Mitigating The Power Fluctuation Of PMSG Wind Turbine In A Microgrid By Optimal Usage Of SMES With FCL Using PID Controller

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Abstract— The major problem of PMSG wind turbine are power fluctuation. And this problem is overcome by new optimization technique and circuit model of the Superconducting Magnetic Energy Storage (SMES) with Fault Current Limiter (FCL) in a micro grid. Normally, SMES-FCL circuit which contain superconducting coil. In case of without fault condition, SMES-FCL act as the SMES unit to mitigate the power fluctuation of PMSG. Under fault condition, the SC is automatically connected to the system and it can be used as FCL to reduce the fault current. Then, the voltage drop of PMSG and fault current unit will be mitigated. By the energy function method is used to determine the optimal problem. Finally, this MATLAB result shows the superior control effect compare to the conventional method.
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Index Terms—Energy Function Method, Fault Current Limiter, Optimization, Permanent Magnet Synchronous Generator, Power Fluctuation, Superconducting Magnetic Energy Storage, Wind turbine

1 INTRODUCTION

Today quality of electrical power has become a major operating concern. The most one of the power fluctuation problem to form a transient. From this disturbances are high frequency, voltage spikes, typically in the micro second ranges. Next, power fluctuation will makes the voltage sag or surges. Brown out is also one of the problem of the power fluctuation. These are the problems which mostly problems occurring from the power fluctuation.

In generally, Permanent Magnet Synchronous Generator are used in the central power station and also control the field to regulate the reactive power. And then it is used to help power system stability against to overcome the fault condition. Usually, there are three sets of stator windings, physically offset so that the rotating magnetic field produce three phase current, displaced by one third of a period with respect to each other. The effect of power fluctuation will cause the blackouts.

In this paper to overcome the power fluctuation and nearer to critical point an economically feasible. For the recent years, the smart renewable energy source gives best for the variable- speed wind turbine with PMSG in the micro grid. Moreover, the power fluctuation is the most problem for the PMSG wind turbine for the both with and without fault condition. This problem may overcome by effective countermeasures.

The AC power is solved by the mentioned above circuit model SMES-FCL. The voltage and current can be alleviated by integrated superconducting coil into rotor side converter of the PMSG.

And also power fluctuation and voltage drop can also mitigated by usage of series and parallel connection of the wind turbine. Therefore, the reduction of fault current and smoothing the power fluctuation by the combination of SMES and SMES with FCL. The solution technique is very much suitable and optimal for the above mentioned problem mitigation of power fluctuation and to elimination high fault current. And this control effect is optimal and absolute Evaluation by the study of simulation comparing the conventional technique.

2 STUDY SYSTEM AND CIRCUIT MODEL

2.1 Study System

In this system, it can be stores energy in the creation of magnetic field due to the flowing of DC current in a coil of super conducting. This system is very simple and this super conducting coil is cooled one. And it has been cooled cryogenically to below its super conducting critical temperature.

2.2 Circuit Model

The new circuit model can be mainly consists of two chopper with superconducting coil. Whenever the normal operating condition, the SMES- FCL only acts as an SMES unit, is used to mitigate the power fluctuation by a control of power discharging and power charging. When the fault occurring in the system, the superconducting coil is automatically connected the bus.

Then voltage drop and fault current are limited in the PMSG. From that operation SMES-FCL returns to operate as an SMES unit this can be used to reduce the remaining power fluctuation. However, in this proposed system does not required inverter and the series transformer for the impedance transformation which are used in the AC grid compared to the existing system.

2.3 Model of SMES-FCL

In this model, circuit formation is similar to the bridge circuit and it is very simple. Simply it consists of electronic devices to make a

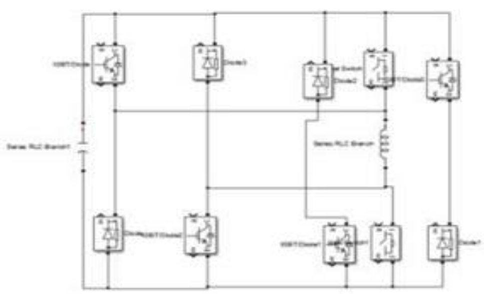


Fig Circuit of SMES-FCL

simple circuit.

