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Research paper

Intelligent power transformer protection relay based fuzzy logic

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Abstract

The main issue of differential relay is to sense the varying of power transformer current during any working conditions. . Recently, the improvement of core steel decreases the 2nd harmonic of current in inrush state, but that will produce maloperation of relay in the case of low second harmonic inrush current and in the case of high second harmonic internal fault. The fuzzy based differential relay is used for power transformer protection which consists of harmonic restraint, flux-differential current derivative curve and percentage differential characteris-tic curve. The proposed approach was implemented in MATLAB /Simulink (R2010B) environment. Numerical results obtained have veri-fied the effectiveness of the proposed scheme when tested for all fault types

Keywords: *Differential Relay; Smart Relay; Fuzzy Controller; Power Transformer Protection.*

1. Introduction

Protection relays are one of the most important equipment in the protection of power system. These are economic, flexible and well-known devices that provide fast, reliable and inexpensive protection. There are many types of protection relay such that; differential relay, over current relay and distance relay that was used to improve power system stability. The differential relay is used to protect power transformer because its important part in power system and expensive. Power transformer internal fault may be a source of global damage or losing of power system stability. Therefore, different techniques were used to avoid shutting down of power supply and terrible loss. The traditional protection can't meet the fast growing of electrical power system. Differential relay show certain limitation in detection of a differential current [1-6]. To overcome this problem can be used the artificial intelligence methods as an improvement to the existing protection relay function. This paper describe fuzzy logic-based differential relay by using Partial flux over partial subtraction of current, Second harmonic component of subtraction of current and Percentage of restraint over subtraction of current as inputs to the fuzzy controller[13,14].

2. Related works

The first work were based on giving delay time to the relay to beat the transients [18] these paths are unacceptable because the transformer perhaps insecure for a large unprotected period of time. so far, another work based on the ratio of second harmonic component to the fundamental component was applied recognized as differential relay based on harmonic restraint [21], which amended dependability and security was wandered .yet, another researchers have notified the presence of big magnitude of second harmonic component in some winding faults [20-21] also the power transformers have a core with low-loss amorphous ,which have inrush current with higher magnitude and lower harmonic contents [21] .In such cases , some writers have develop the ratio of dividing second harmonic component to the fundamental component criteria by having another value of ratios explained at a higher frequency [22]. But another author apply wave shape comparison and estimation of error technique [23], method of fuzzy logic [20] , analysis of principal component [24] and technique of correlation analysis [25] to separate internal fault from normal conditions. There are many protection gauge have been developed to support the traditional differential relay like neural network and fuzzy logic controller [7-8]. In [7], discriminate between inrush and internal fault by using artificial neural controller. In [8], differential relay to protect power transformer based on fuzzy controller. Most of these ways are liable in the case of low component of second harmonic of inrush current and high component in internal fault.

3. Differential relaying of power transformer

The differential relay is a relay that operate when the difference between two or more electrical values is more than predetermined value

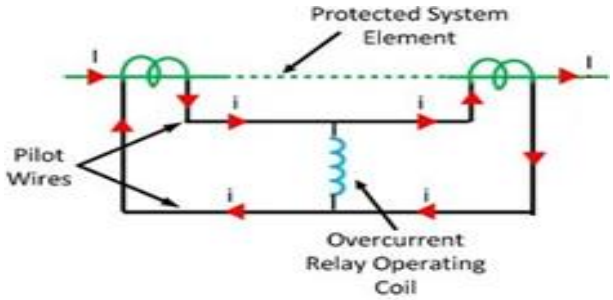

Fig. 1: layout of Differential Relay.

3.1. Partial flux over partial subtraction of current slop

Partial flux over partial subtraction of current method is not changes by changing of residue or initial flux since it use $\left(\frac{d\varphi}{did}\right)$ relation, which can be implemented on problem of prior flux current method is calculated by equation

$$\left(\frac{d\varphi}{did}\right)_n = \frac{\{\frac{\Delta t}{2}(V_{p.n}-V_{p.n-1})-L_p(i_{p.n}-i_{p.n-1})\}}{(i_{p.n}-i_{s.n})-(i_{p.n-1}-i_{s.n-1})} \quad (1)$$

Where

(p) = primary side, (s) = secondary side, (Δt) = specimen time;
(id) = subtraction of current, (L_p) = n_{th} sample leakage inductance of the primary side

3.2. 2nd harmonic component of subtraction of current

when high current pass into the transformer and cause magnetization inrush current which 6-10 double of maximum current pass only throw the primary side) which produce large subtraction of current, the ratio of 2nd harmonic of it to the fundamental component of it is large. Since the transformer core steel is improved which can be represented by magnetizing resistance reduction, and the chance to make EHV underground cable where we can increase the power system capacity in the fault case the 2nd harmonic component of current is big value.

