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STABILIZATION OF WIND GENERATOR USING SUPERCONDUCTING ENERGY STORAGE SYSTEM

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ABSTRACT

Superconducting magnetic energy storage (SMES) is considered to be a very effective energy storage device capable of storing large amount of electric energy in the form of magnetic field. The time response of SMES is very fast and charging/ discharging efficiency is over 95%. Due to random variations of wind speed, output voltage and power changes rapidly and may pose serious problems to the power system performance. So a SMES unit is capable of handling the fluctuation which occurs in the wind system. So in this paper a simulation model is developed in SIMULINK/MATLAB, SMES is incorporated to mitigate the power fluctuation.

Keywords: SMES Coil; Power Conditioning System, Thyristor Based System, Cryogenic System.

I. INTRODUCTION

A number of storage technologies are commonly available in the market are pumped storage hydroelectric systems, battery energy storage systems (BESS), and superconducting magnetic energy storage (SMES) systems. Some of the drawbacks of pumped hydro electric plants are big unit sizes, topographical and environmental limitations while that of BESS includes limited time period of working ,magnitude of voltage and current , and potential environmental hazards. SMES is a superconducting coil which is capable of storing large electric energy in the magnetic field. According to system power requirements, SMES is capable to exchange large real and reactive power rapidly. Application of SMES system is increasing in the electrical power system due to their fast response and high efficiency (up to 95%). The one major benefit of the SMES coil is that a large amount of power can be discharged in a small period of time.

An SMES device is a dc current device where the energy is stored in the form of magnetic field [6]. When dc current flows through a superconducting coil it creates a magnetic field [9]. Since energy is stored as circulating current, it can be drawn from the SMES unit [5]. An almost instantaneous response is obtained with the energy stored or delivered over periods ranging from a fraction of second to several hours [8][12].

This paper presents an overview of main parts of SMES system, detailed working of thyristor based SMES system and also a simulation model of thyristor based SMES system that is used to stabilize the wind generator system by providing power during the wind fluctuation and result are shown.

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The organization of this paper is as follows. Section II describes the component of SMES system. Section III describes about the wind energy system. In Section IV, working of thyristor based SMES system is explained. Section V described the developed system. Section VI details about working of SMES coil, in section VII results is shown in section VIII conclusion and future scope of work is observe .

II. COMPONENT OF SMES SYSTEM

The main components of a SMES system consist of a power conditioning system, cooling system and SMES coil

A. Power conditioning system

A power conditioning system (PCS) exchanges the power between the superconducting coil and the ac system [10]. There are three types of PCSs are used , named as, the thyristor-based PCS , voltage source converter (VSC)-based PCS and current source converter (CSC)-based PCS .

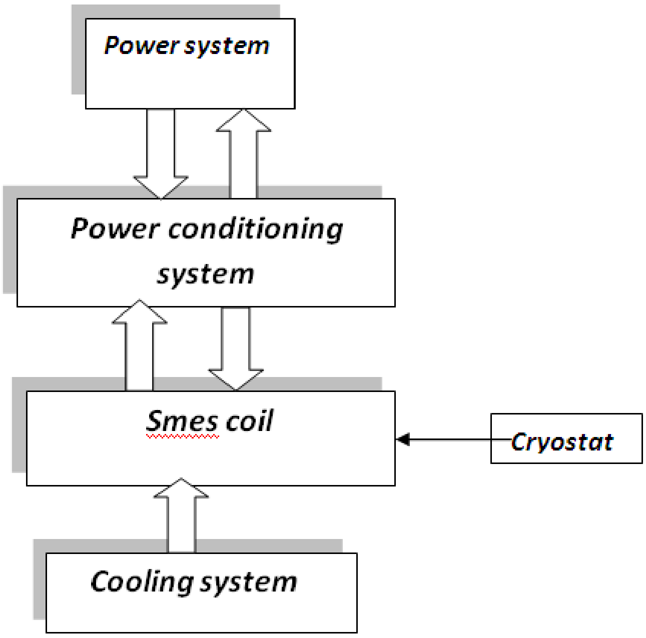

Figure 1: Basic Component of SMES System

In a thyristor based PCS total harmonic distortion and ripple in voltage is comparatively high in case of thyristor based system but it is having only one AC to DC module so easy to control.

