Fault analysis in High voltage line controlled by fault current limiter driven by various algorithms

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Abstract: *An increase in the power generation capacity of power supply systems has resulted in an increase in the fault current, which can exceed the maximum short-circuit resistance of the switchgear. The main objective of this study is to design a test system with redundant fault current limiters. This system is intended to be used to verify the various AI-based control algorithms for the operation of the relays. Reduce SFCL uptime and quickly identify fault currents to overcome their effects. The conclusion shows the effectiveness of the proposed optimization control based on CFO for the operation of the relay according to SFCL in the circuit. The first two test systems conclude that the system with SFCL reduces the rise in fault current and prevents the voltage from dropping to zero, although no AI-based technology is used and the operating time remains the same. . Technologies based on artificial intelligence further reduce uptime, making the system more efficient.*

Keywords: *SFCL, DG, CFO, PSO.*

I. Introduction

The increase in the power generation capacity of the power supply systems has resulted in an increase in the fault current level, which can exceed the maximum short-circuit values of the switchgear. Many conventional protective devices installed to protect against excessively high residual currents in electrical power plants, particularly in power plants, are circuit breakers, which are tripped by overcurrent protection relays. To overcome the high residual current, many types of residual current limiting devices have been used in the past decades. Current limiting fuses, series inductances and high resistance transformers were used. They have a response delay that allows two and three cycles of initial fault current to pass before they are activated. However, these alternatives can lead to other problems, such as loss of power system stability, high costs, and increased power dissipation, which can ultimately lead to reduced flexibility and reliability. Superconducting Residual Current Limiters (SFCL) are innovative electrical devices capable of reducing the residual current level during the first residual current cycle. SFCLs have zero impedance in the normal state and high impedance in the fault state. There are several types of SFCL used to limit current, for example: B. SFCL for the cure of saturated iron, inductive SFCL and resistive SFCL. Each type of SFCL has its advantages and disadvantages and can be implemented with low temperature superconductors (LTS) and high temperature superconductors (HTS). The SFCL saturated iron core uses LTS, with inductive SFCLs and resistive SFCLs typically developed by HTS. A high temperature superconducting fault current limiter (SFCL) can be a solution to reduce the short circuit current during a fault. SFCLs can make a significant contribution to increasing the safety and availability of power systems in power plants. According to experts, they also play an important role in expanding the power grid.

II. Literature Review

ArqumShahid et al. [1] This research analyzes the positioning of resistive SFCL and inductive SFCL in AC and DC microgrids (MG) in two different positions; at the integration point of the conventional source and the distributed generator (DG) and at the point where DG is added to the system. AC and DC microgrids contain industrial and residential loads while using their respective main source of wind and photovoltaic energy, as well as conventional electricity provided by the main grid.

A.Y.Hatata et al. [2] This document presents a new approach to the implementation of resistive superconducting residual current limiters (SFCL) with DG units in order to obtain an optimal regulation of the protection system. The protection coordination parameter is optimized by the Particle Swarm Optimization (PSO) technique. The proposed algorithm is tested on a power distribution system with nine bus lines and the effects of SFCL on the connected DG network protection system are analyzed.

Vaishnavi B V et al. [3] In this article, the concept of superconducting fault current limiter (SFCL) features two types of superconducting materials. First, the resistive SFCL (which is connected directly in series with the circuit to be protected). Second, the inductive SFCL (a transformer shorted by a superconducting tube). We are also exploring some of the proposed uses of SFCLs to limit the leakage current that occurs in the electrical system. The fault current level has become a serious problem in the operation of transmission and distribution networks.

O.Mahesh et al. [4] In this thesis, a superconducting fault current limiter is proposed to protect the energy storage system in a micro-grid. Decentralized generation (DG) in the form of renewable electricity generation systems is currently preferred for the production of clean electricity. However, with the unpredictable type of production, an energy storage system is integrated into the grid. Energy storage devices must be used to ensure that the load is always covered. Energy storage systems (ESS) are fundamental technologies for new and consolidated applications such as B. Compensation of power peaks, stability objectives, integration of renewable energies.

