Design and optimum over-current relay coordination for ring main distribution system

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the degree of

MASTER OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

Electrical Power system

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May 2020

CERTIFICATE

This is to certify that the Major Project Report entitled **"Design and optimum over-current relay coordination for ring main distribution system"** submitted by **Mr. Chintan R. Akbari(18MEEE01)** towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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I, **Mr. Chintan R. Akbari, Roll No. 18MEEE01**, give undertaking that the Major Project entitled **"Design and optimum over-current relay coordination for ring main distribution system "** submitted by me, towards the fulfillment of the requirements for the degree of Master of Technology (Electrical Engineering) in the field of Electrical Power System of Nirma University, Ahmedabad is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere;it will result in severe disciplinary action.

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First of all, I would give life time's appreciation to my guide Prof. Shanker Godwal and Prof. Shivam Shrivastav who expertly guided me with his firm enthusiasm, which kept me constantly engaged with the my major project work.

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Abstract

In a distribution network, there are mainly primary distribution system (11kV) and secondary distribution system (440V). On the primary distribution side radial feeder topology is generally establish with overhead lines. Now a day, this topology is converted to ring main system by introducing Ring Main Units (RMU) for the protection of distribution system. RMU's are used to provide multiple power sources to the load maintain continuity of power supply at the time of fault. The main problem in ring main system is relay co-ordination because many relays are present in the system for protection purpose. If relays are not coordinated properly, mal-operation, instantaneous tripping, cascade tripping may result in such system configuration. Hence, it is required to design proper relay coordination to reduce these types of problems.

ACRONYMS

GA Genetic Algorithm

SFCL Superconducting fault current limiter

CT Current transformer

PS Plug Setting

TMS Time Multiplier Setting

CTI Coordination Time Interval

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Chapter 1

Introduction

1.1 Distribution System

- Power is generated at different power station at voltage 11/33 kV.It is transmitted by transmission line at high voltage depending on how much power is supplied.(66kV,132kV,220kV,400k distribute to consumer through distribution line.Large consumer get power directly from 11kV distribution line and residential consumer get supply through secondary distribution system.There are three types of distribution system which is discuss below.

1.1.1 Radial Distribution System

- In the early days of electrical power distribution system, different feeders radially came out from the substation and connected to the primary of distribution-transformer.

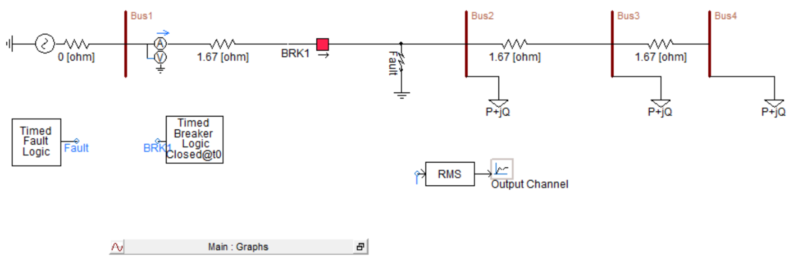

Figure 1.1: Radial distribution system simulation without fault

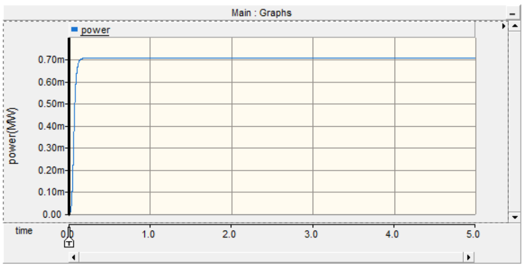

Figure 1.2: Power

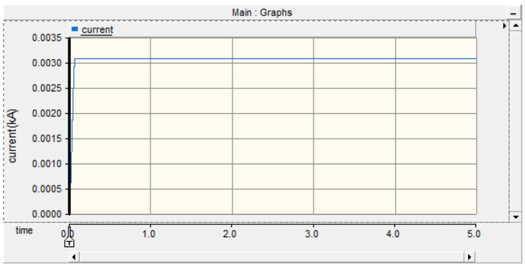

Figure 1.3: Current

1.1.2 Parallel Distribution System

- The initial cost of this system is much more as the number of feeders is doubled. Such system may be used where reliability of the supply is important or for load sharing where the load is higher.

