Review on the SFCL Control Techniques in Grid System

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Abstract: In this paper, the authors present a comparative study of inductive and resistive superconducting residual current limiters (SFCLs) from the perspective of current limiting and transient stability of the power supply system. Different types of SFCL can be used to reduce the magnitude of the fault current in a power system. The two most commonly used types are the resistive type (rSFCL) and the inductive type (iSFCL). The study aims here to analyze the performance of SFCL using various switching algorithms when a fault occurs in a simple high voltage (HV) network.

Keywords: Power system, SFCL, faults, artificial intelligence.

I. INTRODUCTION

A fault current limiter (FCL) is a device that limits the probable fault current in the event of a fault. In general, fault current limiters are superconducting fault current limiters. A residual current limiter (FCL) limits the amount of current flowing through the system and allows continuous, uninterrupted operation of the electrical system, in the same way that surge protective devices limit currents that are harmful to household appliances.

A. Concept of a DC Resistive Type SFCL

One type of SFCL resistor directly uses the transition from the superconducting state to the normal state that a superconducting material (SC) shows when the transport current exceeds the critical value [1].

In practice it consists of a non-inductive winding consisting of a superconducting wire or strip connected in parallel to an external shunt, which can be resistive or inductive. The external shunt provides an alternating path for the current during the fault and thus reduces the Joule heating of the superconductor. An external resistive shunt is advantageous from the point of view of the power supply system, because it does not delay the zero crossing of current and does not reduce the transition stability of the network [2].

Usually, the non-inductive winding consists of a two-wire spiral or other arrangement of pancakes. A superconducting

channel, suitably cut on the surface to create a current path similar to that of a two-wire coil, can also be used to make a resistive SFCL [3].

To avoid the risk of hot spots, the superconductor must be in contact with a normally conductive matrix (as in the case of BSCCO and MgB₂ composite tapes or wires) or a branch layer (as in the case of conductors coated with YBCO or BSCCO tube). The role of the matrix or shunt layer is to promote uniform propagation of the quench; therefore, they have a high thermal and electrical conductivity.

Fig. 1: Circuit scheme of a resistive-type SFCL.

Figure 1 shows a circuit diagram of an SFCL-type resistor. Nonlinear resistance R_{SC} is given by the parallel equivalent of the superconductor and the normal conductive matrix or shunt layer. The presence of the low resistivity material allows only a low value of the equivalent resistance even after the complete transition [4].

The only way to get an appropriate value for the SFCL resistor is to increase the length of the superconductor. However, this leads to an increase in AC losses to unacceptable values for high voltage applications where a sufficiently high resistance is required to keep the fault current at an acceptable level [10,11].

An ideal rectifier of the SFCL type: it consists of a direct current source integrated in a diode bridge (see Fig. 1). 2 a).

Due to symmetry, the direct current I_0 is divided into two equal parts, which flow through the pairs of diodes D1-D3 and D2-D4. Now consider a positive iSFCL current through the device. Due to the fact that all diodes are forward biased, this current splits into two equal parts which flow through the diode pairs D1-D4 and D3-D2 respectively, thus bypassing the current source.

Fig. 2: Rectifier-type SFCL. (a) Conceptual rectifier-type SFCL. (b) Possible rectifier-type SFCL. (c) Practical rectifier-type SFCL.

The total voltage across the device is just given by the sum of the voltage drops across the diode pairs, which is negligible; therefore the SFCL has zero impedance.

In this situation diodes D1 and D2 carry a current i_{D1D2}

$$i_{D1D2} = I_0/2 + i_{SFCL}/2 ;$$

while diodes D3 and D4 carry a current i_{D3D4}

$$i_{D3D4} = I_0/2 - i_{SFCL}/2.$$

When the current of the iSFCL device tries to exceed the direct current I_0 , diodes D3 and D4 are reverse biased and cut the current. The direct current source is then connected in series to the protected circuit and maintains its current at the value I_0 . The SFCL behaves as an ideal current source with infinite equivalent impedance.

In principle, the inductance could also be implemented using an ohmic copper coil; However, it is possible to use a superconducting coil to avoid permanent losses. The circuit diagram of a more real SFCL type rectifier is shown in Figure 2 (b). Since the superconducting coil operates in direct current, the only losses are due to the thermal revenues of the power lines and the cryostat, and are considerably reduced compared to the SFCL type resistance. Also, the superconductor does not turn off as long as the current is limited. In fact, during a fault, there will be a small overcurrent with respect to the constant value I_0 in the coil. The recovery time of such a limiter is immediate. The practical difficulty of the SFCL type rectifier is the implementation of the DC voltage source [6]. To avoid this problem, the configuration without the DC voltage source shown in Fig. 2 (c) has been widely considered. There are some advantages to using these devices:

- SFCL is applied with the distribution generation
- SFCL reduce the level of short-circuit current during a fault.
- No external control s needed.
- Rapid response.
- SFCLs are invisible in normal operation and do not introduce unwanted side effects.
- SFCLs are economically competitive with expensive conventional solutions.
- Negligible loss during normal system operation [12].

