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A Novel Hybrid Fuzzy Logic Controller based RFLC for fault limiting in Transmission Networks and it's Dynamic Analysis

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Abstract

The introduction of the resonant fault current limiter (RFCL), which is based on fuzzy logic, is examined in the abstract. The fuzzy logic controller responds quickly and keeps errors close to zero. The ability of fuzzy can improves the stability of the system. According to the study's findings, RFCLs are useful tools for lowering the currents caused by failures in bulk power systems. Compared to a traditional PI controller-based RFCL network, the fuzzy logic controller-based RFCL transmission network has improved transient stability and dynamic stability. The MATLAB/Simulated software environment is used to test and assess the fuzzy system that is proposed.

Key word

Fuzzy logic controllers, transmission networks, fault analysis, network compression, RFLC, and stability are some relevant keywords.

INTRODUCTION

The demand for electricity has been rising dramatically, and many nations are spending a lot of money to ensure a steady supply. The construction of more generation facilities and transmission links led to the complexity of the power networks increasing. Large-scale generation facilities and long-distance major transmission lines are both common. More transmission lines must be connected in order to handle higher loads. But those features of power systems have been contributing to issues with fault currents and system stability. In the distribution and transmission sections, a number of strategies are being tried to address the fault current issues. Analysis of fault current and stability has been investigated independently since network configuration affects both issues in the other direction. Fully meshing transmission systems tend to produce fault current issues rather than stability issues. On the other hand, stability issues rather than fault current issues may surface when power is transmitted through high impedance transmission lines. However, those two issues coexist as power systems get more intricate thanks to mesh transmission networks that are connected by long-distance, high-power transmission lines. As a result, countermeasures to cope with the fault current have a greater impact than before on the stability of the power system. Future power systems will be significantly impacted by the importance of employing sustainable energy sources, which has already boosted the use of distributed generation (DG), microgrids, DC systems, and power electronic gadgets. These advancements increase the variety of electrical sources and loads, complicating system control and protection. In many cases, fault current levels will rise in order to accommodate these fundamental changes in future power systems. For instance, both grid and isolated networks need to be resilient against blackouts. This could be necessary among other things because greater electrical network interconnection typically results in higher fault current levels.

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The linking of DG can potentially drastically worsen coordination between protective systems and raise fault levels. Furthermore, power-dense marine vessel and aviation power systems have naturally high fault current levels. Operating a safe network safely in systems with a high fault level is quite difficult. Power system malfunctions have the potential to seriously harm both people and the equipment directly affected by the problem as well as any equipment transporting fault current. Higher fault currents result in higher circuit breaker expenses, hence circuit breakers must be rated to clear faults for a specific system fault current level. The use of fault current limiting in electrical systems is a crucial remedy for these problems. Normal power system functioning is normally not impacted by fault current limiter (FCL) devices, but they quickly take action to reduce destructive and other unfavourable impacts brought on by power system faults.

RFLC DESIGN AND FUNCTION

One of the three stages of an RFCL's structure is shown in Fig. 1. To reduce the impact of the RFCL during usual activity, the design thunderous circuit consists of a current-limiting reactor and a full capacitor that are adjusted to the needed frequency of the power network. A small amount of stage movement is inevitable because it is very impossible to perfectly tune a resounding circuit. The diagram depicts a metal-oxide varistor, a bypass switch, and a thyristor-controlled bypass circuit in parallel to the capacitor. The thyristor valves are turned on and the current switches from the capacitor to the bypass circuit when a short-circuit fault is identified. In this manner, the RFCL's impedance quickly shifts from almost 0 (under normal operation) to the impedance of the reactor, maintaining the advancement of a large blame current. By comparing a part of the line current where the RFCL is located with a predetermined edge esteem, the cause is identified. On the other hand, it is possible to identify a fault using a combination of the current greatness, its pace of progress, and the duration of their occurrence. In contrast to conventional thyristors, a string of direct light activated thyristors used in the bypass circuit work in conjunction with a release current-limiting reactor and a damping resistor (see Fig. 3.1). These thyristor valves have a high ability during turn-on and are more likely to function at their maximum capacity with a simpler activating circuit. The design of the bypass circuit aims to reduce motions of the release current while performing the bypass work as well as to limit the pace of progress of the release current and its maximum incentive after activating the thyristor valves. After a defect is detected, the bypass circuit keeps running the current.

