Proposed New Technique for Smart Earthing System

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الخلاصة

اخطاء الخط الواحد المتلامس مع الارض واخطاء الخطين المتلامسين مع الارض تحدث في نظام توزيع القدرة والتي تؤدي الى رجوع تيار خطأ عالي الى هذاالنظام من خلال موصل التأريض . هذا البحث يقترح طريقة تأريض ذكية لتقليل هذا التيار. متحكم المنطق المضبب استخدم في هذه التقنية لغرض زيادة او تقليل قيمة مقاومة التأريض التي تصل نقطة التعادل للمحولة الى نقطة الارض بالاعتماد على تيار الخطأ المقاس. استخدمت ميزة المحاكاة في برنامج الماتلاب لاختبار اداء هذه التقنية. هذه التقنية طبقت في نموذج لنظام توزيع القدرة ذو المستوى (11) كيلو فولت والذي صمم وفق بيانات حقيقية اخذت من محطة توزيع ثانوية في مدينة كربلاء. تقنية التأريض الذكية هذه تتعامل مع أي خطأ ارضي غير متماثل والذي يحدث عند أي موقع في شبكة التوزيع مع أي مقاومة خطأ.

الكلمات المفتاحية

الخطأ الأرضي ذو الخط الواحد، الخطأ الأرضي ذو الخطين، نظام التأريض الذكي، متحكم المنطق المضبب.

Abstract

Single line to ground and double line to ground faults occurred in distribution power system which leads to high fault current that is returned to this system through earthing conductor. This paper proposed smart earthing technique to reduce this current. The fuzzy logic controller is used in this technique to increase or decrease the earthing resistance which connects the neutral of the substation transformer to the earth point depending on the measured faulted current. MATLAB/Simulink is used to test the performance of this technique. This technique applied to (11) KV distribution power system model with real data from distribution substation in Karbala city. This smart earthing technique deals with any unsymmetrical earthing fault that occurs at any location in the distribution network with any fault resistance.

Keywords

SLG: single line to ground fault; DLG: double line to ground fault; smart earthing system; FLC: fuzzy logic controller.

1. Introduction

Under normal or safe operating condition, the electrical equipment of power system network operates at rated voltage and current. Occasionally, asymmetrical earthing faults occur in power system causing this system to operate in an abnormal condition. So, the voltage and current magnitudes deviate from their normal ranges. In some cases, very high current will return to supply equipment such as generator or transformer, while in others, earthing faults are not necessary to be solid short circuit faults and this will lead to reduction in the magnitude of the current that returns to the system [1]. Whenever there is increase in this magnitude, there will be more damage to power system equipment and vice versa. The faulted current passes through an earthing conductor which connects the neutral point of the system to the earth. So, the magnitude of this faulted current depends on how the neutral point is connected to the earth (earthing techniques) which signifies the importance of earthing in power system network. For these reasons there is a need to search for earthing system and to suggest a new earthing technique to reduce the damage.

Physically, the neutral earthing is the connection of transformer neutral point, generator neutral point or star point of loads or circuits to the earth [2]. The conductor which satisfies this connection is called earthing conductor. The distribution system has several neutral points and the points of the same system are not necessarily connected to the earth by the same technique.

There are two main objectives of system earthing, the first is the detection of earthing faults and the second is to determine the returned fault current in order to prevent the hazard voltage between the structure of the faulted equipment and the earth caused by its high magnitude [3].Earthing of power system has many advantages. The main advantage is that the power system can be divided into several subsystems without interconnected zero sequences. Another advantage is that earthing system can be considered as the most important parameter which affectsearthing faults. Thisresults that it significantly affects the behavior of distribution power system when subjected to earthing faults.

In this paper, a new technique of smart earthing system by using control circuit composed of FLC and controller block will be proposed. This technique is considered a new technique because that it composed of different earthing resistances values that activated depending on operation condition to compensateany change that occurs in fault resistance value or location keeping the returning current magnitude in low level. The control circuit is used to control the operation of the bank of earthed resistances for the purpose of reducing earthing fault current that passes through earthing conductor. This smart earthingtechniqueis applied to distribution system model of (11) KV which implemented in MATLAB simulation by using real data of substation located in Karbala city. This work deals with unsymmetrical earthing faults (SLG and DLG).

2. Literature Review

Researchers where interested to study this subject because of its importance and great effect on the protection of distribution power systems and their employees. For examples: a research is presented about sizing high resistance grounding in power system with consideration of system earthing capacitance. This research discussed the problems that concerned with earthing capacitance in high voltage and gave the procedure of determining earthing capacitance of the system, the greatest value permitted for high earthing resistance and the pickup setting of an over current relay [4]. The main neutral grounding methods that including un-grounding neutral method, neutral grounding by using a Peterson coil method and neutral grounding by using low resistance value method are discussing in [5]. The methods which used to ground the neutral point of Shanghai Fengxian (35) kV and (10) kV power grid are discussed in [6]. Discuss the phasor diagram and flow directions of the faulted current in case of single phase to ground bolted fault when the HRG method is used in power system be done in [7]. The researches mentioned above discussed the traditional earthing techniques used in different applications. These techniques deal with any earthing fault without the need to know the fault characteristics. So, many problems can occur such as breakdown of the insulation when there is failure in fault detection or damage to the system equipment.