3.3. Percentage of restraint over subtraction of current principle

Percentage of restraint over subtraction of current concept applied to defeat the tap changer problems, pilot wire different in length and characteristic of CT [3].

4. Fuzzy based differential relay

Fuzzy deduction is an approach that resolve was made in parallel. Since of this advantage, the data is not lost during the resolve and the result is last fault disclosure will be further accurate than traditional differential relay methods.
Now, the inputs to the intended fuzzy based differential relay are:
L1 represent the ratio$\left(\frac{d\varphi}{did}\right)$.
L2 represent second harmonic component of subtraction of current.
L3 represent restraint current to subtraction of current (ir/id).
The intended differential relay technique was be seen in fig (2)

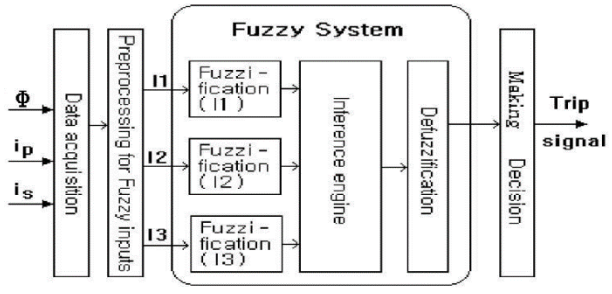

Fig. 2: Differential Relay Block Diagram.

4.1. Suggested technique membership functions

Membership function is used to set the input to a value from 1 to 0, the portions of it form concern on the planner practice and the issue under seeing.
The membership function for differential relay technique include three set as be seen in fig (3-5). Where: (FL1) appear for the membership function of partial flux over partial subtraction of current, which include (large) and (small) as be seen in fig (2), (FL2) appear for the membership function of 2nd harmonic component of subtraction of current, which include (large), (medium) and (small) as be seen in fig (3), (FL3) appear for the membership function of percent of restraint over subtraction of current, which include (large), (medium) and (small) as be seen in fig (4)
The center of area defuzzification method leads to the output of proposed relay result. The membership function of output is be seen two portion (trip, non-trip) the output is trip if it's value is greater than or equal to 2.1 and non-trip if the value is less than 2.1, as shown in fig(6)

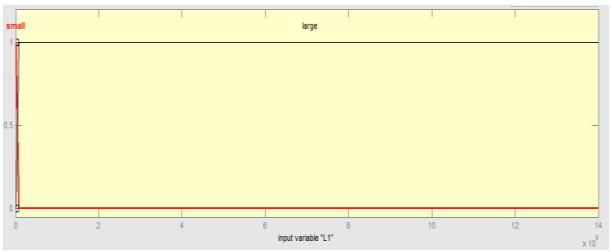

Fig. 3: L1 Fuzzy Membership Function.

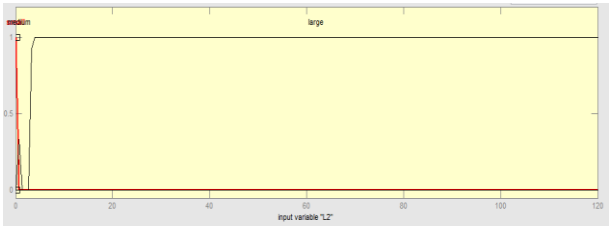

Fig. 4: L2 Fuzzy Membership Function.

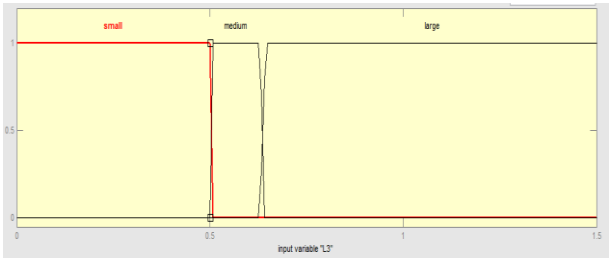

Fig. 5: L3 Fuzzy Membership Function

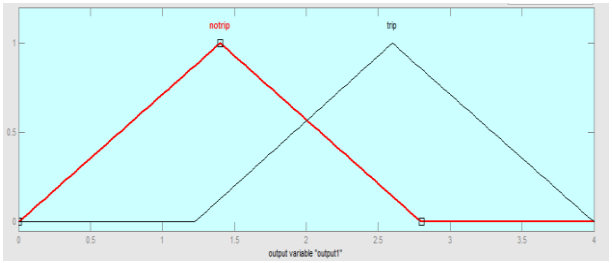

Fig. 6: Output Fuzzy Membership Function.