III. Objective

This thesis will target on the following main objectives:

- Designing of test system comprising of superfluous fault current limiter. This system shall be used to check the different AI based control algorithms on relay operation.
- The coordination and control of the relay based in accordance with the SFCL operation by using an efficient artificial based technique.
- To reduce the operating time of sfcl and senses the fault current quickly to overcome its effects.
- The comparative study shall conclude the effectiveness of AI based optimization algorithms in the coordination control of the relay based SFCL on the high tension line.

IV. Methodology

The increase in the power generation capacity of the power supply systems has resulted in an increase in the fault current level, which can exceed the maximum short-circuit values of the switchgear. Many conventional protective devices installed to protect against excessively high residual currents in electrical power plants, particularly in power plants, are circuit breakers, which are tripped by overcurrent protection relays.

Superconducting Fault Current Limiter (SFCL) is an innovative electrical device capable of reducing the fault current level during the first fault current cycle. The application of the residual current limiter (FCL) would not only reduce the load on the network equipment, but could also provide a link to improve the reliability of the power system. A superconducting residual current limiter (SFCL) in series with a downstream circuit breaker could represent a practical solution for controlling the residual current level in power distribution networks. To integrate SFCL into power grids, we need a way to conveniently predict SFCL performance in a given scenario.

In our work we have also designed a test system where SFCL is handled cordially with a circuit breaker and relay circuit. The various algorithms based on artificial intelligence are tested to predict the trip time of the switch and the SFCL. This chapter describes the different methods used for its tests and thus how the SFCL is finally installed on an IEEE 9 bus system for the cooperative operation of various relay circuits.

A. 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 [3].

In practice it is a non-inductive winding consisting of a superconducting wire or tape which is connected in parallel to an external shunt, which can be ohmic or inductive. In the event of a fault, the external shunt offers an alternating path for the current and thus reduces the Joule heating of the superconductor. An ohmic external shunt is advantageous from the point of view of the electrical network, because it does not delay the zero crossing of the current and does not reduce the transient stability of the network.

Usually, the non-inductive winding consists of a two-wire helical coil or an alternating arrangement of pancakes. Additionally, a properly cut surface superconducting bulk tube can be used to create a current path equivalent to that of a two-wire coil to create a resistive SFCL.

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

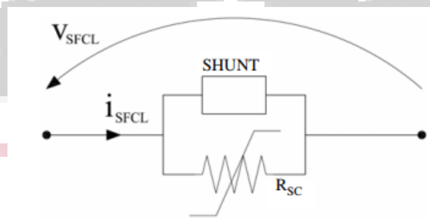

Fig. 1 Circuit scheme of a resistive-type SFCL.

A circuit diagram of an SFCL resistor is shown in Fig. 1. The non-linear resistance RSC 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 a complete transition.

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 prohibitive levels for high voltage applications where a sufficiently high resistance is required to keep the fault current at an acceptable level.

B. PSO algorithm

PSO Particle Swarm Optimization is a new swarm optimization algorithm originally proposed by Kennedy as an evolutionary algorithm based on bird behavior. PSO uses a set of particles, each of which suggests a solution to the optimization problem. It is based on the success of all particles emulating a population, the position of each particle depends on the position of the agent, to determine the best Pbest solution using the actual particles of the population G. The position of each particle xi is around,

$$x_i^{k=1} = x_i^k + v_i \qquad (3.1)$$

where the velocity component vi represents the step size and is calculated by:

$$v_i^k = wv_i^k + c_1 r_1 \left(P_{best_i} - x_i^k\right) + c_2 r_2 (G - x_i^k) \qquad (3.2)$$

where x is the weight of inertia, c1 and c2 are the acceleration coefficients, r1 and r2 are random values belonging to the interval of [0, 1], Pbest_ii is the best position of the particle i and G is the best position in l ' entire population.
The operation shown in the flowchart can be analyzed in five steps, namely initialization, assessment of suitability, updating of individual and overall bests, updating of the speed and position of each particle, and determination of convergence. In the first step, the particles are randomly initialized in the distribution space or initialized on the described grid nodes that extend into the search space.

Likewise, the initial speed values are set randomly.

The fitness value of each particle is evaluated in the second phase, in which the fitness evaluation is performed in order to provide a candidate solution for the objective function. In the third step, the best individual and overall fitness values are determined, with p_{best}_ian and g_{best} determined in each case.