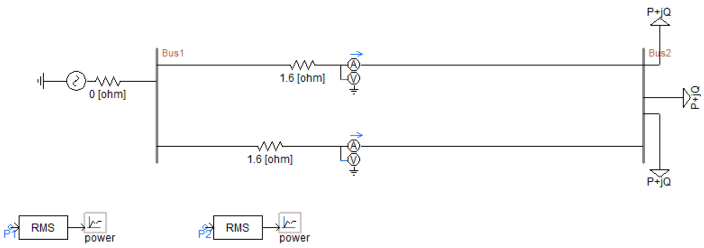

Figure 1.4: Parallel distribution system simulation without fault

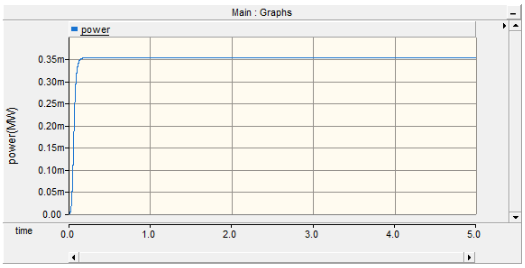

Figure 1.5: Power in line 1

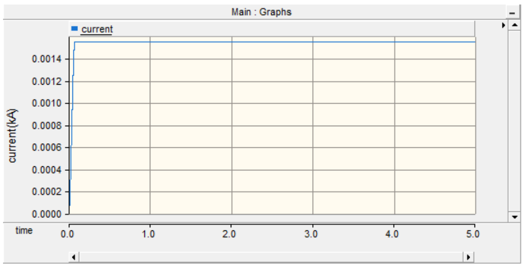

Figure 1.6: Current in line 1

1.1.3 Ring-main Distribution System

- The drawback of radial electrical power distribution system can be overcome by introducing a ring main electrical power distribution system. Here one ring network of distributors is fed by more than one feeder. In this case, if one feeder is under fault or maintenance, the ring distributor is still energized by other feeders connected to it. In this way, the supply to the consumers is not affected even when any feeder becomes out of service. In addition to that, the ring main system is also provided with different section isolates at different suitable points. If any fault occurs on any section, of the ring, this section can easily be isolated by opening the associated section isolator on both sides of the faulty zone transformer directly.

