IMPROVEMENT OF POWER QUALITY OF A DISTRIBUTED GENERATION POWER SYSTEM

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ABSTRACT

The aim of this work is to improve the power quality for Distributed Generation (DG) with power storage system. Power quality is the combination of voltage quality and current quality. Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The electrical power quality is more concerned issue. The main problems are stationery and transient distortions in the line voltage such as harmonics, flicker, swells, sags and voltage asymmetries. Distributed Generation (DG) also called as site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from the many small energy sources. In recent years, micro electric power systems such as photovoltaic generation systems, wind generators and micro gas turbines, etc., have increased with the deregulation and liberalization of the power market. Under such circumstances the environment surrounding the electric power industry has become ever more complicated and provides high-quality power in a stable manner which becomes an important topic. Here DG is assumed to include Wind power Generation (WG) and Fuel Cells (FC), etc. Advantages of this system are constant power supply, constant voltage magnitude, absence of harmonics in supply voltage, un-interrupted power supply. In this project the electric power qualities in two cases will be compared. Case I: With the storage battery when it is introduced. Case II: Without the storage battery. The storage battery executes the control that maintains the voltage in the power system. It will be found that the electric power quality will be improved, when storage battery is introduced. The model system used in this Project work is composed of a Wind Turbine, an Induction Generator, Fuel Cells, An Inverter and a Storage Battery. A miniature Wind Power Generator is represented by WG. A fuel cell module is represented by FC. Transmission lines will be simulated by resistors and coils. The combined length of the lines from synchronous generator to the load terminal is 1.5 km. This model will be simulated using MATLAB/SIMULINK.

KEYWORDS: *Power Quality, Voltage Sag, Energy Storage, VSC, SVPWM, Distributed generation (DG) power system,. Wind generation system, fuel cell modules.*

I. INTRODUCTION

One of the major concerns in electricity industry today is power quality problems to sensitive loads. Presently, the majority of power quality problems are due to different fault conditions. These conditions cause voltage sag. Voltage sag may cause the apparatus tripping, shutdown commercial, domestic and industrial equipment, and miss process of drive system. The proposed system can provide the cost effective solution to mitigate voltage sag by establishing the appropriate voltage quality level, required by the customer. It is recently being used as the active solution

Distributed Generation is a back-up electric power generating unit that is used in many industrial facilities, hospitals, campuses, commercial buildings and department stores. Most of these back-up units are used primarily by customers to provide emergency power during times when grid-connected power is unavailable and they are installed within the consumer premises where the electric demand is needed. The installation of the back-up units close to the demand center avoids the cost of transmitting the power and any associated transmission losses. Back-up generating units are currently defined as distributed generation to differentiate from the traditional centralized power generation model. The centralized power generation model has proven to be economical and a reliable source of energy production. However, with the lack of significant increase in building new generating capacity or even in expanding existing ones to meet the needs of today's mega cities' demand, the whole electrical power industry is facing serious challenges and is looking for a solution.

The technological advancements have proven a path to the modern industries to extract and develop the innovative technologies within the limits of their industries for the fulfillment of their industrial goals. And their ultimate objective is to optimize the production while minimizing the production cost and thereby achieving maximized profits while ensuring continuous production throughout the period. As such a stable supply of un-interruptible power has to be guaranteed during the production process. The reason for demanding high quality power is basically the modern manufacturing and process equipment, which operates at high efficiency, requires high quality defect free power supply for the successful operation of their machines. More precisely most of those machine components are designed to be very sensitive for the power supply variations. Adjustable speed drives, automation devices, power electronic components are examples for such equipments.

Failure to provide the required quality power output may sometimes cause complete shutdown of the industries which will make a major financial loss to the industry concerned .Thus the industries always demands for high quality power from the supplier or the utility. But the blame due to degraded quality cannot be solely put on to the hands of the utility itself .It has been found out most of the conditions that can disrupt the processes are generated within the industry itself.

For example, most of the non-linear loads within the industries cause transients which can affect the reliability of the power supply.

II. DISTRIBUTED GENERATION (DG) SYSTEMS

Distributed Generation (DG) also called as site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from the many small energy sources. In recent years, micro electric power systems such as photovoltaic generation systems, wind generators and micro gas turbines, etc., have increased with the deregulation and liberalization of the power market. Under such circumstances the environment surrounding the electric power industry has become ever more complicated and provides high-quality power in a stable manner which becomes an important topic. Here DG is assumed to include Wind power Generation (WG) and Fuel Cells (FC), etc.

Wind energy is the world‘s fastest-growing energy technology. It is a clean energy source that is reliable, efficient and reduces the cost of energy for homeowners, farmers and businesses. Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid for more widespread electricity distribution. They can even be combined with other renewable energy technologies. For utility-scale sources of wind energy, a large number of turbines are usually built close together to form a wind farm. Several electricity providers today use wind farms to supply power to their customers.