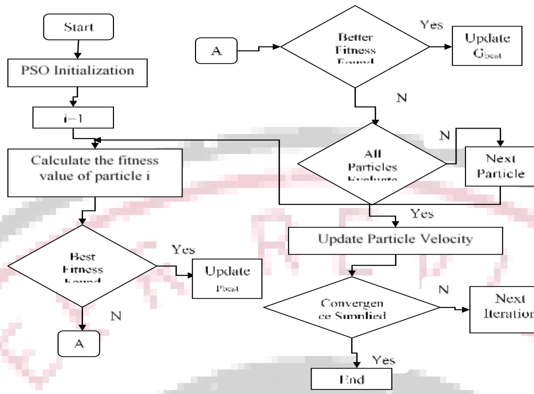

Fig. 2 PSO- controller Technique implemented in MATLAB/SIMULINK

Then the positions are updated and replaced with better fitness values when they are found. In the fourth step, the speed and position of each particle are updated. The last step of the flowchart checks the convergence criterion. If the criterion is met, the process is complete. Otherwise the iteration number is incremented and the process returns to step 2.

C. CFO Algorithm.

CS is based on the parasitism of the brood of some species of cuckoo. Furthermore, this algorithm is extended by the so-called Levy flights and not by simple isotropic random walks. Recent studies show that CS is potentially much more effective than PSO and GA.

Cuckoos lay eggs in the nests of other host birds (usually other species) with amazing skills such as selecting nests with recently laid eggs and removing existing eggs to increase the likelihood of their own eggs hatching. . Some of the host birds are able to combat this parasitic cuckoo behavior and lay foreign eggs that find or build a new nest in a certain location. This cuckoo breeding analogy is used to develop the CS algorithm. Yang and Deb [39] have simplified the cuckoo breeding process into three idealized rules.

(1) An egg is a solution and is kept in a nest. An artificial cuckoo can only lay one egg at a time.

(2) The cuckoo searches for the most suitable nest to lay eggs (solution) in order to maximize the survival rate of its eggs. An elite breeding strategy is used so that only high quality eggs (best solutions close to optimal value) that most closely resemble host bird eggs have the opportunity to develop (next generation) and become adult cuckoos.

(3) The number of host nests (population) is fixed. The host bird can discover the foreign egg (worse solutions beyond the optimal value) with a probability of p_a [0, 1] and these eggs are discarded or the nest is abandoned and a completely new nest is built. a new location. Otherwise, the egg will mature and live until the next generation. The new eggs (solutions) laid by a cuckoo choose the Levy Flights nest to obtain the "best current solutions".

From the implementation point of view, in the CS operation, a population, $E^k\{e_1^k, e_2^k, e_3^k \dots \dots \dots \dots e_N^k\}$ of N eggs (individuals) is evolved from the initial point (k=0) to a total gen number iterations (k=2. gen). Each egg, e_i^k (i ∈ [1, . . . , N]), represents an n-dimensional vector, $\{e_{i,1}^k, e_{i,2}^k, e_{i,3}^k \dots \dots \dots \dots e_{i,n}^k\}$, where each dimension corresponds to a decision variable of optimization problem to be solved. The quality of each egg, e_i^k (candidate solution), is evaluated by using an objective function, $f(e_i^k)$, whose final result represents the fitness value of e_i^k.Three different operators define the evolution process of CS: (A) Levy flight, (B) replacement of some nests by ´ constructing new solutions, and (C) elitist selection strategy.

Levy Flight (A). ´ One of the most powerful features of cuckoo search is the use of Levy flights to generate new ´ candidate solutions (eggs). Under this approach, a new candidate solution, e_i^{k+1} (∈ [1, . . . , N), is produced by perturbing the current e_i^k with a change of position c_i. In order to obtain c_i, a random step, s_i, is generated by a symmetric Levy distribution. For producing ´ s_i, Mantegna's algorithm is employed as follows:

$$S_i = \frac{u}{|v|^{1/\beta}}$$

where $u(u_1......u_n)$ and $v(v_1..........v_n)$ are n-dimensional vectors and β = 3/2. Each element of u and v is calculated by considering the following normal distributions:

$$u \sim N(0, \sigma_u^2), \qquad V \sim N(0, \sigma_v^2)$$

$$\sigma u = \left(\frac{\Gamma(1+\beta).\sin(\pi.\beta/2)}{\frac{\Gamma(1+\beta)}{2}.\beta.2^{(1+\beta)/2}}\right)$$

where Γ(·) represents the gamma distribution. Once s_i has been calculated, the required change of position c_i is computed as follows:

$$C_i = 0.01.S_i + (e_i^k - e^{best})$$

where the product ⊕ denotes entrywise multiplications whereas e^{best} is the best solution (egg) seen so far in terms of its fitness value. Finally, the new candidate solution, e_i^{k+1}, is calculated by using

$$e_i^{k+1} = e_i^k + c_i$$

Replacement of Some Nests by Constructing New Solutions (B). Under this operation, a set of individuals (eggs) are probabilistically selected and replaced with a new value. Each individual, e_i^k (i∈ [1, . . . ,N]), can be selected with a probability of p_a∈ [0, 1]. In order to implement this operation, a uniform random number, r_1, is generated within the range [0, 1]. If r_1 is less than p_a, the individual e_i^k is selected and modified according to (5). Otherwise, e_i^k remains without change. This operation can be resumed by the following model:

$$e_i^{k+1} = \begin{cases} e_i^k + rand.(e_{d_i}^k - e_{d_2}^k) & with\ probability\ p_\alpha \\ e_i^k & with\ probability\ (1-p_\alpha) \end{cases}$$

where rand is a random number normally distributed, whereas d_1 and d_2 are random integers from 1 to N.

Elitist Selection Strategy (C). After producing e_i^{k+1} either by operator A or by operator B, it must be compared with its past value e_i^k. If the fitness value of e_i^{k+1} is better than e_i^k, then $e_i^{k+1}$is accepted as the final solution. Otherwise, $e_i^k$is retained. This procedure can be resumed by the following statement:

$$e_i^{k+1} = \begin{cases} e_i^{k+1}, & if\ f\left(e_i^{k+1}\right) < f(e_i^k) \\ e_i^k, & otherwise \end{cases}$$

This elite breeding strategy requires that only high-quality eggs (best solutions near optimal value) that are most similar to the host bird's eggs have a chance to develop (next generation) and become mature cuckoos.

cuckoos search (cs) algorithm

(1) input: p_α N and gen
(2) initialize E^0 (k=0)

(3) until (k=2, gen)
(4) $E^{k=1} \leftarrow$ Operator A(E^{K})
(5) $E^{k=1} \leftarrow$ Operator A(E^{K}, E^{K+1})
(6) $E^{k=2} \leftarrow$ Operator A(E^{K+1})
(7) $E^{k=1} \leftarrow$ Operator A(E^{K+1}, E^{K+2})
(8) end until

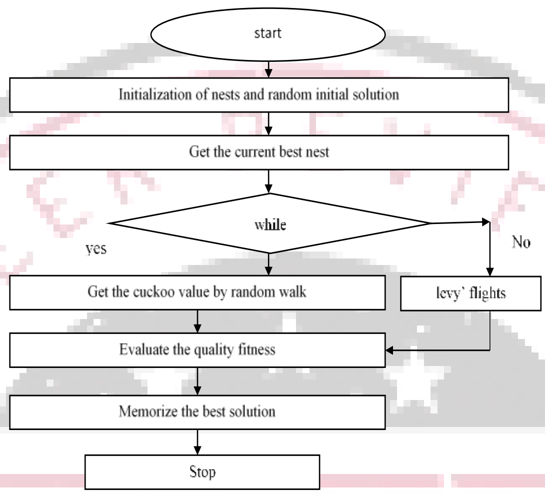

Fig. 3 Cuckoo algorithm implementation for fault current detection and elimination flow chart