3. Earthing techniques

Earthing technique has small influence under normal operation of the distribution system, but becomes very important and effective when an earthing fault occurs [8]. The neutral point can be isolated from the earth (unearthed) or connected to the earth by using different techniques. These techniques aresolidly earthing, resistance earthing, reactance earthing andpeterson coil earthing. Solidly and LRG are called effective eathing techniques but the HRG, unearthing and resonance techniques are called ineffective earthing technique [9].

4. Smart Earthing system

In this type of earthing, operation condition of the power system determine an earthing connection to the neutral point of the substation transformer. This is done by connecting the neutral point of the distribution system to the earth by using bank of resistances. There are so many cases of the earthing fault which may occur in distribution system due to different magnitudes of the fault resistance and the location of this fault. So, in each case certain magnitude of the faulted current that returns through an earthing conductor is produced. In some cases, the faulted current is very high reaching values up to thousands of amperes and consequently can cause shutdown if there is a compatible protection system or can entirely damage the equipment which may lead to arc explosion resulting in burning or electrical shock to the personnel that could be working adjacent to the equipment faulted. In other cases, the faults may occur at a remote location or across high fault resistance which causes failure in detection of this fault [10, 11, 12]. So, the fault current magnitude is considered as a critical factor in the power system and it is directly related to earthing method being applied [13]. To detect the fault current passing through an earthing conductor and to reduce it to low level for each case of earthing fault, the connection between the neutral point of substation transformer to earth changes in very short period depending on magnitude of this current. i.e. the smart earthing system overcomes these problems by increasing the equivalent earthing resistance according to the magnitude of returning current to allow low value of this current to passes through earthing conductor. So, nearly neglecting the effect of fault resistance and fault location is the result. The progress of smart earthing technique is represented by the flow chart as shown in Fig (1). This figure represents the flowchart of controlling an earthing fault current by using bank of resistances which controlled by FLC and controller block. The smartearthing system consists of measurement device, FLC, Processor block and bank of resistances.This smart earthing system is applied in distribution system model of (11) KV which implemented in MATLAB simulation.

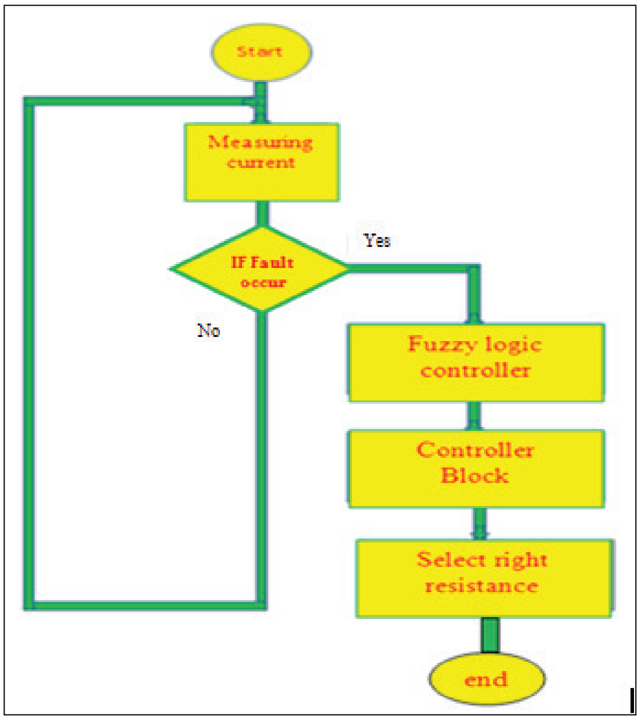

Fig (1): Flow chart of smart earthing technique.

4.1. Fuzzy logic controller

When utilizing fuzzy logic, the solution to the issue can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already effectively performed by humans. It represents a technique that eases the control of a complicated system without having knowledge of mathematical description for this system. Fuzzy logic in reality represents an accurate problem-solving methodology.The most important advantages of the fuzzy logic system are:

- Capability to deal with the uncertainty and nonlinearity.

- Simplicity of implementation.
- Using of linguistic variables.
- Simplicity of adding new data or rules to the old fuzzy system as required.

The four main stages in fuzzy knowledge-based control are:

- Fuzzification
- Rule base
- Inference engine
- Defuzzification

There are need to control the operation of the bank of earthing resistances by changing the output signal of FLC according to measured current by ammeter located in the return path of faulted current.

