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Ananlysis and Application of Fault Current Limiter For Induction Motor Drive

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Abstract

The main paradigm of choosing the FCL into the distribution system is to knock down the fault current. During a normal operation, the FCL has a very small impedance value as it is a series connected. In case of fault condition, the FCL gradually increases its impedance so that it prevents over-current stress which provides results as detrimental, decline, extra heating, mechanical forces of electrical equipment. One of the dominant competitors for a commercial fault current limiting devices is saturated core fault current limiter (SCFCL). In traditional SCFCL designs, the essential problem of transformer coupling is found and it is swamped by the placement of an open magnetic circuit and a closed dc magnetic circuit. For a full cycle of ac current limiting it indulge the usage of a single magnetic core. SFCL is used to secure and diminish over currents in the induction motor drive. The performance can be analyzed by using MATLAB/SIMULINK model. In extension the proposed Fault current limiter is applied for Induction motor protection**.**

Keywords: *SCFCL, Fault currents, Magnetic core saturation, Induction Motor Drive***.**

1. Introduction

One of the most standard current devices to safeguard the system and electrical equipments is Superconducting fault current limiter [RamaRao.P.V.V, M.Swathi]. The performance of SFCL provides the most adequate way to curb the fault current and results in large-scale preserving from not having to take advantage of immense capacity circuit breakers in the power system. Superconducting materials are being utilized by superconducting fault current limiters to supply a DC bias current and to decrease the level of the current directly that it alters the magnetization level of a saturated iron core [Debaprasadkastha, B. K. Bose]. For commercial notion many SFCL design concepts are being estimated, advancements in superconducting materials for improving technology from past 20 years have been motivated. In 1986, the exploration of high-temperature superconductivity (HTS) intensely improved the possibility for very much fiscal operation of various superconducting devices.

In a power system superconducting fault current limiter (SFCL) is a relevant approach to confine the fault current. Normally a superconductor which holds non-linear properties is used in SFCL to minimize the fault current. SFCL has no impact in a normal operating condition on the system due to the practically in superconductors with zero resistance below its critical current. But in case of occurrence of a fault, system goes to abnormal condition when current exceeds the critical value of superconductors resulting in the SFCL to go to a protective state [J. C. Knott]. This potential of SFCL to go off a finite resistive value state from zero resistance can be used to curb the fault current.

SFCL is fed with induction motor drive and the system is used as an application. Induction motor (IM) drive system is used in marine propulsion, electrical vehicles and other industrial applications as its low maintenance, robustness and high performance [F.Fajoni]. The induction motor has advantage as an uncomplicated construction, authenticity, potency and economical has found very extensive in industrialized appellations. When using induction motor in speed regulated industrial drives these advantages are occupied by control problems [D.Sarkar,2009]. The basic subsystems of the machine are stator and rotor of an induction motor. The motor case, ribbed outside for better cooling, the stator core is housed with a three phase winding on the boundary of the core placed in slots. To reduce the eddy current losses in the system individual laminations are covered on both sides with insulating lacquer. The adamant motor electrical part is the stator [N. Vilhena]. Several hundred thin laminations are built in the stator core of NEMA motor. In this paper the behavior of fault mode with SFCL and without SFCL of an induction motor drive in the distribution system has been investigated for the faulty currents.

2. The Open Core SCFCL

Fig.1. shows an open core SCFCL, designed by [F. Moriconi]. The magnetic core present is minimized to two limbs in this design; an AC coil is mounted on each limb to form a magnetic circuit open type for the AC magnetic flux. The AC coils are mounted in a way such that for each half cycle of the AC current one of the coils generates a magnetic flux which encounters the DC flux in an opposing way. For minimizing the fault current fully there is a need for two window shape cores per phase thus it eliminates the open core design. To reduce some of the AC-DC transformer coupling is done due to the arrangement of AC coils in an opposing way and because of its construction in the AC flux lines are closing partially within the DC coil. However, DC magnetic circuit which is open type requires very high Ampere-turns in the DC coil so that it can intensely saturate the core region covered in the AC coils. The reason behind high transient fault currents are necessarily required to fully de-saturate the core, hence the configuration of open core undergo from comparably low fault current clipping ratio.