CS is a relatively simple algorithm with only three adjustable parameters: pa, population size, N and the number of gen generations. The convergence rate of the algorithm is not strongly influenced by the value of p_a and it is recommended that p_a = 0.05 to 0 To use 25. The CS operation is divided into two parts: the initialization and the evolutionary process. On initialization (k=0), the first population,$E^{0}\{e_1^0, e_2^0, e_3^0 \dots \dots \dots e_N^0\}$, is produced. The values, $\{e_{i,1}^0, e_{i,2}^0, e_{i,3}^0 \dots \dots \dots \dots e_{i,n}^0\}$ of each individual,e_i^k , are randomly and uniformly distributed between the prespecified lower initial parameter bound, b_j^{low}, and the upper initial parameter bound, , b_j^{high}. One has

$$e_{i,1}^0 = b_j^{low} + rand.(b_j^{high} - b_j^{low})$$

i= 1,2……., N; j= 1,2…..n

In the process of evolution, operators A (Levy Flight), B (replacement of some nests by building new solutions) and C (elite selection strategy) are used iteratively until reaching the number of iterations k = 2. gen. The complete SC procedure is illustrated in algorithm 1. From algorithm 1, it is important to note that the elite selection strategy (C) is used twice immediately after the execution of operator A or operator B.

V. Results

The section discusses the work on the basis of following few descriptions:
CASE 1: Test system study without using SFCL
CASE 2: Test system study with SFCL in line and no AI operation.
CASE 3: Test system study with SFCL in line and PSO based AI operation and control.
CASE 4: Test system modeled with SFCL and Relay circuit with CFO technique.
The relay-based SFCL-MATLAB / SIMULINK model takes care of the relay circuit response and SFCL power dissipation when the error occurs. The proposed system with ACO-based control of the relay to detect the fault current

should give the best result, namely the dissipation of the current and the restoration of normal operation in a short period of time when the system is exposed to temporary instability.

To test the operation of the SFCL in the three-phase circuit, a test system was initially created.

The simulation time is set to 1 second for testing purposes. The three-phase fault is generated 0.05 seconds after the start of the simulation.

The circuit consists of a relay circuit and a circuit breaker. This switch should work when the fault occurs to remove the load and protect it from the effects of the large current flow that persists during the fault. The system is tested for its transient stability before being integrated into an SFCL model.

The response of the system to the fault and its ability to recover from it is first examined in CAS 1. Then the system is used with the SFCL to reduce the leakage current in the Rsh of the SFCL, as well as an algorithm is designed to coordinate its operation with the relay switch circuit so that it eliminates the effects of the system within a minimum time interval of an error. The entire system is simulated for 1 second in a MATLAB / Simulink environment for analysis.

5.3 Study of the CAS 1 test system without SFCL

In this case, the test system is independent of the SFCL devices and algorithms. The system relay is activated after a high current flow is detected in the circuit during the fault condition. The circuit breaker disconnects the load from the mains. The system is examined for its ability to automatically correct the error.

The voltage output and current output curves are analyzed in the following figures.

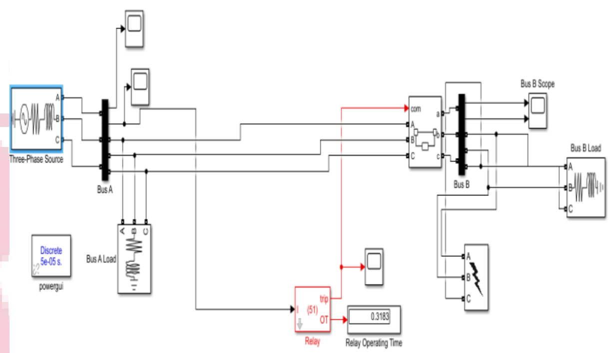

Fig. 4Test system without any SFCL for limiting the fault current

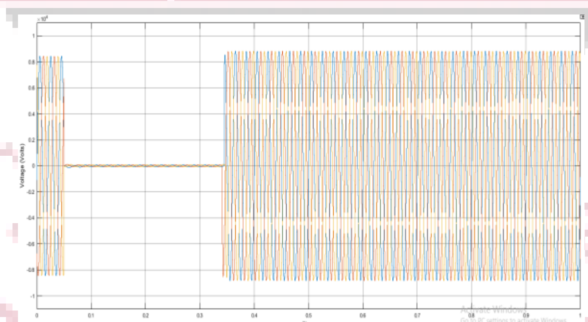

Fig. 5 Voltage at the line in test system with fault having no SFCL control

The figure shows the voltage output of the test system without SFCL. When the fault occurs, the voltage is reduced from 9 KV to 0 volts zero. This completely isolates the power from the system. To solve this problem, we used sfcl in the following models. Sudden disconnection of sources from the network is highly undesirable. A transient voltage stability scheme based on a superconducting residual current limiter (SFCL) is presented for use in wind farms driven by a dual-power induction generator (DFIG) during mains failures.

