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Performance Study of SMES sourced SVPWM Inverter And Traditional SVPWM Inverter

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ABSTRACT: The increasing focus on large scale integration of new renewable energy sources like wind power and wave power introduces the need for energy storage. Superconducting Magnetic Energy Storage (SMES) is a promising alternative for active power compensation. Having high efficiency, very fast response time and high power capability it is ideal for levelling fast fluctuations. Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its temperature. In today's world inverters are used to generate a single or multiple phase AC voltages from a DC supply source. Various types of inverters such as 1-phase inverters and 3-phase inverters are used for various industrial applications. In 3-phase inverters SVPWM technique is the most efficient technique for switching of inverter compared to other PWM techniques due to less THD, greater PF and less switching losses because SVPWM utilizes advance computational switching technique to reduce THD. Since SMES is an emerging field of energy source, its application with SVPWM inverter will give a perfect energy source for the industrial world. In this paper work performance comparison of traditional SVPWM Inverter and SMES sourced SVPWM Inverter is performed using MATLAB/SIMULINK. THD is compared and analysed.

KEYWORDS:Space Vetcor Pulse width Modulation (**SVPWM)** ,Superconducting Magnetic Energy Storage (SMES), total Harmonic Distortion (THD),Current source inverter (CSI), Voltage source inverter(VSI)

I.INTRODUCTION

Pulse Width Modulation variable speed drives are increasingly applied in many newindustrial applications due to their superior performance. Recently, developments in power electronics and semiconductor technology have leadimprovements in electrical systems. Hence, different circuit configurations namely multilevel inverters havebecomepopular and many researches are going on them.Variable voltage and frequency supply to ac drives is invariably obtained from a three-phase voltage source inverter. A number of Pulse width modulation (PWM) schemes are used to obtain variablevoltage and frequency supply. The most widely used PWM schemes for three phase voltagesource inverters are space vector PWM (SVPWM). The Space vector based modulating technique is a digital technique in which the objective is to generate PWM load line voltages that are on average equal to given loadline voltages.Space vector pulse width modulation (SVPWM) technique is the importantmethod for increasing the output voltage compared to other PWM techniques. In theSVPWM technique, the duty cycles are computed rather than derived through comparisons in SPWM. The fundamental voltage can be increased up to a square wave modewhere a modulation index of unity is reached. SVPWM is accomplished by rotating a reference vector around the state diagram, which is composed of six basic non-zero vectorsforming a hexagon. A circle can be inscribed inside the state map and corresponds tosinusoidal operation. The area inside the inscribed circle is called the linear modulationregion or under-modulation region. The area between the inside circle and outside circle of the hexagon is called the nonlinear modulation region or over-modulation region.The concepts in the operation of linear and nonlinear modulation regions depend on themodulation index, which indirectly rejects on the inverter utilization capability.There is an increasing

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trend of usingspace vector PWM (SVPWM) because of their easier digital realization and better dc busutilization.Even though SVPWM technique has proven the most efficient techniques the traditional SVPWM inverter has a limitation in using the conventional dc source. The perfect remedy for this drawback is SMES (Superconducting Magnetic Energy Storage) which is an emerging field of energy source. SMES is a grid-enabling device that stores and discharges large quantities of power almost instantaneously. The system is capable of releasing high levels of power within a fraction of a cycle to replace a sudden loss or dip in line power. Strategic injection of brief bursts of power can play a crucial role in maintaining grid reliability especially with today's increasingly congested power lines and the high penetration of renewable energy sources, such as wind and solar. Since the present energy sources has certain drawback such as stability issues and limited time of availability, the reliability of this system is low. To overcome these issues we propose a combination of SMES and SVPWM to obtain a stable unlimited power supply system for fulfillingthepresentrequirementsofthesociety. The proposed scheme and traditional scheme is analysed and compared.

II.SPACE VECTOR PWM

The most emerging inverter technology used today is Space Vector PWM.SVPWM is accomplished by rotating a referencevector around the state diagram, which is composed of six basic non-zero vectors forming a hexagon as shown in fig.1. A circle can be inscribed inside the state map and corresponds to sinusoidal operation. The area inside the inscribed circle is called the linear modulationregion or under-modulation region. Here the hexagon is divided intosix equal sectors and the switching operation of each leg is controlled by calculating the time period for each switching. where$V_a(t)$,$V_b(t)$ and $V_c(t)$ are three sinusoidal voltages of the same amplitude andfrequency but with 120 phase shifts. The space vector at any given time maintains itsmagnitude. As time increases, the angle of the space vector increases, causing the vectorto rotate with a frequency equal to that of the sinusoidal waveforms. When the outputvoltages of a three-phase six-step inverter are converted to a space vector and plotted onthe complex plane, the corresponding space vector takes only on one of six discrete anglesas time increases[5]. The central idea of SVPWM is to generate appropriate PWM signals sothat a vector with any desired angle can be generated. The width of each PWM signal will depends on the switching time of corresponding switch. The appropriate PWM waveform for each sector is shown in fig 1.