3 CONTROL PART OF SMES

3.1 Control Of SMES

First and foremost, the objective aim of the control technique is to keep the power flow and stored energy in the superconducting coil within the system. Basically, SMES is major part to control our system. And this energy storage device is a grid enabling device and it proceeds storage and discharge of large quantities of almost power instantaneously. Whenever the SMES is release high level of power is capable within a fraction of a cycle to replace the sudden losses, dip in the power line (or) line power.

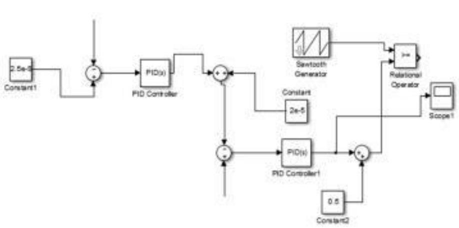


Fig: control of SMES

Here we are using PID Controller for the controlling technique. And the input signal of the PID1 Controller is the difference between the actual power and reference power. Then the output will be added to the reference current. And then external current will be added to the summation of the reference current and output of the PID1 controller. This is the input signal of the PID2 Controller .this output will be added to the limiter constant.

It can play a major role in reliability. And for our day today life increasing the congested power lines and the penetration of renewable energy sources etc., And it has more advantages of using the control parts. Because of lot of improvements in the power quality from the control SMES. Then, this control part improves load leveling in the transmission and distribution network.

3.2 Involvement of Duty Cycle

When the electric energy is depend on the duty cycle in this control part. Here, the charging system is occur during duty cycle greater than 0.5. And discharging system is occur during duty cycle lesser than 0.5.

TABLE I.

S.NO	DUTY CYCLE	ELECTRICAL ENERGY
1	> 0.5	charged from the system
2	< 0.5	discharged from the system

While comparing to the other storage system environmentally beneficial, it does not having the chemical reaction and no toxins. Consider the above mentioned, it has enhancing the transmission line capacity and performance. And it most compact and it cost wise more benefit.

3.3 Switching Modes Of Operation

The switching modes are used to turn ON and turn OFF the electronic devices. This modes of sequences are capable to activate the devices. And the possible modes are given below,

TABLE II
SWITCHING OPERATION OF DC CHOPPER OF SMES-FCL

SWITCHES	NORMAL OPERATION		DURING FAULT	
	CHA	DISCHA	CHAR	DISCHAR
S_1	on	Off	On	Off
S_2	on	Off	On	Off
D_1	Off	On	Off	On
D_2	Off	On	Off	On
S_3	On	On	Off	Off
S_4	on	On	Off	Off
D_3	on	On	On	On
D_4	On	On	On	On
S_{W1}	off	Off	On	on
S_{W2}	off	off	On	on

When the charging and discharging of the devices taken an account from this modes only This way of approaches well known to turning devices ON or OFF for the generation and protection of the overall system and electronic devices The output of the PID2 is the duty cycle deviation For the special purpose saw tooth signal and duty cycle signal are compared by the usage of Comparator.

4 CONTROL PART OF FCL

The aim of this controlling FCL is used to eliminating the Fault current. The super conducting fault current limiters will enhance the quality of electric grids. And it should be innovative control of appliance energy technology; it is used for mainly preventing the occurrence of high fault current in the grid.

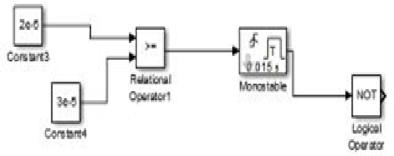


Fig : Control of FCL

Whenever fault occurs in the system, automatically superconducting coil (SC) will be connected to the bus. And then bus current is compared with reference fault current. When the bus current is greater than the reference current, the monostable circuit sends the turn ON signals to SW1, SW2 and the turn OFF signals to S3, S4.

In generally, fault current limiter represents the application of high temperature superconducting material. High fault current resulting from the more number of parallel connections of electricity grids and though more decentralized supplies. And it can be prevented (or) limited outdated conventional switch gears and protections. Fault current limiter does not require the series transformer.

5 OPTIMIZATION TECHNIQUE

By the usage of the energy function method is used to determine the optimization parameters. And the kinetic energy stored in the rotor and rotor speed of PMSG highly increased during fault occurring in the system. From that condition, power output and voltage of PMSG suddenly drop. Whenever SC is series with the system act as the SMES-FCL to mitigate the increase in fault current as well as stored kinetic energy. Then, the abrupt reduce in power output and voltage of PMSG can be mitigated.