Fuzzification converts a set of crisp inputs to the corresponding fuzzy sets. The defuzzification process decides the crisp output" by resolving the applicable rules into a single output value. Fuzzification process used (13) triangle membership functions to represent the input from ammeter. Also, Defuzzification process consists of (13) trapezoidal membership functions to represent the output of FLC. Inference step described by creating of rules and computing degree of membership. 13 rules are used in this fuzzy logic controller and the rule viewer of fuzzy controller as shown in Fig (2).

The input status words are Class 0, Class 1, Class 2, Class 3, Class 4, Class 5, Class 6, Class 7, Class 8, Class 9, Class 10, Class 11 and Class 12. This class refers to the magnitude of the fault current in the earthing system and the increasing of a number of the classesrefers to increasing this current. The output status words are No action, Part 1, Part 2, Part 3, Part 4, Part 5, Part 6, Part 7, Part 8, Part 9, Part 10, Part 11 and Part 12.The rule base are:

If the measured fault current belongs toclass 0, then take no action.

If the measured fault current belongs to class 1, then connect part 1 of the bank.

If the measured fault current belongs to class 2, then connect part 2 of the bank.

If the measured fault current belongs to class 3, then connect part 3 of the bank.

If the measured fault current belongs to class 4, then connect part 4 of the bank.

If the measured fault current belongs to class 5, then connect part 5 of the bank.

If the measured fault current belongs to class 6, then connect part 6 of the bank.

If the measured fault current belongs to class 7, then connect part 7 of the bank.

If the measured fault current belongs to class 8, then connect part 8 of the bank.

If the measured fault current belongs to class 9, then connect part 9 of the bank.

If the measured fault current belongs to class 10, then connect part 10 of the bank.

If the measured fault current belongs to class 11, then connect part 11 of the bank.

If the measured fault current belongs to class 12, then connect part 12 of the bank.

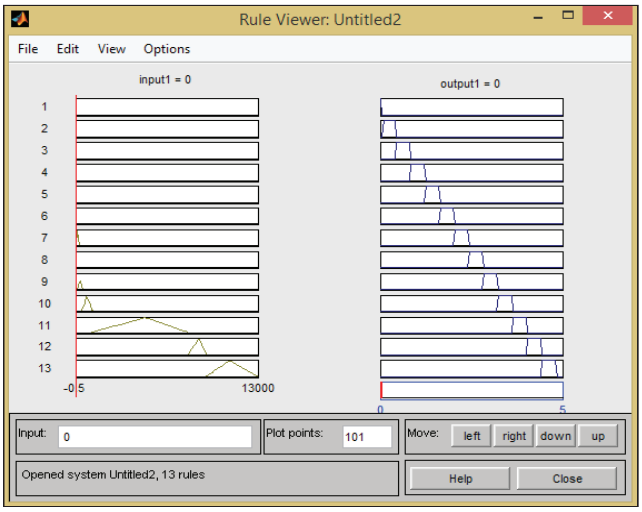

Fig (2): the rule viewer of fuzzy logic controller.

4.2. Controller block and Embedded MATLAB Function

This is a block of sub designed model implemented to receive the controlled signal output from FLC. According to this signal it will send 13 signals output to the earthing resistances block to activate some part of these resistances and separate the other parts. This activated resistance is responsible for reducing the faulted current passing through an earthing conductor. So, the constructions of controller block are:

• One input port which received the output controlled signal from FLC.

• 13 output ports used to control the resistances.

• Many Embedded MATLAB Function blocks.

4.2.1. Embedded MATLAB Function block

An Embedded MATLAB Function block allows using a MATLAB function within Simulink model. The Embedded MATLAB Function block is obtained from the User Defined Functions Library and it is inserted into a model in the same method as any other Simulink block. Embedded MATLAB Function blocks support a subset of the functions obtainable in MATLAB. These functions involve functions in common categories such as Arithmetic functions like plus, minus, and power, Matrix operations and Trigonometric functions like sin, cos, sinh, and cosh. The Embedded MATLAB Function block deals with inputs of any type that Simulink supports.The construction of the controller block shown in Fig (3).

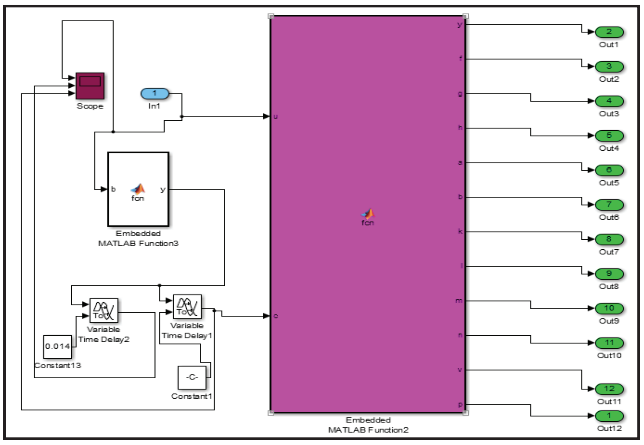

Fig (3): the internal design of controller block.