Fuel cell systems have high energy efficiency. The efficiency of low temperature proton exchange membrane (PEM) fuel cells is around 35-45%. High temperature solid oxide fuel cells (SOFC) can have efficiency as high as 65%. The overall efficiency of an SOFC based combined-cycle system can even reach 70%. Renewable energy and fuel cell systems are environmentally friendly. From these systems, there is zero or low emission (of pollutant gases) that causes acid rain, urban smog and other health problems; and, therefore, there is no environmental cleanup or waste disposal cost associated with them.

Why distributed generation (DG) system:

The five major factors that contribute to the renewed interest in distributed generation (DG) system:

- Electricity market liberalization
- Developments in DG technologies

- Increased customer demand for highly reliable electricity.
- Environmental concerns.
- Constraints on the construction of new transmission lines.

Advantages of DG systems:

Utility perspective:

- On-site power supply avoids transmission and distribution losses.
- Increasing the efficiency compared with central power generation.
- Diversification of power sources.
- A possible solution to constraints on new transmission lines.
- Provides cleaner power by using renewable sources such as wind and sun.
- Better quality of power.
- Hedge against uncertain load growth and high market.

Customer perspective:

- Improving energy efficiency and reducing green house- gas emission through combined heat and power (CHP) plants and renewable sources.
- Improved reliability by having back-up generation.
- Receiving compensation from the utility for making their generation capacity available to the power system in areas with power shortages.

Commercial power producer:

- distributed generation systems with their comparatively small size and short lead times as well as their different technologies, allow players in electricity market to respond in a flexible way to changing market conditions.
- To sell ancillary services (such as reactive power and stand by capacity etc.)

Why alternative/renewable energy?

The term ―alternative energy is referred to the energy produced in an environmentally friendly way (different from conventional means, i.e., through fossil-fuel power plants, nuclear power plants and hydropower plants). Alternative energy considered in this dissertation is either renewable or with high energy conversion efficiency. There is a broad range of energy sources that can be classified as alternative energy such as solar, wind, hydrogen (fuel cell), biomass, and geothermal energy. Nevertheless, as mentioned in the previous section, at present the majority of the world electricity is still generated by fossil fuels, nuclear power and hydropower. However, due to the following problems/concerns for conventional energy 5 technologies, the renewable/alternative energy sources will play important roles in electricity generation. And, sooner or later, today‘s alternatives will become tomorrow‘s main sources for electricity.

- Conventional generation technologies are not environment friendly
- Conventional energy sources are not renewable
- The cost of using fossil and nuclear fuels will go higher and higher
- Hydropower sources are not enough and the sites are normally far away from Load centers.
- Political and social concerns on safety are pushing nuclear power away.

Alternative /Renewable powers have the following advantages:

1) **Renewable energy resources are not only renewable, but also abundant**: For example, according to the data of 2000, the U.S. wind resources can produce more electricity than the entire nation would use. The total solar energy from sun in a day at the earth surface is about 1000 times more than the all fossil fuels consumption.

2) **Fuel cell systems have high energy efficiency**: The efficiency of low temperature proton exchange membrane (PEM) fuel cells is around 35-45%. High temperature solid oxide fuel cells (SOFC) can have efficiency as high as 65%. The overall efficiency of an SOFC based combined-cycle system can even reach 70%.

3) **Renewable energy and fuel cell systems are environmentally friendly**: From these systems, there is zero or low emission (of pollutant gases) that causes acid rain, urban smog and other health problems; and, therefore, there is no environmental cleanup or waste disposal cost associated with them.

4) **Different renewable energy sources can complement each other**: Though renewable energy resources are not evenly distributed throughout the world, every region has some kinds of renewable

energy resources. At least, sunlight reaches every corner in the world. And different energy resources (such as solar and wind energy) can complement each other. This is important to improve energy security for a nation like the U.S. which is currently dependent on the foreign energy sources.
These renewable/alternative power generation systems normally have modular structure and can be installed close to load centers as distributed generation sources (except large wind and PV farms). Therefore, no high voltage transmission lines are needed for them to supply electricity. In general, due to the ever increasing energy consumption, the rising public awareness for environmental protection, the exhausting density of fossil-fuel, and the intensive political and social concerns upon the nuclear power safety, alternative (i.e., renewable and fuel cell based) power generation systems have attracted increased interest.

III. PROPOSED SYSTEM

The block diagram of proposed model system is shown in below fig.1. In this work the electric power qualities in two cases will be compared. Case I: With the storage battery when it is introduced. Case II: Without the storage battery. The storage battery executes the control that maintains the voltage in the power system. It will be found that the electric power quality will be improved, when storage battery is introduced. The proposed model system used in this work is composed of a Wind Turbine, an Induction Generator, Fuel Cells, An Inverter and a Storage Battery. A miniature Wind Power Generator is represented by WG. A fuel cell module is represented by FC. Transmission lines will be simulated by resistors and coils. The combined length of the lines from synchronous generator to the load terminal is 1.5 km. The electric power qualities in two cases will be compared. In first case with the storage battery when it is introduced and second case is without the storage battery. The storage battery executes the control that maintains the voltage in the power system. It will be found that the electric power quality will be improved, when storage battery is introduced. This model will be simulated using MATLAB/SIMULINK.

