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Optimal coordination techniques for Directional over Current Relay

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ABSTRACT: In interconnected power system stability of entire system is concern of the principal importance. With interconnection a large number of protective relays are required. These relays are needed to be coordinated to give their optimal load flow and protection level. This work out regarding load flow analysis, fault level computations along with listing the primary & back up pair is going to be really monotonous. This work out can be quite difficult simply because we have to make collection of contingencies along with relay setting , which are to be decide using the worst circumstance. This paper represents different methodologies used to treat the problem of optimization of relay coordination of direction relay in interconnected power system. Attempts have been produced to cover all the methods used for over current relay coordination. Conventional techniques and new approaches like Artificial intelligence (AI) and Genetic algorithm (GA) are described briefly. Also MATLAB software based approach is explained by a case study and the results are also provided , so that the reader can easily understand DCOR relay coordination.

KEYWORDS: Over current coordination , Different network topologies, genetic algorithm (GA), ANN , Link-net structure – MATLAB.

I. INTRODUCTION

In economically immerging countries like India demand of electrical power is increasing drastically . This increase in electrical energy has also resulted in increased complexity of the power system . Due to this designing challenges have also increased . So it has been one of the mandatory function for power system to reach all the load points with equal reliability and efficiency . With increased requirements of power , higher and higher system voltages are used to deliver bulk power at high efficiency . Due to these increased system voltages , abnormal conditions like Over voltage , over load , under frequency , etc faults occur frequently . These faults are more likely to damage equipments connected hence results in interruption of supply [11] . The faulted components must be identified and isolated to guarantee the energy supply to the largest number of consumers as possible.

To protect transmission line and equipments in case of any faulty condition , two types of protective schemes , primary protection and back protection are used [1] . This protective systems check , analyze and perform quick switching operation , so that the system remains stable . To insure stability of the protective scheme , the back-up protection scheme shouldn't come into action unless the primary protection scheme (main) fails to take the appropriate action [10]. In other words, it should operate after a certain time delay known as Protection Coordination Time Interval (PCTI) [9] , giving the Chance for the primary protection to operate. The prime function of any protective scheme is covered under the requirement of reliability, selectivity , sensitivity and operating speed.

To meet this requirement all the transmission lines and their protection system are designed by a comprehensive and careful relay coordination . It is very important to develop a correct scheme for relay coordination to avoid mal function for protective systems . In this paper , in section 2 some conceptual and historical data for coordination of DCORs are covered . Different techniques for relay coordination are covered in section 3 , and in section 4 software based technique with a case study data and its analysis on ETAP software is covered.

II. PERCEPTION AND NARRATION

Power system protections is mainly distributed in protective zones. Each zone is accountable for avoidance and protections operate in separate zone of responsibility as quickly as possible from the system when fault occur in the

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International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

system . Directional Over Current Relays (DOCRs) are generally used for protection of Interconnected power system and distribution system [12] . With respect to location of fault , the relays may work as primary and back up protection . That means , the relay should work as primary protection for all the faults of its own zone and should work as back up protection for fault outside its zone of protection .

Over the last few decades , various methods have been developed to proper relay setting . Traditional approaches were not suitable for large power systems as they suffered delays in convergence rate due to a large number of iterations needed to reach a optimal relay setting [5] . Than new approaches invented that concerned graphical techniques and control functional dependency of relay settings , which determines break point of system [5] . Than even more advanced techniques were adopted such as Artificial intelligence (AI) and Genetic Algorithm (GA) [3 , 6 ,8] . Latest trends is to achieve optimal relay setting point by hign speed computers and software based techniques [10] . These techniques are very successful in solving wide range of optimization problems.