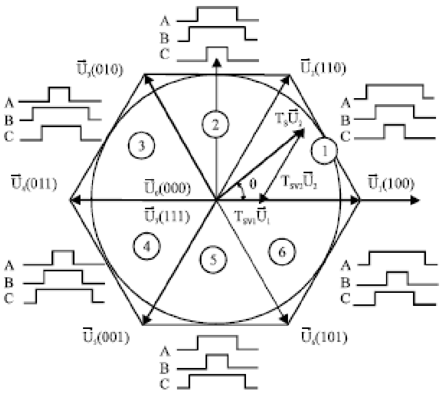

Fig. 1 Switching Patterns of Six Sectors in Circle

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The switching time for each switches in various sector can be calculated as shown in the table [1]

Table 1. Switching Time Calculation at Each sector

Sector	Upper Switches(S_1,S_3,S_5)	Lower Switches(S_2,S_4,S_6)
1	$S_1=T_1+T_2+T_0/2$ $S_3=T_2+T_0/2$ $S_5=T_0/2$	$S_4=T_0/2$ $S_6=T_1+T_0/2$ $S_2= T_1+ T_2+ T_0/2$
2	$S_1=T_1+T_0/2$ $S_3=T_1+T_2+T_0/2$ $S_5=T_0/2$	$S_4= T_2+ T_0/2$ $S_6= T_0/2$ $S_2= T_1+ T_2+ T_0/2$
3	$S_1=T_0/2$ $S_3=T_1+T_2+T_0/2$ $S_5=T_2+T_0/2$	$S_4= T_1+ T_2+ T_0/2$ $S_6= T_0/2$ $S_2= T_1+ T_0/2$
4	$S_1= T_0/2$ $S_3=T_1+T_0/2$ $S_5= T_1+T_2+T_0/2$	$S_4= T_1+ T_2+ T_0/2$ $S_6= T_2 + T_0/2$ $S_2= T_0/2$
5	$S_1=T_2+ T_0/2$ $S_3=T_0/2$ $S_5= T_1+T_2+T_0/2$	$S_4= T_1+ T_0/2$ $S_6= T_1+ T_2+ T_0/2$ $S_2= T_0/2$
6	$S_1=T_1+T_2+T_0/2$ $S_3=T_0/2$ $S_5=T_1+T_0/2$	$S_4= T_0/2$ $S_6= T_1+ T_2+ T_0/2$ $S_2= T_2+ T_0/2$

In traditional SVPWM inverter the source is ordinary dc source which is limited in time of application .There for the availability of power source will be only for a limited time period. As a result Ultra-High field operation enables long term usage will be costly in material and system cost.

III.SMES

SMES is a grid enabling device that stores and release large quantities of power almost instantaneously. The organisation is capable of releasing high levels of ability within a fraction of a cycle to replace sudden loss or dip in line power. Strategic injection of brief bursts of power can play a crucial part in maintaining grid reliability, especially with today increasingly congested power lines and the high penetration of renewable energy sources such as wind and solar. A typical SMES consists of two parts- cryogenically cooled superconducting coil and power conditioning system which are motionless and result in higher reliability than many other power storage devices. Ideally, once the superconductivity coil is charged, the current will not decay and the magnetic energy can be stored indefinitely.[9]]Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its temperature. A typical SMES system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. A typical SMES system is shown in Fig.2. [10]