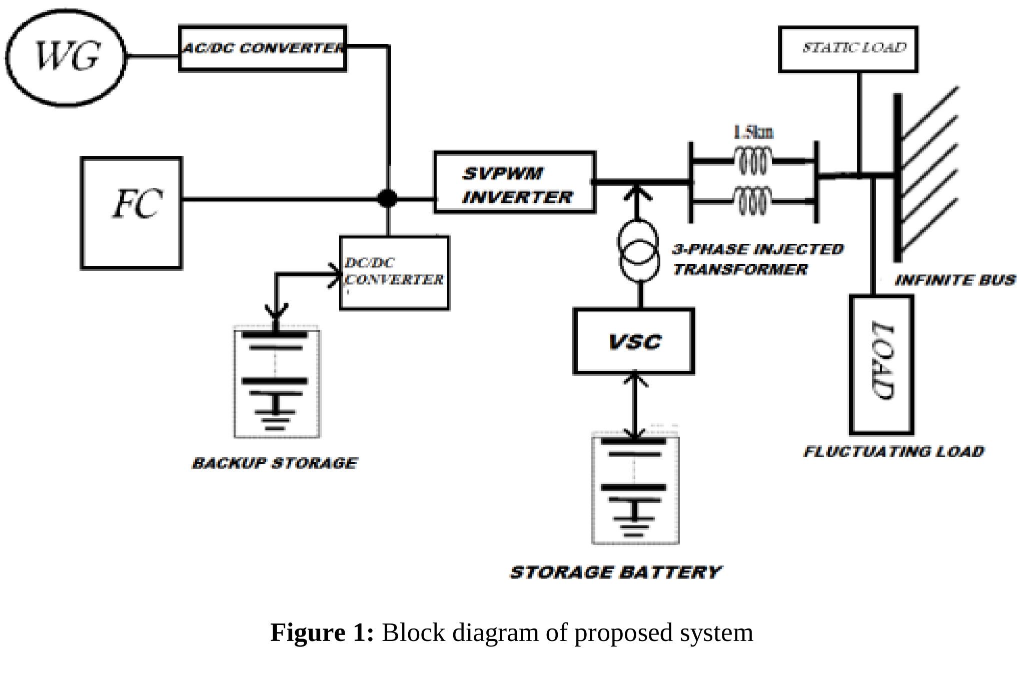

Figure 1: Block diagram of proposed system

The proposed system consists of following main sections:

1. Wind generator: A wind turbine and an induction generator is used as wind generator. It will convert the wind energy into electrical energy. The induction generator is the most common generator in wind energy system applications due to simplicity and rudeness, more than 50 years life time, same machine can be use as motor or generator without modification, high power unit mass of materials and flexibility in speed range of operation. The main drawbacks in induction generator are its lower efficiency and the need for reactive power to build up the terminal voltage. However the efficiency can be improved by modern design and solid-state converters can be used to supply reactive power required.

Induction generators are widely used in nonconventional power generation. Self-excited, squirrel cage induction generators are ideally suited for remote, stand-alone applications due to their robust construction. A new closed loop IGBT based PWM controller is proposed for a self-excited induction generator.

2. Fuel cell module: Fuel cell systems have high energy efficiency. The efficiency of low temperature proton exchange membrane (PEM) fuel cells is around 35-45%. High temperature solid oxide fuel cells (SOFC) can have efficiency as high as 65%. The overall efficiency of an SOFC based combined-cycle system can even reach 70%. Renewable energy and fuel cell systems are environmentally friendly. From these systems, there is zero or low emission (of pollutant gases) that causes acid rain, urban smog and other health problems; and, therefore, there is no environmental cleanup or waste disposal cost associated with them.

3.Energy Storage Unit: It is responsible for energy storage in DC form, flywheels, lead acid batteries, superconducting magnetic energy storage (SMES) and super-capacitors can be used as energy storage devices, the estimates of the typical energy efficiency of four energy storage technologies area: batteries 75%, Flywheel 80 %, Compressed air 80%, SMES 90%.

4. SVPWM Inverter: 3-phase voltage source inverter (VSI) is used as inverter. It is used to convert from DC storage to ac by using svpwm technique. Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, FACTS, var compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators). The standard three-phase VSI topology is shown in Fig.2. and the eight valid switch states are given in Table.1. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. Of the eight valid states, two of them (7 and 8 in Table.1) produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components

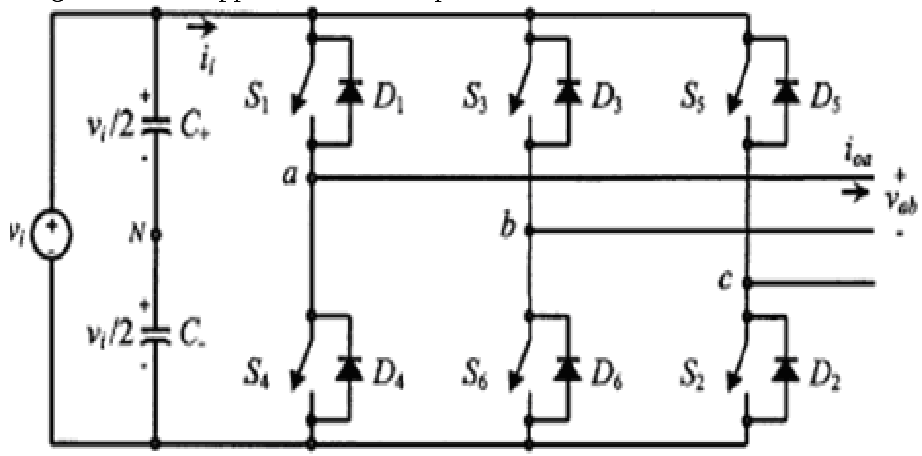

Figure 2: Three phase Voltage Source Inverter (VSI)