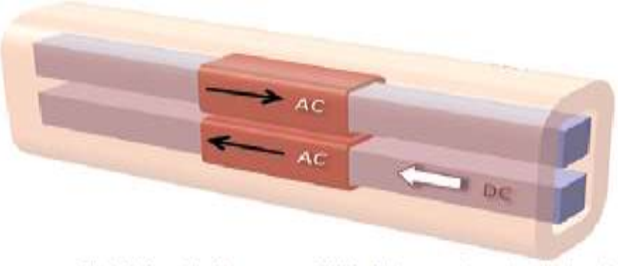


Fig.1. CAD model of the open core SCFCL. Black arrows denote the direction of the ac magnetic field, and the white arrow denotes the dc field.

3. The Open-Closed SCFCL

An extension in the development is targeting to reduce the Ampere-turns in the DC bias coil, and the clipping factor of the SFCL improved was illustrated. The design, superimposes a AC magnetic circuit which is open type and a DC magnetic circuit which is closed type and whereas both coils are right angled to each other. The AC coils which is mounted on the long limbs of the core generating parallel AC magnetic field lines as the magnetic core is an elongated window core. At the axis of symmetry the AC fields of two coils cancel each other in between the coils as long as the core magnetization state is similar for both the long limbs. The resulting AC magnetic field pattern is attained with AC flux lines from an open circuit closing through air. The configuration of the AC coils creates an ideal speck for mounting the DC coils at this axis of symmetry on the short limbs of the core so that the DC coils are exposed to minimize the net AC flux and the problem of transformer coupling is reduced. The direction of the current in the DC coils flows on a closed magnetic circuit of DC flux of both coils.

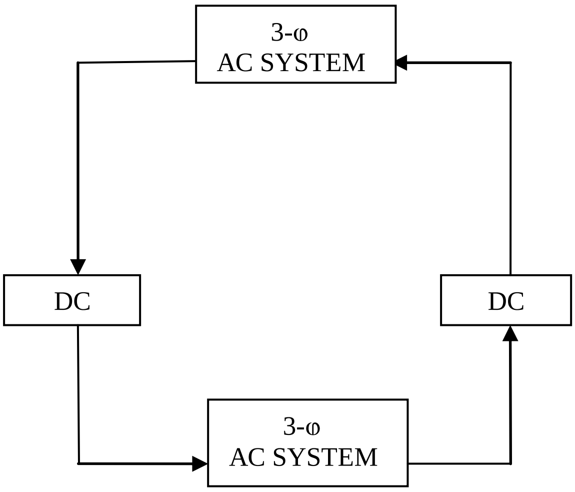


Fig.2 Block diagram representation of open–closed three phase SCFCL design

The SFCL design of open-closed can be prolonged to 3-φ limiting operation with a single core design can be supported. All fault scenarios, namely 1-, 2- and 3-phase symmetrical faults in which Fig.3 demonstrates a design that can handle the problems. Limiting a single core SFCL when a 3-φ symmetrical fault is experienced is a challenge. One of the reasons behind this is when all the three phase coils are reinforced on the same core, it undergoes an identical hike in level of current value as the vector sum of all magnetic fields induced by the coils is zero, as a result core remains saturated and this leads to the failure of current limiting operation. A built in asymmetry has been introduced into the design to overcome this problem. To de-saturate the core of a three phase symmetrical fault the R, Y & B phase coils add up asymmetry are designed in a way that the vector sum of the magnetic field of all coils is sufficient. This asymmetry is achieved by placing the phase coils on different segments of the core limb where the level of magnetic saturation is position dependent, by varying the coil diameters and/or by varying the number of turns between the phase coils. For nominal current operation noting that the cancellation partially of the coils field during nominal condition helps in reducing the device impedance making it even more transparent.