In VSC based PCS the flow of real and reactive power between the SMES coil and power system is independent and also it can provide rated VAR capacity to the system at any value of coil current or in case of zero coil current. This topology requires an AC to DC circuit and a DC to DC chopper so the control is complicated from the previous one [18]. The total harmonic distortion is less in this topology but there appears ripple in output voltage in SMES coil.

A CSC based converter also allows an independent control of real and reactive power which flows between coil and power system and also able to supply the reactive power. A CSC based system depends on coil for supplying the reactive power .in this topology. It is having only one module so it is easy to control and also have low harmonic distortion .The ripple in output voltage of coil is low by using a twelve pulse converter in this topology so ac losses are reduced in the coil.

B. Cooling system

An SMES unit consists of a superconducting coil that is kept at a cryogenic temperature. Cryogenic temperature means very low temperature (123k). A cryostat is used to maintain the low temperature that contains helium or nitrogen liquid vessels. .The recent emerging element that is using for the SMES coil is magnesium diboride (MgB2). The cost of magnesium diboride material is low and shows superconductive behavior at a critical temperature of about 40k[19] . the strands of magnesium diboride work as superconducting magnets at a temperature of 10-20K so the efficiency of cooling system is high in comparison to traditional superconducting materials such as niobium titanium(NbTi) or triniobium tin(Nb3Sn) which shows superconductivity at low temperature(4.2K)[1].

C. SMES Coil

During the superconducting state of a coil the resistance of a coil is ideally zero. But, the Refrigeration system used to keep the superconductor cool needs electric power and this *energy* should be considered when calculating the efficiency of SMES system. As the stored energy increases by a factor of 100,ining the Integrity of the Specifications refrigeration cost rise up by a factor of 20. The heat loads that must be removed by the cooling system includes conduction, radiation from hotter to colder surfaces, AC losses in the conductor (during charge and discharge), and losses from the cold to warm power leads that connect the cold coil to the power conditioning system. . Lead losses can be minimized by proper designing of the leads. AC losses depend on the design of the conductor, the duty cycle of the device. But structural cost of HTSC is higher because the strain tolerance of the HTSC is less than the LTSC [14], such as Nb3Ti or Nb3Sn [17], and demands more structure materials. Thus, in the maximum cases, at a high the HTSC cost cannot be reduced by reducing the coil size. we can also see that the maximum required radius of LTSC is always lesser for a HTSC magnet than the LTSC magnet due to higher magnetic field operation [4] or In the case of solenoid configured SMES coils, the height or length is smaller for HTSC coils than that of LTSC, but still higher than in a toroidal geometry (due to low external magnetic field).

III . THE WIND ENERGY SYSTEM

In the global the consumption of electrical energy is continuously rising & there is a huge demand to increase the electrical power. It is expected that the demand of power will be doubled in incoming 20 years [15]. The generation, distribution and use of energy should be as efficient as possible and incentives to save energy at the end-user should also be set up. Deregulation of energy has in the past reduced the investment in most of power plants, which indirectly means the need of new electrical power sources will increase in the coming days [11]. There are many technologies that will play important roles to solve the future problem and change the electrical power sources from the conventional (hydro, thermal etc), coal based (and short term) based energy sources to renewable energy resources [2]. Wind energy is changing from minor energy source to important power source in energy system. The wind turbine technology started in the 1980'es with a few tens of KW power capacity to today with multi- MW size wind turbine that are being installed. The main advantages of wind energy are that it has a low operating cost& doesn't impose any extra burden on environment. Some of the benefits of Wind Power are that It's a pollution free fuel source. Wind energy doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas. It is one of the lowest-priced renewable energy technologies available today [3].

In the wind mills output power is proportional to the cube of wind velocity [16]. Since the velocity of wind is uncertain output power and the output voltage of wind generator varies randomly [22] and an uncertain output power and voltage directly transferred to the power system [21] .Since an SMES unit is capable of controlling the active and power at the same time of the wind generator system or in turn a power system network [6][7][13]. it can be used to decrease voltage and power fluctuations .

IV. MATHEMATICAL MODEL AND EQUATIONS

In SMES systems, Thyristor based PCS transfers the power between the SMES unit and the power system. The thyristor based SMES is generally used to control the active power, because it has a little ability to control the reactive power. Therefore, the applications where the active power control is required, thyristor based SMES system is used.