The remaining states (1 to 6 in Table.1) produce nonzero ac output voltages. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi , 0, and -Vi. The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

Table 1: Valid switching states for three phase VSI

STATE	STATE	V_{AB}	V_{BC}	V_{CA}	SPACE VECTOR
S1 , S2 and S6 are ON & S4 , S5 and S3 are OFF	1	V	0	-V	V1=1+j0.577
S2 , S3 and S1are ON & S5 , S6 and S4 are OFF	2	0	V	-V	V2=j1.155
S3 , S4 and S2 are ON & S6 , S1 and S5 are OFF	3	-V	V	0	V3= -1+j0.577
S4 , S5 and S3 are ON & S1 , S2 and S6are OFF	4	-V	0	V	V4=-1-j0.577
S5 , S6 and S4 are ON & S2 , S3 and S1are OFF	5	0	-V	V	V5=-j1.55
S6 , S1 and S5 are ON & S3 , S4 and S2 are OFF	6	V	-V	0	V6=1-j0.577
S1 , S3 and S5 are ON & S4 , S6 and S2 are OFF	7	0	0	0	V7=0
S4, S6 and S2 are ON & S1 , S3 and S5 are OFF	8	0	0	0	V8=0

5. Voltage source converter (VSC): it is used in storage system to inject the ac voltages during the stationery and transient distortions in the line voltage.
6. Dc/dc converter: it is used to convert dc to dc storage.
7. **Passive Filters:** It is clear that higher order harmonic components distort the compensated output voltage. Filter is used to convert the PWM inverted pulse waveform into a sinusoidal waveform. This is achieved by removing the unnecessary higher order harmonic components generated from the DC to AC conversion in the VSI.
8. 3-phase voltage Injection Transformers: In a three-phase system, three Single-phase transformer units or one three phase transformer unit can be used for voltage.

IV. SPACE VECTOR PULSE WIDTH MODULATION

The topology of a three-leg voltage source inverter is shown in Fig.3. Because of the constraint that the input lines must never be shorted and the output current must always be continuous a voltage source inverter can assume only eight distinct topologies. These topologies are shown on Fig.4. Six out of these eight topologies produce a nonzero output voltage and are known as non-zero switching states and the remaining two topologies produce zero output voltage and are known as zero switching states.

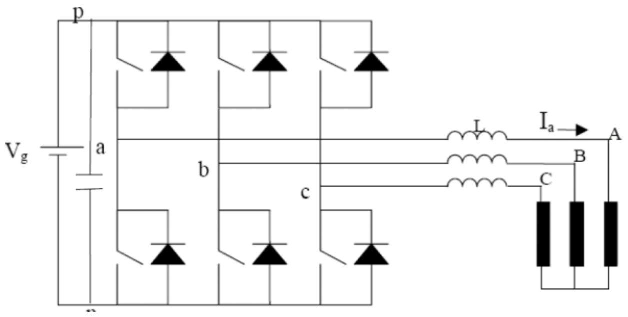

Figure 3: Topology of a three-leg voltage source inverter

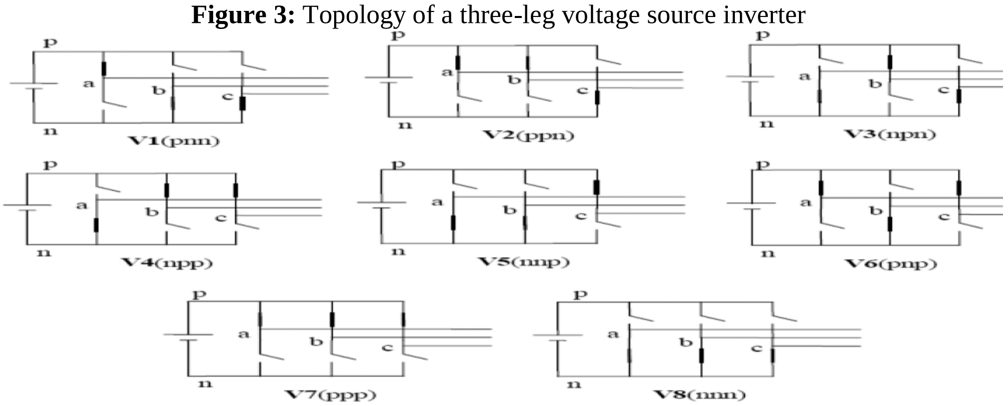

Figure 4: Eight switching state topologies of a voltage source inverter.