The open-closed SCFCL configuration is holding one of its important feature compactness and proportionately short DC orthogonal coils, which allows the core to be concise in size and by using low Ampere-turns as a result, the magnetized core can be done. To achieve the saturation of core widely using copper coils normally for distribution of voltage devices is possible. It is one of the feature to allow the overcoming barrier of entry of utilities and postponing of superconducting bias coils introduction to larger devices.

It has been explored that the transition between the magnetic states of the core in the three SFCL designs described above; the original design [RamaRao.P.V.V, M.Swathi] the open core SFCL and the open-closed SFCL. The dynamics of the transition between the saturated and desaturated core states was analyzed introducing core length effectively—the length of the de-saturated section of the core limb relative to the full limb length. It was shown that during a fault, the de-saturated core section propagates from the limb center towards the limb edges where the dynamics of the increase in the effective core length depends on the SFCL configuration. This design is first to de-saturate because its saturation state is the "weakest" of all three since the magnetic path for the flux from the DC coil to the AC coil is the longest hence, the magnetic reluctance is highest.

4.. Induction Motor Drive

An induction motor, is an AC electric motor in which the electric current in the rotor is needed to produce torque and it is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor's rotor can be either categorized as wound type or squirrel-cage type. 3-φ squirrel-cage induction motors are widely used in industrial drives because they are robust, reliable and economical.

For smaller loads, single-phase induction motors are used such as household appliances extensively like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. The most widely used induction motors is the squirrel cage induction motors in both fixed-speed and variable-frequency drive (VFD) applications.

The induction motor has many advantages in simple construction, reliability, ruggedness and low cost has been found very wide industrial appellations. In speed regulated industrial drives, these advantages, however, are occupied by control problems when using an induction motor. Speed control (v/f control) of induction motor requires two stage conversion (ac-dc and dc-ac), but most of the inverters gives poor performance. A Reversing Voltage topology in five-level and seven-level inverter is implemented for induction motor load which has superior characteristics in terms of required components as control requirements, switches, reliability and voltage balancing. Induction motor drive does not need any brushes and there are no contacts on rotor shaft. It is easy to manufacture almost maintenance free except for bearings and other external mechanical parts. The main criterion is to reduce the fault current limit but not to bring the fault current to line current value.

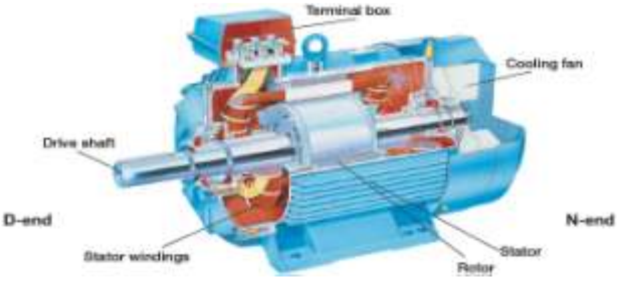


Fig.3. Induction Motor Drive

A. Control of Induction Motor Drive

A three phase induction motor is a constant speed motor so it's somewhat difficult to control its speed. The speed control of induction motor is done at the cost of decrease in efficiency and low electrical power factor. The basic formulas of speed and torque are considered below to obtain constant characteristics.

B. Synchronous speed

$$N_s = \frac{120\,f_1}{P_1} \qquad (1)$$

Where f_1 = frequency, P_1 is number of poles.

The induction motor speed is given by,

$$N_1 = N_s(1-s_1) \qquad (2)$$

Where N_1 is rotor speed of IM,
N_s is synchronous speed,
s_1 is slip.

Three phase induction motor produces the torque and it is denoted as,

$$T = \frac{3}{2\pi N_S} \times \frac{s_1 E_2^2 R_2}{R_2^2 + (s_1 X_2)^2} \qquad (3)$$

When rotor is in standstill, slip s_1 is one.
Torque equation is,

$$T = \frac{3}{2\pi N_s} X \frac{E_2^2 R_2}{R_2^2 + X_2^2} \qquad (4)$$

Where E_2 is the e.m.f of rotor
X_2 is the rotor inductive reactance
R_2 is the rotor resistance
N_s is the synchronous speed

5.MATLAB/SIMULINK RESULTS

Consider a three phase ac system connected with a powergui, convectional power plant, an internal primary load100MW, transformer of 100MVA 11KV/220KV, bus-bar, a three phase fault and a load of 75MW is applied to the system. Here we can observe the characteristics of SFCL in the scope2 of the block diagram. In this case we can obtain the characteristics of fault current without SFCL in three phase system.