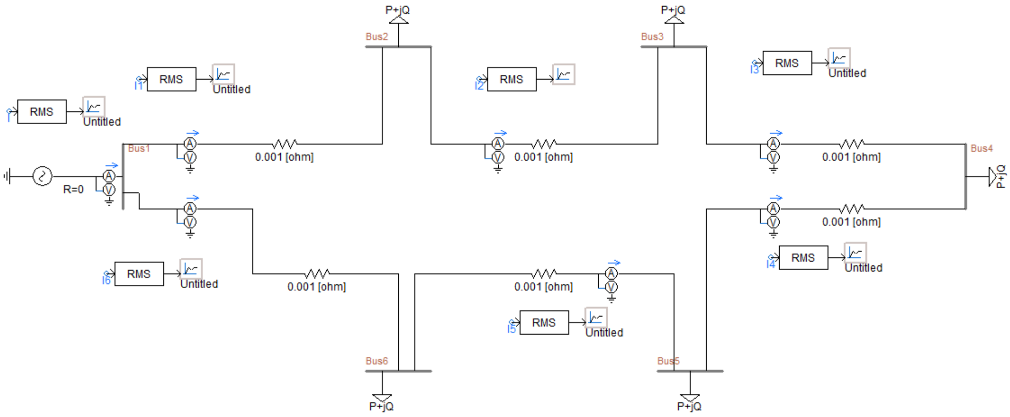

Figure 1.7: Ring-main distribution system simulation without fault

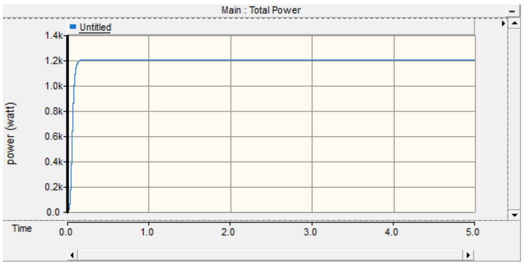

Figure 1.8: Total Power

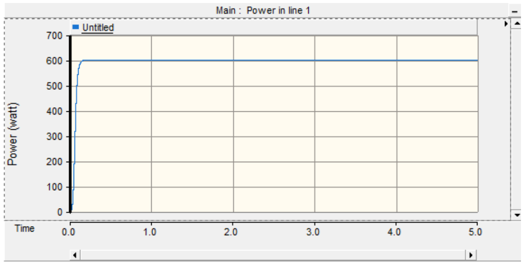

Figure 1.9: Power in line 1

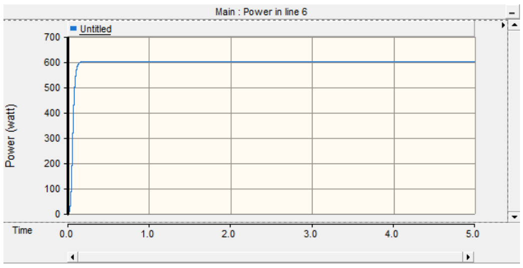

Figure 1.10: Power in line 6

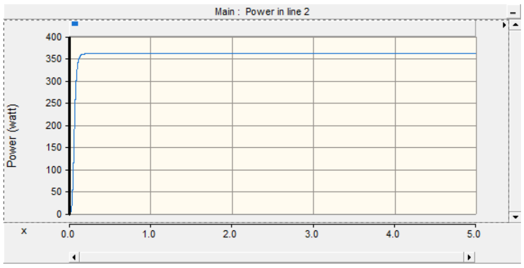

Figure 1.11: Power in line 2

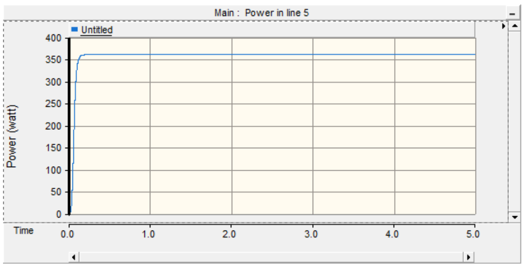

Figure 1.12: Power in line 5

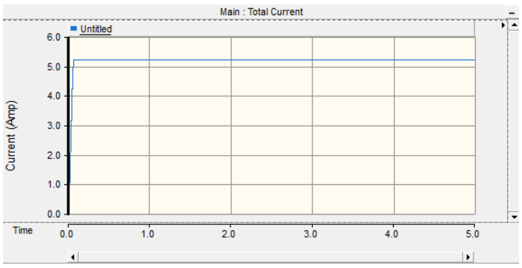

Figure 1.13: Total Current

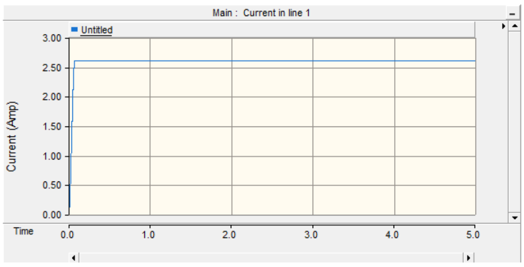

Figure 1.14: Current in line 1

1.1.4 Protection of Radial Distribution System

- Radial feeder, the power flows in one direction only, which is from source to load. This type of feeders can easily be protected by using either definite time relays or inverse time relays.Now,suppose fault occur at in between bus 1 and 2 which is shown by below figure.In this case relay gives trip signal to circuit breaker and circuit breaker will open.So other load which is connected to this radial feeder don't get power.

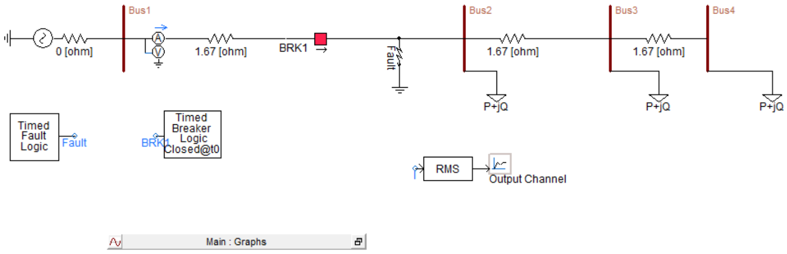

Figure 1.15: Radial distribution system with fault

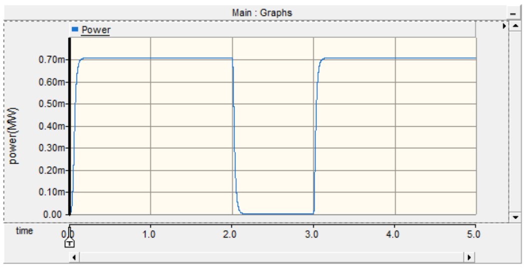

Figure 1.16: Power

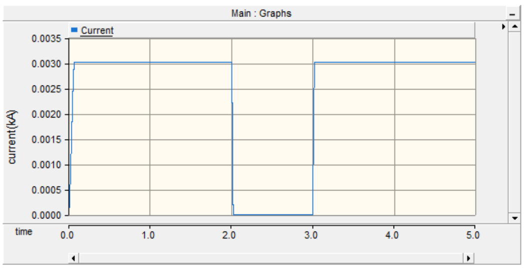

Figure 1.17: Current

1.1.5 Protection of Parallel Distribution System

- For maintaining stability of the system it is required to feed a load from source by two or more than two feeders in parallel. If fault occurs in any of the feeders, only that faulty feeder should be isolated from the system in order to maintain continuity of supply from source to load. This requirement makes the protection of parallel feeders little bit more complex than simple non direction over current protection of line as in the case of radial feeders. The protection of parallel feeder requires to use directional relays

