ANN Adapting Auto_Reclosing Relay In a Simulated Iraqi Super Grid

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Abstract: - In this paper the concept of Artificial Neural Network (ANN) was implemented in constructing an Adaptive Single Phase AR (ASPAR) relay. The heart of this relay is an ANN trained to discriminate healthy system, permanent fault, transient fault and extinguishing of the secondary arc. Thus issuing right decisions. The proposed ANN method is trained only to recognize single phase to ground fault types (both transient and permanent) simulated on TL Model between Baijie Thermal Power Station and Mosul Super Grid Sub-Station 400Kv from Iraqi North Regional Grids (INRG).

Key-Words: - Adaptive Auto_Reclosing, Non Discriminating Protection (NDP), ANN.

1 Introduction: -
Auto_Reclosing (A/R) relay is one of the important protections in HV networks, which restore Transmission Lines after transient faults. Specially most of the faults on Over Head Transmission Lines (OHTL) are transients in nature [1-3]. So A/R affects stability and improves reliability of the transmission system [4]. Over the last two decades, a large number of papers have appeared in the area of AI in power system protection [5-7]. Some particularities of Automatic Reclosing application in Russian electric networks in new conditions caused by the former USSR Separation are briefly characterized in [8], with a statistical data proving A/R effectiveness are given.
A Numerical Algorithm for Blocking A/R During Permanent Faults on Overhead Lines were proposed by [9]. The algorithm proposed in this paper determines the nature of the fault from the arc voltage amplitude estimated using the least error squares technique and blocking Auto_Reclosing relay during permanent faults. Simulation and laboratory results are included.

Development of Novel Adaptive Single-Pole Autoreclosure Schemes for Extra High Voltage Transmission Systems Using Wavelet Transform Analysis, have been proposed in [10]. The discrete wavelet transform is adopted to analyze the fault transients caused by the secondary arc and permanent faults. It is shown that certain wavelet components can be effectively used to detect and identify the fault characteristics.

2 Artificial Neural Network (ANN):  
ANN method is used because it is simple and quite suitable to the problem of A/R protection than other AI methods [5].

2.1 Model Implementation:  
The power system block set has been implemented by means of Matlab-Simulink. For the investigations of the effects of the secondary arc on the “dead time” of the single phase Auto_Reclosing relay operation. Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation [11]. Matlab Simulated power System block sets used to simulate the Iraqi North Regional Super Grid (INRSG). Two Lines between Mosul SG and Baijie 400 KV Sub Stations, of the types twin conductor per phase, each three phase conductors horizontally aligned and one circuit on single tower configuration. So there is no mutual effect between the two circuits. Both S/S’s Bus Bars (BB) have been represented. Baijie Power plant BB represented by the load Generated behind it, while Mosul SG BB, by the short circuit level on it’s 400 Kv BB.

TL’s parameters were simulated, using the equivalent pi cascaded sections, representing transposed TL, in which the mutual coupling effect is considered. The simulated circuit of Iraqi transmission system shown in fig.1. Single phase to Ground faults are simulated on Mosul – Baijie No(1). The protection system at both ends pick-up and
initiate circuit breakers trip, in this case only the faulty phase will be isolated, the other two healthy phases will continue on service while the recommended power will flow through the parallel circuit (Mosul- Baijie No.2), and also through the shadow HV transmission Network; this is to maintain synchronism and increase the reliability & stability margin of the system.

There will be induced voltage in the faulty phase due to the current flowing in the sounded phases according to the mutual phenomena[1]. This voltage will feed the secondary arcing current via the fault path.

2.2 Circuit description:
Two 400 kV parallel lines, each of 183 km long, single circuit configuration, capable of transmitting 2000 MW of power from a generation plant (6 generators, each of 220 MVA) to an equivalent network having a short circuit level of 6650MVA. The generation plant is simulated with a simplified synchronous machine of Sub Transient reactance of 0.22 pu. As shown in fig 1, the machine is connected to the transmission network through a 13.8 kV/ 400 Kv Star-Delta transformer.

Line Baijie _Mosul 2 is shunt compensated by a reactor of 50 MVAR, connected at Baijie BB.

2.3 Arc Model:
The arc is modeled by a fixed or non-linear resistance $R = f(I_{arc\_rms})$. It extinguishes when it’s rms current falls below a certain threshold value (typically 20 A) defined in the arc model block. Actual arc extinction occurs at next current zero-crossing [11]. The mean arc resistance is programmed as an exponential function of the rms current, and it’s resistance increases when the rms arc current decreases so that the time for arc current to decay below the threshold value is shortened.

The fault is applied at $t = 20$ msec. Then, the opening command is sent to both breakers at $t = 80$ msec (3 cycles time for fault detection +1 cycle for CB opening time), then the two CBs are Reclosed at $t = 34$ cycles time after a dead time of 30 cycles time, during which the arc creating the fault should be extinguished.