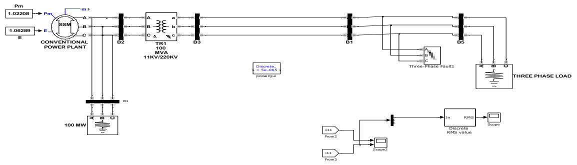


FIG.4 MATLAB/SIMULINK model without SFCL

In this graph, it is observed that voltage decreases when fault current increases in the system. When fault level in the system increases at 0.08secs after there is a change in voltage to reduced voltage as it experiences LLLG type fault and more variation in fault current level. Such that current experiences a fault condition in severe level. This fault level can be decreased by placing SFCL in the line at the external load.

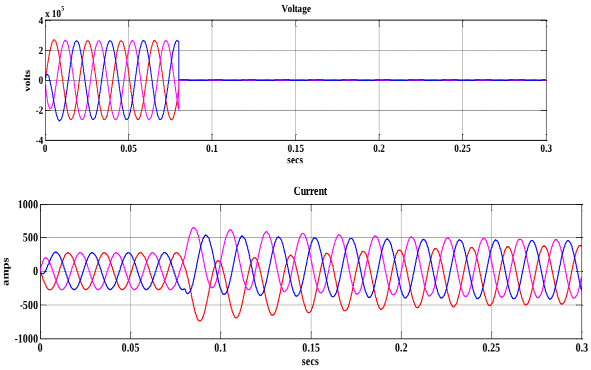


Fig.5. Simulation waveform for source voltage and SFCL installed for prospective fault currents in 2- φ R and T system.

Consider a three phase ac system connected with a powergui, convectional power plant, an internal primary load100MW, transformer of 100MVA 11KV/220KV, bus-bar, a three phase fault and a load of 75MW is applied to the system. Here we can observe the characteristics of SFCL in the scope2 of the block diagram. In this case we can obtain the characteristics of fault current with SFCL in a single circuit 3- φ system.

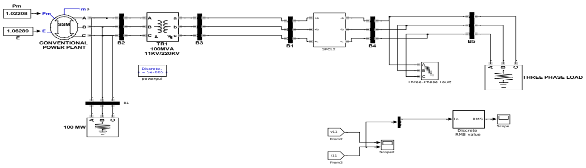


Fig.6. System with FCL for MATLAB/ SIMULINK circuit.

Designing of SFCL:

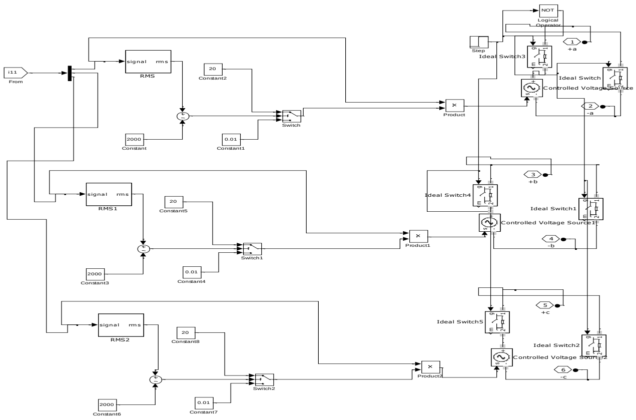
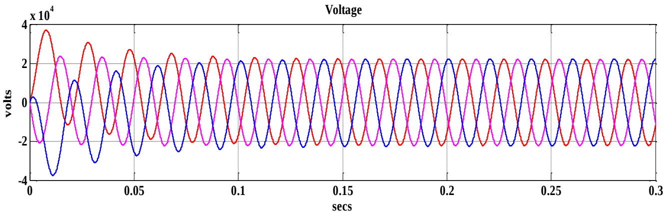


Fig.7. MATLAB/SIMULINK model for SFCL control circuit.