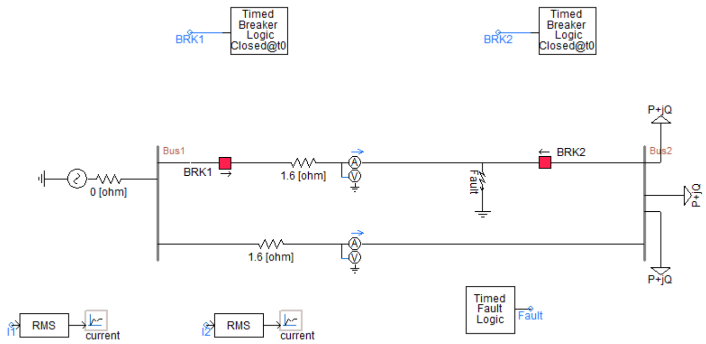

Figure 1.18: Parallel distribution system with fault

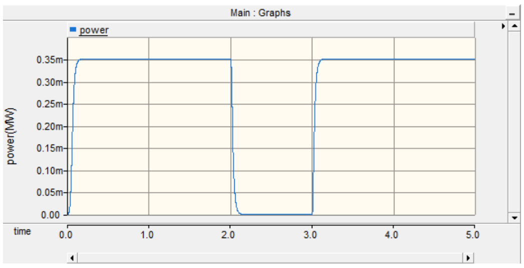

Figure 1.19: Power in faulted line

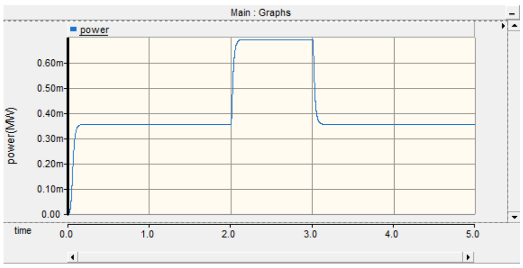

Figure 1.20: Power in healthy line

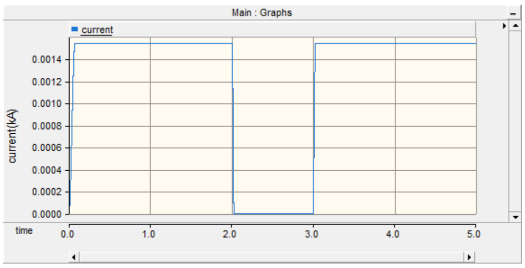

Figure 1.21: Current in faulted line

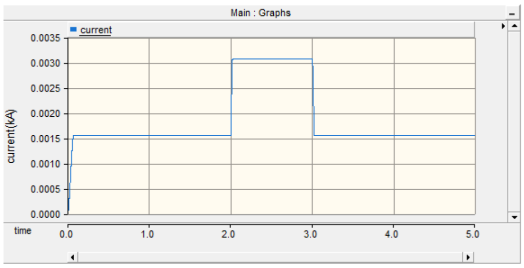

Figure 1.22: Current in healthy line

1.1.6 Protection of Ring-main Distribution System

- Ring main is a system of interconnection between a series of the power station by a different route. In the main ring system, the direction of power can be changed at will, particularly when the interconnection is used. Suppose fault occur at line 1 which is shown by below figure.So faulted portion of system is isolated by circuit breaker.But all the load is getting power by other line.So Ring-main system improve the continuity of supply of power

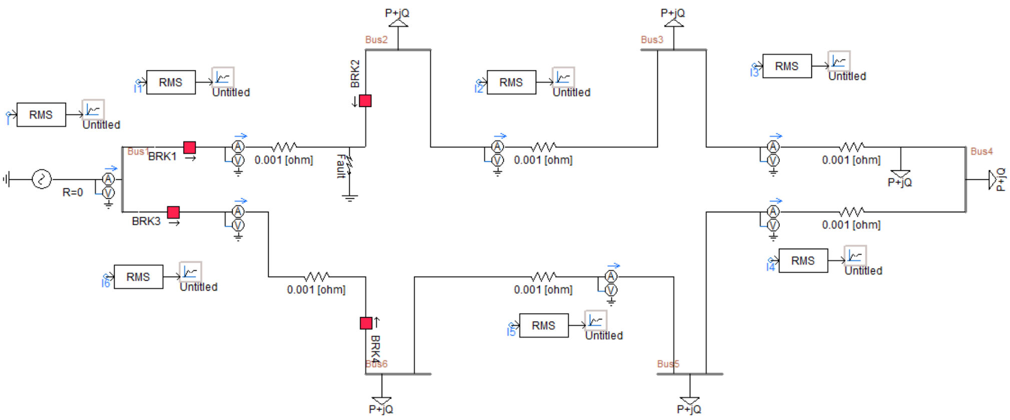

Figure 1.23: Protection of Ring-main Distribution system

- In above figure of ring-main distribution system, there are five load of rating 240watt. As we know,

$$P = V * I \tag{1.1}$$

- Where,P=Total power V=Voltage I=Total Current
- Total load is 1200watt and voltage is 230V. So,

$$1200 = 230 * I \tag{1.2}$$

$$I = 5.217Amp \tag{1.3}$$

- Now if all the lines are symmetrical, then current is divided in two part(half of total current)
- If I1=Current in line 1 I6=Current in line 6
- Then I1=I6=2.60 Amp

- Now if any fault occur at any line(here suppose at line 1 total current and power flow through line 6) current and power flow through other line