4.3. Earthing resistance

Neutral earthing resistance (NER) is used in electrical power distribution facilities to limit earthing fault current and to avoid many problems related to use of solidly earthing and unearthing techniques.NER can be categorized into low resistance grounding

(LRG) and high resistance grounding (HRG) and both of these types are applied to reduce the earth fault current and they differ from each other by the level of earth fault current allowed to flow. The two main techniques of connecting medium voltage system neutrals to earth point are carried out by using neutral grounding resistance (HRG method and LRG method). The most important issue regarding the use of resistance in earthing process is to select a proper value for this resistance. There are different opinions about what is better to use, high resistance or low resistance for distribution power system. In fact, there is no standard for defining earthing resistance [4]. Some considerations such as charging current value and pickup current should be taken in to account for selecting the value of earthing resistance. The value of this resistance must be less than earthing capacitance value. If this condition is not satisfied, a great part of current will return through this capacitance to the system if there is an earthing fault in distribution power system. This will result in increase in the electrical system's charging current leading to high transient over voltage. So, the system charging current should be known to apply an earthing resistance. The charging current for an electrical distribution system can be measured or estimated. Typical charging currents are less than (15) A for (11) KV power system [14]. This means that the neutral grounding resistance setting is normally selected so that it let-through a current greater than the total capacitive charging current, 3ICo, of the system when an earthing fault occurs. This determines the rate of fault damage which is considered acceptable under earth fault condition.

The other condition is that the resistance mustn't allow reducing the faulted current to a value less than the pickup current of the protection device (over current device). So, the pickup current should be set at value greater than that of the current passing through neutral earthing conductor by safety factor. So, using of the bank of earthing resistances provide the solution to this problem by change the equivalent earthing resistance value i.e. change the connection between neutral of the system and the earth by using resistances of different value. Note also the value of these resistances selected by applying the consideration above. It provides a dynamically earthing resistance that changed its value in very short time (in mille seconds) so as to treats the wide variations which exist in earthing faults. This leads to keep the faulted current through earthing conductor in small range of amperes which doesn't causes problems to the power system. Earthing resistance might be connected to the neutral point of a power transformer or across the broken delta secondary of the three phase to earth connected distribution transformers.

At normal operation, the earthing conductor doesn't carry current and the measurement device (ammeter) measures zero current approximately. This makes the magnitude of signal input to FLC zero. So, the earthing connection in this case is implemented by using the lowest resistance value and there is no need to change it.

When earthing fault occurs in power system, the fault current will return to the system through earthing conductor and the magnitude of this current depends on the fault resistance and location in distribution power system. So, the ammeter measures this faulted current and sends its magnitude to FLC. The fuzzy controller immediately processes the magnitude of this fault and decides the magnitude of its output signal according to its rules. This magnitude varies from zero to (5) V and it will be sent to controller block. Accordingly, the controller block will send 13 controlling signals output to disconnect a resistance which operates at the normal condition and activates other part of resistances from bank of earthing resistances to reduce the faulted current that passes through an earthing conductor as required (the higher the NER value, the lower the faulted current magnitude) [15].

5. Advantages of changing the value of earthing resistance

1-Reduce faulted current that returns to the system.

2-More safety when there is failure in protection or detection device.

3-Easy to detect the earthing fault in case of the current magnitude is very small.

4-Overcomes on the problems that exist when using fixed value of resistance (high resistance or low resistance value).

5-Reduce the overvoltage problem.

6. TYPES OF FAULTS

In general, there are two types of faults may be occurred in three-phase power distribution systems. These faults are symmetrical and unsymmetrical fault which may be short circuit or open circuit. Short-circuit faults can occur between lines, or between lines and earth. Short circuits may be one-line to earth, line to line, two-lines to earth, three-lines without connected to earth and three-lines to earth. Unsymmetrical fault short circuit divides to three subtypes which are SLG fault, line to line fault and DLG fault. Earth fault typically means an unintentional connection of power line with metallic parts being connected with the earth. An asymmetrical earth fault current is a current that passes to earth and has a magnitude that depends on the techniques of system earthing. In this work, many faults of SLG and DLG type are used due to two reason; the first are these faults depends on how the neutral point connected to earth. And the second are the single-line to earth fault is proven to be a type of fault that most possibly occurs in the distribution network with the neutral un-effectively grounded system [16]. These faultsare tested in (11) KV distribution system model. The magnitude of the fault current depends on location of fault in the system and fault resistance. So SLG and DLG faults will be tested across different fault resistance values and locations.