The voltage varies with the fault current value. If the fault current is limited then the voltage is in normal operating condition such it is observed as three phase ac system but in case of fault current existence the voltage in any one of the phases comes to zero. The voltage at 0.1 seconds experiences a fault current and it changes its value to zero in one phase.



The source current is limited by the SFCL component and it shows a three phase ac system at normal operating condition after eliminating the fault level in the system with 50% limitation of fault current. It is observed that due to transients the current value reaches to 2000amps by placing the SFCL in the line the fault current is limited to 1000amps.

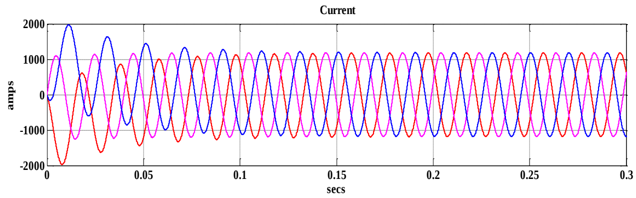


Fig.8. Simulation waveform for voltage and fault currents in 2-φ system R and T with FCL

The system consists of conventional power plant, a primary load of 100MW, transformer with 100MVA voltage rating of 11KV/220KV, three phase faults, RLC series load with 75MW. The results are observed in scope2 of the below diagram. In case of faults occurring simultaneously at a time without SFCL gives an idea about the fault currents existing in the system.

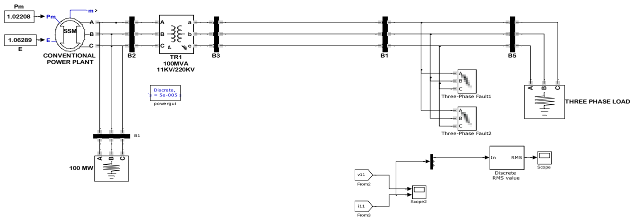
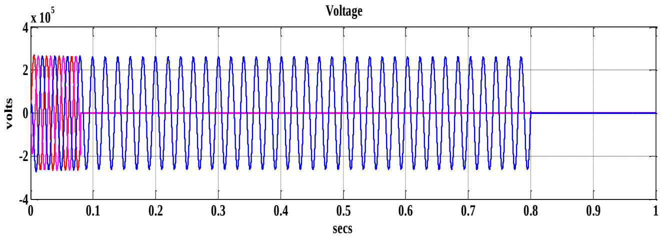


Fig.9. MATLAB/ SIMULINK circuit for Proposed System with 2-φ fault event evolving into 3-φ fault



The voltage in the system without SFCL varies at 0.1 seconds to minimum value of voltage and such that after 0.7 seconds the voltage value again fluctuates to nearly zero as the fault current increases to maximum value.

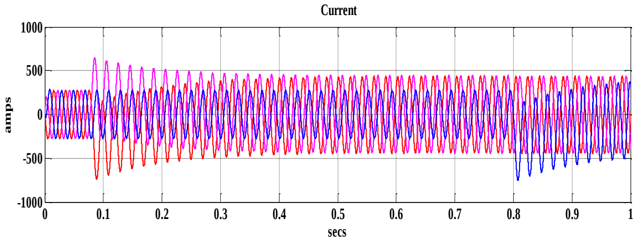


Fig.10. Simulation waveform for voltage and fault currents with 2-φ fault event evolving into 3-φ fault

The system consists of conventional power plant, a primary load of 100MW, transformer with 100MVA voltage rating of 11KV/220KV, three phase faults, RLC series load with 75MW. The results are observed in scope2 of the below diagram. In case of faults occurring simultaneously at a time with SFCL gives an idea about the fault currents existing in the system can be limited.