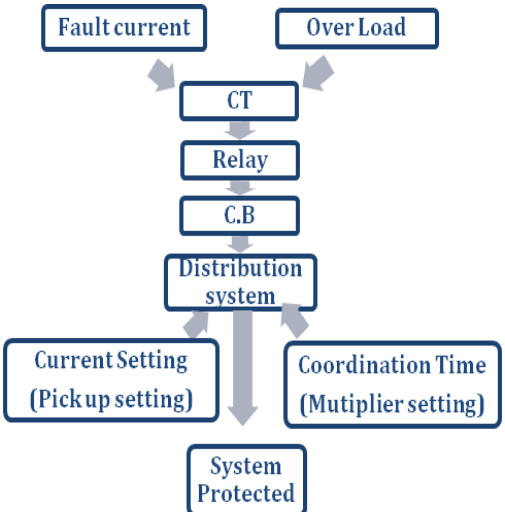

Fig : 1 : Process Frame work for DCORs.

III.DIFFERENT METHODOLOGIES

A. Conventional Methods

a) Trial and Error

This method was one of the first method adopted for solving relay setting problems .This method was iterative method required large time for calculation and result validation. With increase in system size , this method become more and more complex and suffered slow convergence time [9] . Which made in non suitable for large power system networks

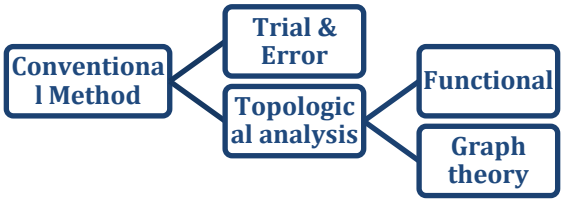

Fig: 2 :Conventional Method of coordination

b) Topological analytical method

Topological methods which include functional and graph theory are used to determine break points . In the functional method, the constraints on the relay settings are formulated by a set of functional dependencies. Other topological analysis which is linear graph theory has been extended to analyze all simple loops of the network in both directions considering the minimum set of breakpoints and so as the primary and backup relay pairs. The solution found using this method is the best of option settings considered but not optimal in any strict sense. Meaning that, the

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

TSM or time dial settings (TDS) of the relays are high [14] . Furthermore, due to the complexity of the system, topological analysis are time consuming and not optimal

B. Optimization

Optimization technique in general is more beneficial over conventional approach as in this techniques we need not to arrange all the relays before considering for coordination . This feature eliminates the need to find the minimum set of break points [4] . This technique became very popular along researchers .This technique basically defines process of coordination as Linear programming (LP) problem [12]. This reduces time taken for relay to operate on faults. Only constraints here are relay characteristics and relay setting limit [14].

In optimization , non-linear approach was also used by few researchers. The approach commonly known as mixed integer non-linear programming (MINLP) and is solved by using General Algebraic Modelling System (GAMS) software However , the discrete pick up current Ips was simulated by binary variables , which was time consuming and more complex [9 , 14] . Due to more complexity in non-linear technique , the optimization was done through linear method only. The only disadvantage of this system was , the pickup current Ip was assumed to be known and time taken for every relay to operate is considered as linear multiplier of TDS.

C. Artificial neural network

Artificial neural network (ANN) is an artificial intelligence (AI) based optimization technique. During last few decades, various research is being done on utilization of Artificial Neural Network for various purpose such as memory simulation and logical reasoning [9] . Since D. N. Vishwakarma proposed DCORs using ANN , various methods of AI have been developed and their application on the power system protection gave encouraging results. Some of the ANN methods like fuzzy logic and expert system (adaptive system) [13] overcome the traditional methods as it follows parallel distributed architecture for data processing and quicker operating speed.

With AI techniques , if linear programming (LP) is used , the results will represent only TMS (Time Multiplier Setting) for given value of I , but to find out optimal TSM of relays , non linear programming method is used[15] . A new method for modelling over current relay characteristics curves based on a combined adaptive network and fuzzy inference system (ANFIS) , over current relay modelling was done using ANFIS for two types of over current relays (RSA20 and CRP9) with different types to bring out the optimal design [15].