7. MATLAB SIMULATION

The power model implemented using MATLAB/SIMULINK to test the smart earthing system under SLG, and DLG faults occurred in the (11) KV distribution system. The MATLAB / Simulink simulation model is illustrated in Fig (4). This model represents real power network which powered from distribution substation on Karbala city. It composed from three phase programming voltage source of (33) KV connected (Yn). Three phase two winding transformer of capacity (31.5) MVA to transform (33) KV to (11) KV which connected as follow:

Winding 1 is delta

Winding 2 is Yn

This transformer is representing distribution substation and the neutral of this transformer connected to earth by using smart earthing technique. This substation consists from 6 feeders of (5) MVA. The feeder 1 supplies the load by using three phase distribution line of length (5) km, the feeder 2 supplies the load by using three phase distribution line of length (7.5) km, the feeder 3 supplies the load by using three phase distribution line of length (10) km, the feeder 4 supplies the load by using three phase distribution line of length (2.5) km, the feeder 5 supplies the load by using three phase distribution line of length (12.5) km and the feeder 6 supplies the load by using three phase distribution line of length (15) km. Three-phase ammeter and three-phase voltmeter were used to measure the current and voltage respectively. All feeders' supplies 12 transformers of capacity (400) KVA to transform (11) KV to (0.4) KV with connection as follow:

Winding 1 is delta

Winding 2 is Yn

This transformer supplied four lines to the consumers which are three phase line and neutral. This neutral of solidly connection to earth and each one of these transformers supplies loads of (340) kW connected as Yn. Three phase fault block are used to act as SLG or DLG fault.

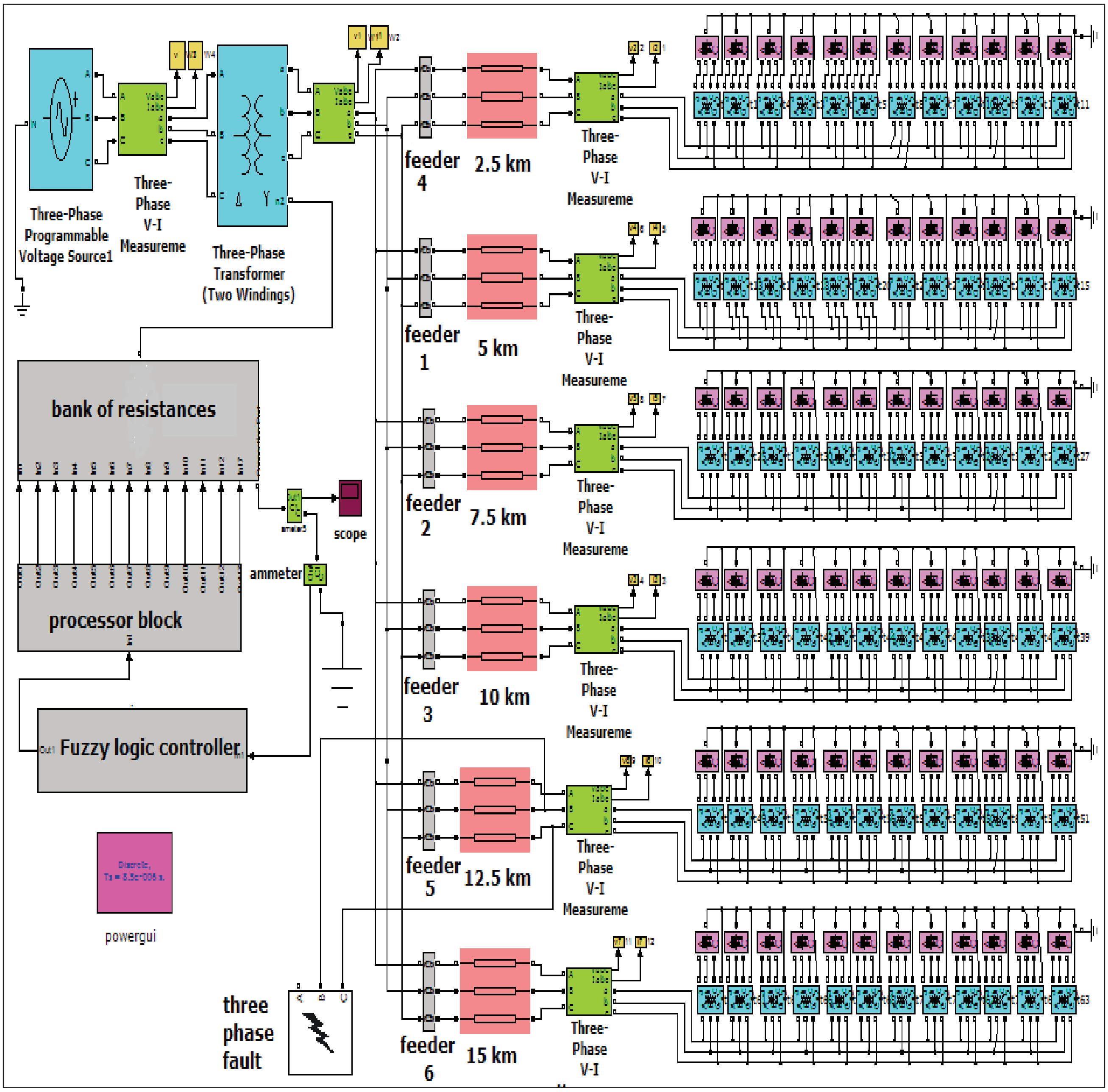

Fig (4): Simulink model of distribution system earthed by smart earthing system.