3 Feature extraction:
Feature extraction is the process of selecting out from a range of possible data measurements the data which will be used to represent the problem, and whether this data will require transformation into different form [5, 12]. The choice of feature extraction method is problem dependent.
window from class do not reclose and it needs a
time to distinguish the secondary arc current and
regain the dielectric properties of the air insulant.
sufficiently to withstand the restoration of full system

![Fig.2: Permanent Fault from class 1.](image1)

3.2.2 Class 2, (Safe to reclose):  
This case represents a nominally healthy
phase voltage which may occur due to an incorrect
trip event or a post secondary arc of transient fault.
This condition is shown in Fig.4.
As can be noted from Figures 3 and 4 that it is a
transient fault in the first case, the second class does
not

![Fig.3: Transient fault with window from class1.](image2)

voltage. The classification of data windows into
these classes therefore requires some form of
decision support and algorithmic consideration
before being acted upon by a relay.

![Fig.4: Transient fault with window from class 2.](image3)

4 Frequency and amplitude analysis:
The voltage signal taken from the faulted
phase of the transmission line varies with time, and
the frequency components within the waveform
evolve with time during the progression of the fault.
Fast Fourier Transform (FFT) analysis which take
an input array and produce a frequency domain
representation are a powerful technique for
examining the behavior of sequential wave form.
The basic premise of a frequency domain
representation is that the signal can be fully
represented, over an interval, by the superposition
of a number of frequency harmonics [12]. One method
for obtaining the frequency spectra of a discrete
array is to use a discrete Fourier transform (DFT)
which transforms the input array into an array of
complex coefficients [10]. These coefficients
specify the amount of each frequency harmonic
required.

4.1 Transient fault:
When the frequency spectra for different wave
forms of data were examined, certain characteristic
behavior was apparent. There is more high
frequency energy while a secondary arc exists than
when it has extinguished as can be seen in fig.5.
Post arc transient fault waveforms contain a system
frequency component usually larger than that of the
permanent fault.
It is clear that the behavior of some frequencies is
representative of particular stages of the faulted
voltage waveform.

![Fig.5: Secondary arc voltage harmonics content.](image4)

4.2 Permanent fault waveforms:
The constant impedance permanent fault waveforms
contain only a small system power frequency
component. The size of this component depends on
the fault impedance, the position of the fault and the
coupling between healthy phases. A feature
extraction method which measures the energy in
seven different frequency bands was used to
implement the ASPAR. A discrete 3-phase sequence analyzer blocks are used to observe and calculate the fundamental and harmonic components of the measured signal. The magnitudes of seven discrete 3-phase sequence analyzer blocks are used to monitor the positive-sequence of the fundamental, DC, second and seventh harmonic voltages (Va, Vb, Vc), the negative-sequence component of the third and fifth harmonics and zero-sequence component of the ninth harmonics.

4.3 Method of input vectors selection:
The DFT windows along each case has been thoroughly analyzed. Fault location and type (whether it is transient or permanent fault) at every ten Kilometers through the hall TL from Baijie BB to Mosul SG BB, have been tried and simulated in order to achieve the required array of training and test data of ANN. Each frequency domain snapshot of the system derived from any window, can be associated with a particular desired outcome; ‘safe to reclose’, or ‘do not reclose’. Every other frequency domain feature set is combined with its desired outcome to produce a training set suitable for training the ANN. These seven frequency bands provide the core of the feature extraction process.

5 Artificial Neural network training:
There are many techniques for training a neural network. The training process will adjust the weights associated with neuron inputs [6, 12]. Supervised training works by showing the network a series of matching in cut and output examples. The network will adjust its weights to accommodate each training example. The training process is complete when the network produces the correct output for every input case. The network's weights are then 'frozen' in their trained states and the network is ready for use. New input data can now be presented to the network, and the network will determine the appropriate output based on its trained connection weights. Although the training process itself can be slow, trained networks are very fast in their operation.

It is this training process that makes neural computing different from conventional computing. Conventional computer systems have to be explicitly programmed. The problem has to be analyzed in sufficient depth to enable a programmer to write down an explicit, step-by-step series of instructions that the computer should follow to solve the problem. By contrast, neural computing applications are trained to solve the problem and take responsibility for their own internal 'programming' by automatically adjusting the weights.

5.1 ANN Topology selection:
Even if all the previous steps were taken properly, the ANN topology optimization is still not done. Some topologies may appear to be at the same competitive level. At this moment, engineering judgment is necessary to decide which one is "optimal". The basic consideration is that large number of hidden layer neurons can improve the ANN’s diagnostic accuracy to some extent by increasing its complexity, but the improvement may not justify the addition of required resources (memory and processing time).