D. Genetic Algorithm (GA) & Hybrid GA.

Genetic algorithms can be defined as the automated search and optimization- algorithm based on the techniques of natural genetics and natural selection [6] . For optimal coordination of over current relay and to overcome mis-coordination problem by minimizing the operation time of relays , the concept of genetic algorithm was introduced in mid 60s [3]. In GA decision variables are encoded into binary string as a set of genes corresponding to chromosomes in biological systems. A group of the chromosomes are called a population [16] . The GA is essentially a method to generate a new population or generation from a given population. Members of each generation are ranked according to a specific criterion called fitness , which is derived from the objective function and constraints of optimization problem[16]. In each generation, the genetic operators (i.e., selection, crossover, and mutation) are applied to the individuals in the current population

I_{set} 1		I_{set} n	TMS_1		TMS_n
	....			....	

Fig : 3 :Structure of chromosome in the GA method.

To increase the computational efficiency of GA, it is beneficial to hybridize GA with conventional optimization methods. In this research work, using LP method, a new hybrid technique is presented and applied to DOCRs coordination problem. In hybrid GA method , conventional GA is used to solve only non-linear part of optimization problem. The output of this is value of I_{set} . So each population of chromosome re presents only value of I_{set} as shown in figure:4 [7] . Thus by extracting the non-linear part of coordination is determined and only linear part of TMS is left to

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

be determined . Due to decreasing the length of the genetic string in the proposed method, the GA's search space is significantly reduced [16] and hence operating speed is also increased.

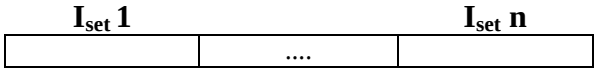

Fig : 4 :Structure of chromosome Hybrid GA

IV. SOFTWARE BASED APPROACH

Power system study and its analysis are important regions of power process architectural. The past number of years power engineers are focusing on the power system analysis employing computer software equipment [5 ,10] . Here few computer based methods are discussed .

A. MATLAB – Link-net structure [2]:

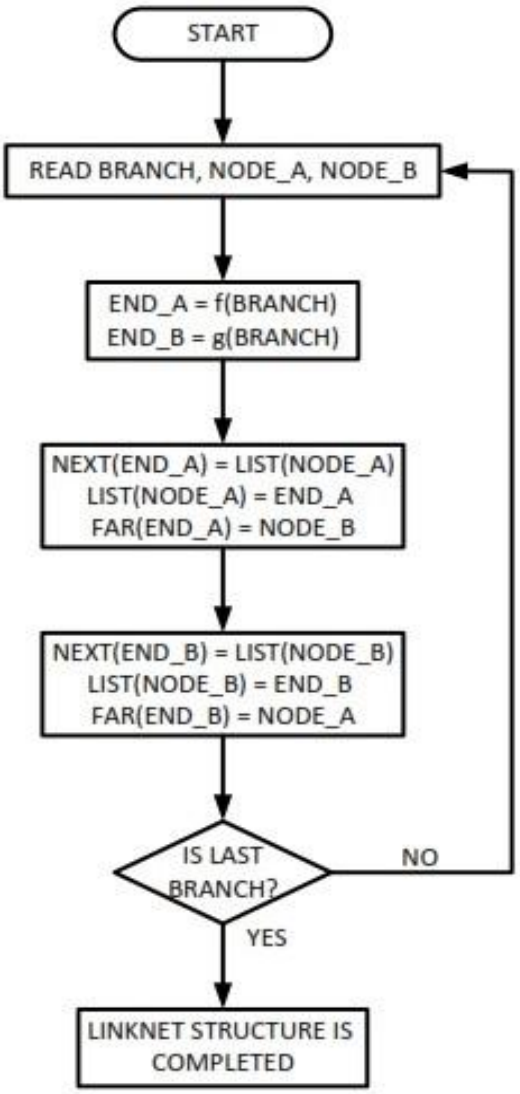

FIG: 5 :ALGORITHM TO FIND OUT LINK-NET STRUCTURE.