4.1. Voltage Space Vectors

Space vector modulation (SVM) for three-leg VSI is based on the representation of the three phase quantities as vectors in a two-dimensional (α β **)** plane. This is illustrated here for the sake of completeness. Considering topology 1 of Fig.4., which is repeated in Fig. 5(a) we see that the line voltages ***Vab, Vbc,*** and ***Vca*** are given by

$V_{ab} = V_g$
$V_{bc} = 0$
$V_{ca} = -V_g$ …………………………….…….. (1)

This can be represented in the **,** plane as shown in Fig. 5(b), where voltages *Vab*, *Vbc*, and *Vca* are three line voltage vectors displaced 120 in space. The effective voltage vector generated by this topology is represented as **V1** (pnn) in Fig. 5(b). Here the notation "pnn" refers to the three legs/phases a, b, c being either connected to the positive dc rail (p) or to the negative dc rail (n). Thus "pnn" corresponds to „phase a" being connected to the positive dc rail and phases b and c being connected to the negative dc rail

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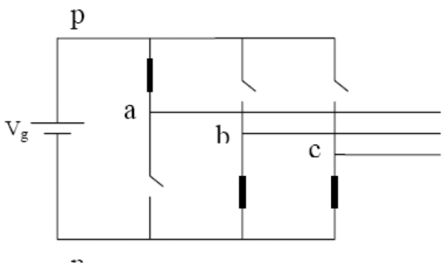

Figure 5(a): Topology 1-V1 (pnn) of a voltage source inverter.

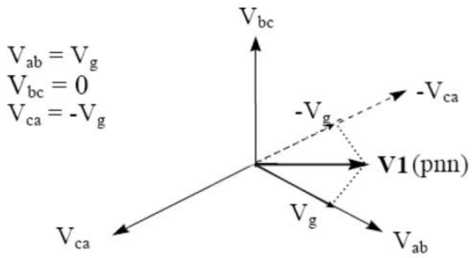

Figure 5(b): Representation of topology 1 in the ,α-β plane.

Proceeding on similar lines the six non-zero voltage vectors (**V1 - V6**) can be shown to assume the positions shown in Fig.6. The tips of these vectors form a regular hexagon (dotted line in Fig.6). We define the area enclosed by two adjacent vectors, within the hexagon, as a sector. Thus there are six sectors numbered 1 - 6 in Fig.6.

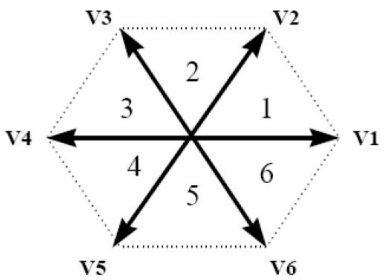

Figure 6: Non-zero voltage vectors in the α-β plane

Considering the last two topologies of Fig.4 which are repeated in Fig. 7(a) for the sake of convenience we see that the output line voltages generated by this topology are given by

$V_{ab} = 0$
$V_{bc} = 0$
$V_{ca} = 0$ …………………………..…….. (2)

These are represented as vectors which have zero magnitude and hence are referred to as zero-switching state vectors or zero voltage vectors. They assume the position at origin in the **,** plane as shown in Fig. 7(b). The vectors **V1-V8** are called the switching state vectors (SSVs).

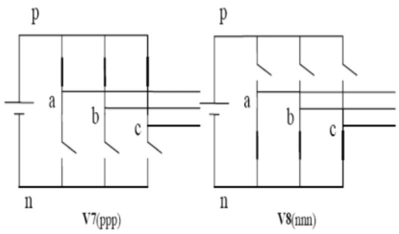

Figure 7(a): Zero output voltage topologies

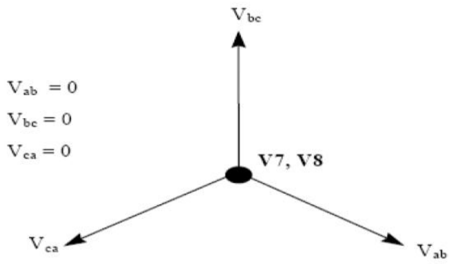

Figure7(b): Representation of the zero voltage vectors in the α-β plane.

4.2. Space Vector Modulation

The desired three phase voltages at the output of the inverter could be represented by an equivalent vector **V** rotating in the counter clock wise direction as shown in Fig. 8(a). The magnitude of this vector is related to the magnitude of the output voltage (Fig. 8(b)) and the time this vector takes to complete one revolution is the same as the fundamental time period of the output voltage.

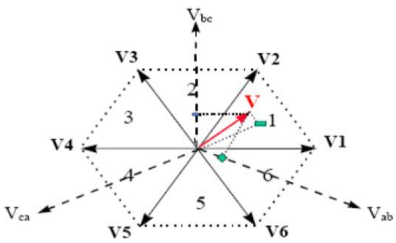

Figure 8(a): Output voltage vector in the plane

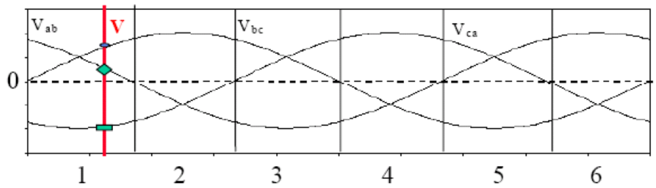

Figure 8(b): Output line voltages in time domain.

