VOLTAGE CONTROL IN TRACTION SYSTEM BY USING STATIC VAR COMPENSATOR(SVC)

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Abstract — This paper will discuss and demonstrate how Static VAR Compensator (SVC) has successfully been applied to voltage control of traction system using static VAR compensator and effectively regulate system voltage. SVC is basically a shunt connected static VAR generator whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power variable typically the control variable is the SVC bus voltage. One of the major reasons for installing the SVC is to voltage control and thus increases the system load ability. Firstly, to design a controller for SVC on TRACTION SYSTEM, a Single Machine Infinite Bus (SMIB) system is modeled. This paper presents a method of modeling AC traction drive using MATLAB. Power system Block set/simulation software focusing on Rectifier –Inverter – Motor systems. Three phase induction motor used in electric locomotive has been considered for the model. The inverter has been simulated to operate in two modes i.e. six step and Pulse Width Modulation (PWM) mode with rectifier block. The inverter fault condition has also been simulated to study the performance of electric traction drive under loaded condition. Simulation results will be provided by using MATLAB programming. The SVC can more effectively enhance the transient stability and increase the transmission capacity.

Index Terms - Voltage control, static VAR compensator, FACTS, Traction system, transient stability.

I. INTRODUCTION

The focus of this paper and research is the application of Static Var Compensator to solve voltage regulation and system dynamic performance in traction system. SVC is thyristor based controller that provides rapid voltage control to support electric power transmission voltages during or immediately after major disturbances. Since the advent of deregulation and the separation of generation and traction systems in electric industry, voltage stability and reactive power-related system restrictions have become an increasing growing concern for electric utilities'. When voltage security or congestion problems are observed during the planning study process, cost effective solution must be considered for such problems. One approach to solve this problem is the application of "Flexible AC Transmission System" (FACTS) technologies, such as the Static Var Compensator (SVC). In an ideal ac power system, the voltage and frequency at every supply point would be constant and free from harmonics; the power factor would be unity.

There are two types of voltage stability: transient voltage stability and longer-term voltage stability. Long-term voltage stability involving loads that are inherently voltage sensitive has been of greatest interest in recent years. Voltage stability involves the load, transmission, and generation-sub systems of large power systems. Three keys aspects of voltage stability are:

1. The load characteristic as seen from bulk power network.
2. The available means for voltage control at generators and in the network and
3. The ability of the network to transfer power, particularly reactive power, from the point of production to point of consumption.

II. MODELING OF THE SVC

1. TCR/FC SVC:-

A static VAR compensator (or **SVC**) is an electrical device for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a static VAR compensator has no significant moving parts (other than internal switchgear). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks.

In industrial applications, SVCs are typically placed near high and rapidly varying loads, such as arc furnaces, where they can smooth flicker voltage. Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations, a voltage depression, or even a voltage collapse. A rapidly operating Static VAR Compensator (SVC) can continuously provide the reactive power required to control dynamic voltage swings under various system conditions and thereby improve the power system transmission and distribution performance. Installing a SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. In addition, an SVC can mitigate active power oscillations through voltage amplitude modulation.

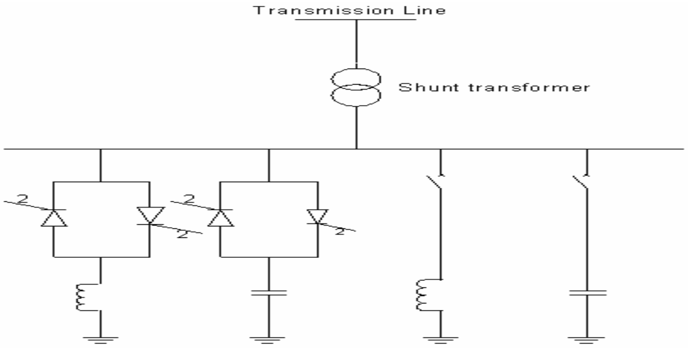


Fig1.SVC arrangement

The SVC provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled reactive devices.