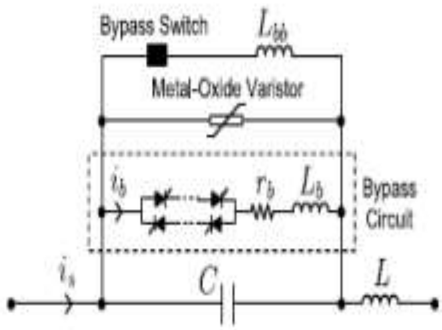


Fig-1. Design of a single phase RFLC.

When the fault is cleared by a successful tripping of the CB located near the fault location, the firing pulses of the thyristor valves are suppressed, and the capacitor is inserted into the circuit and, thus, the RFCL impedance reduces to zero. If the capacitor is required to remain bypassed for a longer period of time after the inception of the fault, then the bypass switch can be used to commutate the current from the bypass circuit. The inductor limits the rate of current commutation to the bypass switch. Also, the varistor should be properly rated to protect the capacitoragainst transient over voltages, whenever the capacitor is not bypassed. The IEEE nine-bus test power system, whose data are given, is illustrated in

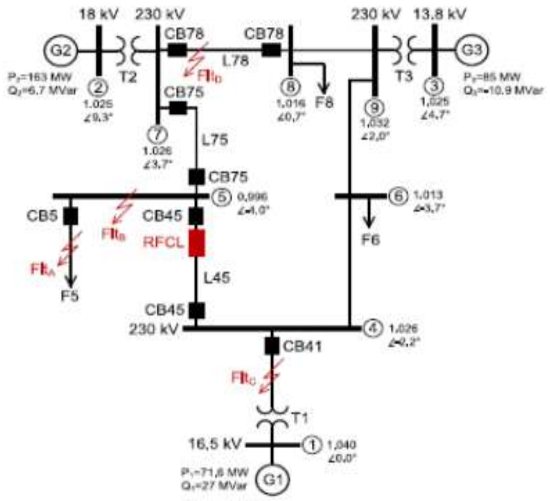


Fig. 2. Test power system with an RFCL inserted between bus 5 and 4

In a same vein, suppose bus 5's breakers CB45 are rated for a 3LG solid fault (labeled as FltB). The addition of generation at bus 1, for instance, in response to the installation of loads at bus 4 or the growth of load at feeder F5, can prevent the breakers from interrupting the fault current if the interrupting capability of each of the aforementioned breakers is only marginally greater than the current that flows through it due to a fault at feeder F5 (for CB5) or bus 5 (for CB45). In order to limit the current via the line in the event of faults and striking the system, the breakers must either be replaced or, as an alternative, an RFCL can be connected in series with line L45, as shown in Fig. 2. As a result, the current through breakers CB45 (for fault B) and, subsequently, breaker CB5 (for fault A), is reduced, with the RFCL having little effect during normal operation.

DESIGN RFCL

The method used to design the components of an RFCL is described in this work along with Fig. 3.2. Assume that feeder F5 has a three-phase-to-ground (3LG) solid fault and that breaker CB5 is appropriately rated for it (labeled as FltA).

Analytical analysis and iterative numerical simulations are used to evaluate its transient operation in a host power system. Therefore, a more efficient and quicker design process can be achieved by using an equivalent network of the overall power system, starting from the RFCL's location, that accurately reproduces, during the time period of interest, the same instantaneous values of voltages and currents as those in the overall system. As soon as a defect is identified, which happens within a quarter cycle after the fault strikes the system, the bypass circuits in the three stages of the RFCL in Fig. 3.2 are activated. After that, the resonant capacitors' current through line L45 is switched over to the bypass circuits. Therefore, the equivalent network must reproduce a steady state current through line L45, similar to that in the overall system, before the occurrence of the fault and must also emulate the instantaneous line current for a quarter cycle after the strike of the fault in order to capture the transient voltage and current stresses in the bypass circuits.

Reactor With Limited Current

The value of the current-limiting reactor can be determined by solving the following equation, using the equivalent network's parameters and the desired amount of line current reduction, in order to reduce the current through line L45 for faults FltA and FltB below its value in the case without RFCL:

$$r_t^2 + (x_t + \omega_0 L)^2 = \left(\frac{|\overrightarrow{v_{re4}}|}{k|\overrightarrow{i_{sc}}|} \right)^2$$

Bypass Circuit Design

When a problem is found, the bypass circuit's thyristor valves are activated, which causes current to begin flowing from the resonant capacitor into the bypass circuit. Along with the fault current, there is also a discharge current flowing through the bypass circuit. Since the allowable maximum values for the discharge current and its peak instantaneous value are dictated by the current withstanding ratings of the valves, the bypass circuit's components should be built to keep these values below those limits. The bypass valves are activated at the highest feasible instantaneous voltage across a resonant capacitor, which is also equivalent to the protection level voltage of the varistor, to produce the highest rate of change of discharge current. Additionally, when the valves are triggered, the reactor regulates the initial rate of change of the discharge current.