Let us consider the situation when the desired line-to-line output voltage vector **V** is in sector 1 as shown in Fig.9. This vector could be synthesized by the pulse-width modulation (PWM) of the two adjacent SSV‟s **V1** (pnn) and **V2** (ppn), the duty cycle of each being d1 and d2, respectively, and the zero vector (**V7**(nnn) / **V8**(ppp)) of duty cycle d0:

$$d_1V_1+d_2V_2=V=mV_ge^{je} \quad (3)$$

$$d_1+d_2+d_0=1 \quad (4)$$

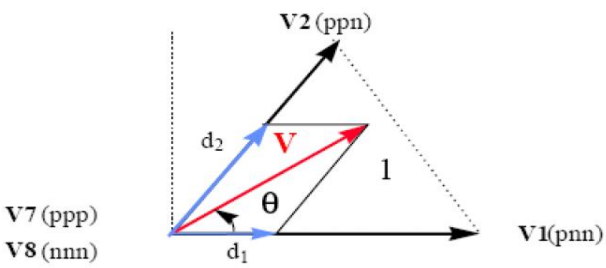

Figure 9: Synthesis of the required output voltage vector in sector 1

All SVM schemes and most of the other PWM algorithms use Eqns. (3) and (4) for the output voltage synthesis. The modulation algorithms that use non-adjacent SSV‟s have been shown to produce higher THD and/or switching losses and are not analyzed here, although some of them, e.g. hysteresis, can be very simple to implement and can provide faster transient response. The duty cycles d1, d2, and d0, are uniquely determined from Fig.9, and Eqns. (3) and (4) , the only difference between PWM schemes that use adjacent vectors is the choice of the zero vector(s) and the sequence in which the vectors are applied within the switching cycle.
The degrees of freedom we have in the choice of a given modulation algorithm is:

- The choice of the zero vector; whether we would like to use **V7**(ppp) or **V8**(nnn) or both,
- Sequencing of the vectors
- Splitting of the duty cycles of the vectors without introducing additional commutations.

Where, 0 *m* 0.866, is the modulation index. This would correspond to a maximum line-to-line voltage of 1.0Vg, which is 15% more than conventional sinusoidal PWM.