An SVC is typically made up of the following major components:

1. Coupling transformer
2. Thyristor valves
3. Reactors
4. Capacitors (often tuned for harmonic filtering)

In general, the two thyristor valve controlled/switched concepts used with SVCs are the thyristor-controlled reactor (TCR) and the thyristor-switched capacitor (TSC). The TSC provides a “stepped” response and the TCR provides a “smooth” or continuously variable susceptance.

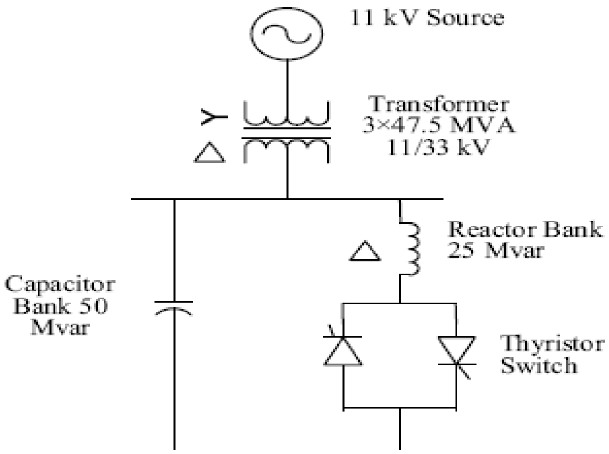


Fig2.Single line diagram of the system

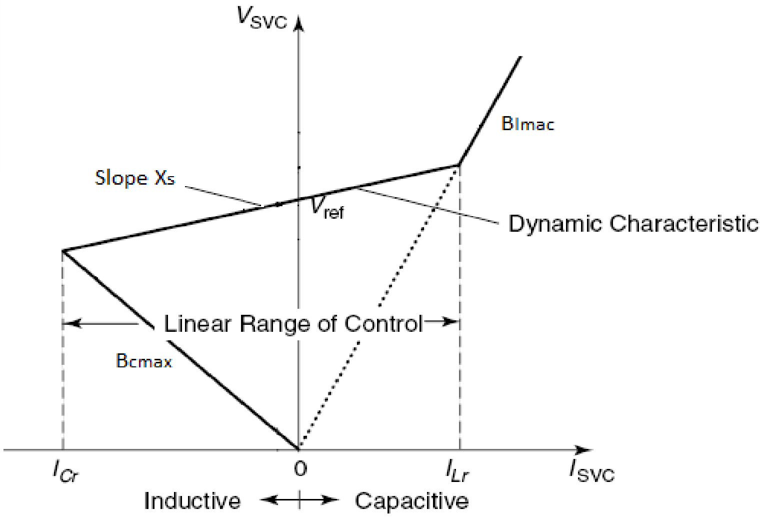


Figure-3.4 SVC V-I CHARACTERISTIC

Description of Static Var Compensator:-

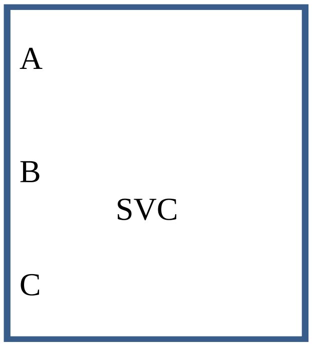


Fig.4 SVC Block in MATLAB

The static VAR compensator (SVC) is a shunt device of the flexible AC transmission systems (FACTS) family using

Power electronics to control power flow and improve transient stability on power grids. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR).

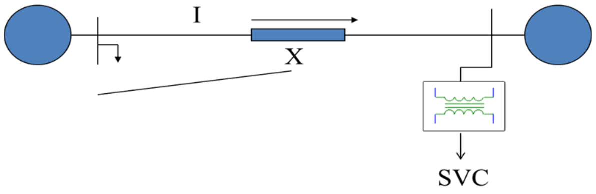
2. SVC IN POWER SYSTEM:-

There are two machine three bus systems, which are very important characteristics to describe the behavior of system, it is extremely useful to explain the general concepts of power systems dynamic performance and is relatively simple to study. During the faulty condition the transmitted electrical power suddenly decrease significantly while mechanical input power to generate or remains constant, consequently, the generator continuously accelerates as can be seen in the generator speed and power angle. When the faulty condition is recovered, the speed is continuously increasing and system is unable to retain stability due to the lack of damping. During course of the fault, the generator terminal experiences voltage sag without the SVC.