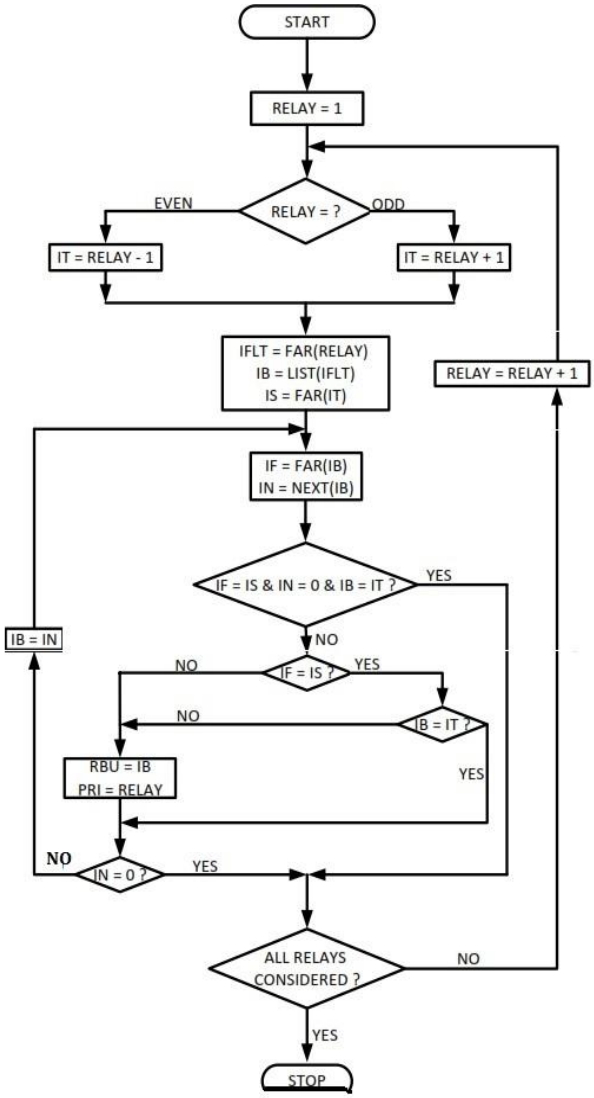

Fig : 7 : Algorithm to find out Primary-Backup relay Pairs – relay coordination

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

B. Program for linknet structure

```
% THIS PROGRAM IS FOR MAKING LINKNET STRUCTURE OF GIVEN NETWORK (Fig :6)
clc, clear all,
B=input('No of branch=');
a=1; b=2;
Node=zeros(2,B);
End=zeros(2,B);
List=zeros(2,B);
Far=zeros(2,B);
Next=zeros(2,B);
 %==========LOOP FOR GIVING NODE(A) & NODE(B) OF BRANCHES============
for l=1:1:B;
   fprintf('Enter Node A of branch %d =',l);
   Node(a,l)=input('');
   End(a,l)=(l*2-1);
   fprintf('Enter Node B of branch %d =',l);
   Node(b,l)=input('');
  End(b,l)=(l*2);
end
%==========LOOP FOR FIND OUT END(A) & END(B) OF BRANCHES============
for l=1:1:B;
   End(a,l)=(l*2-1);
   List(a,l)=End(a,l);
   End(b,l)=(l*2);
   List(b,l)=End(b,l);
end
%==========LOOP FOR FIND OUT FAR(END) OF BRANCHES============
for l=1:1:B;
   Far(a,l)=Node(b,l);
   Far(b,l)=Node(a,l);
end
%==========LOOP FOR FIND OUT NEXT(END) =LIST(NODE) OF BRANCHES=========
for l=1:1:B;
   if l==1;
      Next(a,l)=0;
      Next(b,l)=0;
   elseif l>0;
%=====FOR FINDING NEXT(A) OF ALL BRANCHES
      x=l;
      while (x>1)
if  Node(a,l)==Node((b),(x-1))
           Next(a,l)=End((b),(x-1));
         elseif Node(a,l)==Node(a,(x-1))
              Next(a,l)=End(a,(x-1));
         end
         if Next(a,l)==0
            x=x-1;
         else
            x=0;
```