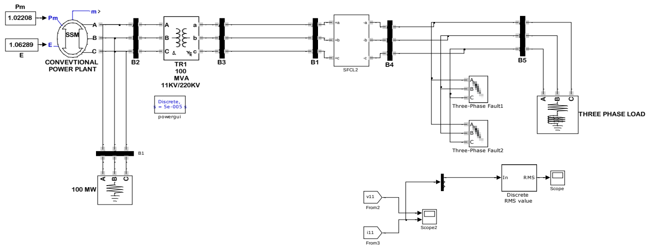


Fig.11. MATLAB/ SIMULINK circuit for Proposed System with 2-φ fault event evolving into 3-φ fault

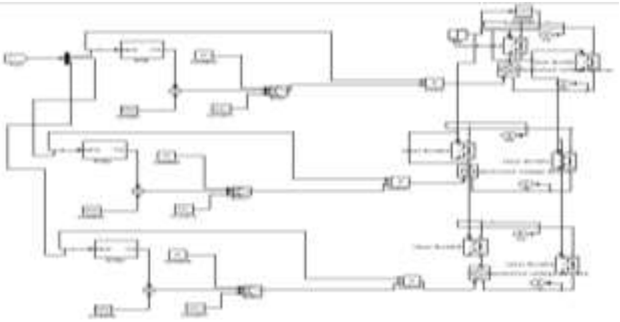
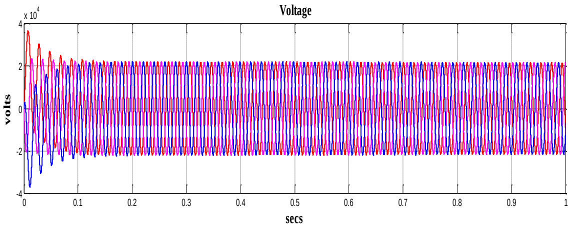


Fig.12. MATLAB/ SIMULINK circuit for SFCL Control circuit

The voltage in the double circuit with SFCL varies at 0.1 seconds to minimum value of voltage and such that after 0.7 seconds the voltage value again fluctuates to nearly zero value current value. The source current is varied according to SFCL characteristics such that it leads to normal working condition.



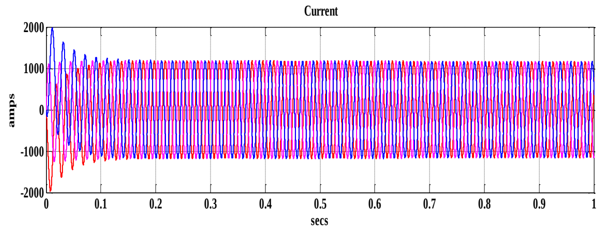


Fig.13. Simulation waveform for source voltage and fault currents with SFCL 2-ω fault event evolving into 3-ω fault

The current in the system is being resolved from fault condition such that SFCL is placed in the line diagram to eliminate the fault condition levels in current values. The current value limits after fault condition value varies from 0 to 1 second in the x-axis and the voltage varies in the range of -3000V to 3000V in a double circuit system.

The induction motor consists of various components like universal bridge, PW generator and various components. Here we find the rotor speed, torque and current. The universal bridge block implements a universal three phase power converter that consists of upto six power switches connected in bridge configuration. The universal bridge is the building block for two level voltage sourced converter.

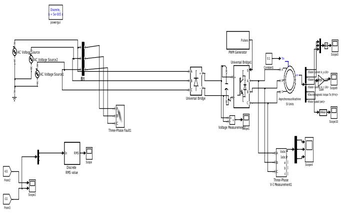
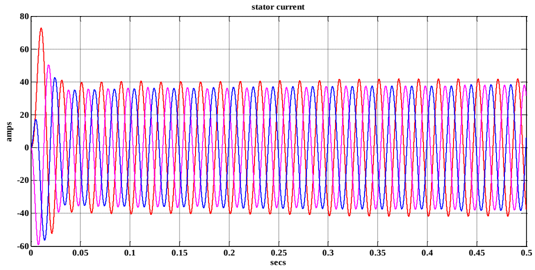
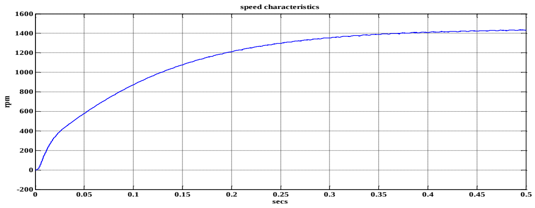