This voltage is not recovered after the fault clearance due to the insufficient reactive power support, the shaft of the turbine generator set are caused high torsion oscillations and force as seen in the electromechanical torques. If the proper compensation of the ac power system requires some specific variation in the amplitude of the terminal voltage with time or some other variable, then an appropriate correcting signal derived from the auxiliary inputs, is summed to the fixed reference Vref in order to obtain the desired effective (variable) reference signal Vref that closed-loop controls the terminal voltage V t.

As the SVC is connected to the system midpoint terminals, SVC controller adapts the value of the inverter firing angle according to system requirements. As shown in fig. the firing angle should remain zero at normal operating conditions and there is no reactive power exchange between the system and the SVC. When the fault occurs, the angle is changed instantly and the reactive power is supplied by the SVC to the system. When the system is recovered faulty condition, the firing angle is reduced to zero again and the SVC back to the ideal condition.

E_1 / δ_1 P&Q E_2 / δ_2



3. FACTS IN RAIL TRACTION:-

Power grids feeding railway systems and rail traction loads benefit enormously by using SVC and STATCOM. These benefit reduces, if not eliminate, the investments needed to upgrade, the railway power feeding infrastructure.

FACTS devices in a system also enable adequate power quality to be achieved with in feed at lower voltages than would otherwise be possible. This means, for example, that it may be sufficient to feed a railway system at 123 kv rather than at 220 kv or even 400 kv.

On the traction side any one of two transformer schemes can be used to supply high and efficient power the booster transformer and auto-transformer scheme. In the booster transformer scheme, the main voltage is transformed into a single-phase catenary voltage. One end of the power transformer traction winding is grounded and the other is connected to the catenary wire. In the auto-transformer scheme, the traction winding is grounded at its midpoint. One end of the winding is connected to the catenary wire while the other end is linked to the feeder wire. In both schemes the grounded pointes are connected to the rail.

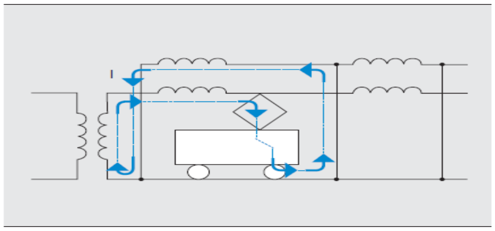


Fig5. Booster transformer scheme

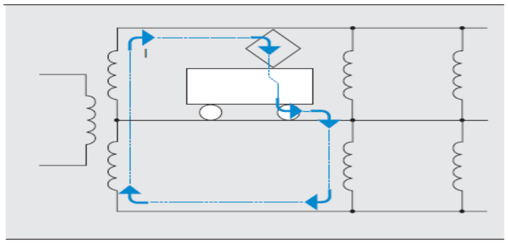


Fig6. Auto transformer scheme

On the transmission network side the power transformer is connected between two phases. Frequently, two isolated rail sections are fed from the same feeder station, and in this case the power transformers are then connected between different phases.

TECHNICAL DATA:-

1. Make:- ABB
2. Motor type:- 6 FRA 6068
3. Insulation: -Class 200
4. Suspension: -Axle hung. Nose suspended
5. Ventilation:- Forced air cooling
6. Weight:- 2100 kg
7. Gear ratio:- 107 : 21 WAG9, 72 : 20 WAP7
8. Continuous Rating:-850 kW, 2180V (phase to phase), 270A, 1283 rpm, supply frequency 65 Hz, power factor 0.88, motor efficiency 0.95
9. One-hour Rating:-850 kW, 2089V (phase to phase), 290A, 1135 rpm, supply frequency 57.5 Hz, power factor 0.86, motor efficiency 0.95
10. Short time over-load rating:-850 kW, 1660V (phase to phase), 370A, 892 rpm, supply frequency 45.7 Hz, power factor 0.86, motor efficiency 0.95