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

```
        end
      end
%==========FOR FINDING NEXT(B) OF ALL BRANCHES===============
      y=l;
      while (y>1)
      if  Node(b,l)==Node((a),y)
          Next(b,l)=End((a),y);
        elseif Node(b,l)==Node(b,(y-1))
            Next(b,l)=End(b,(y-1));
        End
        if Next(b,l)==0
          y=y-1;
        else
          y=0;
        end
      end
   end
end
```

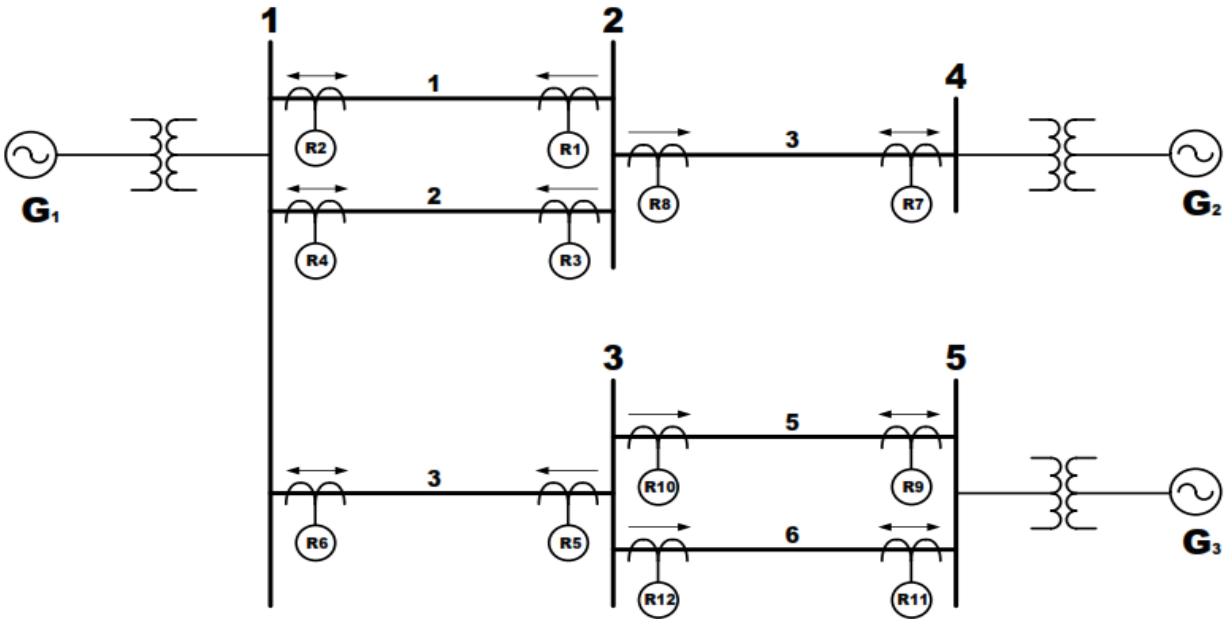

Fig :6 : Power system network for coordination

Above program and algorithm in fig :5, gives linknet structure . To find out optimal relay coordination of primary and back up relay for the network given in fig:6 , the algorithm of fig :7 and program below should be followed .

C. Program for relay coordination

```
relay=B*2;
NodeR=zeros(1,relay);
FarR=zeros(1,relay);
NextR=zeros(1,relay);
EndR=zeros(1,relay);
ListR=zeros(1,relay);
```