B. Faults in grid system

An electrical grid (EPG) is a dynamic system based on four main operations: generation, transmission, distribution and control [5]. Technological developments over the past decade, notably through the increased use of information and communication technologies (ICT), have exposed EPGs to a whole new set of threats [7]. Like any system, an EPG is not completely error free. An error can occur anywhere on the network, including natural causes, operational errors, cyber-attacks, or physical attacks [8].

The errors that can occur at different levels of the system can be classified as follows:

1. Physical Device / Component Errors: These errors occur when a physical item is malfunctioning.
2. Communication errors: These errors occur in the communication devices / channels. Related to errors in physical connections or errors in establishing communication in a critical period of time.
3. Software / Hardware Errors: These errors occur when a control center component fails to execute a command and / or operation.

The new network system model should include the modeling and identification of actual network conditions, as well as the collection and processing of heterogeneous information from different information systems. Taking into account the classification models, network systems should be able to identify fault conditions using the decision function, which is interpreted as the reliability of the classification. The power grid failure model is of the utmost importance for distinguishing faults from standard operating states. Network and microgrid protection systems (μ Gs) take into account the Internet of Energy (IoE) concept, used for the operation and coordination of protection to maintain an efficient and dynamic infrastructure.

II. LITERATURE REVIEW

[1] This article examines the benefits of superconducting residual current limiters (FCLs), which are economically competitive compared to costly conventional solutions. Superconducting FCLs are invisible during normal operation and cause no unwanted side effects. The performance of a particular type of limiter, the Matrix Fault Current Limiter (MFCL), is shown, and examples are given of how it can solve fault current overload problems. The use of this device in a specific application on American Electric Power's 138 kV transmission grid (AEP) is also discussed.

[2] This document describes basic application guidelines for the use of superconducting residual current limiters in various power systems. To ensure safe and correct use of SFCLs, we also introduce some future considerations on the interaction between SFCLs and power systems. In power systems, superconducting residual current limiters (SFCLs) can limit expected short circuit currents to lower values so that undervalued switchgear can operate safely. This article provides a detailed theoretical analysis of how to improve power system stability using SFCL.

[3] Nexans Super Conductors have designed, built, tested and installed a number of these SFCL systems in different fields and operational cases with different requirements and specifications than the DNO or the power generation industry. Projects, tests and operational results are presented. The expected short circuit currents of the order of 50 kA have been limited to less than 10 kA depending on the design of the limiter. The limiters have demonstrated reliable operation in field tests, each lasting approximately one year.

[4] This article examines various concepts of SFCL and the research and technological development status of SFCL. SFCLs are not currently available for commercial applications in power systems, but field tests have recently been successfully completed.

III. PROBLEM FORMULATION

The demand for electricity is increasing with the arrival and creation of smart cities and Industry 4.0. Fault analysis is important for improving performance and minimizing interruptions in the intelligent power system. Detecting, locating and correcting faults at all levels of the fuel system is essential for the fuel system to continue to operate normally. This activity requires intelligent control in order to be able to work quickly and efficiently. This investigation covers various aspects of fault detection in network systems using SFCL. The aim is to indicate topics relevant to future development in order to bridge the gap between SFCL and future defect detection techniques, which may include AI-based detection and restriction.

IV. PROPOSED TECHNICAL METHOD

The methodology suggested the use of some AI-based algorithms to switch the SFCL device, which should result in a more efficient improvement of the transition stability of the power system for symmetrical and asymmetrical failures when using DC resistive SFCLs. Reduction of large voltage drops and high level of current in the power system model, thus reducing the power loss in the system, thus improving efficiency and reliability. Work should focus on comparing voltage and current situations without using SFCL, then on a system with an SFCL resistor type driven by an AI-based control algorithm to minimize fault current within a minimum time frame.

V. ARTIFICIAL INTELLIGENT CONTROLLER

Genetic algorithms, fuzzy logic, and neural networks are artificial intelligence-based digital computing techniques that are popular in the field of computing. However, more and more applications based on these new approaches to digital computing are developing for practical applications in science and technology.

Observers or estimators based on artificial intelligence techniques lead to better dynamics and accuracy and are more robust. Your deliveries are very good even with large deviations in the machine parameters. However, the need for perfect knowledge of the adjustment or estimation system and the lack of specialist knowledge of the system limits current applications to a very specific area.

VI. FUZZY LOGIC CONTROLLER

Fuzzy logic allows us to formulate mathematically inaccurate concepts and derive precise actions from fuzzy rules resulting from observations. The most common tool used in fuzzy logic applications is the fuzzy rule base. A fuzzy rule consists of three phases: fuzzification, inference and Defuzzification.