4. TRACTION LOAD:-

Nowadays, the traction load, P_{load}, tends to be relatively large, often with power ratings between 50 MW and 100 MW per feeding transformer. These loads will create imbalances in the supply system voltage if they are connected between two mains phases. As a rule of thumb, if the fault level of the grid is represented by S_{SSC}, the imbalance, $U_{imbalance}$, is equal to

$$U_{imbalance} = P_{LOAD} / S_{SSC}$$

A common requirement is that the negative phase sequence voltage resulting from an unbalanced load should not exceed one percent. Assuming loads of between 50MWand 100MW , the feeding system must have a short-circuit level of at least 5,000 MVA to 10,000 MVA if it is to stay within the imbalance requirements'. In many cases the traction system is relatively far from strong high-voltage transmission lines. Weaker sub transmission lines, however, normally run somewhere in the vicinity of the rail and can therefore be used to supply the rail in cases where an imbalance caused by the traction load can be mitigated.

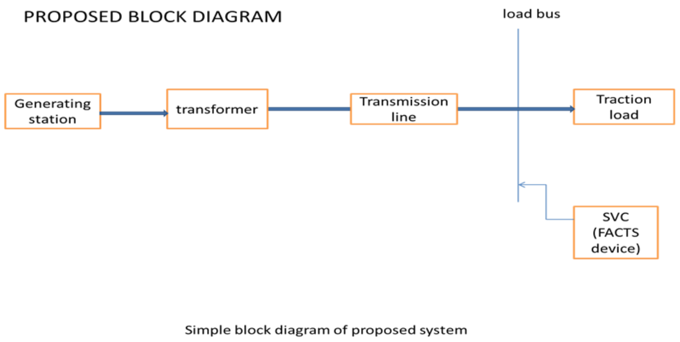


Fig7:- Simple block diagram of proposed system

5. LOAD BALANCING BY MEANS OF SVC:

An SVC is a device that provides variable impedance, which is achieved by combining elements with fixed impedances (e.g. Capacitors) with controllable reactors. Surprisingly, this combination is capable of balancing active power flows. The reactors also have fixed impedances but the fundamental frequency component of the current flowing through them is controlled by thyristor valves, which results in apparent variable impedance. In this type of reactor is known as a thyristor controlled reactor (TCR).

A TCR is a shunt (parallel) branch consisting of a reactor in series with a thyristor valve-5. The branch current is controlled by the phase angle of the firing pulses (firing angle control) to the thyristors, i.e., the voltage across the reactor equals the fully system voltage at a firing angle of 90 degrees and is zero at firing angle of 180 degrees. The current through the reactor is the integral of the voltage; thus it is fully controllable between the natural value given by the reactor impedance and zero.

To address the issue of space as well as benefiting from advanced semiconductor technology, the thyristor valves make use of a bi-directional device, a semiconductor component which allows the integration of two anti-parallel thyristors in one silicon wafer. Using these thyristors reduces the amount of unites needed in the valves by 50 percent. The thyristor is a five-inch device with a current handling capability of about 2,000 a (rms).

In the conventional SVC, load balancing is achieved when, by controlling the reactive elements, active power is transmitted between the phases. In its simplest form the load balancer consists of a TCR connected between two power supply phases and a fixed capacitor bank in parallel with a TCR connected between two other phases .Power factor correction is obtained by a fixed capacitor between the remaining two phases. Harmonics are normally suppressed by the addition of filters. These can be connected either in a way formation or directly in parallel with the reactors.

The control of the load balancer may be based either on the fact that three line-to-line voltages with the same magnitude cannot contain a negative phase sequence components and acts to counteract the negative one. The control of the positive sequence voltage normally has a lower priority compared with that of the negative, i.e. It is only fully controlled when the load balancer rating is large enough to allow for both balancing and voltage control. Considering the realized powers especially for so called light transport systems such as electrical automobiles, electrical scooters but even light railroad vehicles, where the possibilities of direct individual wheel driving is suggest. This system enables the train to maintain a constant voltage automatically and can be activated at any speed.