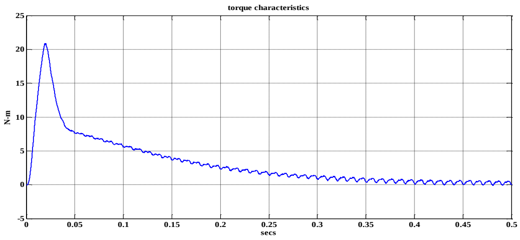
Fig.14. MATLAB/ SIMULINK circuit for Proposed System without SFCL fed Induction Motor Drive



(a) Stator current



(b) Speed



(c) Torque

Fig.15. Simulation waveforms for without SFCL fed Induction motor drive of (a) stator current, (b) Speed and (c) Torque

The induction motor drive describes about the values regarding the stator current, speed and torque characteristics such that it gives clarity that all characteristics are high at starting of motor such that they limit to constant value after reaching certain time.

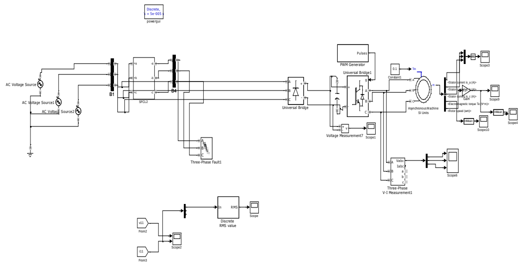


Fig.16. MATLAB/SIMULINK circuit for Proposed System with SFCL fed Induction Motor Drive

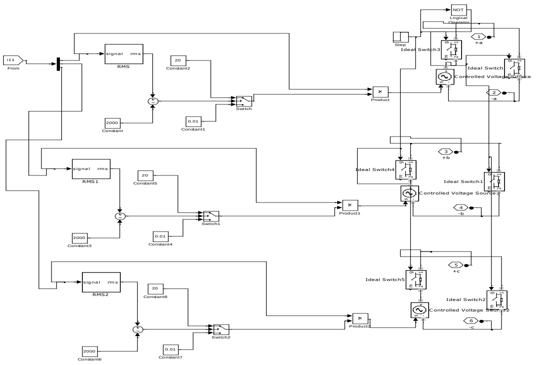
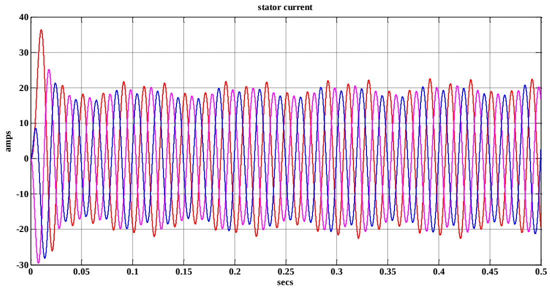
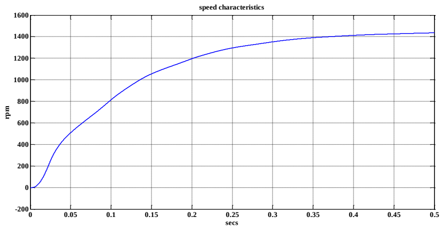


Fig.17. MATLAB/ SIMULINK MODEL FOR SFCL control circuit



a)stator current



b) speed characteristics

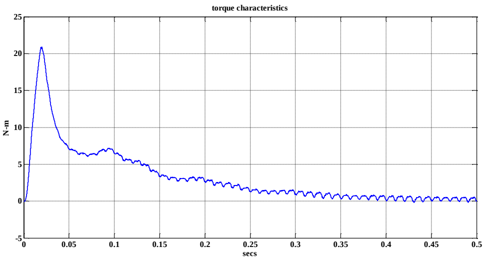


Fig.18. MATLAB/SIMULINK results for an induction motor drive fed with SFCL a) stator current b) speed characteristics and c) torque characteristics.