The fuzzy controller consists of two input variables, the error (e) and the error variation (de / dt), and an output variable. The error of the input variable results from the difference between the reference models with the actual rotor speed. The membership function for determining the input and output variables is determined based on the experience of the system failure [13].

VII. ARTIFICIAL NEURAL NETWORK

Neural modeling is chosen to circumvent the parametric variations of the mathematical model of the engine. First, the neural network is taken offline; In other words, the network elements are used after the application of all training pair data for a fixed network is complete.

The training is then carried out online so that the neural model can be adapted at any time. This type of training allows you to design adaptive control. The neural network can describe the behavior of a nonlinear dynamic system without having to know its parameters.

The neural network used for education has a multilayer structure with a hidden layer activated by the sigmoid function, while the output layer is activated by a linear function. Its programming is performed by a backward gradient propagation algorithm with an adaptive learning rate. The general principle of learning algorithms is based on the minimization of a quadratic cost function of the differences between the network outputs and the desired values.

Fig. 3 Neural architecture proposed for the implementation of controller.

Several other optimization and learning algorithms are associated with artificial intelligence techniques, which can be used in conjunction with the SFCL model for error detection and elimination.

VIII. CONCLUSION

For grid systems to function efficiently, it is important to understand the main types of power grid outages and the benefits of the production resources available in the system in the event of an outage. This article looks at different types of errors that can occur in the power system. The underlying fault management approaches offer various fault detection and localization techniques for intelligent grid systems using SFCL, which is controlled by artificial intelligence algorithms for rapid detection and elimination.

REFERENCES

- [1] Leonord Kolvalsy, Xing Youn, Alber Keri, Frank Beuara, "APPLICATION OF SUPERCONDUCTING FAULT CURRENT LIMITER IN ELECTRIC TRANSMISSION SYSTEM" superconductivity conference 2005 Germany.
- [2] Lin Ye, Liang Zhen Lin, and Klaus-Peter Juengst, APPLICATION STUDIES OF SUPERCONDUCTING FAULT CURRENT LIMITERS IN ELECTRIC POWER SYSTEMS, IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, Vol. 12, No. 1, March 2002.

- [3] Achim HOBL Steffen ELSCHNER Joachim BOCK, Simon KRÄMER Christian JÄNKE Judith SCHRÄMM, SUPERCONDUCTING FAULT CURRENT LIMITER – A NEW TOOL FOR FUTURE IN GRID. CIRED Workshop - Lisbon 29-30 May 2012 Paper 0296.
- [4] SUPERCONDUCTOR FAULT CURRENT LIMITER: A REVIEW by 1.R.A Desai, 2.M.R Bongale 3. H.T. Jadhay in 2012.
- [5] Fang, X.; Misra, S.; Xue, G.; Yang, D. Smart Grid—The New and Improved Power Grid: A Survey. IEEE Commun. Surv. Tutor. 2012, 14, 944–980. [CrossRef]
- [6] INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT: ISSN: 2278-0211 Vol2 Issue5, May 2013.
- [7] Hare, J.; Shi, X.; Gupta, S.; Bazzi, A. Fault diagnostics in smart micro-grids: A survey. Renew. Sustain. Energy Rev. 2016, 60, 1114–1124. [CrossRef]
- [8] Hosseini, S.; Barker, K.; Ramirez-Marquez, J.E. A review of definitions and measures of system resilience. Reliab. Eng. Syst. Saf. 2016, 145, 47–61. [CrossRef]
- [9] S. M. Mueen, R. Takahashi, M. H. Ali, T. Murata, and J. Tamura, "TRANSIENT STABILITY AUGMENTATION OF POWER SYSTEM INCLUDING WIND FARMS BY USING ECS," IEEE Trans. Power Syst., Vol. 23, No. 3, pp. 1179–1187, Aug. 2008.
- [10] M. Kayikci and J. V. Milanovic, "ASSESSING TRANSIENT RESPONSE OF DFIG-BASED WIND PLANTS-THE INFLUENCE OF MODEL SIMPLIFICATIONS AND PARAMETERS," IEEE Trans. Power Syst., Vol. 23, No. 2, pp. 545–554, May 2008.
- [11] L. Ye, M. Majoros, T. Coombs, and A. M. Campbell, "SYSTEM STUDIES OF THE SUPERCONDUCTING FAULT CURRENT LIMITER IN ELECTRICAL DISTRIBUTION GRID," IEEE Trans. Appl. Supercond., Vol. 17, No. 1, pp. 2339–2342, Jun. 2007.
- [12] Vaishnavi B V, Angelin Suji R S, Trivenishree D P, Nidha Nabi, Sowmya G J, "SUPERCONDUCTING FAULT CURRENT LIMITER & ITS APPLICATION", International Journal of Scientific & Engineering Research, Volume 7, Issue 5, May-2016