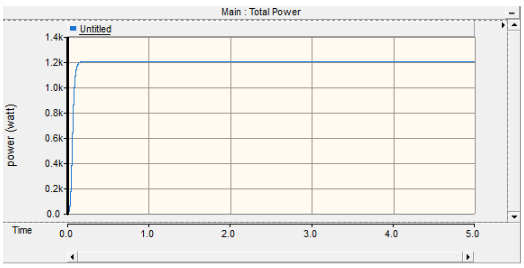

Figure 1.24: Total Power

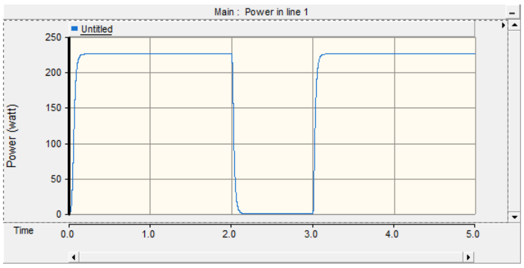

Figure 1.25: Power in faulted line

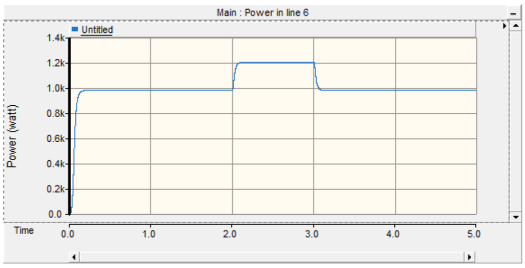

Figure 1.26: Power in healthy line

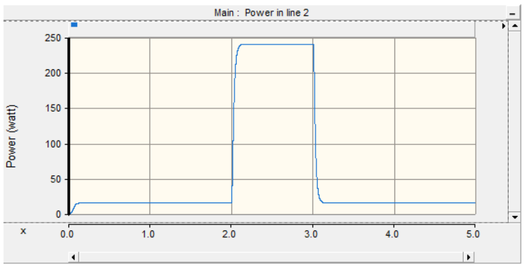

Figure 1.27: Power in healthy line

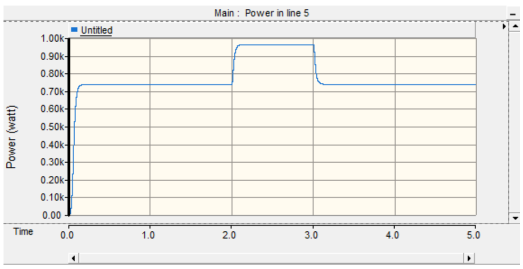

Figure 1.28: Power in healthy line

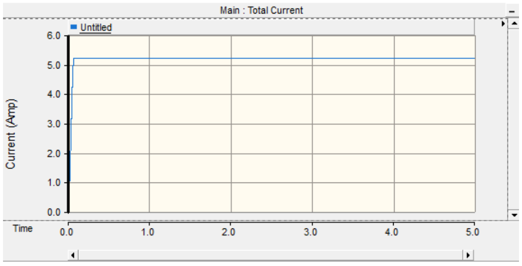

Figure 1.29: Total Current

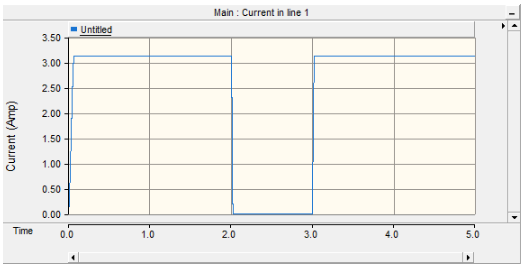

Figure 1.30: Current in faulted line

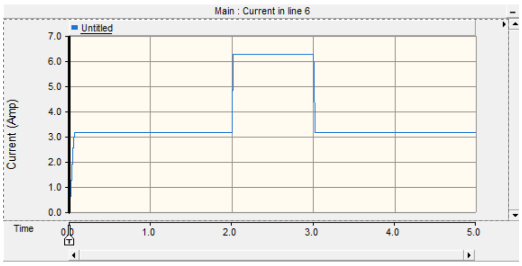

Figure 1.31: Current in healthy line

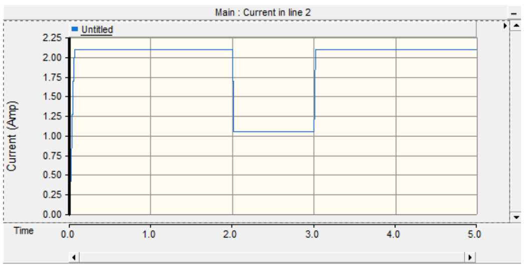

Figure 1.32: Current in healthy line

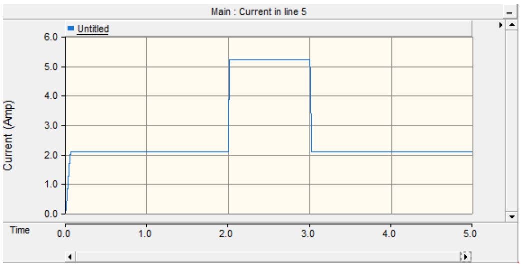

Figure 1.33: Current in healthy line

Chapter 2

Literature Review

2.1 IEEE Research Papers

1. Baiken Zholdaskhan, H.S.V.S Kumar Nunna, **"Adaptive Coordination Mechanism of Overcurrent Relays using Evolutionary Optimization Algorithms for Distribution Systems with DGs"**

- Directional current relays are one of the most common relays that are used in the protection of transmission and distribution lines. They provide reliable protection for the transmission lines. However, increasing proliferation of distributed energy sources may violate established relay coordination. This is caused by changes in fault current levels at the fault points, and thus coordination time interval of the relays are violated. This basically means that primary and backup relays do not operate in coordination with each other. Thus, it is vital to optimizing the relay settings in accordance with changing fault current levels.

2. Margo Pujiantara, Aditya Indrasaputra , **"The Automation of Time Dial Setting Calculation and Inverse Type Curve Selection for Over Current Relay Based on Numerical Computation in Real Industrial Electrical System"**

- A radial or ring distribution system is mostly used in industrial application with electrical components that are very complex and require a lot of attention in terms of the protection coordination of the electrical system. In the coordination of Over Current Relay (OCR), the setting is usually obtained by trial and error which is very subjective and time consuming. Therefore, a new program based on numerical computation algorithm is proposed, specifically to facilitate the calculation of Time Dial Setting (TDS) and the selection of the Time-Current Characteristic (TCC) curve for setting the inverse over current relay on the real electrical system.

Chapter 3

Relay Coordination

3.1 Introduction

- Relay coordination is the process of determining the "best fit" timing of current interruption when abnormal electrical conditions occur. The main aim of power system protection is to minimize an outage to the greatest extent possible.Relay coordination is also handled through dividing the power system into protective zones. If a fault were to occur in a given zone, necessary actions will be executed to isolate that zone from the entire system.There are mainly three types of discrimination method for relay coordination.

3.2 Terms related to Relay coordination

- Plug Setting Multiplier:

  It is the ratio of fault current in the relay to its pick up current

  Time Setting Multiplier:

  It is adjustment of travelling distance of an electromechanical relay is known as time multiplier setting of relay.

  Resetting time:

  It is defined as the time taken by the relay from the instant of isolating the fault to the instant when the fault is removed and the relay can be reset.

3.3 Time discrimination

∗ By adding time lag features to the controlling relays of a number of circuit breakers it is possible to trip the breaker nearest the fault prior to those farther off the point of fault. This simple scheme may be applied in a radial feeder shown in Fig. (3.1).