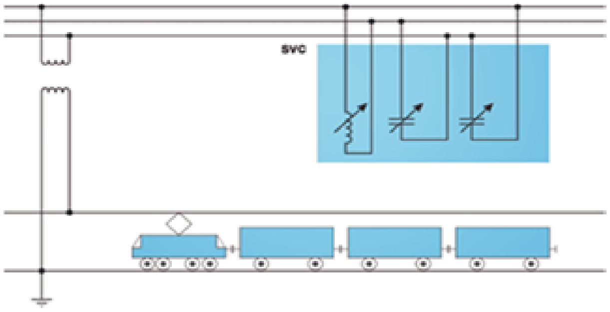


Fig8:-LOAD BALANCING AND REACTIVE POWER COMPENSATION BY SVC

6. EFFECT OF USING SVC:

- Non-symmetrical loads fed from two phases of three-phase supplying grids are dynamically balanced.
- Voltage fluctuations in the feeding grids caused by heavy fluctuations of the railway loads can be dynamically mitigated.
- Harmonics injected into supply grids from traction devices can be eliminated.
- SVC and STATCOM provide dynamic voltage support of catenaries feeding high power locomotives. This in turn prevents harmful voltage drops along the catenary and allows heavy traction capability to be maintained despite weak feeding. If an outage happens to occur at a feeding point, the locomotives will still receive adequate power. In fact the use of SVC and STATCOM may help reduce the number of feeding points required.
- Regardless of load changes and fluctuations, power factor correction occurs at the point of common coupling. This means the power factor is high and stable at all times.
- From a power quality point of view, the feeding grid can be chosen with a lower voltage with FACTS, for example, 132 kV instead of 220 kV or higher.
- And finally, FACTS devices provide dynamic voltage control and harmonic mitigation of AC supply systems for DC converter fed traction (typically underground and suburban trains).