The thyristor-based PCS can be configured by using,

- Six pulse converter
- Twelve pulse converter

In the above figure, the configuration of a thyristor-based SMES unit is shown, which consists of a Wye to Delta transformer, an ac/dc three phase thyristor controlled full wave converter, and a superconducting coil or inductor is shown. The output voltage of a converter may be positive or negative depending on the value of firing angle i.e.' α'[21][23]. If the value of firing angle 'α' is less than 90, the output voltage of a converter is positive power flows from ac network to coil. If α is greater than 90, the output voltage of a converter is negative and converter operates in the inverter mode (discharging)[10].

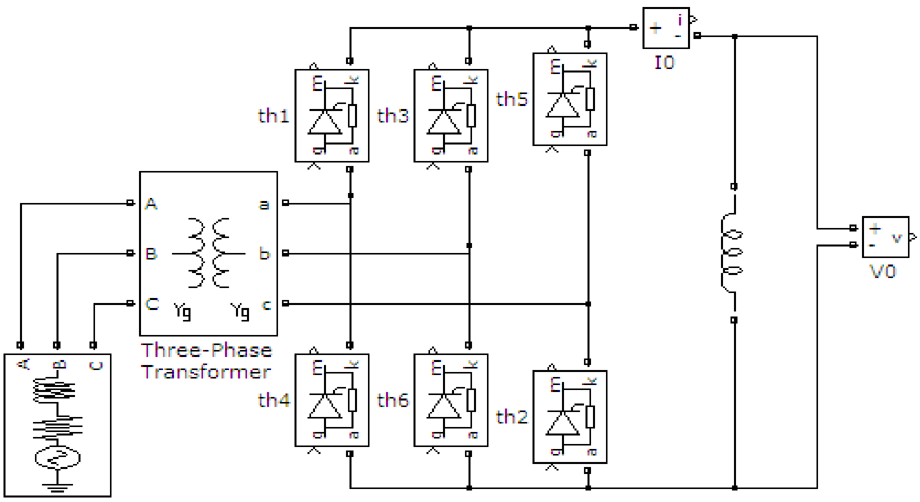

Figure 2: Thyristor Based SMES System

The voltage Vo at DC side of converter can be expressed by-

$$Vo = Vom\ cos\alpha$$

…………(1)

And current can be expressed by -

$$Io = \frac{1}{Lo}\int_{t0}^{t} Vo\,dt + Iom$$

……………(2)

And real power absorbed or delivered to system is given by-

$$Po = Vo\ Io$$

…………..(3)

Energy stored in the coil is given by-

E= ½(LI^2) ………..(4)

So direction of power flow will depend on firing angle

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V. PROPOSED SYSTEM

In this system shown below, an isolated generator, having capacity of 150 KVA, 50 hz is connected to a load of 80 KW via a transmission line of 20 km. This isolated generator is connected to a wind-turbine system having maximum capacity of 30 KVA, 50 hz through a circuit breaker. The genarator and wind turbine system combinely supply the load. The load angle and power(p.u.) of the isolated generator is 36 degree and 0.5 pu respectively. The simulation model is operated for 5 seconds. When the system is oparating, in between, from 2 to 3 seconds the circuit breaker is opened. During this time the output power of the isolated generator is increased which is shown in the output waveform[Fig-7].