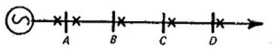

Figure 3.1: Radial feeder protection by time discrimination

breakers at A, B, C and .D are identical and are set to operate for a given value of current. For a fault in any section, say CD, if the fault current exceeds the set value the breakers at A, B and C will trip and the whole feeder beyond A becomes dead.

For providing time lag to the circuit breakers at A, B, C, and D the tripping is delayed in the following manner:

D-no added time lag

C-0.4s added time lag

B-0.8s added time lag

A-1.2s added time lag

With such a scheme obviously if the fault occurs in the section CD the breaker at C will trip after a time of 0.4s and thus wilt clear the fault with the result that the feeder up to C will remain alive. A 0.4s step time lag is necessary to account for the time of operation of circuit breaker and its relay operation times.

3.4 Current discrimination

· This depends on the current magnitudes as the magnitude of the fault current will also vary with the location of the fault. If the relays are set to pickup at a progressively higher current towards the source then a simple feeder system pf the type shown in Fig. (3.2) can be protected. Such a scheme is known as current graded scheme.

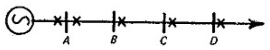

Figure 3.2: Radial feeder protection by current discrimination

3.5 Current-Time discrimination

· In the case of a ring main which forms a closed loop it is not possible to isolate the faulty section with the help of time alone. Consider the ring main shown in Fig. (3.3). In one case non-directional relays with same current setting but different time lags are provided which shows that proper discrimination cannot be obtained nor can this position be improved by varying the time lags from those shown in the diagram.

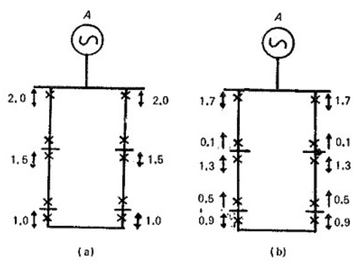

Figure 3.3: Ring-main feeder protection by Time and Current discrimination

In the second case for the same ring main directional feature is also introduced as shown by arrows. Now it can be seen that a fault occurring on any section will be discriminatively cleared without loss of supply.

Chapter 4

Genetic Algorithm

· GA is an optimization technique inspired by nature. In this method the chromosome (population) gets evolved so as to reach their maximum fitness value

Unlike any other algorithm GA algorithm begins by defining constrains and the objective function. The result obtained is considered to be accurate if the most accurate and optimized solution is obtained.

The procedure used for numerical optimization is reproduction, crossover and mutation

Reproduction is the process of selecting the individuals based on the fitness value when compared to their counterpart population. The selection is not random and is based on the fitness value (chromosomes with greater fitness value have greater chance of selection) and they are proceeded further for mating and subsequent genetic action. Chromosomes with greater fitness value live and reproduce and lesser fitness value chromosomes die.

Now crossover takes place in which a new chromosome is formed by combining part of information of both the parents. The offspring obtained from crossover are placed in new population

For crossover first the strings are selected from mating pool and then the swapping between two strings take place and then new offsprings are mixed with the population.

After that mutation is undertaken in which there is random alteration of binary digit in a string.

4.1 Relay coordination of ring main distribution system using GA

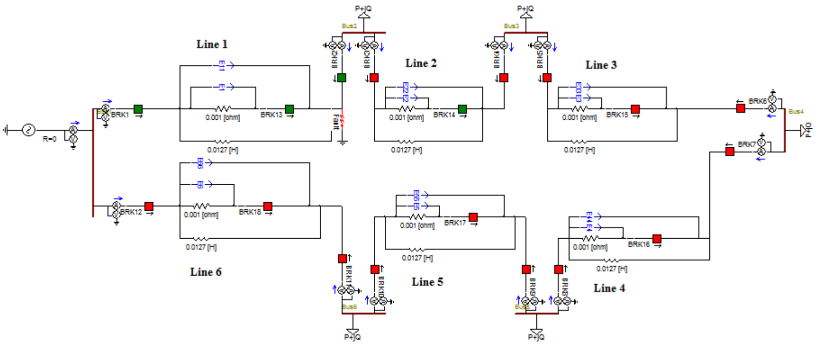

Figure 4.1: Ring-main distribution system

· Initially a simple ring main distribution system shown in above figure is considered.In this fault occur at line 1.There are total 12 relays.Here CTI is taken as 0.3s.

4.1.1 Objective Function

· The main aim is to minimize the total operating time of relays.

$$minz = \sum_{n=1}^{12}(0.14 * TMSn)/((Ifn/PSn)^{0.02}) - 1) \tag{4.1}$$

4.1.2 Constraints Function

$$(0.14 * TMSn)/((Ifn/PSn)^{0.02}) - 1) >= 0.2 \tag{4.2}$$

Where n=1,2,...,12

$$(0.14*TMSn)/((Ifn/PSn)^{0.02})-1)-(0.14*TMSn-1)/((Ifn-1/PS(n-1))^{0.02})-1) > \tag{4.3}$$

Relay	TMS	PS
1	0.421	100%
2	0.3	75%
3	0.35	75%
4	0.4	100%
5	0.1	100%
6	0.1	150%
7	0.15	150%
8	0.9	50%
9	1	50%
10	0.5	75%
11	0.55	75%
12	0.6	100%

· 4.2 MATLAB optimization tool result

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Chapter 5

Relay coordination for SFCL used ring-main distribution system

- SFCL is superconducting fault current limiter. In this type of protection scheme superconducting material is connected in line and current limiting reactor connected in parallel with line.

