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Winding Capacitive Charging Current Improve by Genetic Algorithm for a High-Voltage Cable-wound Generator

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Abstract: - This paper presents a method which can be used to compensate the capacitive current wholly to improve the reliability of the differential protection .the ga method use for tune best parameter of circuit. It is proved that the capacitive current in the case of normal operation, external fault and internal fault can be calculated using the same dividing method.

Keywords: **Power former Graded insulation Cable capacitance**

I. INTRODUCTION

In the protection zone of the differential protection, the currents of some branches possibly cannot be measured, like the capacitive current of direct earth capacitances of the long transmission lines, which will lower the reliability of the protection. The differential relay can compensate this charging current to improve the stability of the protection, which has been implemented in the protection of the long transmission line for many years. Actually, large conventional generators are confronted with the problem of the increasing capacitive charging current as well. At the end of the 21 the century, a new type of high-voltage generator, power former, was invented by Dr. Mats Legion ET ai. At ABB power company for eight years research and development. The stator windings of the high-voltage generator make use of cable. This novel generator is called power former and it offers a direct connection of the power network without the need for a step-up transformer. Some experts in this field praise this technique as the power generation technique of the 21th century. as far as protection of power systems is concerned, some theories and criteria should be optimized so that they can adapt to the change of the ideal of generator winding design. The method using to compensator capacitive current for long transmission line has been implemented for many years. And hence for protection of generators, this problem was not very important in the past. However, with the development of generator capacity and the application of new technique, generator differential protections are confronted whit the problem of the increasing capacitive charging current as well. The windings of the power former make use of cross-linked polyethylene cable that formerly used in the transmission lines. The cable of power former can be considered as a capacitor with charges on the electrodes which are, in this case, the inner and the outer semi conducting layers. On the other hand, the electrical charge on a phase winding of the power former at voltage maximum is 30 times larger than the charge on a Phase winding of a conventional generator with the same rated apparent power. Therefore, the impacts on the reliability of differential protection should no longer be negligible. There are some literatures available in the field of compensated differential protection. But most of them focus on the charging current compensation for long transmission line, instead of for generator. The winding capacitive current contributes to the differential current during normal operation. The differential protection for generator rarely considers the influence of capacitance in the protection zone because the current differential protection itself has already met the requirement of conventional AC electrical machines, where the value of the direct earth capacitance is quite low. Similar to the analysis of the capacitance of the transmission line, the equivalence of winding capacitance of the generator can refer to. in which the capacitance distribution along with the winding is represented by lump capacitance with 50% at the phase terminal and 50% at the neutral point. This assumption is suitable for the cases of capacitance evenly distributing, like the transmission line and the winding of conventional generator. However, it will lead to errors for analyzing the stator winding of the power former in that the winding capacitance does not actually distribute evenly along with the stator winding. As known, the winding of the power former adopts graded insulation, which leads to the various cable thicknesses in different portion of the winding, and thus, the uneven capacitance distribution. A scheme is proposed in to cope with this problem. In this scheme, the winding capacitance is divided into two portions in lump parameter. One portion pCw of the total phase-to-earth capacitance of the winding Cw can be associated with the voltage at the neutral end of the phase winding while the rest (1- p) Cw can be associated with the voltage at the line terminal of the winding. This makes it possible to represent a winding with graded insulation. With this arrangement, the capacitive current can be calculated with the above lump equivalent capacitance and the voltages of the terminal and neutral, as the compensated differential protection of the transmission line does. Therefore, some fundamental work must be done before this scheme is implemented. Firstly, the above equivalent partition of the winding capacitance must be proved. Secondly, the coefficient p must be calculated or measured in advance before the protection is put into service. This paper proves that the capacitive current in the case of normal operation, external fault and internal fault can be calculated using the same dividing method. The formula of the partition coefficient is provided and the characteristic of the coefficient is explored by MATLAB software.