The energy function voltage is,

$$V = V_K(\omega_1(t)) + V_P(\delta_1(t)) . \quad (1)$$

Where , V_K is the kinetic energy, V_P is the potential energy, ω is the rotor angle and δ is the rotor speed.

The derivative of V with respect to time, when the derivative is in negative values it show how decays the total system energy. Then the negative derivative is maximized the faster and higher system damping can be calculated.

The kinetic energy will be in the form of the mechanical power with angular speed of the turbine

$$V_C = (\omega_1(t))P_e \quad (2)$$

Whenever short time period fault occurs, δ , V_P , P_e are rapidly changed. And then variation of derivative is changed gradually, the power will increase or decrease. And almost important thing is fault current limiter part is maximize the voltage by the way of controlling the power then the derivative become negative.

After the control part of FCL, during the normal operation condition super conducting magnetic energy storage system will mitigate the power fluctuation. Thereafter, an integral absolute error(IAE) power deviation will be ,

$$|\Delta p(t)\, dt| \rightarrow \min imum \ (with\ time\ difference\ 't') \quad (3)$$

Then, the superconducting coil inductance and its current are optimally change so that the initial storage energy will be in the form,

$$E_{SCO} = L_{SC} I^2{}_{SCO} \rightarrow Minimum \quad (4)$$

Where, E_{SCO} is the initial storage energy.

In this optimization technique focus the multiple optimization problem and it will be

$$\min imize\ V_C + |\Delta P(t)|dt + E \quad (5)$$

Then it will take some of them subject to constrains which have to follow values of L, I, K(inductance, current, particular integral gain value)subject to,

(1) $0.01 \le L_{SC} \le 5H, (ranges\ of\ inductance)$

(2) $0.01 \le I_{SCO} \le 2kA, (ranges\ of\ current)$

(3) $0.01 \le K \le 20, (ranges\ of\ PID\ gains)$

Wind speed of PMSG Output

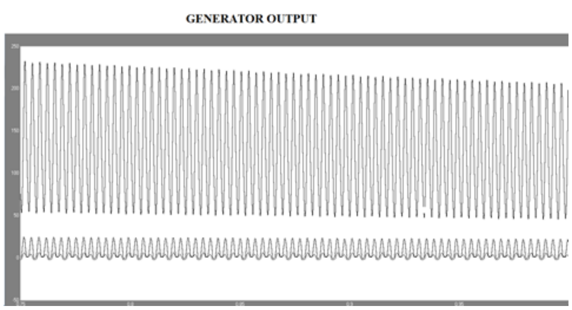


Fig: wind speed of PMSG

The above mentioned constrains will make optimization of SMES-FCL values. The PID control parameters are able to optimize with the subject to constrain. And it can play a major role in the reliability. Then and there, mitigate the congested power in the renewable energy sources.

It has some benefits, to the power quality for critical loads, balancing the transmission network, ecofriendly system, enhancing transmission network due to the high dynamic range of SMES, and mainly for cheap and best for the economic condition. From this work, the particle swarm optimization is used to achieve the optimization optimal parameter.

6 SIMULATION STUDY

6.1 Simulation model

The simulation model shows the implementation of this project, it will help the easy way of understanding in discrete manner. The parameters are optimized by under matlab/simpowersystem the wind speed of PMSG. Where time slot it will take some deviation to obtained optimal parameter values. As the result, the convergence values show the inductances, current, particular integral derivation values from the graph. Then the simulation block implementation will be,

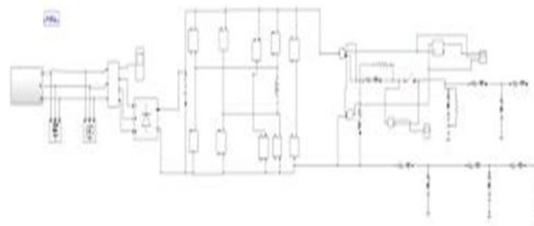


Fig: overall simulation block

This is the overall simulation block which shows the overall project work in this block in a simple manner. The calculated parameters inductances, current, constant values are provided in the table and it shows the comparison result.

6.2 Optimized Parameter

The optimized parameter of SMES-FCL and SMES are provide in the table. It shows result which the optimization solution values are getting in that point of values.