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

```
ListD=zeros(1,relay);
BranchR=zeros(1,relay);
 %=========="BranchR"==========
for i=1:1:B;
   BranchR(2*i-1)=i;
   BranchR(2*i)=i;
end
%=========="EndR"==========
for i=1:1:B;
   EndR(2*i-1)=End(1,i);
   EndR(2*i)=End(2,i);
end
%=========="ListD"==========
for i=1:1:B;
   ListD(2*i-1)=List(1,i);
   ListD(2*i)=List(2,i);
end
%=========="NodeR"==========
for i=1:1:B;
   NodeR(2*i-1)=Node(1,i);
   NodeR(2*i)=Node(2,i);
end
% FIND THE LIST OF RELAY
y=max(NodeR);
for i=1:1:y;
   for NR=1:1:B;
       if Node(1,NR)==i
          ListR(i)= List(1,NR);
      elseif Node(2,NR)==i
          ListR(i)= List(2,NR);
      end
   end
end
% FOR FIND OUT PRIMARY/BACK-UP RELAY PARIS
RBU=null(relay,relay);
IF=zeros(1,relay);
IN=zeros(1,relay);
IT=zeros(1,relay);
IFLT=zeros(1,relay);
IB=zeros(1,relay);
IS=zeros(1,relay);
% TO FIND OUT, IS THE RELAY ODD OR EVEN?
for R=1:1:relay;
rr=R;
while (rr>2)
   if rr>2
      rr=rr-2;
   end
end
if rr-1==0
   IT(R)=R+1;
   IFLT(R)=FarR(R);
```

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

```
   IB(R)=ListR(IFLT(R));
   IS(R)=FarR(IT(R));
elseif rr-2==0
   IT(R)=R-1;
   IFLT(R)=FarR(R);
   IB(R)=ListR(IFLT(R));
   IS(R)=FarR(IT(R));
end
rbu=1;
v=relay-1;
while(v>0)
IF(R)=FarR(IB(R));
IN(R)=NextR(IB(R));
% CHECK FOR "IF=IS" & "IN=O" & "IB=IT"
if IF(R)==IS(R) && IN(R)==0 && IB(R)==IT(R)
   v=v-v;
else
   if IF(R)==IS(R)
      if IB(R)==IT(R)
         if IN(R)==0
            v=v-v;

else
            IB(R)=IN(R);
            v=v-1;
         end
      else
         RBU(R,rbu)=IB(R);
         rbu=rbu+1;
         if IN(R)==0
            v=v-v;
         else
            IB(R)=IN(R);
            v=v-1;
end
   end
   else
      RBU(R,rbu)=IB(R);
      rbu=rbu+1;
      if IN(R)==0
         v=v-v;
      else
         IB(R)=IN(R);
         v=v-1;
      end
   end
 end
end
end
end
```

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

D. Simulation results

Input ::

No of branch=6
Enter Node A of branch 1 =1
Enter Node B of branch 1 =2
Enter Node A of branch 2 =1
Enter Node B of branch 2 =2
Enter Node A of branch 3 =1
Enter Node B of branch 3 =3
Enter Node A of branch 4 =2
Enter Node B of branch 4 =4
Enter Node A of branch 5 =3
Enter Node B of branch 5 =5
Enter Node A of branch 6 =3
Enter Node B of branch 6 =5

Output ::

LINKNET STRUCTURE FOR GIVE NETWORK
""

Branch	Node	End	Next	List	Far
1	1	1	0	1	2
1	2	2	0	2	1
2	1	3	1	3	2
2	2	4	2	4	1
3	1	5	3	5	3
3	3	6	0	6	1
4	2	7	4	7	4
4	4	8	0	8	2
5	3	9	6	9	5
5	5	10	0	10	3
6	3	11	9	11	5
6	5	12	10	12	3

PRIMARY / BACK-UP RELAY PAIRS IF GIVEN NETWORK ""

Back up Primary	1st	2nd
1	7	4
2	5	3
3	7	2
4	5	1
5	11	9
6	3	1
7	0	0
8	4	2
9	12	0

ISSN 2350 - 0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 5, May 2016

V. CONCLUSION

This paper provides a comprehensive review on Directional Over Current Relay (DCORs) coordination . Various methods and techniques are proposed and implementation of them on interconnected system is studied . New methods like ANN , and GA seems to be reliable and faster than conventional methods. The latest software based approaches are most suitable for very large size of systems . At the end , latest trends on system coordination is presented through a simulation data in MATLAB . The results obtained on a 5 bus system are found to be very decisive. Future work is proposed here to improve the over current relay coordination with the existence of smart grid. The author would like to apologize for any error or any oversight and hope that additional references will be discussed on this publication

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