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2. Capacitance equivalence of the power former cable

As for the power former, the outer semiconductor of the cable used in the winding is grounded at regular intervals. Hence, it is normally a good approximation to assume that the voltage on the outer semiconductor is almost at ground potential. This means that the electric field driven by the voltage differences in the winding is concentrated between the inner and outer semi conducting layers of the cable. The electric field is very low outside the cable so that there is almost no electricity coupling between the turns in cable-wound generator, which is different from the conventional generator. In this case, turn-to-turn and coil-to-coil or phase-to-phase coupling capacitances, which are important in capacitive current of long transmission line, can be ignored when analyzing the power former. According to the above assumption, the electric field in the winding is concentrated between the inner and outer semiconducting layers of the cable. Hence, in the coaxial insulation system, normally only the capacitance between the inner and outer semiconductor ought to be considered. The capacitance per unit length Co between the inner and outer semiconductor can be calculated from the formula for two cylindrical coaxial tubes, which is given by

$$C_0 = 2\pi\varepsilon_0\varepsilon_r/\ln(r_2/r_1) \ (1)$$

Where 80 = 8.854e-12; relative permittivity ξ0=8.85*10-12r1 is the outer radius of the inner semiconducting layer and r2 is the inner radius of the outer semi conducting layer, as shown in Fig. 1. A discrete lumped circuit, representing the displacement current in the cable, can be replaced bya more compact one by a Tay

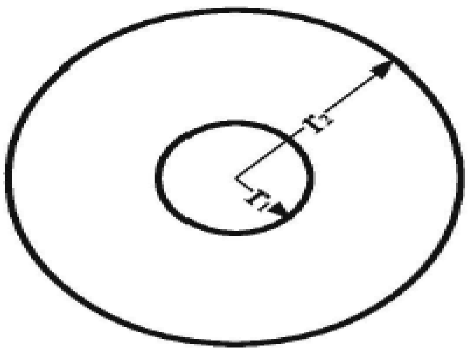

Fig.1. Cross-section of the cable used in the power former.

Lore expansion. The capacitance between the conductor and ground for a piece of cable between two grounded points of the outer semiconductor can be represented by just a capacitor. However, Co should be different at different position of the winding when the insulation thickness of cable of the power former increases stepwise from the neutral to the terminal, as described by(1). Assume that each segment of the cable with the same insulation thickness can be modeled as a tt . Network, as shown in Fig. 2, which illustrates the equivalent circuit of capacitance of the power former cable with N segments. Note that the voltage distribution within the stator winding is still linear along with the winding and is proportional to the turn number of the winding, we can assume that the voltage at any point inside the winding can be equivalent as the linear combination of the voltages of two terminals, the Uo and UN. It is no harm to let

$$U_i = k_{2i} + 1U_0 + k_{2i} + 2U_N \ (2)$$

Where k2i+1' k2i+2are both real numbers.

From Fig. 2 and Eq. (2) the capacitive current of phase a, ira, can be related to the cable capacitance Ci and the voltages of both terminals, as follows:

$$I_{ca} = j\omega \sum_{t=0}^{N} ciui = j\omega \sum_{t=0}^{N} cl\,(k2t + 1u0 + k2t + 2uN)$$

Where Ci is the real distributed capacitance at point i, which can be regarded as a portion of the total winding capacitance. Let Cw be the total distributed capacitance of a stator winding, we will prove the following assumption:

The capacitance combination$\sum_{t=0}^{N} k2t + 2cl$is a portion of the Cw, namely pCw and the$\sum_{t=0}^{N} k2i + 1ci$ is the residual portion of Cw, namely (1 - p)Cw as described in Eq. (3), where p is

a partition coefficient. In this case, Eq. (3) can be rewritten as below:

$$I_{ca} = j\omega \sum_{i=0}^{N} ciui = j\omega \sum_{i=0}^{N} ci\,(k2i + 1u0 + k2i + 2uN) \ (3)$$

$$i_{ca} = j\omega[(1-\rho)C_\omega U_0 + \rho C_\omega U_N] \ (4)$$

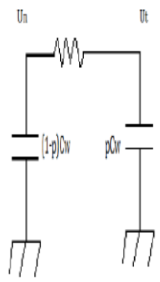

Fig. 5. Equivalent circuit of the powerformer cable to calculate capacitance currents.