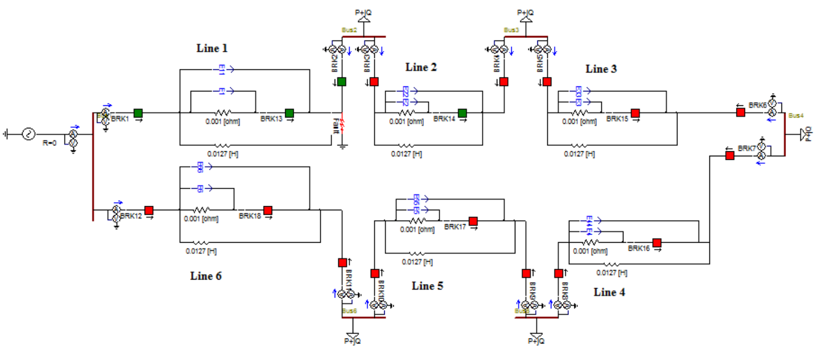

Figure 5.1: Fault in line 1 of ring-main distribution system

- As we see in above figure if fault occur at line 1. The fault current is limited by CLR. But at the same time the current is less so it affect the performance of relay. so in this scheme we use voltage component also.
- Now if fault occur the voltage drop across SFCL (here E1) because of fault current.This voltage drop open the circuit breaker which is connected in

SFCL.

- Now voltage drop E11 is also increase. So by this voltage drop and fault current we can give signal to relay. By this way performance of relay is not affect.

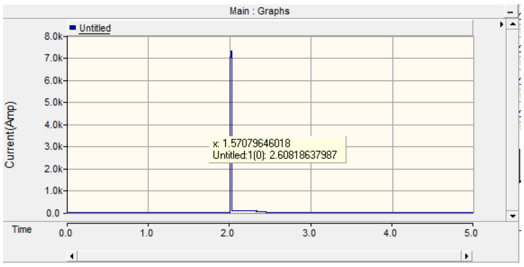

Figure 5.2: Fault current in line 1

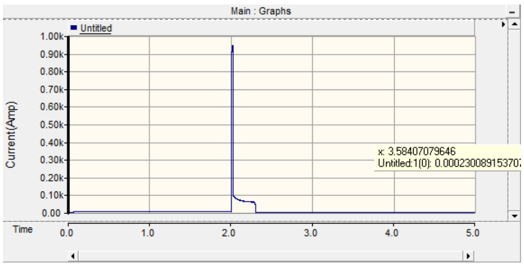

Figure 5.3: Fault Current in line 1

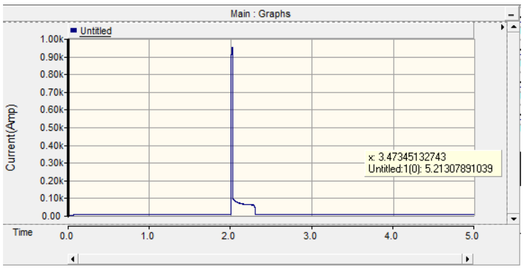

Figure 5.4: Fault Current in line 6

- Suppose fault occur in line 1.So BRK 1 and BRK 2 should be open.So at the time of fault current in line 1 is zero which is shown in figure 4.2 figure 4.3.And total current flow through line 6 which is shown in figure 4.4.

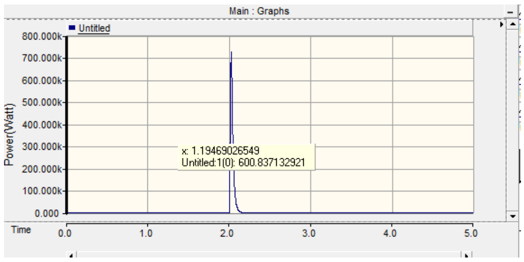

Figure 5.5: Power in line 1

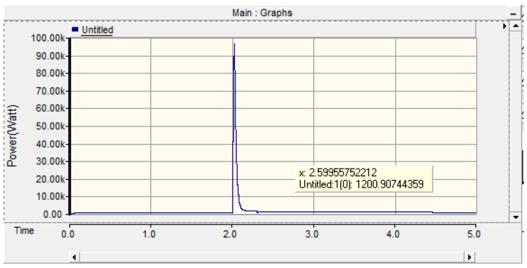

Figure 5.6: Power in line 6

- Here also BRK 1 and BRK 2 should be open.So at the time of fault Power in line 1 is zero which is shown in figure 4.5.And total power is flow through line 6 which is shown in figure 4.6.

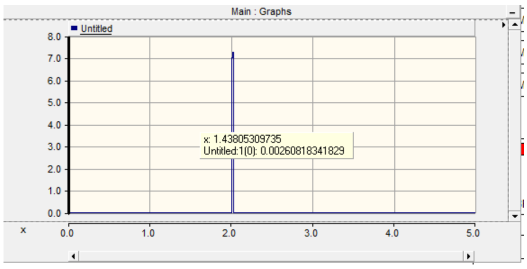

Figure 5.7: Voltage drop across Superconducting material 1

- We know that,

$$V = I * R \tag{5.1}$$

- V=Voltage

  I=Current

  R=Resistance

- Suppose,

  Rsc=Resistance of superconducting material Which is 0.001

Vsc=Voltage drop across superconducting material

Isc=Current through superconducting material

then,

$$Vsc = Isc * Rsc \tag{5.2}$$

· but Isc=2.60A From eq....(1.4)

Rsc=0.001

Therefore,

$$Vsc = 0.001 * 2.60 = 0.0026v \tag{5.3}$$

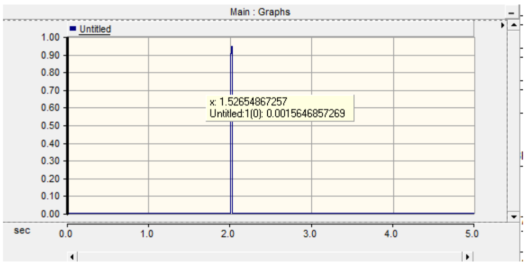

Figure 5.8: Voltage drop across SFCL 2

· In normal condition voltage across superconducting material is very less but at the time of fault voltage drop across it is considerable which is shown in figure 5.7 figure 5.8

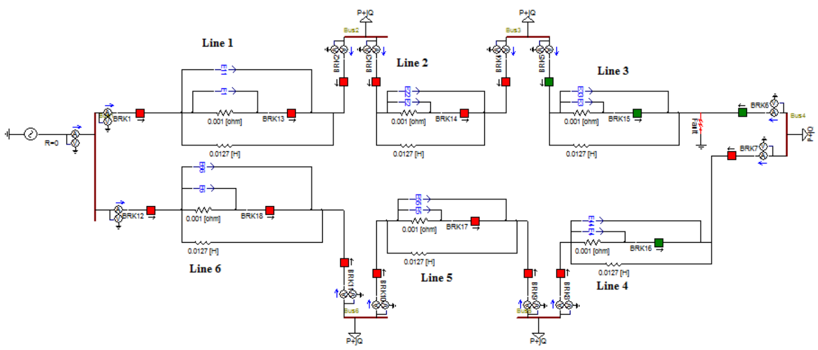

Figure 5.9: Fault in line 3 of ring-main distribution system

· Now suppose fault occur at line 3. So BRK 5 and BRK 6 should be open which is shown in figure 5.9

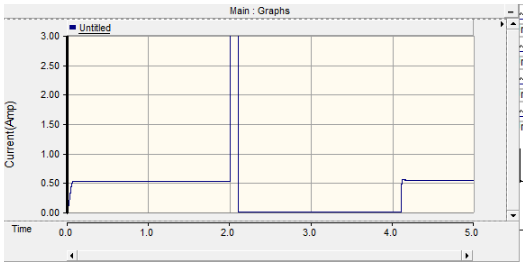

Figure 5.10: Fault Current in line 3

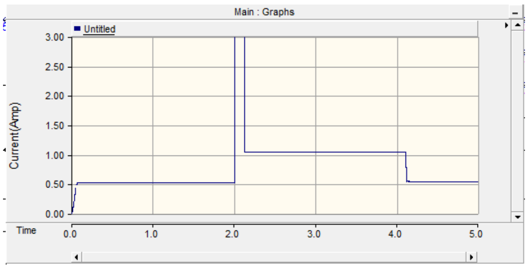

Figure 5.11: Fault Current in line 4

- When fault occur at line 3 BRK 5 and BRK 6 is open. So 3rd load get supplied by line 4 but in healthy condition it is get supplied by line 3 and line 4.(Half of power required flow through both the line)

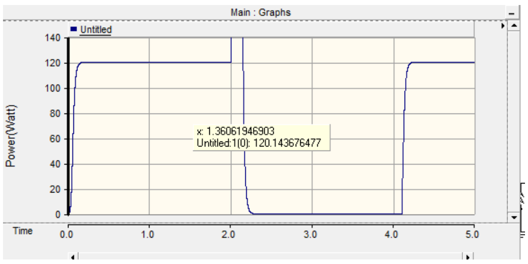

Figure 5.12: Power in line 3

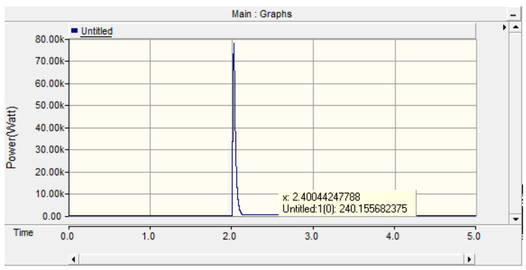

Figure 5.13: Power in line 4

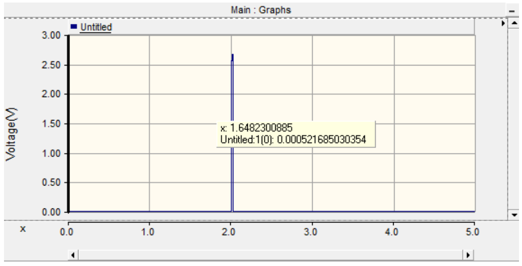

Figure 5.14: Voltage drop across Superconducting material 3

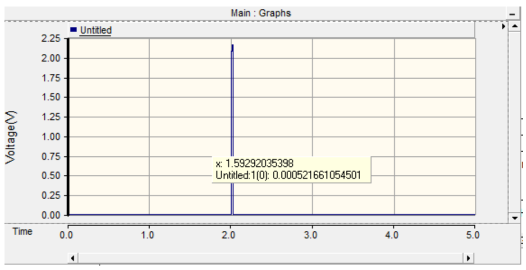

Figure 5.15: Voltage drop superconducting material 4

Chapter 6

Conclusion

- The different types of distribution system has been studied.Most of radial and parallel distribution system is used.Protection of it is not complex but also reliability is less. But in case of Ring-main distribution system relay coordination is more complex but it is more reliable.Earlier trial and error method is used for relay coordination but it is not reliable and time consuming process. But now a days, Soft computing technique is used for relay coordination which is reliable.

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