V. MATLAB MODELLING & SIMULATION RESULTS

1. Simulation Models:

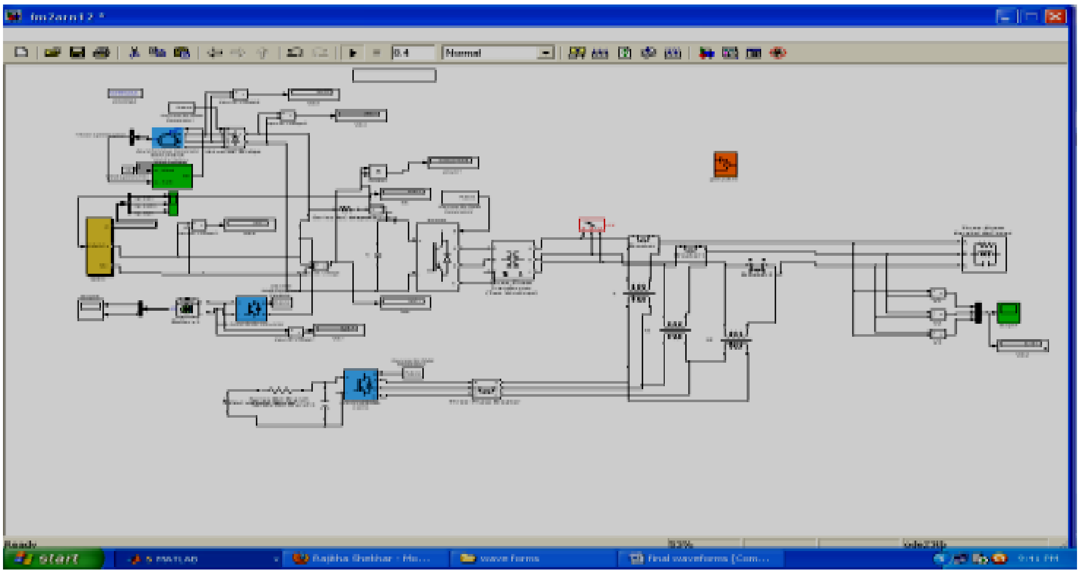

Figure 10: Simulation of final model of my project with storage battery

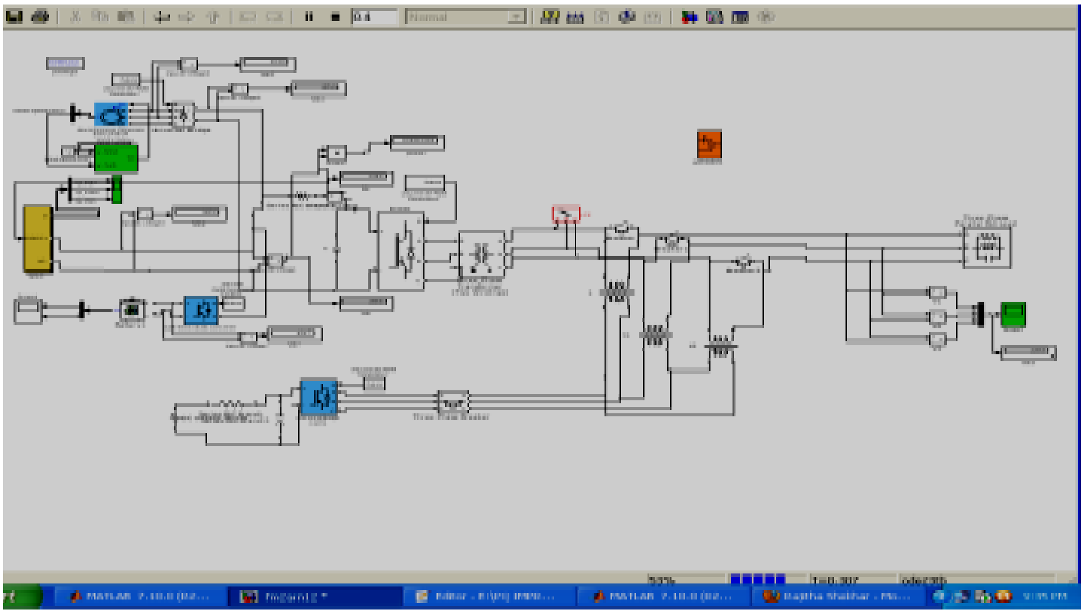

Figure 11: Simulation of final model of my project without storage battery

Detailed simulations are performed on Improvement **of Power Quality of a Distributed Generation Power System** using MATLAB SIMULINK. System performance is analyzed for compensating voltage sag with different DC storage capacity so as to achieve rated voltage at a given load. Various cases of different load condition are considered to study the impact DC storage on sag compensation.

2. Output Waveforms

At the time short duration transient 0.15sec to 0.2 sec. duration is shown in figure12, at 8kw load we can clearly observe the voltage phases will com foreword from its zero crossing point and voltage will decrease is shown in fig.13.variations in the load voltage with fluctuating rlc load. Is shown in figure14.Output wave forms of 3-phase load voltages when battery is introduced is shown in figure15. Figure 16: Output wave forms of load currents are shown in figure 16 and figure 17 which are shown below.

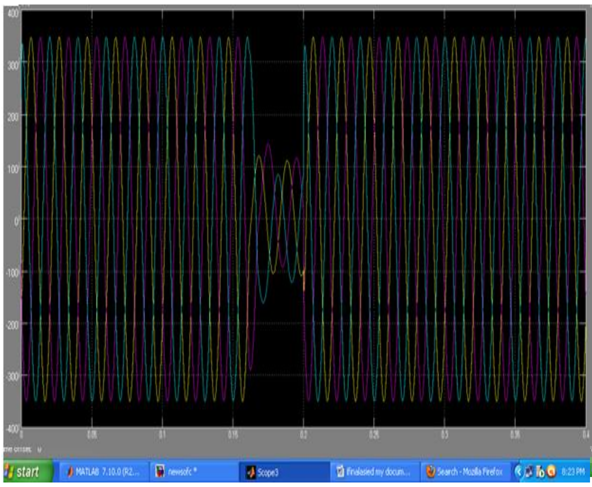

Figure 12: At the time short duration transient 0.15sec to 0.2 sec. duration

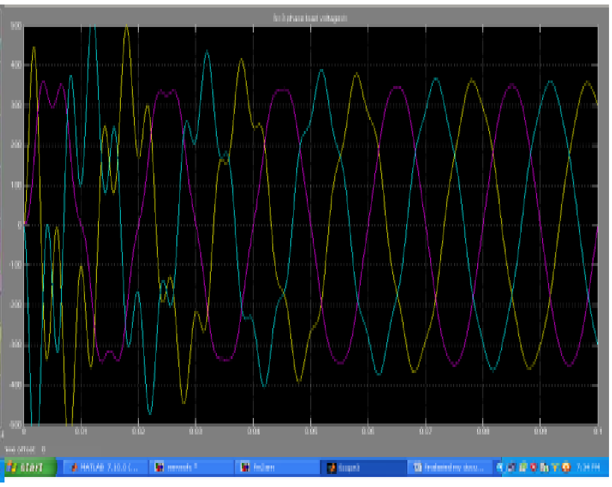

Figure 14: variations in the load voltage with fluctuating rlc load.