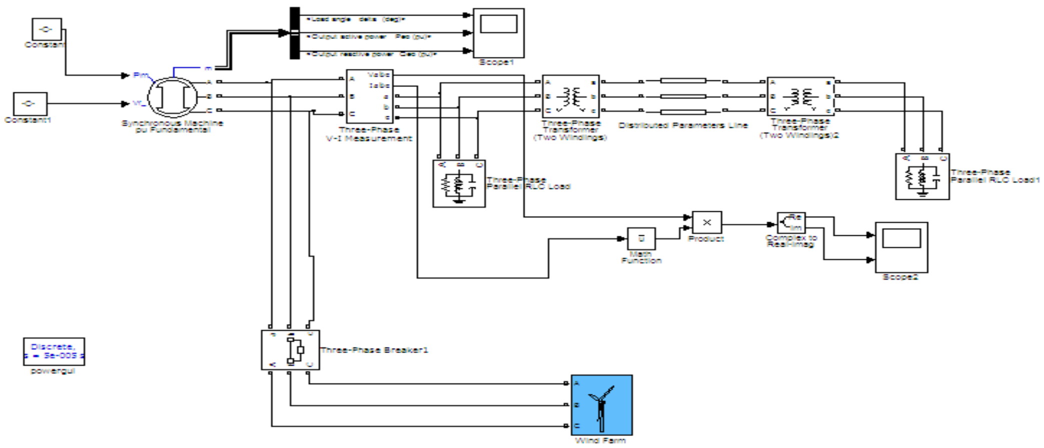

Figure 3: Matlab Model of Isolated Generator Connected to Wind Farm

VI. SMES SYSTEM

The SMES system is a storage system which supplied power during the time the wind- turbine generator is disconnected from the grid. This system consists of an inductor coil with inductance of 1.0 H and it is initially charged. The main idea of connecting this coil to our system is to stabilize the output, i.e., to supply power during the shutdown or fluctuation of wind generation system. SMES system consists of a six pulse converter which is controlled by varying the firing angle ‘α’. When ‘α’ is less than 90 degree, i.e. 15 degree in our case, the coil charges while when the firing angle ‘α’ is more than 90 degree, i.e. 180 degree in our system, the coil discharges and supplies the required power to the load so that the waveform obtained is uniform and stable as given below.

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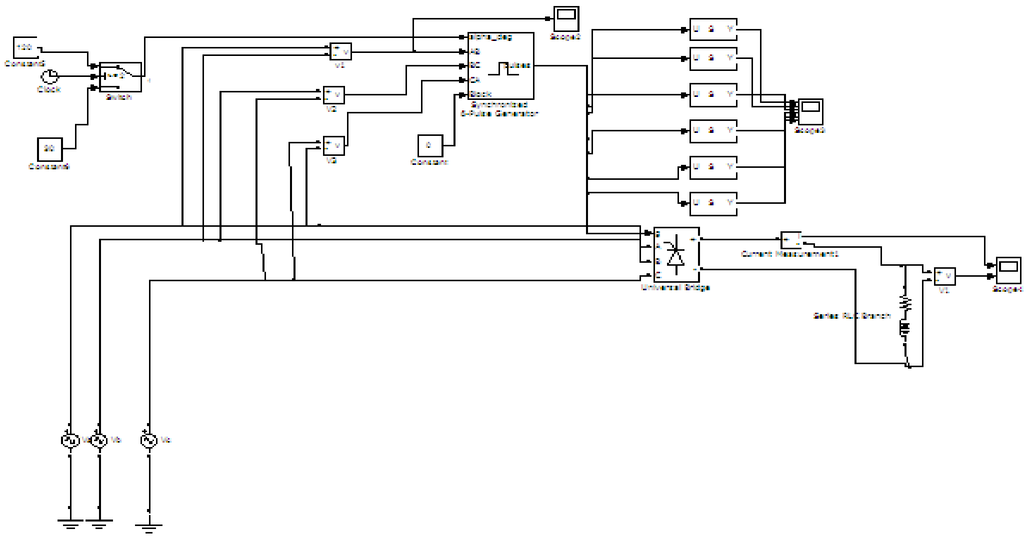
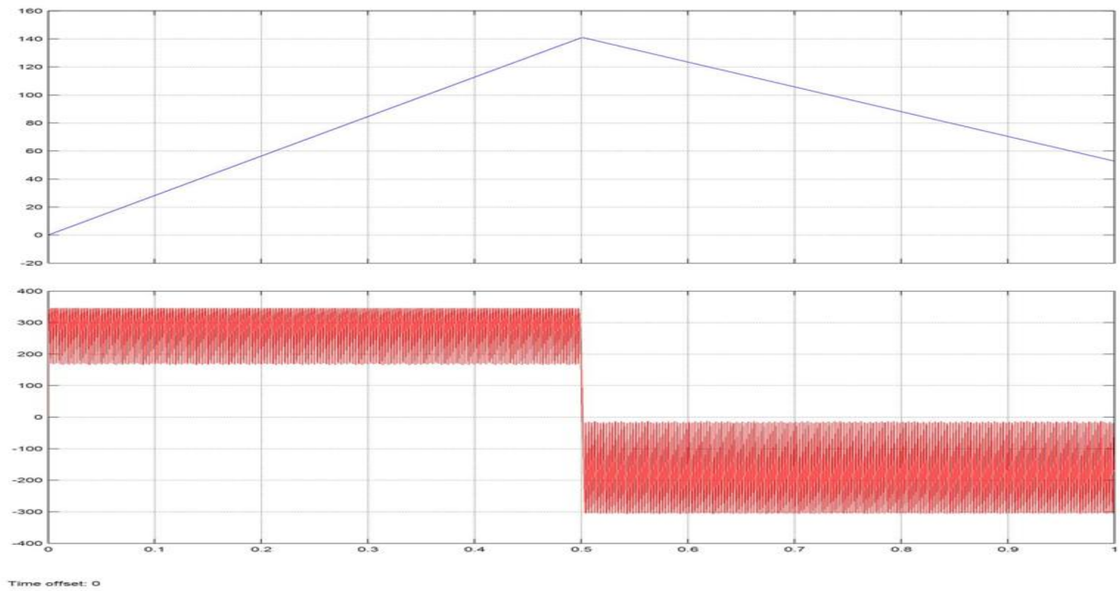