TABLE III
OPTIMIZES PARAMETERS OF SMES AND SMES-FCL

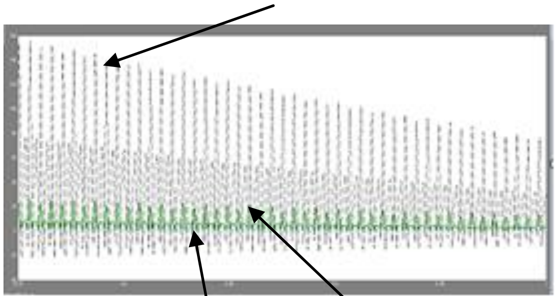
PARAMETER	SMES	SMES-FCL
$LSC\ (H)$	2.1	0.78
$I\ SC\ 0\ (kA)$	1.1	1.12
$ESC\ 0\ (MJ)$	1.6	0.69
$K\ P, K\ I\ 1, KD1$	10.85,0.19,3	13.45,6.25,5
$K\ P\ 2, K\ I\ 2, KD\ 2$	16.24,7.23,4.5	20.15,2.75,6

We have noted in that superconducting inductance and initial store energy of superconducting magnetic energy storage with fault current limiter inductance values are lower than the superconducting magnetic energy storage system unit.

6.3 Simulation Results

The simulation result shows the power fluctuation, current, voltage in the usage of without controller, superconducting magnetic storage system (SMES), SMES-FCL. The power fluctuation is the major problem in our todays life as its mentioned in the introduction part. In the part of power f output waveform says power can be varied with respect to time largely without using controller. And then reduce slightly power fluctuation while comparing previous one by using SMES. Finally, we mitigate the power fluctuation in the usage of SMES-FCL comparatively. These variation and mitigations are similarly shown in the following current and voltage waveforms.

(highly fluctuate the power without controller)



(it clearly shows reduction of power fluctuation using SMES)

(power fluctuation is mitigated using SMES-FCL)

Fig: power flow vs time

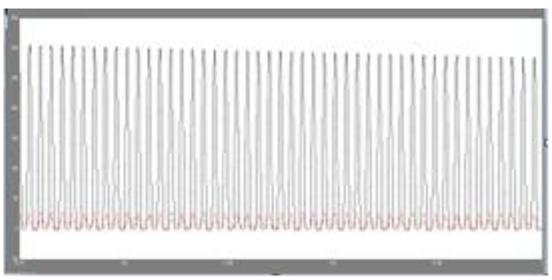


Fig: terminal voltage variation vs time

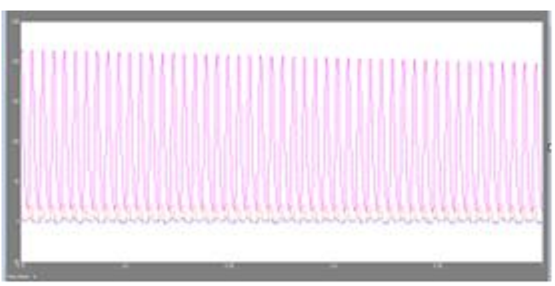


Fig: current flow vs time

And SMES not effectively get through the power fluctuation. But, in the case of SMES –FCL provides better smoothing the power fluctuation. An the other side, it has some voltage drop which is in the range of acceptable grid code. Simultaneously, fluctuating voltage should be completely eliminated. Depicts without using any device and usage of SMES having the transient power drastically fluctuates. Then SMES-FCL which can optimally suppress the damping out power swing and power fluctuation.

TABLE V
NECESSARY MW AND MJ CAPACITIES OF SMES

CAPACITY	SMES	SMES-FCL
MW	2.97	2.57
MJ	2.145	1.17

At the end of the simulation result, the necessary MW and MJ of the SMES and SMES-FCL are provided in the Table V. In SMES shows the maximum value of MW Power output deviation. The MJ capacity shows and useful for formulate the maximum difference between the energy output and initial stored energy of SMES. With the usage of FCL, MW and MJ capacities of SMES-FCL lesser than the capacities of SMES..

7 Conclusion

The improvement of power system stability and mitigation of power fluctuation are implemented. Under fault condition, fault current is eliminated of PMSG wind turbine in a micro grid. The result enhance that the SMES-FCL with low Superconducting coil and MW/MJ provides better control effect than SMES. In future SMES-FCL expected as a smart device to involved not only the power stabilizing effect, but also significant economic benefit in the DC power grid.

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