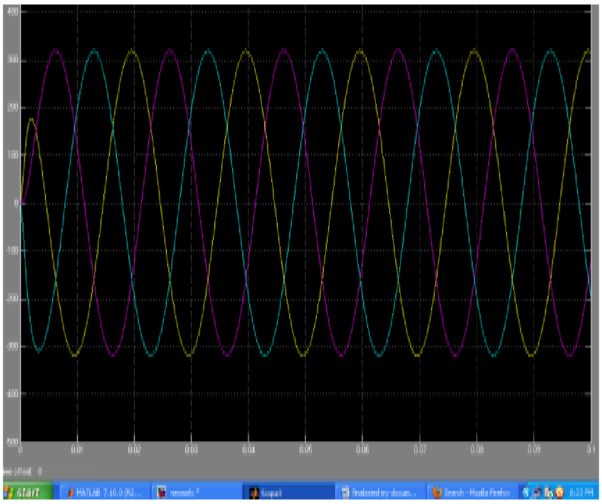

Figure 13: at 8kw load we can clearly observe the voltage phases will com foreword from its zero crossing point and voltage will decrease.

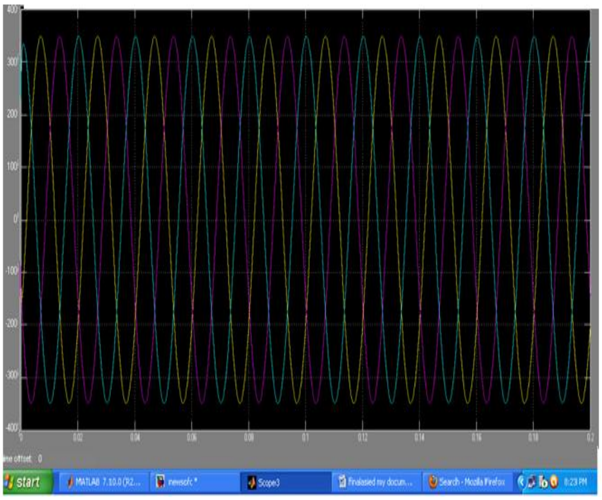

Figure 15: Output wave forms of 3-phase load voltages when battery is introduced

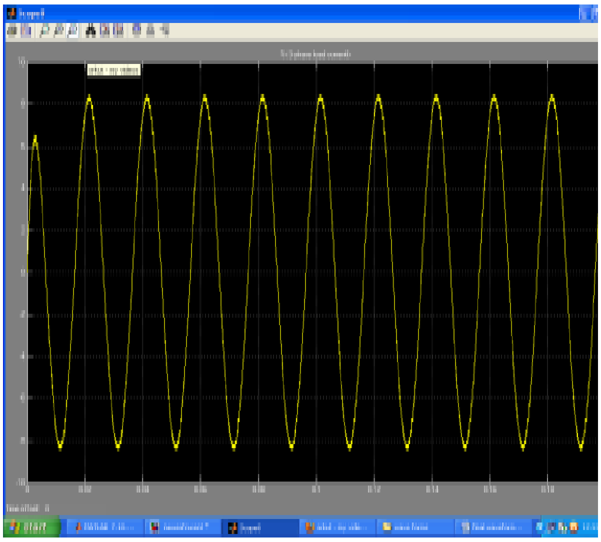

Figure 16: Output wave forms of load currents

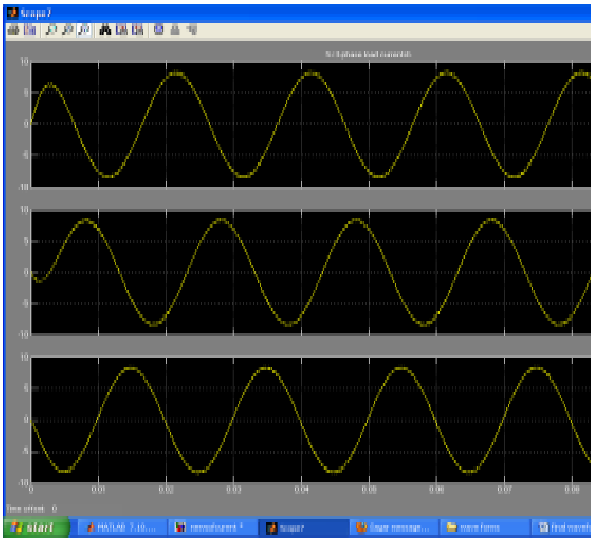

Figure 17: Output of three phase load currents

VI. CONCLUSION

Based on the analysis of test system, it is suggested that voltage sag values are major factors in estimating the DC storage value. Investigations were carried out for various cases of load. The effectiveness of a proposed system mainly depends upon the rating of DC storage rating and the percentage voltage sag. In the test system it is observed that after a particular amount of voltage sag, the voltage level at the load terminal decreases. The major role play is that it can be supply constant power to varying loads, sag is reduced completely, THD of the system is very less. This scheme of implementation can be applied to various kinds of loads and systems in future.

VII. FUTURE SCOPE

- As Future scope of this Project is The storage Battery with good control Structure can be added to a DC bus of Hybrid Distributed Generation (DG) power system.
- By designing with the high Quality components and good controller the storage battery system can be integrated to the hybrid system to improve power quality which is not covered in this scope of project.
- This scheme of implementation can also be applied higher ratings of power generation.
- The major role play is that it can be supply constant power to varying loads, sag is reduced completely, THD of the system is very less.
- This scheme of implementation can be applied to various kinds of loads and systems in future.

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