After examining Table 1 and applying engineering judgment, 7-21-1 type ANN is selected to be the optimal topology for the adaptive A/R relay shown in fig.6.

| Table 1: Performance accuracy (%) of ANN based feature Input vector N for data set |
|---------------------------------|-------------------------------|
| N-35-1                          | 72.25                         |
| N-28-1                          | 81.5                          |
| N-21-1                          | 91.75                         |
| N-14-1                          | 79.15                         |
| Topology                        | N = 5                         |
| N = 7                           | 96.25                         |
|                                 | 93.75                         |

6 Adaptive Single phase A/R relay description:
In the simulation Model only single – phase to Ground fault at different locations along the TL is simulated because it is most popular one (85% of the faults) [1]. Adaptive Single Phase Auto Reclosing (ASPAR) technique was developed. The processing technique is an ANN which has been trained to recognize secondary arc extinction from the feature extraction of the faulted phase voltage. A feed–forward type ANN paradigms is used with the error back–propagation training algorithm. Levenberg–Marquardt (LM) found to be the best suited algorithm to the problem. Despite that LM training method require large memory, but it is fast in approaching to the recommended decision [12].

The ANN as discussed in chapter two section 3, is a collection of simple processing elements called neurons which are connected together by weights of different strengths. The weights are adjusted by the training procedure upon presentation of examples of data to allow the ANN to classify the tripped phase via a processing...
Fig.6: Topology of the selected ANN of 7x21x1.

stage as a Boolean output of safe to reclose = TRUE or FALSE, 1 or 0, respectively. The "safe to Reclose" = TRUE condition is represented by output "1", is used to initiate circuit breaker reclosure. If the secondary arc is not extinguished yet, the tripped phase will not be capable of withstanding the restoration of full system voltage immediately. This means that confidence that "safe to recluse" is TRUE must be incorporated with consideration of the post secondary arc deionization time. Those factors have been incorporated into an ANN output processing scheme with in the ASPAR. The situation where confidence in a decision is required is often encountered in power system protection and numbers of techniques such as distance measuring multi-zones and inverse time Over Current (O/C) relays, that is Non Discriminating Protection (NDP) characteristics are commonly employed to address it [5]. The "unsafe to reclose" = FALSE in the ASPAR will prevent circuit breaker reclosure onto a permanent fault. However, in the case of conventional Auto_Reclosing scheme, unsuccessful reclosing onto a permanent fault will follow a three phase tripping and lock out operation. Thus ASPAR preventing a second shock and avoiding voltage dip to the system.

7 Proposed ASPAR relay application:

The suggested block diagram of adaptive single phase A/R relay application as shown in fig.6. Three phase analog values secondary voltages from the TL terminal CVTs (R, S and T) will be the inputs of the anti-aliasing filter. All these CVTs have an output voltage of 110/√3 volts. An anti-aliasing filter is used to avoid possible errors in reconstructing the input signal, which is carried out after the A/D Sample/Hold section. Any signal sampled at a frequency of N*50 Hz, can exhibit aliasing when reconstructed, if the signal contains harmonic components of order N±1, 2N±1, …., xN±1. An anti-aliasing filter has to cut off all signal components above the Nyquist rate of N/2, i.e. the cut-off frequency for anti-aliasing filter should be set not higher than (N/2)*50 Hz. In practice however, such a filter cannot remove all out of band frequencies, so the cut-off frequency for the anti-aliasing filter is typically set at about (N/3)*50 Hz. Analog to Digital (A/D) converter sample and hold block will normalize and convert the three phase voltages to digital values suitable to be processed by the ANN block which is consist of the algorithm stored in the processor. Feature extraction and the trained ANN is the core of this digital relay. The output of this block is the decision that have been judged from the input signals to the relevant single phase drive mechanism of the circuit breaker after conversion of this commands from digital to analog values.

8 Conclusions

a) After comparing the study of ANN, two-layer single output ANN based network was identified as the best choice for HV OHTL AR protection. Feed Forward supervised back propagation ANN with 7 neuron in the input layer, 21 neuron in the first hidden layer, 1 neuron in the output layer identified as the best choice for TL reclosing decision advisor.

b) ANN based Adaptive Single Phase Auto_Reclosing (ASPAR) relay was developed via modification of international standards and addition of special rules. This new adaptive relay successfully advise reclosing commands avoiding reclosures onto permanent fault and recognizes secondary arc extinction, thus issuing right decisions.

c) The ninth zero sequence harmonics have been chosen together with six harmonics sequences to represent the OHTL status (whether it is healthy or not; safe to reclose or do not reclose).
d) Developed ASPAR trained to identify only Single Line to Ground faults both transient and permanent fault types.

e) The modeled circuit which implemented in MATLAB power system block sets, failed to simulate close single phase earth faults to both Bus Bars of Baijie TPS or Mosul SG S/S (up to 6% of TL length), due to the huge fault currents so the simulated system become unstable.

f) A suitable dead time must be adequately chosen to assure secondary arc extinguishing and re-healing of the fault path. Otherwise, despite it is transient fault, the A/R will fail to reclose the TL due to the secondary arcing current.

References:


