more groomed in the field of power engineering would avoid to use the term "surge" unless it is specified as to what exactly the term "surge" refers to. Transient can be divided into two categories i.e. the oscillatory transient and the impulsive transient.

ii. Oscillatory Transient:

A voltage or a current whose values change polarity rapidly are part of oscillatory transient. In case of a steady state of voltage and current when there is a sudden non-power frequency change or when there is a non-power frequency change in positive and negative polarity values, such a change is termed as an oscillatory transient.

iii. Impulsive Transient:

Impulsive transients are mostly caused due to lightning. Unlike the oscillatory transient, the impulsive transient is such a condition when there is sudden change of non-power frequency in a steady state condition of voltages and currents that is unidirectional in polarity. Impulsive transients also have the ability to produce oscillatory transients by exciting the natural frequency of a power system.

iv. Short Duration Voltage Variations:

Short duration voltage variations are usually caused by faults in the power system. Short duration voltage variations consists of sags which are caused depending on the system conditions and faults that are caused in the power system. It really depends on what kind of fault is caused in the power system under what condition which may lead to voltage drops, voltage rise and even interruptions in certain conditions. When such faults takes place, protective devices are used in order to clear the fault. But, the impact of voltage during such faulty conditions is of short-duration variation.

Interruptions:

When there are reductions in the voltage or current supply interruptions take place. Interruptions may occur due to various reasons, some of them being faults in the power system, failures in the equipment, etc.

Sagging:

A short duration voltage variation is often referred to as sagging. When there is a decrease between 0.1 to 0.9 pu in rms voltage sagging takes place. There are many ways to obtain the magnitude of sagging from the rms voltages. Most of the times lowest value obtained during the event is considered. Sagging normally has constant rms value during the deep part of the sag. Thus, lowest value is an acceptable approximate value.

v. Long Duration Voltage Variations:

Long duration voltage variations are comprised of over voltages as well as under voltages conditions. These under voltage and over voltage conditions are caused by variations in the power system and not necessarily due to the faults in the system. The long duration voltage variations refers to the steady state condition of the rms voltage of the power system. The long duration voltage variations are further divided into three different categories i.e. interruptions, over voltage and under voltage.

Under Voltage:

There are many reasons for the under voltage conditions in the power system. When there is a decrease in the rms ac voltage to less than 90% of a power system for some amount of time then under voltage condition exists. Load switching on or switching off of a capacitor bank can also cause under voltage condition. Also, when a power system is overloaded it may result into under voltage condition.

Over Voltage:

Compared to the under voltage condition, over voltage is an increase in the rms ac voltage to greater than 110% of the power system for some amount of time. Unlike under voltage condition, load switching off or capacitor bank getting energized are main reasons for the over voltage conditions.

B. Harmonic Reduction in Inverters

i. DC-AC Inverter:

DC to AC inverters are those devices which are used to produce inversion by converting a direct current into an alternating current. If the output of a circuit is AC then depending on the input i.e. either AC or DC, the devices are called as AC-AC cyclo converters or DC-AC inverters. DC to AC inverters are such devices whose AC output has magnitude and frequency which is either fixed or variable. In case of DC to AC inverters the output AC voltage can be either single phase or three phase. Also, the magnitude of the AC voltage is from the range of 110-380 VAC while the frequencies are either 50Hz, 60Hz or 400Hz. Some of the basic applications of inverters would be an UPS (uninterruptible power supply). When the main power is not available UPS uses batteries and inverter to supply AC power. A rectifier is used to recharge the batteries used when the main power is back. Other applications of an inverter included Variable frequency drives. The variable frequency drives controls the frequency and voltage of power supplied to the motor, thus controlling the speed of AC motor. An inverter is used in the variable frequency drives to provide controller power. An inverter is also used in an induction motor to regulate the speed by changing the frequency of AC output.

As explained in earlier chapters, the harmonics can be present in any system. Similarly, the harmonics are present in a system where inverters are used as well. Ideally, the main aim of using an inverter is to produce an ac output from the dc source. Theoretically the output voltage waveform is expected to be sinusoidal, but in practical terms there is definitely going to be distortions due to harmonics present in the system which results into distorted output waveforms. As a result of this, inverters are used in a system in order to produce output waveforms which are purely sinusoidal and distortion free.

Figure shows a circuit showing DC-AC inverter along with filters which are used to reduce the effect of harmonics to provide distortion free output ac signal. The front part of the circuit consists of AC to DC converters. These AC to DC converters has one ac frequency i.e. the line frequency and it relies on line communication for switching. The system also consists of DC to AC inverters which are used to turn on or off the power switches. Unlike AC to DC converters in DC to AC inverters, the ac frequency is not the line frequency. The figure also shows a voltage control where variable frequency drives are used to control the speed of motors and provide variable output voltage. Due to this complex structure, the inverter circuits require proper control signals to produce the expected ac output voltage. The figure also shows a filter circuit which is used to reduce the harmonics in the system to produce clean sinusoidal output ac voltage. A comparator circuit is also employed which compares the output ac voltage with the reference ac voltage. If he output ac voltage is more distorted as compared to the reference ac voltage then filter circuits are used again to produce the desired clean sinusoidal AC voltage.[6][7]

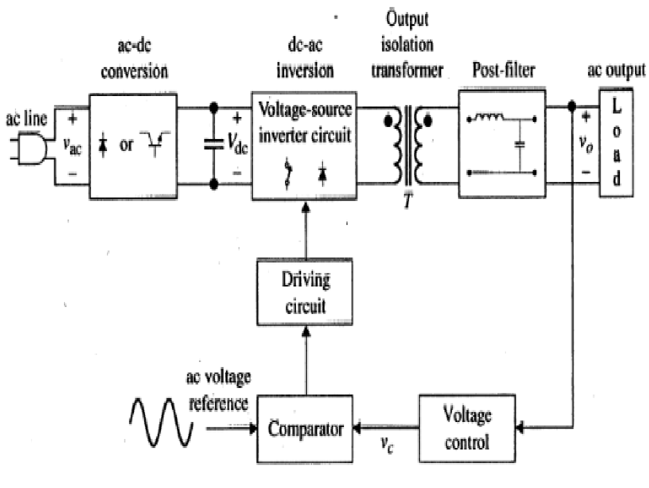


Fig.1.1: Power Electronic Circuit with DC-AC inverter.

ii. Single Phase Inverters:

There can be many different topologies that can be used for inverter circuits. Inverter circuits are designed differently depending on the way the inverter is intended to be. The figure 11 shows a single phase inverter. The way the switches and the load are connected, it is also called a H bridge inverter. H Bridge can be called a circuit which is used to apply voltage to the load in both the directions. This single phase inverter consists of four IGBT devices (also called power control devices) where two each IGBTs are connected in series with each other.

Each power control devices have diodes connected in parallel with each other but in opposite direction. There are also loads connected between the two IGBT devices and the diodes. The way these diodes are connected is, if the two IGBT devices are turned off, then the diodes provide a path for the current of load to flow. For eg. If the IGBT2 is turned on, it will carry current towards the negative bus and through the diode which is connected in parallel. Now when this IGBT2 is turned off, the current will travel through the diode which is connected in parallel in opposite direction and reach to the IGBT1. Also, controllers can be used in order to control the turning on and off of the IGBT circuits. The controllers will command the switches such that when IGBT1 is on, IGBT2 will be off and when the IGBT2 is on, IGBT1 will be off.

For the single phase inverters, the modulation of the left IGBT circuits will be inverse of the right IGBT circuits and right IGBT circuits will have large duty cycle for the lower IGBT while left IGBT circuits will have it for upper IGBT. The output of an inverter with a sinusoidal frequency is given by the following formula:

$$V_{ac1}\ (t) = m_a \ . \ V_{dc} \ . \ \sin(w_1 .t)$$

m_a = modulation factor, where $0 \leq m_a \leq 1$

Vdc = input voltage

Vac1 = output voltage

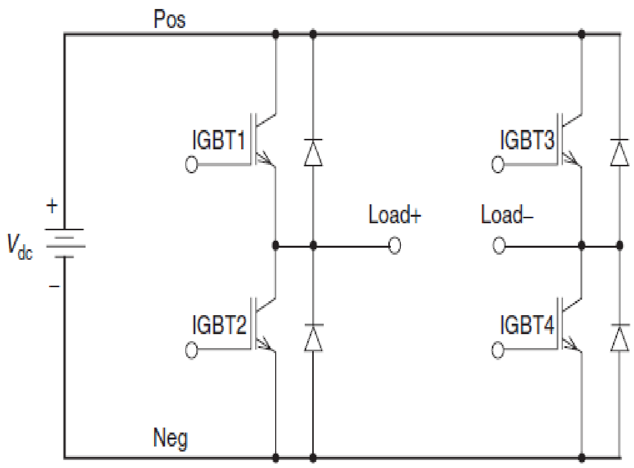


Fig. 1.2: Single Phase Inverter.

iii. Three Phase Inverters

Similar to the Single Phase Inverters, the Three Phase Inverters also have different topologies which can be used. Figure 12 shows a three phase inverter circuit. It is an extension of H bridge circuit as it consists of three single phase inverters each connected to one of the three load terminals. In case of single phase inverter, there is a phase shift of 180 degrees between different legs, while in case of three phase inverter there is a phase shift of 120 degrees. This phase shift of 120 degrees in three phase inverter helps in eliminating the odd harmonics from the three legs of the inverter. Also, if the output is pure AC waveform then the even harmonics can be eliminated as well. In order to modulate the output of a three phase inverter, the amplitude of output voltage is reduced by a factor with respect to the input voltage. This factor is given by the following equation:

$$\frac{3}{2\pi} \ . \ \sqrt{3} \ = \ 82.7\ \%$$

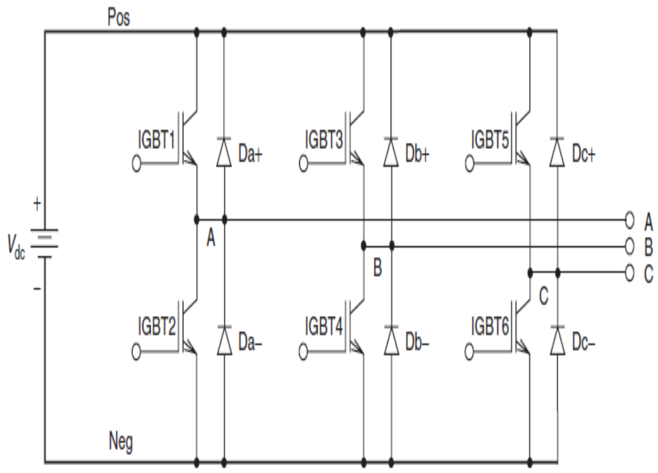


Fig.1.3: Three Phase Inverter.

iv. Pulse Width Modulation Technique:

Figure shows a single phase inverter block diagram with a high frequency filter that is used in order to remove the harmonics from the output waveform. Here, vo is the ac output while vin is the input dc voltage.

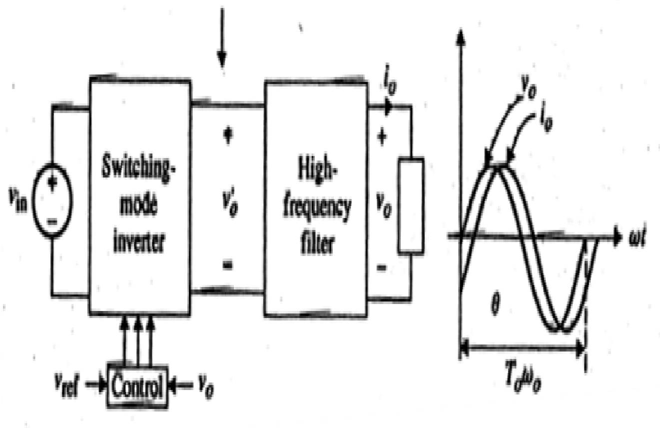


Fig 1.4: Single Phase Inverter with Filter

Figure shows output waveforms that gets produced based on the Pulse width modulation technique when it is employed.

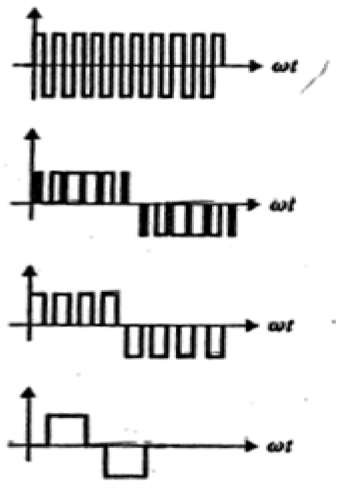


Fig. 1.5: Output waveforms Produced Based on PWM Technique

In a single phase inverter, the varying width of the output pulse is used to control the output voltage. Thus, this process of controlling the output voltage of inverter in order to reduce the harmonics is known as Pulse Width Modulation. The Pulse Width Modulation is classified into three techniques.

v. Non Sinusoidal Pulse Width Modulation:

In case of Non sinusoidal pulse width modulation, all the pulses that have same pulse width are modulated together. The pulse widths of pulses are adjusted together in same proportion on order to remove the harmonics from the system. A typical representation of Non sinusoidal pulse width modulation is shown in figure 16 shown below.[6]

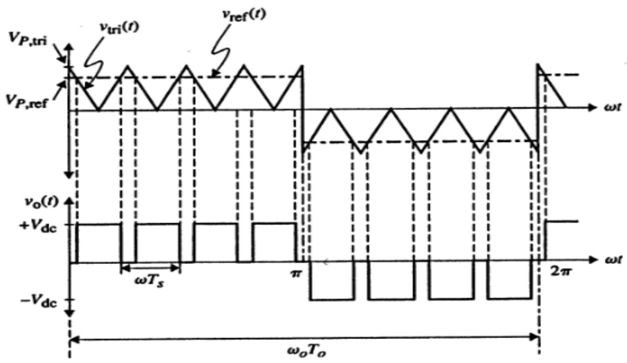


Fig. 1.6: Representation of Non Sinusoidal Pulse Width Modulation

vi. Sinusoidal Pulse Width Modulation

Sinusoidal Pulse Width Modulation is a bit different compared to the Sinusoidal Pulse Width Modulation. In case of sinusoidal pulse width modulation, all the pulses are modulated individually. Each and every pulse is compared to a reference sinusoidal pulse and then they are modulated accordingly to produce a waveform which is equal to the reference sinusoidal waveform. Thus, sinusoidal pulse width modulation modulates the pulse width sinusoidally.[6]

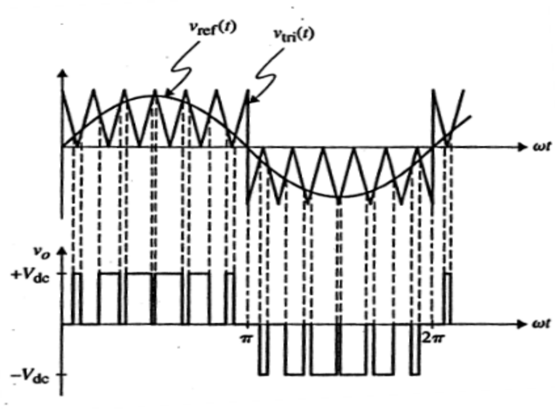


Fig.1.7: Representation of Sinusoidal Pulse Width Modulation

Note:

For figures 1.6 and 1.7,

- ts = Time of the triangular waveform
- fs = frequency of the triangular waveform
- Vref = Reference voltage of the square or sinusoidal waveform
- Vp,ref = Peak value of the reference voltage
- to = Time of the output waveform of the Inverter which is desired
- fo = Frequency of the output waveform of the Inverter which is desired
- ma = Amplitude modulation index of Inverter
- mf = Frequency modulation index of Inverter
- k = Number of pulses per half cycle

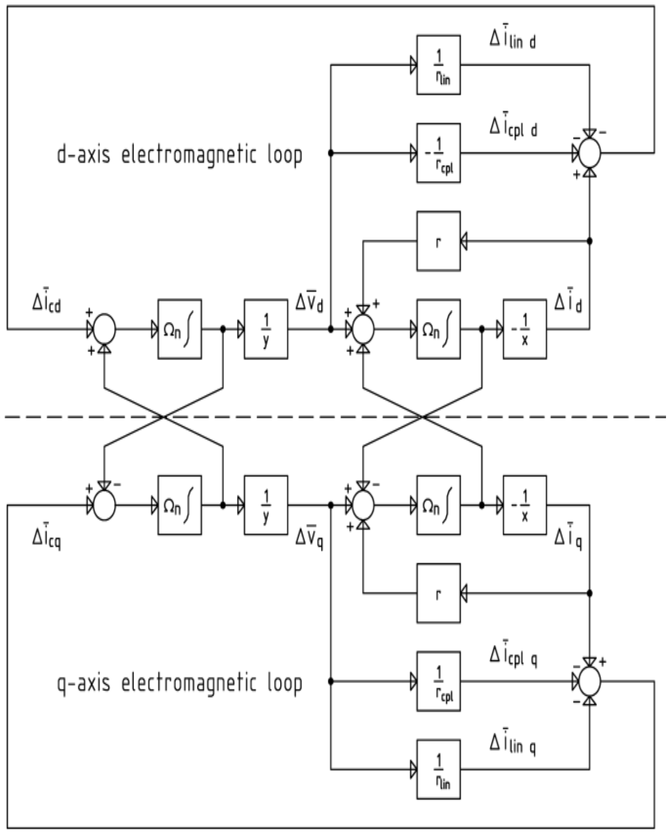
vii.Space Vector PWM Modulation

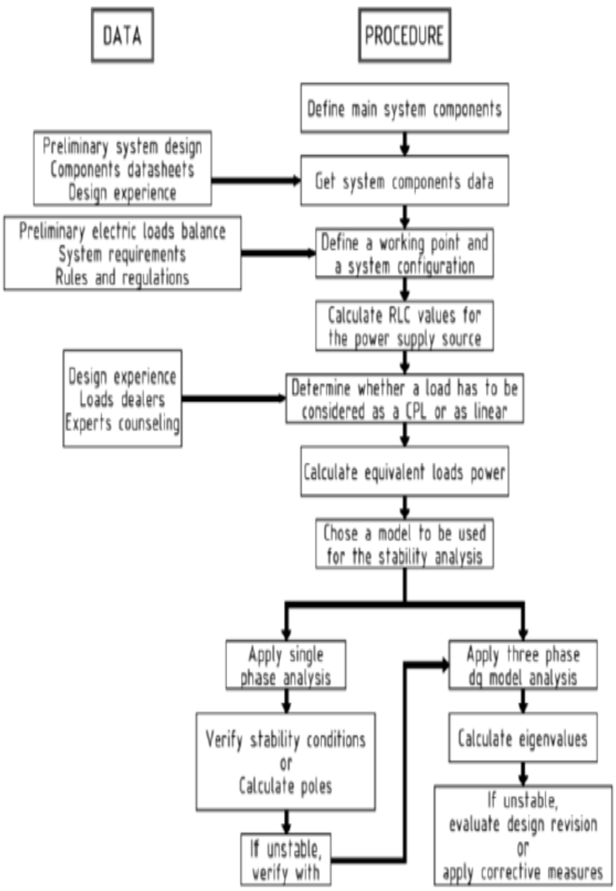
The space vector PWM modulation technique is popular for bi-level PWM converter control. It can be extended to multilevel converters. Figure.18 shows space vectors for the traditional three-, five-, and seven-level converters. These vector diagrams are universal regardless of the topology of multilevel converter. Therefore it can be used for diode-clamped, capacitor-clamped, or cascaded converters. The adjacent three vectors can synthesize a desired voltage vector by computing the duty cycle for each vector according to the following:

$$\vec{V}^* = \frac{T_j\vec{V}_j + T_{j+1}\vec{V}_{j+1} + T_{j+2}\vec{V}_{j+2}}{T}$$

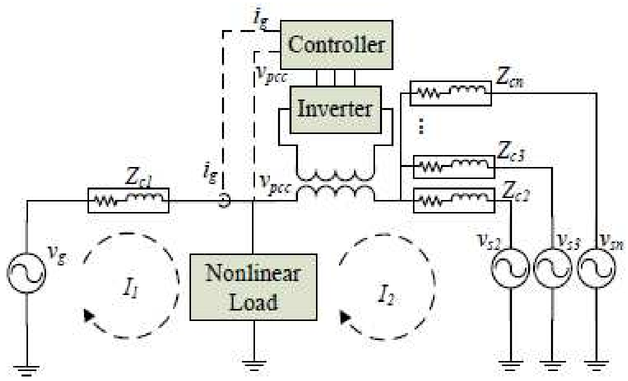
III. Operational Analysis

A family of wind or solar energy systems with integrated functions of active power transfer, reactive power compensation, and voltage conversion and harmonics elimination is presented. The wind energy systems and photovoltaic systems using solid-state transformer (SST) can effectively suppress the voltage fluctuation without additional reactive power compensator. Anyhow SST design is not our basic work, because it is already suggested in VOLTAGE INJECTOR systems.





In this paper stability analysis approach has been proposed, to help in evaluating stability already in system's design stage. The models have been then applied to two case studies, to highlight their differences. The stability analysis has to be done with new stability metric called as " Lyapunov Exponents' Which is recently emerging metric to evaluate the stability regions of a system.



A. Isolated Injection/ Booster transformer:

The Injection / Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side. Its main tasks are, It connects the VOLTAGE INJECTOR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

In addition, the Injection / Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

B. Harmonic Filter:

The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

C. Voltage Source Converter:

A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. In the VOLTAGE INJECTOR application, the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing.

There are four main types of switching devices: Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Each type has its own benefits and drawbacks. The IGCT is a recent compact device with enhanced performance and reliability that allows building VSC with very large power ratings. Because of the highly sophisticated converter design with IGCTs, the VOLTAGE INJECTOR can compensate dips which are beyond the capability of the past VOLTAGE INJECTORs using conventional devices. The purpose of storage devices is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages. The different kinds of energy storage devices are Superconductive magnetic energy storage (SMES), batteries and capacitance.

D. DC Charging Circuit:

The dc charging circuit has two main tasks. The first task is to charge the energy source after a sag compensation event. The second task is to maintain dc link voltage at the nominal dc link voltage.

E. Control and protection:

The control mechanism of the general configuration typically consists of hardware with programmable logic. All protective functions of the VOLTAGE INJECTOR should be implemented in the software. Differential current protection of the transformer, or short circuit current on the customer load side are only two examples of many protection functions possibility.

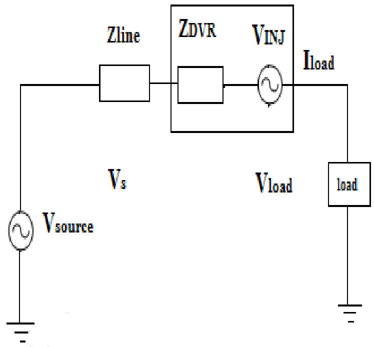


Fig.2.1 Equivalent circuit diagram of VOLTAGE INJECTOR

The system impedance Zth depends on the fault level of the load bus. When the system voltage (Vth) drops, the VOLTAGE INJECTOR injects a series voltage VVOLTAGE INJECTOR through the injection transformer so that the desired load voltage magnitude VL can be maintained. The series injected voltage of the VOLTAGE INJECTOR can be written as

$$V_{DVR} = V_L + Z_{TH} I_L - V_{TH}$$

Where

V_L : The desired load voltage magnitude
Z_{TH} : The load impedance.
I_L : The load current
V_{TH} : The system voltage during fault condition

The load current IL is given by,

$$I_L = \frac{[P_L + jQ_L]}{V}$$

When VL is considered as a reference equation can be rewritten as,

$$V_{DVR}\angle 0 = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta$$

∝, β, δ are angles of V_{DVR}, Z_{TH}, V_{TH} respectively and θ is Load power angle

$$\theta = tan^{-1}\left(\frac{\theta_L}{P_L}\right)$$

The complex power injection of the VOLTAGE INJECTOR can be written as,

$$S_{DVR} = V_{DVR} I_L^*$$

It requires the injection of only reactive power and the VOLTAGE INJECTOR itself is capable of generating the reactive power.

F. Operating modes of VOLTAGE INJECTOR:

The basic function of the VOLTAGE INJECTOR is to inject a dynamically controlled voltage VOLTAGE INJECTOR generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The VOLTAGE INJECTOR has three modes of operation which are: protection mode, standby mode, isolated injection/boost mode.

i. Protection mode:

If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the VOLTAGE INJECTOR will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

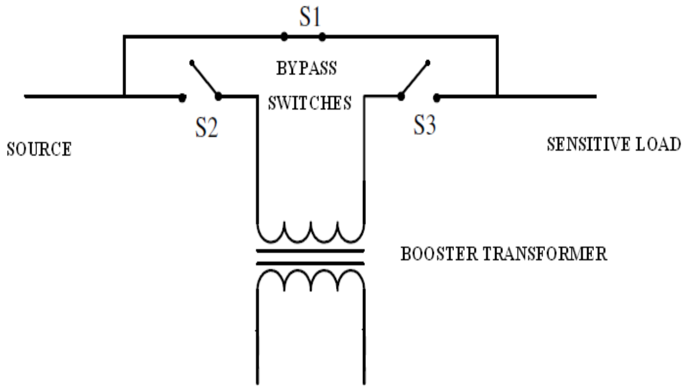
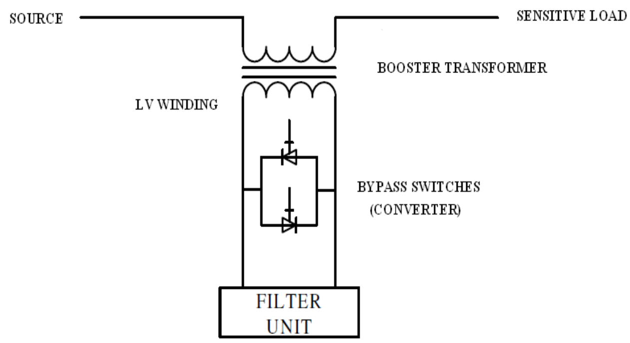


Fig.2.2 Protection Mode (creating another path for current)

ii. Standby Mode:

In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the primary.



iii. Isolated Injection/Boost Mode: (VOLTAGE INJECTOR>0)

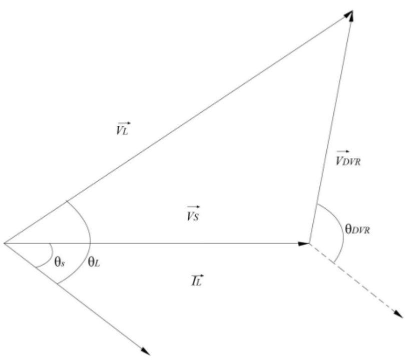
In the Injection/Boost mode the VOLTAGE INJECTOR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

G. Voltage injection methods of VOLTAGE INJECTOR:

Voltage injection or compensation methods by means of a VOLTAGE INJECTOR depend upon the limiting factors such as; VOLTAGE INJECTOR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angel jump and some are sensitive towards change in magnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics.
There are four different methods of VOLTAGE INJECTOR voltage injection which are

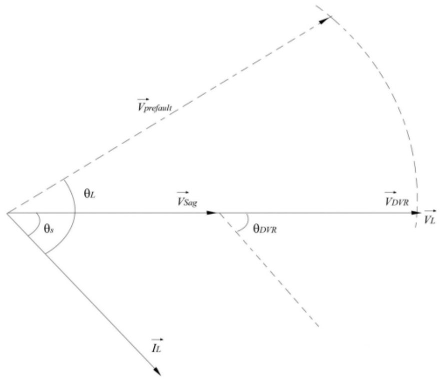
i. Pre-sag/dip compensation method:

The pre-sag method tracks the supply voltage continuously and if it detects any disturbances in supply voltage it will inject the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method. In this method the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions
VOLTAGE INJECTOR = Vprefault - Vsag



ii. In-phase compensation method:

This is the most straight forward method. In this method the injected voltage is in phase with the supply side voltage irrespective of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied.



|VL|=|Vprefault|

One of the advantages of this method is that the amplitude of VOLTAGE INJECTOR injection voltage is minimum for a certain voltage sag in comparison with other strategies. Practical application of this method is in non-sensitive loads to phase angle jump.

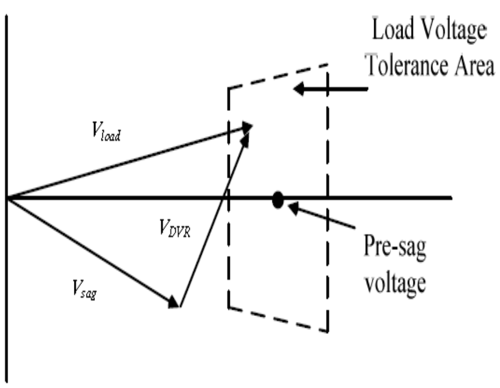
iii. In-phase advanced compensation method:

In this method the real power spent by the VOLTAGE INJECTOR is decreased by minimizing the power angle between the sag voltage and load current. In case of pre-sag and in-phase compensation method the active power is injected into the system during disturbances. The active power supply is limited stored energy in the DC links and this part is one of the most expensive parts of VOLTAGE INJECTOR. The minimization of injected energy is achieved by making the active power component zero by having the injection voltage phasor perpendicular to the load current phasor.

In this method the values of load current and voltage are fixed in the system so we can change only the phase of the sag voltage. IPAC method uses only reactive power and unfortunately, not al1 the sags can be mitigated without real power, as a consequence, this method is only suitable for a limited range of sags.

iv. Voltage tolerance method with minimum energy injection:

A small drop in voltage and small jump in phase angle can be tolerated by the load itself. If the voltage magnitude lies between 90%-110% of nominal voltage and 5%-10% of nominal state that will not disturb the operation characteristics of loads. Both magnitude and phase are the control parameter for this method which can be achieved by small energy injection.



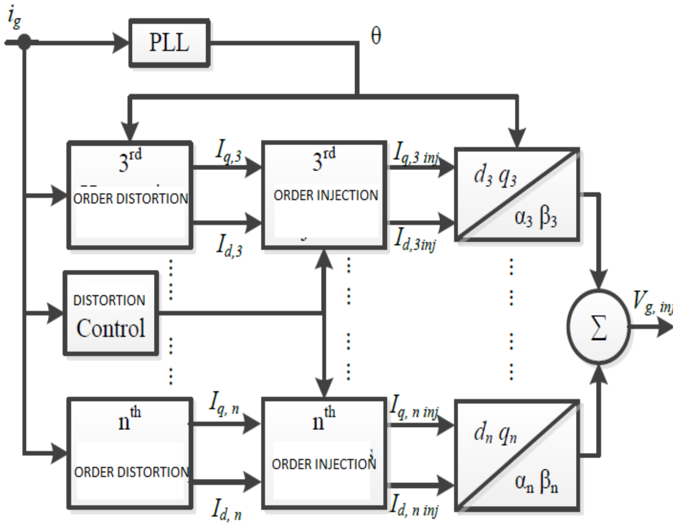


Fig.2.3 Block Diagram of Proposed Control System

The measured current or voltage, is first sensed and filtered using low pass filter , then applied to PLL. In PLL exact phase of the input voltage is determined. Then later the same is applied to various stages, where the distortions are carefully calculated in all harmonics and the same is estimated in the form of dq components. While injection is to be performed, it is converted into alpha beta components. The summed voltage acts as the control signal of an additional inverter which compensates for any voltage stability issues.

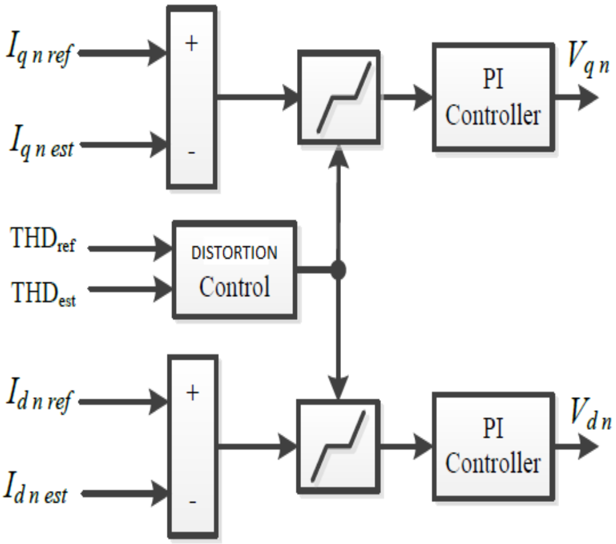


Fig.2.4 Anti Disortion Unit

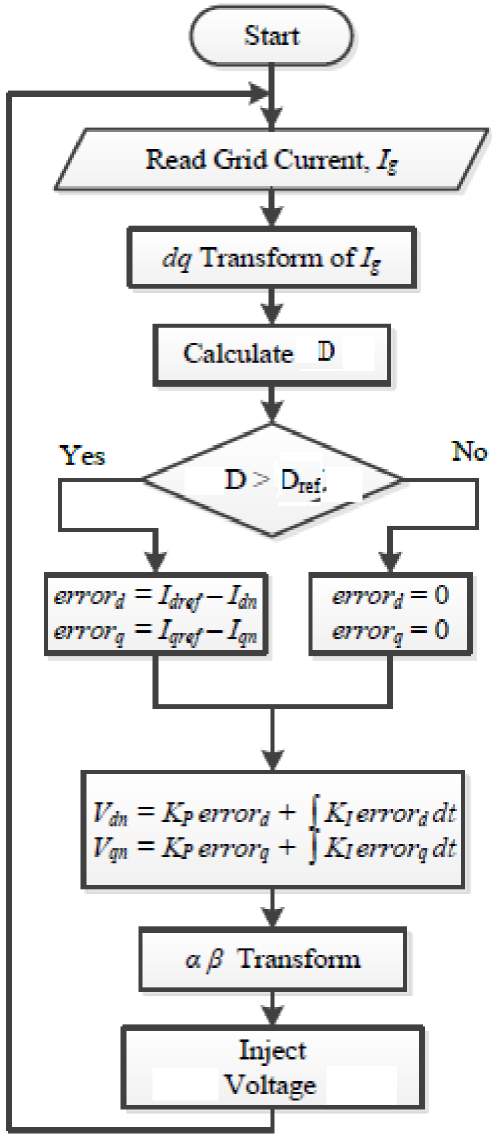
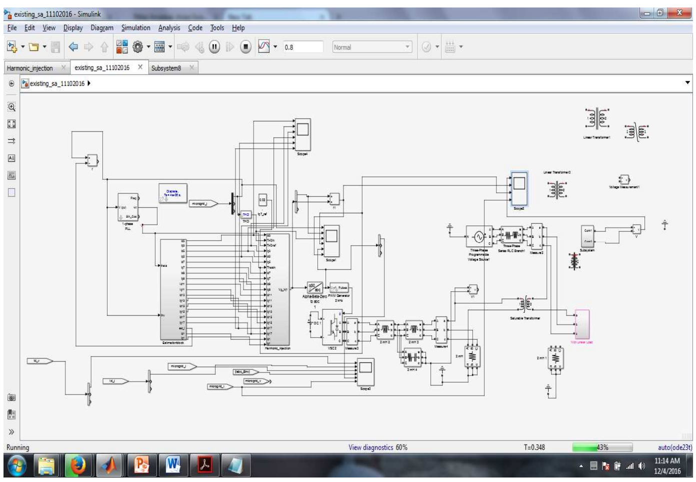
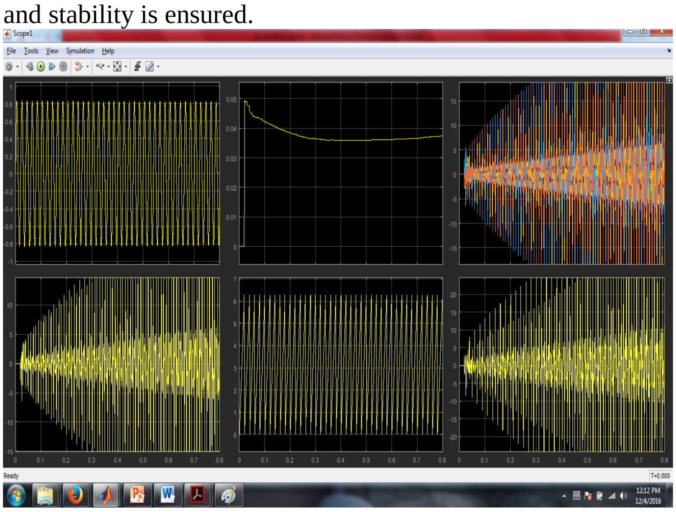


Fig.2.5 Flow Chart of Proposed Control System

IV. Simulation Results



The Simulink model consists of an estimation block and compensation block. Initially the load voltage is sensed and given to PLL to estimate the phase angle. This is applied to estimation block where d and q parameters are evaluated. With the help of dq parameters alpha and beta components are calculated and controlled using PID controllers. The same is further converted into abc parameters to estimate the gate pulses needed to function of inverter. Further the inverted voltage is smoothened using LCL filter and injected in antiphase to the load voltage and hence the voltage distortion and stability is ensured.



The second waveform of first row implies that there is a continual reduction of voltage distortion when the control system is functioning. Third waveform shows that injection is keep on increasing as, the distortion is still existing. Hence the control system try to reduce the error and hence the distortion minimum of 0.03.

V. Conclusion & Future work

In this project, an assessment of voltage stability in large marine integrated electrical and electronic power systems has been made, applying a simplified approach focused on design stage assessment. The CPL loads instability issue has been introduced, together with two different models to analyze the impact of these loads on the system (single-phase equivalent model and three-phase dq model). Then a stability analysis approach has been proposed, to help in evaluating stability already in system's design stage. The models have been then applied to two case studies, to highlight their differences. The single-phase model has led to simple stability conditions, yet being inaccurate near stability border if applied for three-phase systems. Conversely, the three-phase dq model has led to more complex yet exact stability assessment for three-phase systems. The case studies have also demonstrated the applicability of the proposed practical stability analysis approach. Finally, considerations on system's parameters affecting stability and possible solutions to instability issues have been presented. Indeed, applicable standards are starting to address relevant power system issues, and recommending proper solutions and studies to ensure proper system operation.

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