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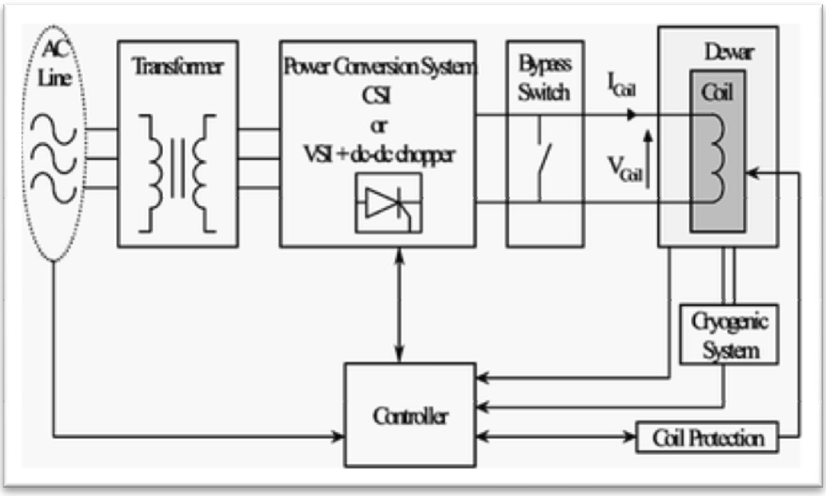

Fig.2Components of a typical SMES system. CSI: Current source inverter, VSI: Voltage source inverter

Energy stored in a normal inductor coil will fade out rather quickly due to theohmic resistance in the coil when the power supply is disconnected. Obviouslythis will not be an acceptable energy storage for use in a power system. Theohmic resistance has to be removed before an inductor can work for thispurpose. This is possible by lowering the temperature of the conductors, andby this making the conductors superconducting. A superconducting wireis in a state where the resistance in the material is zero. In this state thecurrent in a coil can flow for infinite time. This can also be seen from the timeconstant of a coil

$$\tau = \frac{L}{R} \qquad (1)$$

Where R is the ohmic resistance of the coil and L is theinductance of the coil.From equation (1) it is clear that when R goes to zero,then goes to infinity. Once the superconducting coil is chargedthe current will be present permanently in the system. Bydischarging the superconducting coil, the stored energy can bereleased. Power condition system used in the SMES systemare inverter or rectifier, which is used to transform DC currentpower to AC current power and convert AC back to DC currentpower. Since the superconducting material has negative temperature coefficient the output of the SMES device may vary with temperature of the system.

IV.PROPOSED SCHEME

The proposed scheme consist of the combination of an SVPWM Inverter and a SMES device. Here the ordinary dc source to the SVPWM inverter is replaced with a SMES device. The block diagram of the proposed system is shown in fig. 3. Here the output of the inverter is sensed by voltage sensor and current sensor which is fed back to the controller section. The controller section will determine the width of PWM signal by using SVPWM methodology.

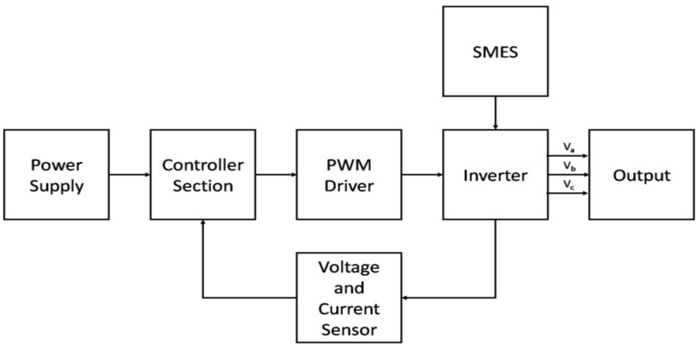

Fig.3: Block diagram of SMES sourced SVPWM inverter

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Here the characteristics of both SVPWM and SMES are combined together to produce a power supply system of high efficiency. Capability of absorbing and delivering large amounts of power, high efficiency,long lifetime, short response time, completely static construction, low maintenance, all electric energy storage are the main advantages of the proposed system.

V.SIMULATION RESULT AND DISCUSSION

The Comparison of SMES sourced SVPWM inverter and Conventional SVPWM inverter is carried out using Matlab/Simulink. Here simulation parameters are Input Voltage V_{dc}=400 V, Output Voltage V_{ac}=415V,Output frequency = 50 Hz. During practical condition the output of SMES system will vary with temperature. This is due to the negative temperature coefficient of the super conducting material. Therefore in actual practice a temperature sensor is added to determine the temperature of the system.In the simulation analysis the quality of output power of the SMES sourced SVPWM inverter and conventional SVPWM inverter is done with the THD analysis

$$THD_F = \frac{\sqrt{{V_2}^2+{V_3}^2+{V_4}^2+\dots}}{V_1} \quad (2)$$

Equation number 2 shows the definition of Total harmonicdistortion. The total harmonic distortion or THD, of a signal is the measurement of the harmonic distortion present and isdefined as the ratio of the sum of the powers of all harmoniccomponents to the power of the fundamental frequency. Inpower systems, lower THD means reduction in peak currents,heating, emissions, and core loss in motors. Our proposedsystem performance shows that it is a good and advanced solutionfor the mitigation of power quality issues and harmonicdistortion in distribution system.
The simulation result of two system SMES sourced SVPWM inverter and Conventional SVPWM inverter is shown in Fig.4. andFig.5.