8. SIMULATION RESULTS

The faulted current which returned to the (11) kV distribution power system through earthing conductor causes big problem to this system. So, the smart earthing is suggested to reducing this faulted current. In this section, many cases of single line to earth faults and double line to earth faults are occurred in this power system and the simulation results of the faulted current due to these fault cases will show in Figs (5)-(10). This simulation results are measured by the ammeter that located in earthing conductor. The showing of this figures will ordered according to the type of unsymmetrical earthing fault and location of this fault by refers to the number of feeder and the distance.

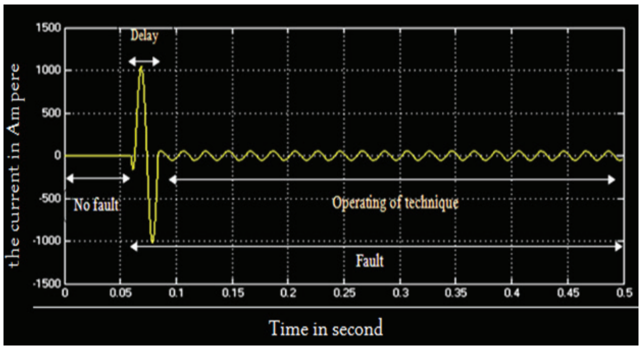

Fig (5): SLG fault at (0.06) sec located in feeder 2 after (7.5) km with Rf=(5.4) ohm.

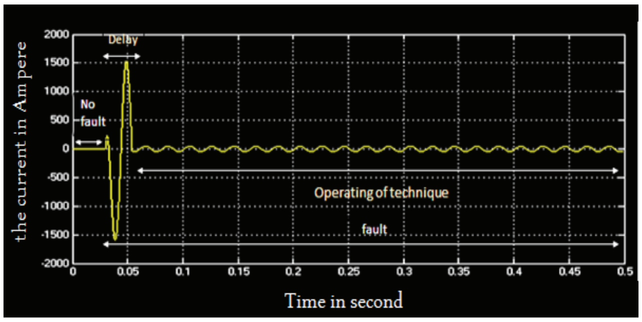

Fig (6): SLG fault at (0.03) sec located in feeder 1 after (5) km with Rf=(3.2) ohm.

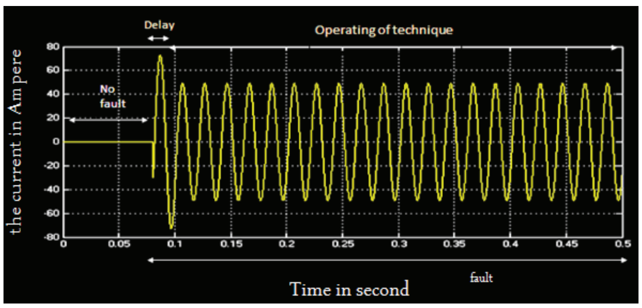

Fig (7): SLG fault at (0.08) sec located in feeder 6 after (15) km with Rf=(120) ohm.

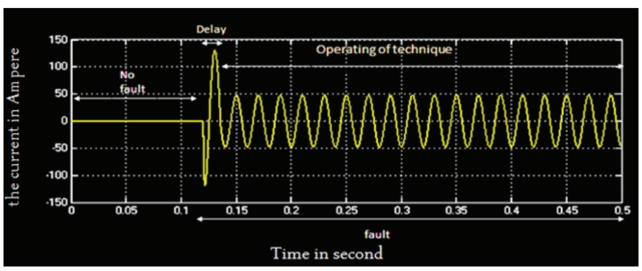

Fig (8): DLG fault at (0.12) sec located in feeder 5 after (12.5) km with Rf=(63) ohm.

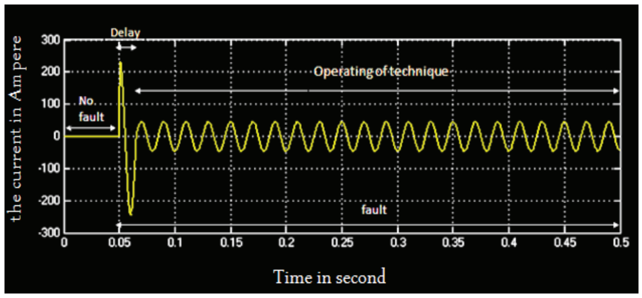

Fig (9): DLG fault at (0.05) sec located in feeder 4 after (2.5) km with Rf=(35) ohm.