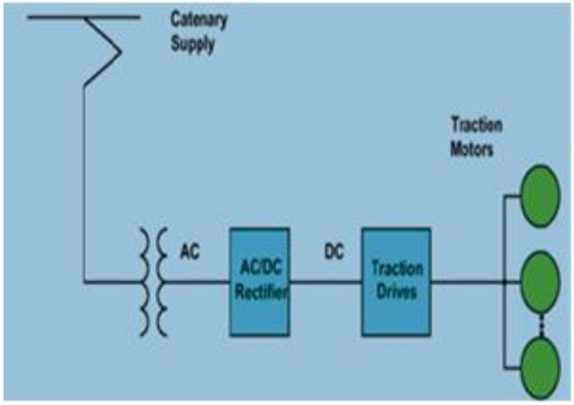


FIG. 10: ELECTRIC TRACTION DRIVE WITH CATENARY SUPPLY

7. SIMULINK DIAGRAM AND EXPECTED RESULTS:-

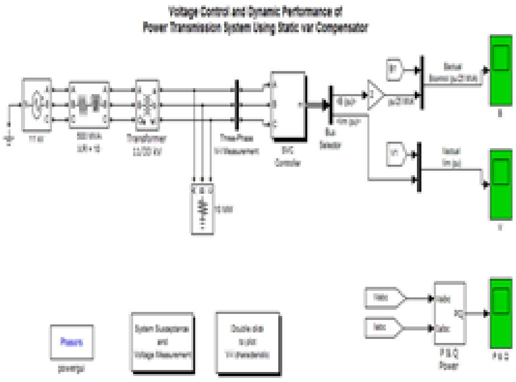


FIG9:-MATLAB SIMULINK MODEL OF SVC

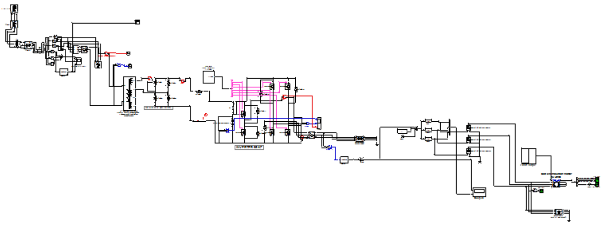


FIG. SIMULINK MODEL OF TRACTION SYSTEM BEFORE SVC

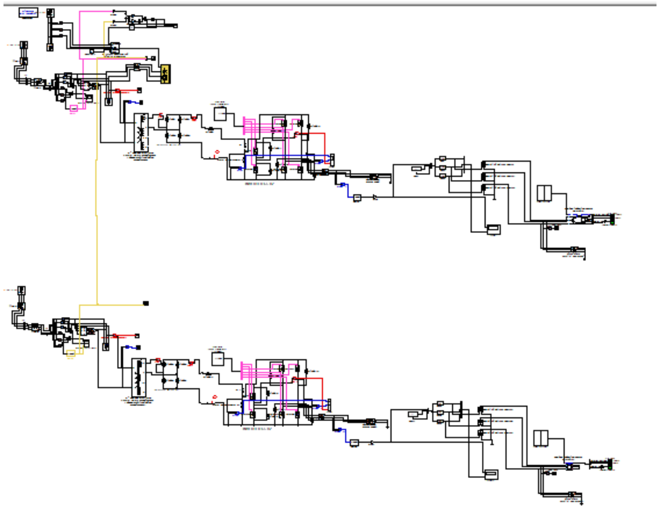


FIG. SIMULINK MODEL AFTER CONNECTING SVC

EXPECTED SIMULATION RESULTS:-

These simulation curves are expected results of this paper

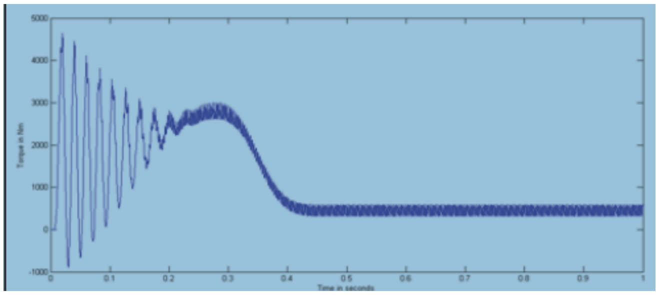


FIG 11 A: TORQUE PROFILE OF MOTOR IN SIX STEP MODE UNDER NORMAL OPERATION

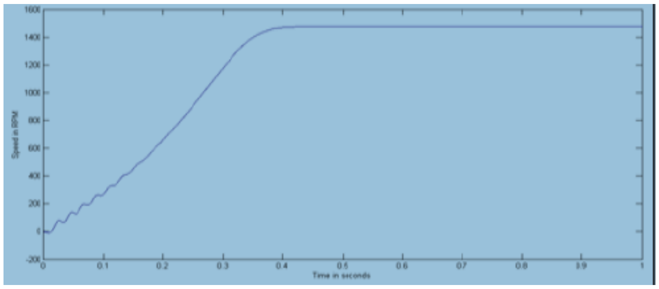


FIG. 11 B: SPEED OF MOTOR IN RPM IN SIX STEP MODE UNDER NORMAL OPERATION

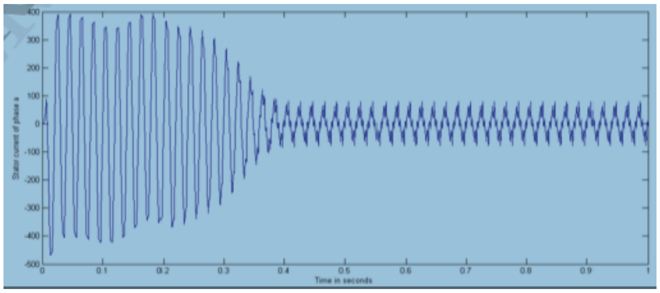


FIG. 11 C: STATOR CURRENT OF PHASE IN SIX STEP MODE UNDER NORMAL OPERATION

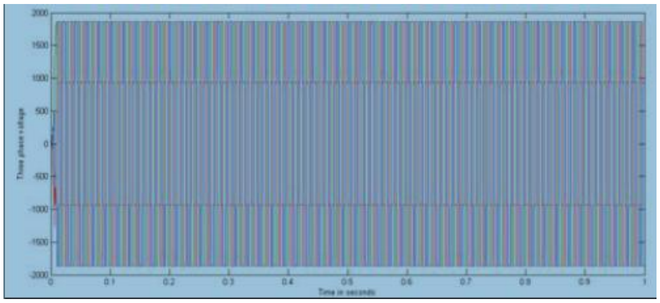


FIG. 11 D: INVERTER VOLTAGES FOR SIX STEP OPERATION UNDER NORMAL OPERATION

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