Varistors' capacity to absorb energy

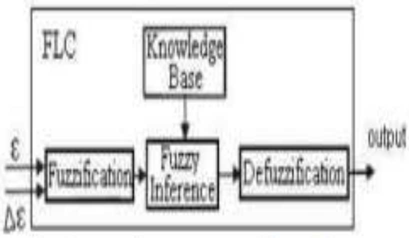
The parallel varistors of the resonant capacitors are necessary to shield the capacitors from transient overvoltages by absorbing the excess energy because, as was already indicated, the resonant capacitors are not bypassed during the transient time periods after the striking of faults. Additionally, the varistors shield the resonant capacitors as they are inserted into the line after being bypassed in reaction to the fault. As a result, it is preferred to insert the capacitor in line L45 when the fault is resolved by opening breaker CB5 in order to compensate the reactor and prevent a reduction in the line L45's maximum power transfer capacity. By integrating the product of the current through the varistor and the voltage across its terminals across time, it is possible to determine how much energy a varistor absorbs over a transient time period. The system's time-domain simulation can then be used to achieve this. Since the varistors in this study are considered to have a perfect volt–ampere characteristic, the voltages across the capacitors are restricted even as additional current is passed via the varistors.

CONTROLLER SCHEME FOR FUZZ

Because it can only calculate the error signal's instantaneous value without taking into account the error's rise and fall, which is represented mathematically by the derivative of the error denoted by, the disadvantage of the PI controller is its inability to respond to abrupt changes in the error signal,. Fuzzy logic control, as it is depicted in Fig. 3, is suggested as a solution to this issue. An inference engine with a rule base that contains if-then rules in the form of tables determines the output control signal. I FLC stipulations.

ε /Δε	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

"IF ε is .... AND Δε is ...., THEN output is ...."



With the rule base, the value of the output is changed according to the value of the error signal ε, and the rate-oferror Δε. The structure and determination of the rule base is done using trial-and-error methods and is also done through experimentation. All the variables' fuzzy subsets for the inputs ε and Δε are defined as (NB, NM, NS, Z, PS, PM, PB). The fuzzy control rule is illustrated in the table I.

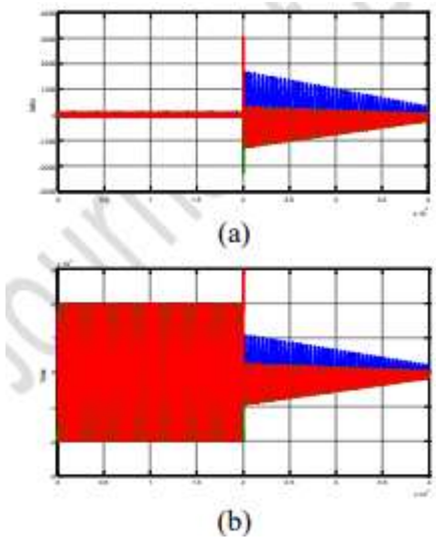


Fig. 4. Responses of the nine-bus system (left column) and its equivalent network (right column) to the strike of fault FltAwith an RFCL in line L45.

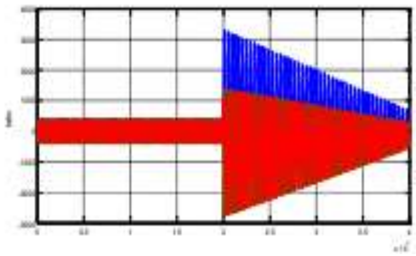


Fig. 5. Instantaneous currents through breaker CB5 in the nine-bus system (left column) and its equivalent network (right column) with the RFCL in line L45.