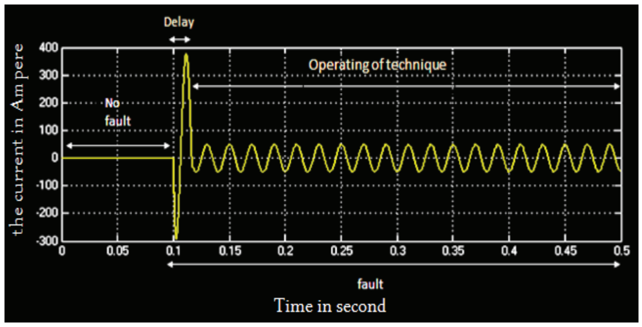

Fig (10): DLG fault at (0.1) sec located in feeder 3 after (10) km with Rf=(17.8) ohm.

8.1. Results discussion

The total period of simulation of these techniques is adjusted to (0.5) sec and divided into three periods which are the period of normal operation before the fault occurrence, delay period and period of technique operation.

At normal operation, the connection between the transformer neutral and the earth is done by using the lowest resistance value and the current through this resistance equals to zero. The time delay period equals to (20) m sec leading to passing one unlimited cycle of the fault current. In this period, the control process is done.

When the fault occurs, its current magnitude depends on fault resistance value and location but these Simulink results show that the neutral earthing current is equal to the same magnitude (around (50) A) in each faulted case which reduces the system equipment damage. To compare these results, some researches results and discussions will addressed below:

Lawrence J. Kingrey, Ralph D. Painter and Anthony S. Locker, IEEE, 2011 [17] made a comparison between HRG and LRG method for grounding the medium voltage system. In the second point of this comparison, they wrote that a LGR let through current (400) A and HGR let through current less than (6) A. In the last point, the system application voltages for LGR is in ((2.4) and (4.16) kV) and for LGR (from (2.4) to (69) kV).So, HRG cannot be used in (11) KV due to high charging current in this voltage level((11) KV) compared to it requirement (6.5) A. The LGR limits the neutral earthing current to (400)A causes equipment damage leadingto that the fault clearing time should be in cycles due to high current magnitude as mentioned in the third point and the problem occurs when the fault isn't detected.

Eng. Hasan Z. Al-Amari and Dr. Abdallah I. Fadel, IEEE, 2013 [18], In this research, the significance and influence of neutral grounding resistance method in (30) KV Western Libyan power system network and its effect in limiting and determining the bolted single line to ground fault current for a network fed by a single or multi sources were addressed. The (10)ohm-neutral grounding resistance installed in (30) KVnetwork decreases the single line to ground fault current toless than (2) kA, (4) kA and (5) kA in the (30) KV network for single,double and triple feeding source respectively.When there is failure in protection device, these magnitudes of fault current cause more damage to the system equipment.

This smart technique allows to 50 A in any earthing fault which reduce the damage less than of LGR technique (400) A or (300) Ain (21.4) ohm as applied in (33/11) KV substation transformer in Karbala city. HRG and non-earthing technique limit the fault current to very low level which allows increasing the fault clearing time reaching to hours but there is high overvoltage in the two healthy phases during this time. This requires increasing the insulation level of the power system equipment. In the smart earthing technique, the fault should be cleared in short time (seconds) leading to there is no need for increase the insulation level.

9. Conclusion

1- The current let through earthing conductor in (11) KV system should be greater than (15) A for any fault condition. This magnitude was estimated for system charging current.

2- Damage problem is very important factor in selecting earthing technique for distribution system and it determined by the current allowed passing through neutral earthing conductor.

3- Bank of resistances is used to connect the neutral point to the earth and its controller is solved by using fuzzy logic controller and controller block. In this bank, there are 13 earthing resistances of different values applied to reduce the faulted current through an earthing conductor. These resistances are connected in parallel connection by using relays. The activation of these resistances depends on the magnitude of the faulted current that returns to (11) KV distribution system. Different values of these earthing resistances are selected to compensate any change that occurs in fault resistance value or location keeping the returning current magnitude in a low level. This will reduce the damage to the system equipmentand allows increasing the fault clearing time for some seconds making the allocation of the earth fault easier. The insulation level doesn't required to increase because the fault clearing time in seconds compared to that in high resistance and non-earthingtechnique which may reach to hours.The obtained results for this earthing technique are remarkable and comparable with respect to the conventional applicable techniques.

References

[1] Tao Cui, Xinzhou Dong, Zhiqian Bo and Andrzej Juszczyk, "HilbertTransform-Based Transient/Intermittent Earth Fault Detection inNon-effectively Grounded Distribution Systems", IEEE, IEEE Transactions on Power Delivery, Vol. 26, Issue 1, pp. 143-151, January, (2011).