The induction motor drive explains the behavior of stator current, speed and torque characteristics such that it is limited by SFCL which limits the stator current and the speed and torque remains constant. The overall characteristics are improved by placing SFCL in the line. The stator current is limited by 50% of the fault current in the line which protects the system from damage.

6.Conclusion

In this paper SFCL concepts have been reviewed. An installation of SFCL in a live grid led to the development, under various scenarios of 1-φ, 2-φ and 3-φ fault events which was proven successful. The SFCL provides the fault current problem a vital solution and in distribution networks adding generation resources and connecting parallel in network segments in parallel. Thus, system transient stability is improved and it provides the system effective damping for low frequency oscillations. The proposed SFCL concept is further implemented with induction motor drive, which is used as an application. Here the performance of SFCL fed induction motor stator currents, speed and torque characteristics are verified.

References :

[1] B.Raju, K. Parton, and T. Bartram, “A current limiting device using superconducting dc bias applications and prospects,” IEEE Trans. Power App. Syst., vol. PAS-101, no. 9, pp. 3173–3177.

[2] Debaprasadkastha, Bimal K. Bose, “Investigation of Fault Modes of Voltage-Fed Inverter System for Induction motor Drive,” IEEE Transaction Industry Applications, VOL 30, NO. 4.

[3] D.Sarkar, A.Upadhyaya, A.B.Choudhury, and D. Roy, “Performance analysis of a saturated iron core superconducting fault current limiter using different core materials,” in Proc. Int. Conf. CIEC, pp. 387–391.

[4] F. Moriconi, N. Koshnick, F.De La Rosa, and A. Singh, “Modeling and test validation of a 15kV 24MVA superconducting fault current limiter,” in Proc. IEEE PES Transmiss.Distrib.Conf. Expo.,Smart Solutions Changing World, pp. 1–6.

[5] F. Moriconi, F. De La Rosa, F.Darmann, A. Nelson, and L.Masur, “Development and deployment of saturated-core fault current limiters in distribution and transmission substations,” IEEE Trans. Appl. Supercond. vol. 21, no. 3, pp.

[6] F.Fajoni, E.Ruppert, C.A.Baldan, and C.Y.Shigue, “Study of superconducting fault current limiter using saturated magnetic core,” J. Supercond. Nov. Magn., vol. 28, no. 2, pp. 685–690.

[7] J. C. Knott, P. A. Comminsa, J. W. Moscrop, and S. X. Dou, “Design considerations in MgB2 based superconducting coils for use in saturated core fault current limiters,” IEEE Trans. Appl. Supercond., vol. 24, .

[8] M. Mordadi-Bidgoli and H. Heydari, “Comprehensive FEM analysis for saturable core fault current limiters in distribution network,” in Proc.IEEE 22nd ICEE, pp. 665–670.

[9] N. Vilhena, P. Arsenio, J. Murta-Pina, A. Pronto, and A. Alvarez, “Amethodology for modeling and simulation of saturated cores fault current limiters,” IEEE Trans. Appl. Supercond., vol. 25.

[10] Rama Rao P .V .V, M.Swathi, “Superconducting Fault Current Limiter in

DC Systems with MLI Fed to IM,"ISSN (PRINT): 2320 – 8945, Volume -3.

[11] S. Wolfus, A. Friedman, Y. Yeshurun, V. Rozenshtein, and Z. Bar-Haim, "A fault current limiters (FCL) With the cores saturated by superconducting coils," U.S. Patent Appl. 20090021875.

[12] W. Z. Gong et al., "Plenary talk—Practical HTS FCL development— Updates of innopower's SFCL R&D projects," in Proc. IEEE Int. Conf. Appl. Supercond. Electromagn. Dev, pp. 256–256.