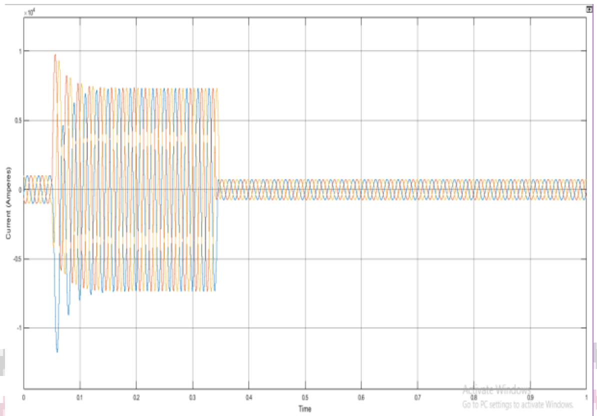

Fig. 6 Current at the line in test system with fault having no SFCL control

The figure shows the current system output without SFCL. If the system is powered up for a full second and the error is generated in the test system after 0.05 seconds, we see that the current rises to a high value of around 6000 amps. The system's ability to clear this fault current is 0.3183 seconds, which means that after this relay run time, the system will be able to recover from the fault. The current is reduced again to about 80 amps.

CASE 2: system study with SFCL in line and no AI operation.

In this system, the source is connected to the load via a superfluous residual current limiter (SFCL). The relay switch is used to protect the load from the effects of high current in the event of a fault. The error is generated at 0.05 seconds while the simulation of the test system runs for one second.

The system's ability to recover from an error is the same as that of the test system where sfcl is not used. With this device, however, a sudden interruption of the mains power can be avoided.

To study the effect of sfcl in a system, the voltage output and current output waveforms are analyzed below,

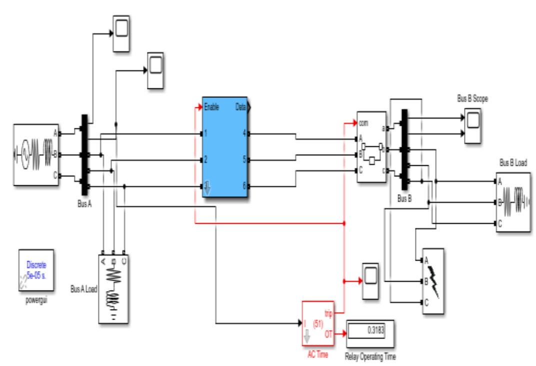

Fig. 7 Test system with SFCL in line

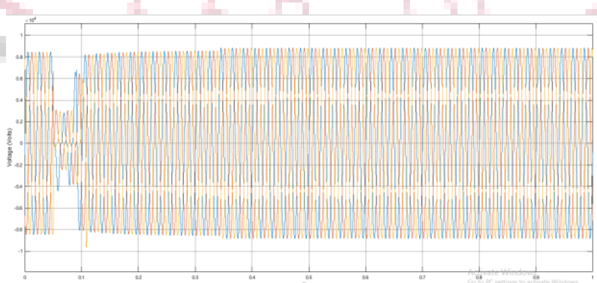

Fig. 8 Voltage variation at the line in test system having SFCL/breaker control without AI optimization

The figure shows the system output voltage where no AI-based technology is used for the relay, but sfcl is used in the circuit. When the fault occurs, the voltage value drops sharply, but in a very short time it begins to recover, because during this time the current in Rsh is diverted from sfcl. When the fault current is reduced by 0.3183 seconds, the system will resume normal operation.

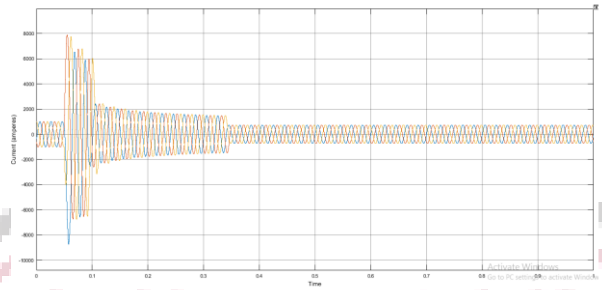

Fig. 9 Current at the line in test system having SFCL/breaker control without AI optimization

The figure shows the waveform of the current output in the system with SFCL but without AI-based control technology for relay circuit coordination control. It is observed that the current rises to 6000 amps after 0.05 seconds when the fault is generated. This large current then passes through the Rsh of the sfcl and therefore its value gradually decreases. After an operating time of 0.3183 seconds, the system finally resumes normal operation and the current reaches around 80 Amps again.