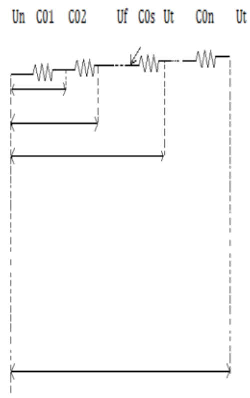

Fig. 6. System representation of N-segment cable during internal fault operation.

II. GENETIC ALGORITHM

GAS work with a set of artificial elements (parameter strings) called a population. An individual (string) in a population is referred as a chromosome, and a single element in a chromosome is called a gene. GAS generate a new population (called off springs) by applying the genetic operators to the chromosomes in the old population (called parents).Each iteration of genetic operations are referred as a generation. A fitness function, i.e. the function to be maximized, is used to evaluate the fitness of an individual. One of the important purposes of GAS is to reserve the better schemata, i.e. the patterns of certain genes, so that the off springs may yield higher fitness than their parents.

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Consequently, the fitness value increases from generation to generation. In most of GAS, reproduction, crossover and mutation are three basic operators. Actually, reproduction and crossover don't introduce new patterns of gene into the population, but mutation does. Mutation can be viewed as a random-work mechanism to avoid the local optimum trapping problem. As a result, GAS would always find a sub-optimal solution that approximate the global one. Although there are a large amount of genetic algorithms had been proposed, the fundamental principle was based on the simple genetic algorithm (SGA). In general, the individual strings that the SGA works on are binary-coded (e.g. 01101110); hence, SGA also known as binary-coded GA. The basic operations of SGA are briefly described as fol lows [2]:

1) Reproduction: the Darwinian "survival of the fittest" is the underlying spirit of reproduction. First ,a fitness value F is assigned to each individual string in a population. A higher F value indicates a better fit(or larger benefit). Next, the old individual strings are probabilistically selected and copied into a mating pool according to their fitness value. The arrangement allows the strings with a higher fitness to have a greater probability of contributing a larger amount offspring's in the new population.

2) Crossover: crossover provides a mechanism for individual strings to exchange information via a
Probabilistic process. Once the reproduction operatories applied, the members in the mating pool are allowed to mate with one another. First , two parents are randomly selected from the mating pool. Next, a random crossover point is picked up, on which the parents will exchange their genes. Finally, the parents 'genetic codes are mixed by exchanging the ircodes following the crossover point. For example, leta, bdenote two parent strings and abbey their children. If the crossover point is selected on the 3rd bit, then we have:

$$a = 10101\underline{010} \qquad a' = 10101\underline{100}$$
$$\Longrightarrow$$
$$b = 01111\underline{100} \qquad b' = 01111\underline{010}$$

This random process provides a highly efficient method to search the string space for finding a better solution.

3) Mutation: every gene is subject to a random change with probability of the pre-assigned mutation rate in each iteration. In the SGA, a mutation operatories nothing but just changes a random-selected bit from 0 to 1 or vice versa.

III. SIMULATION AND RESULT

The r1 and r2 is the parameter than we chose for initializing the first population for ga method. and the equitation 4 is the fitness function the simulation run in 100 iteration and Pmutate=.8, Pcross=.7.the result show in figure 5.

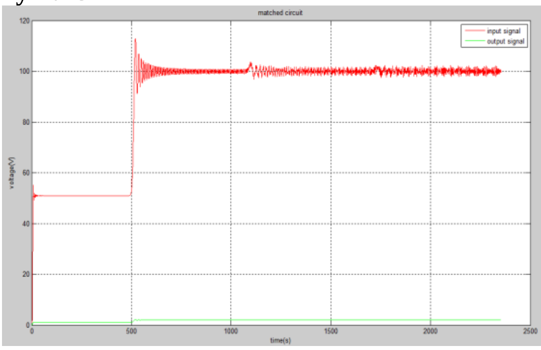

Fig 1: The method can estimate best value of cable size

IV. CONCLUSION

The large capacitive currents and large transient out rush currents resulting from the cable consisting of the stator winding of power former may cause problems to the generator differential protection. It is proved in this paper that the distributed capacitance can be equivalent as the lump circuit with a capacitance partition coefficient p, and p is proved as a constant no matter whether the generator experiences the normal operation, external phase(s) fault or internal phase(s) fault.

V. ACKNOWLEDGEMENT

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