Figure 4: Mat lab Model of SMES Coil



The output waveform of SMES coil: -

Figure 5: Output of SMES Coil

When both the systems are combined together gives the results as –

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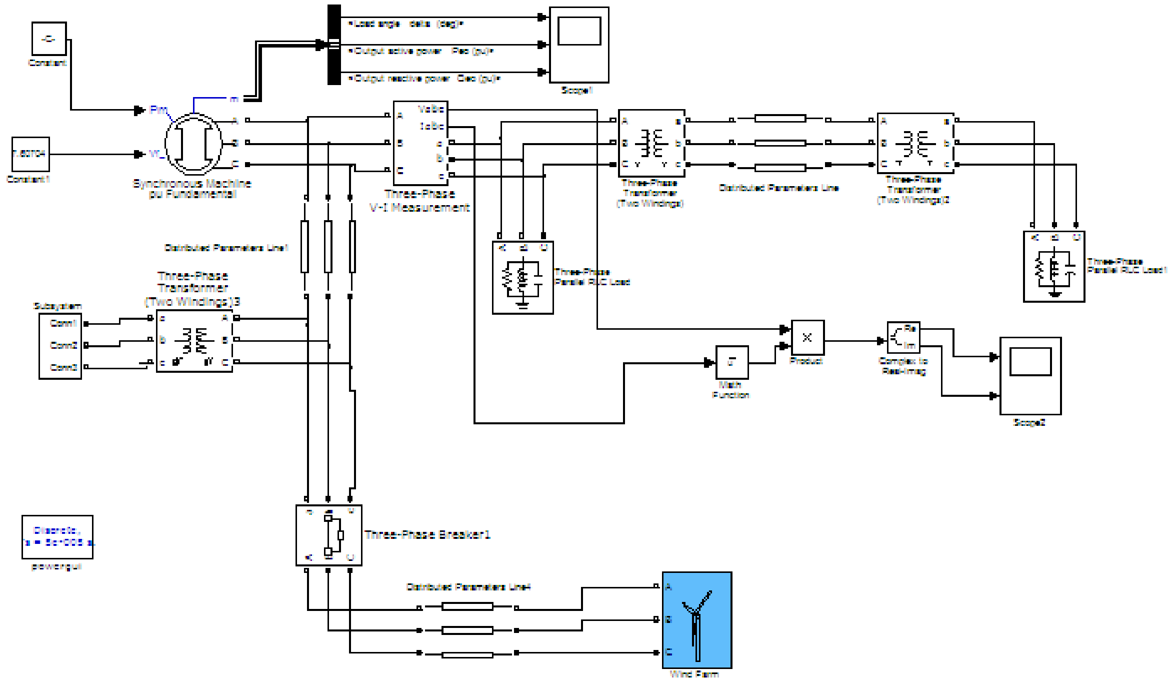