[2] HNIN NU WAI and KYAW SAN LWIN, "Design and Performance ofPrimary Substation Earthing System (230/33 kV)", International journal ofscientific engineering and technology research, Vol.03, Issue 07,pp.1245-250, May, (2014).

[3] Bystrík DOLNÍK and Juraj KURIMSKÝ, "Contribution to earth faultcurrent compensation in middle voltage distribution networks",Przegląd Elektrotechniczny, pp. 220-224, (2011).

[4] Joseph Sottile, Thomas Novak and AnupTripathi, "Best Practices forImplementing High-Resistance Grounding in Mine Power Systems",IEEE, IEEE Transactions on Industry Applications, Vol. 51, Issue 6, pp.5254 – 5260, (2015).

[5] Yundong Song, Shun Yuan, Chunfang Zhao and YanfengJia, "Analysisand Selection of Neutral Grounding Modes in Cable DistributionNetwork", IEEE,International Conference on Power Engineering, Energyand Electrical Drives, pp.518-521, April, (2007).

[6] Siming Hua, Hua Zhang, Feng Qian, Chunjie Chen and Meixia Zhang,"The Research on Neutral Grounding Scheme of Fengxian 35 kV and 10kV Power Grid", Journal of Energy and Power Engineering, pp. 897-901,July, (2013).

[7] Dev Paul PE, "Phasor Diagram of a Single-Phase-Ground Fault Currentin a High-Resistance Grounded Power System", IEEE, 2017 IEEE/

IAS53rd Industrialand Commercial Power Systems Technical Conference(I&CPS), pp. 1-6, (2017).

[8] Abdallah R. Al-Zyoud1, A. Alwadie, A. Elmitwally, and AbdallahBasheer, "Effect of Neutral Grounding Methods on the Earth FaultCharacteristics", PIERSProceedings, Prague, Czech Republic, pp. 1144-1151, July 6-9, (2015).

[9] Xiangjun Zeng, Yao Xu and Yuanyuan Wang, "Some Novel Techniquesfor Insulation Parameters Measurement and Petersen-Coil Control inDistributionSystems", IEEE, IEEE Transactions on IndustrialElectronics, Vol. 57, Issue 4, pp.1445-1451, April, (2010).

[10] M. Michalik, W. Rebizant, M. Lukowicz, Seung-Jae Lee and Sang-HeeKang, "High-impedance fault detection in distribution networks with useof wavelet-based algorithm", IEEE, Vol. 21, Issue 4, pp. 1793-1802, October, (2006).

[11] N. I. Elkalashy, M. Lehtonen, H. A. Darwish, M. A. Izzularab and A. I.Taalab, "Modeling and Experimental Verification of a High Impedance Arcing Fault in MVNetworks", IEEE, 2006 IEEE PES Power SystemsConference and Exposition, pp.1950 -1956, (2006).

[12] Nagy I. Elkalashy, MattiLehtonen, Hatem A. Darwish, Mohamed A.Izzularab and Abdel-Maksoud I. Taalab, "DWT-Based Investigation ofphase currents for Detecting High Impedance Faults Due to Leaning Treesin Unearthed MV Networks", IEEE, 2007 IEEE Power EngineeringSociety General Meeting, pp. 1-7, (2007).

[13] Yan Gao, Xiangning Lin, Pei Liu and Zhiqian Bo, "A GeneralizedMorphological Transform Based Faulty Feeder Selector Suitable for theNon-Effectively Grounded Power Systems", IEEE, 2007 IEEE PowerEngineering Society General Meeting, pp. 1-6, (2007).

[14] J. C. Das, "Ground Fault Protection for Bus-Connected Generators in anInterconnected 13.8-kV System" IEEE, IEEE Transactions OnIndustry Applications, Vol. 43, Issue 2, pp. 453-461,March/April, (2007).

[15] Mahdi MozaffariLegha and Saeed Shokoohian, "A New Algorithms forFaulted Phase Earthing Protection Relays on 20kV Networks", Specialtyjournal of Engineering and Applied Science, Vol. 1 (2), pp. 1-6, (2016).

[16] Ning Tong, Xiangning Lin, Rui Zhang and Shan He, "Fault Identification Method Based on the Neutral Point Medium Resistance Switching-on for the Distribution Network", IEEE, 2014 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), pp. 1-5, (2014).

[17] Lawrence J. Kingrey, Ralph D. Painter and Anthony S. Locker, "ApplyingHigh-Resistance Neutral Grounding in Medium-Voltage Systems", IEEE, Vol. 47, Issue 3, pp. 1220-1231, May/June, (2011).

[18] Hasan Z. Al-Amari and Abdallah I. Fadel, "10 ohm Neutral GroundingResistance in 30kV Western Libyan Network and Effects", IEEE, Power Engineering Conference (UPEC), pp. 1-6, (2013).