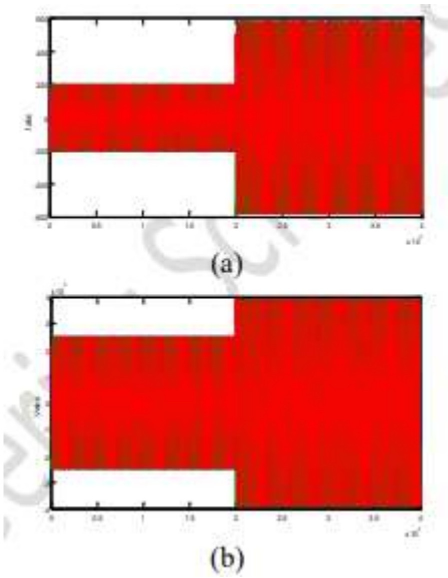


Fig. 6. Responses of the nine-bus system (left column) and its equivalent network (right column) to a 3LG fault at and bus 7, respectively FltD (a) Line currents. (b) Capacitor voltages

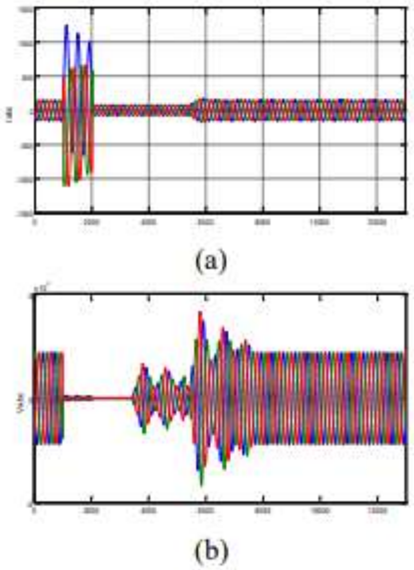


Fig.7. Responses of the nine-bus system subsequent to the strike of fault FltA.(a) Line currents. (b) Capacitor voltages.

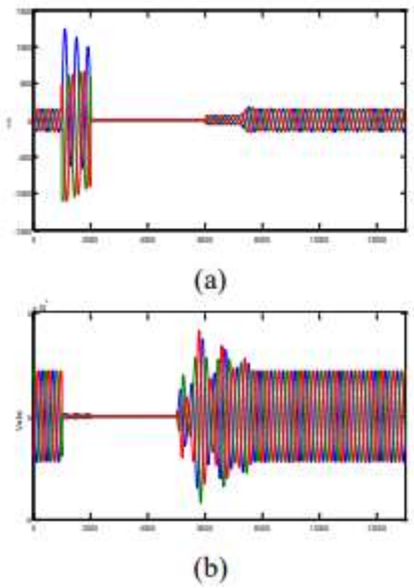


Fig.8. Responses of the nine-bus system subsequent to the strike of fault Fltb.(a) Line currents. (b) Capacitor voltages.

It is observed that subsequent to the fault initially, the voltages across the capacitors increase due to the rise in the line current. Then, after the bypass valves are triggered, the line current commutates to the bypass circuit and the voltages across the capacitors drop. Fig. 2 plot the responses of the nine-bus test system in the two cases of without RFCL and with an RFCL in line L45, where at 0 s, fault strikes the system in each case. In the case of the RFCL, the protection-level voltage of the varistors is selected equal to two times the capacitor voltage under normal operation, that is, 43 kV, and the current threshold is equal to four times the current through line L45 under normal operation, that is, 800 A. It is observed that the responses of the nine-bus system and its equivalent network, in the two cases, are in close agreement during the prefault and a quarter cycles after the inception of the fault. Fig.8 also plot the instantaneous currents through breaker CB5 in the nine-bus system in the two cases of without RFCL and with the RFCL in line L45. It is observed that the peak value of the current is reduced from 5 kA to 3.5 kA, that is, 30% reduction. Fig.8 illustrates the responses of the nine-bus system when the resonant capacitors are inserted in line L45 after the clearance of fault, under the assumption that the system is at steady state before 0 s. Thus, Fig.8 depicts that the responses of the nine-bus system and its equivalent network are generally in agreement despite the discrepancies. Since the capacitor voltages remain below, no energy is absorbed by the varistors.

CONCLUSION

This paper discusses a thorough methodology for designing RFCLs in transmission networks that are based on fuzzy logic. On the basis of the simulated outcomes, the proposed fuzzy system is evaluated and examined. The proposed system's transient reaction is examined. According to the study's findings, RFCLs are useful tools for lowering the currents caused by failures in bulk power systems. Compared to a traditional PI controller-based RFCL network, the fuzzy logic controller-based RFCL transmission network has improved transient stability and dynamic stability.

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