Figure 6: Mat lab Model of Combine System with SMES Coil

VII. RESULTS

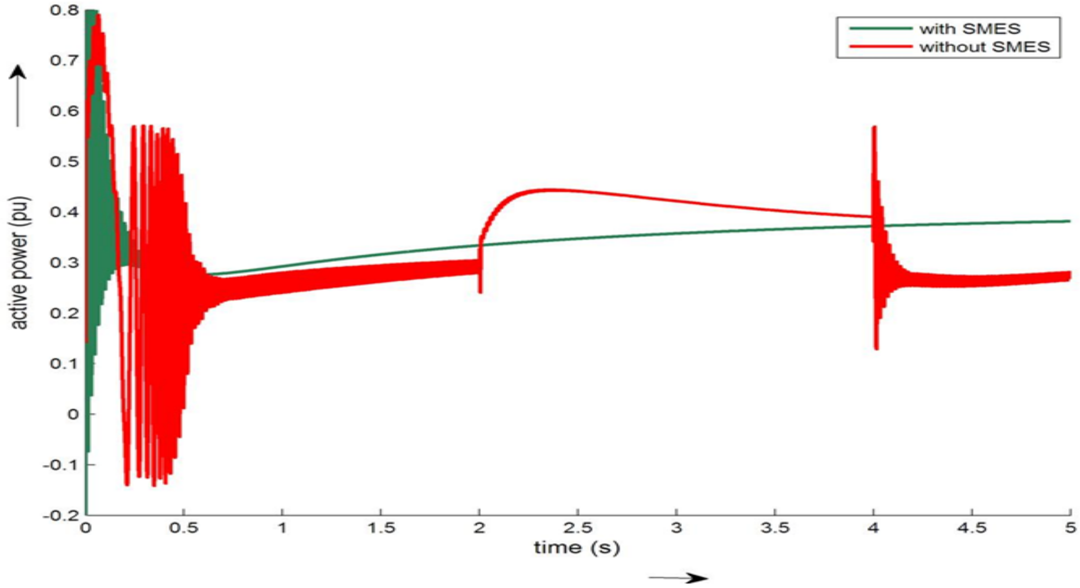

Figure 7: Output of MATLB Model of Active Power

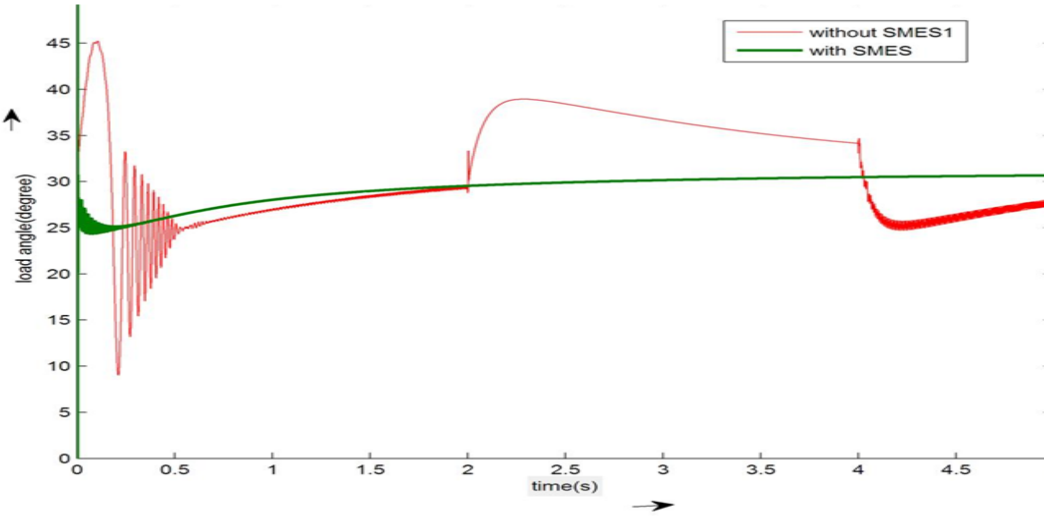

Figure 8: Output of MATLB Model of Load Angle

VIII. CONCLUSION AND FUTURE SCOPE

The SMES is used as a spinning reserve, the thyristor based SMES is used to exchange the extra power demand. It has been observed that by using the SMES coil in power system the output of wind generator become more regulated and the fluctuations are reduced in voltage and power. Apart from using a 6-pulse converter we can proceed for 12-pulse converter or voltage source converter (vsc) or current source converter (csc). Our further work also includes the use of fuzzy logic controller and neural network instead of using P Controller so as to improve the system efficiency.

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