From this model it is concluded that the operating time of the test system in case 1 and that of the test system in case to are the same in sfkl. This model shows the advantage of using ansfcl in the grid system. Even if no AI technology is used, it is still a better choice to prevent the system from being disconnected from the source during the outage.

5.5 CASE 3: Test system study with SFCL in line and PSO based AI operation and control.

The proposed method uses Particle Swarm Optimization (PSO), an algorithm for finding optimal parameters to improve relay detection time and SFCL dissipation. The technology takes the input fault current and optimizes the time by generating a duty cycle for the operation of the SFCL. The voltage should recover from the fault in less time than in the previous case, which is generated at 0.05 seconds when the system is simulated for 1 second.

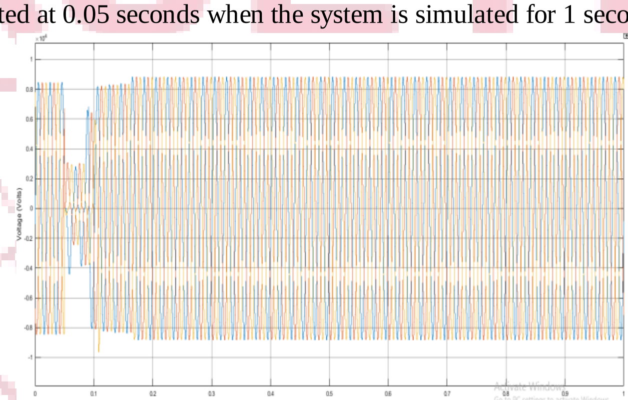

Fig. 10 Voltage at the line in test system having SFCL/breaker control with PSO

The figure shows the system output voltage with a relay that is controlled with the particle swarm optimization technique for its coordination control and also improves the sensitivity of fault current detection. It was found that the use of sfcl does not reduce the voltage to zero during the fault current and improves the transient stability of the system since it is able to recover from the fault in 0.1584 seconds**.**

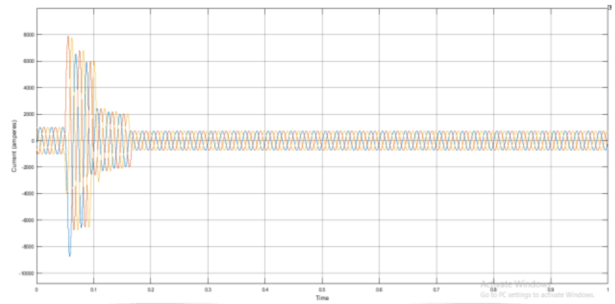

Fig. 11 Current at the line in test system having SFCL/breaker control with PSO

The figure shows the current system output with a PSO-based control. Electricity prices have been found to reach 6000A at 0.05 seconds when the fault is generated. However, the current dissipation occurs in the sfcl and the system returns to normal operation in a short time at 0.1584 seconds.

CASE 4: Test system modeled with SFCL and Relay circuit with CFO technique.

This system uses a CFO-based optimization technique for its relay-based operation. In this model, sfcl is used for current dissipation during the failure time. In this system, the path is also generated at 0.05 seconds, which is degraded in a small interval at 0.1158 seconds when a CFO optimization technique is used for relay operation. The technique detects the fault current and optimizes the output by reducing the operating time for discharging the fault current in sfcl. The post-optimization technique creates a duty cycle that runs SFCL and directs the power to it.

This allows a reduction of the operating time and therefore we can restore the voltage of the error situation in a short time. Therefore, the response of the system to transient failure is improved by using this optimization technique in the relay circuit.