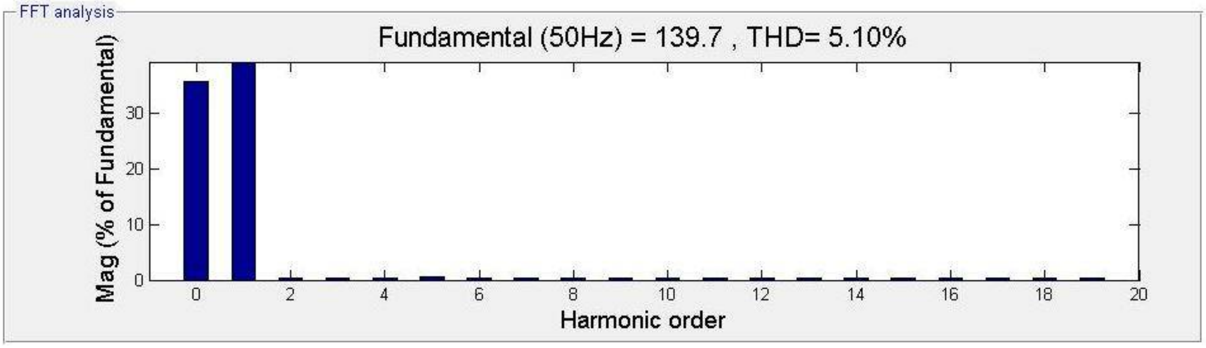

Fig .4. System Current Harmonic Analysis with SMES sourced SVPWM

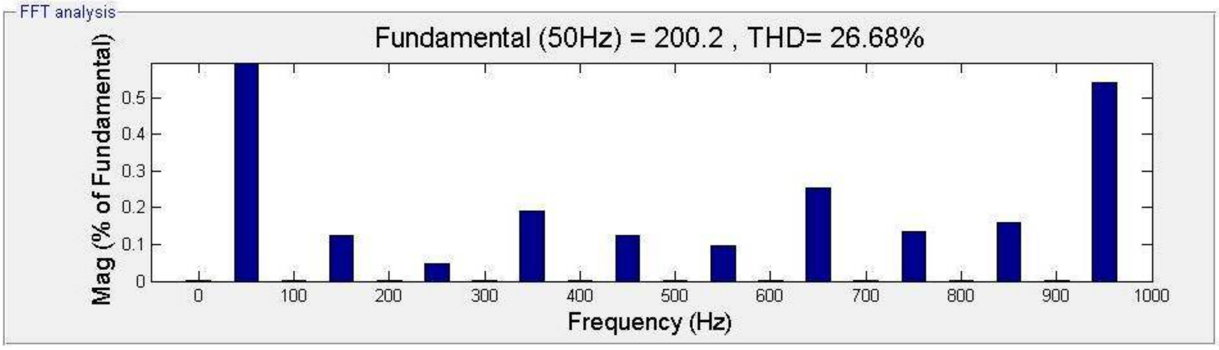

Fig.5. System Current Harmonic Analysis without SMES sourced SVPWM

From the THD analysis we can infer that the proposed system has higher power quality than the traditionally used SVPWM Inverter system.

VI.CONCLUSION

In this paper a SMES sourced SVPWM has been demonstrated. The proposed system is compared with the traditional SVPWM Inverter with the help of THD analysis. From the obtained data we can infer that the proposed scheme has higher power quality than the traditional SVPWM system. The advantages of the proposed scheme are It improves power quality for critical loads and provides carryover energy duringmomentary voltage sags and power outages.It improves load levelling between renewable energy sources and the transmitting anddistribution network. It is environmentally beneficial as compared to batteries, superconductivity does not bank ona chemical reaction and no toxins are brought out in the operation. It enhances the transmission line capability and performanceSMES features a highdynamic range, an almost infinite cycling capability, and an energy recovery rate close to100%.

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