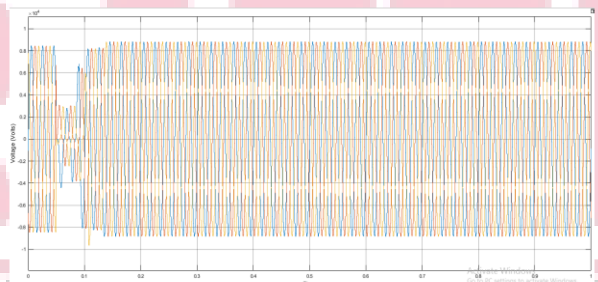

Fig. 12 Voltage variation at the line in test system having SFCL/breaker control with CFO

The figure above shows the output voltage of the proposed technique to optimize cuckoo flakes (CFO) for relay operation. The system voltage is assigned 0.05 seconds when the fault is generated and begins to slowly increase as the current in the sfcl is diverted. With this technique, if the whole system works for 1 second, the whole process happens in a small interval of 0.1158 seconds.

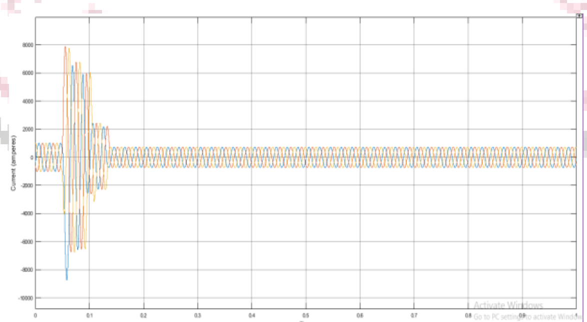

Figure 5.10 Current at the line in test system having SFCL/breaker control with CFO

The figure shows the current output of the CFO-based optimization control system for operating the relay in this state. It has been shown that it takes approximately 0.1158 seconds to clear the error from the system. The current rises to a higher value at 0.05 seconds, where the error is generated, and is reduced in the SFCL in a very short time thanks to this technology.

From this it can be concluded that it is very important to use SFCL in a good system to avoid sudden voltage drops of the sources during blackouts. The fault current is routed to the SFCL to be diverted there and the voltage returns to its normal value. However, if the relay switch control is subject to an AI-based technique that detects the fault current, the operating time of the SFCL and relay circuit will also be reduced. During our research, it was found that the proposed optimization technique based on cuckoo flakes is best suited for controlling the coordination of SFCL-based relays and circuits.

VI. Conclusion

The residual current levels of a composite power grid have generally increased due to the growing demand for electricity. This increase in fault current, if not adequately attenuated, can exceed the maximum rated values of the switchgear. Superconducting Residual Current Limiter (SFCL) is a flexible alternative to using conventional protective devices due to its efficient options for reducing residual current in the first residual current cycle, low weight and zero impedance during normal operation.

Here we offer resistive SFCLs when a fault occurs in a simple high voltage (HV) network. To assess the impact of SFCL in the electrical system under study, a time domain approach is used to evaluate the short circuit current in the electrical system and artificial control techniques are suggested to achieve the goal.

The work led to experiments on a test system and examined the effects of SFCL on it by modifying control algorithms for fast detection and attenuation of fault currents in the relay circuit.

The following table concludes the work of the AI based techniques

Test System and Control algorithms	**Operating time** { seconds }
without SFCL	0.3183
with SFCL but without AI technique	0.3183
with SFCL and with PSO technique	0.1584
with SFCL and with proposed CFO technique	0.1158

The above results complement the effectiveness of the proposed CFO-based optimization control for the operation of the relay according to SFCL in the circuit. The first two test systems conclude that the system with SFCL reduces and increases the fault current and prevents the voltage from dropping to zero even if no AI-based technology is used and the operating time remains the same. AI-based techniques further reduce the operating time, which also makes the system more efficient, as the voltage is restored to its normal value in a short amount of time when the test system is simulated for 1 second in a MATLAB environment / SIMULINK.

VII. Future Scope

Of course, the new SFCL type with a different architecture is still under development. The work can be further integrated with different SFCL circuit architectures and their operation can be examined in these SFCLs. The use of fast switching forced switching devices such as IGBTs with variable resistance shunts can greatly improve system performance under abnormal conditions. Furthermore, the improvement of this design can lead to better performance and also make this system suitable for low voltage driving via LVRT.

VIII. Reference

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