4.2. Rules used in the suggested relay

The linguistic description is the base of control rule of how the proficient will act to obtain the management function .that description based control rule takes the shape if premiums then resultant rule .there are 21 rule of fuzzy deduction for the suggested transformer relaying differential protection. All rules used include two or three ancestry for input and output. The 21 rule are distributed to three groups concerning on the input variable matrix. In this task, the structure fuzzy deduction matrix were using, where to perform a mathematical operation we chose (max-min) method the rules are shown in fig (7).

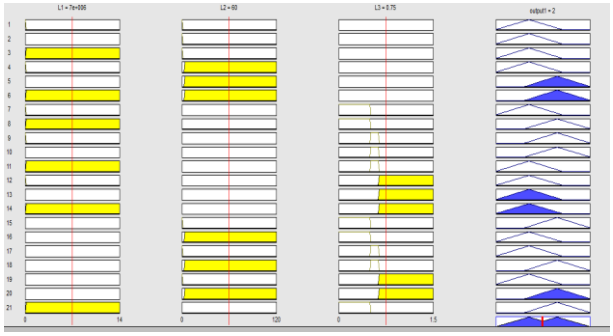

Fig. 7: The Fuzzy Rules.

5. Simulation and results

The (11/33) transformer and there differential relay is implemented in MATLAB environment [14] as be seen in fig (8)

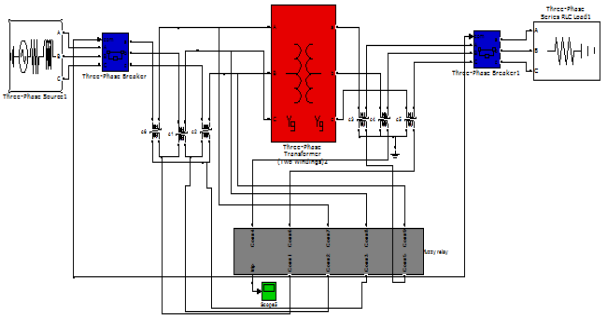

Fig. 8: Proposed 11/33trans and Diff Relay.

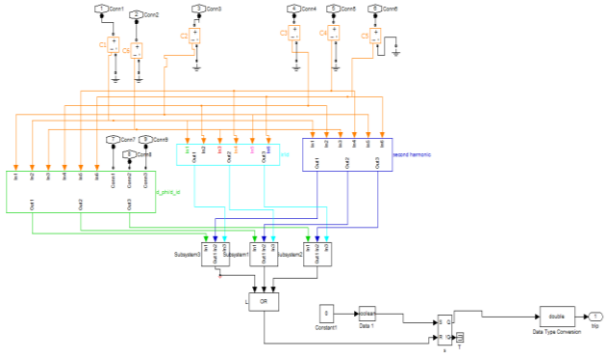

Fig. 9: Fuzzy Based Relay.

The Partial flux over partial subtraction of current is be seen in fig (10)

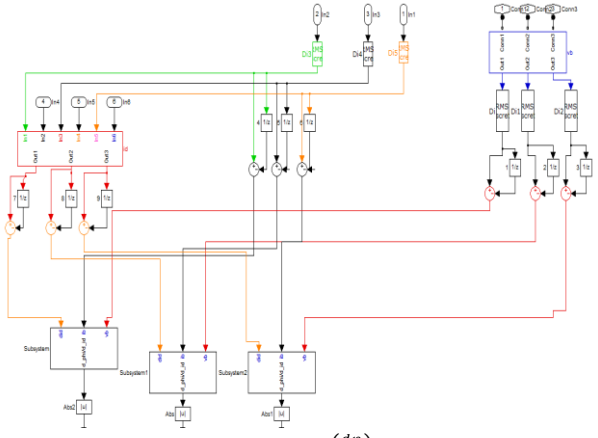

Fig. 10: $\left(\frac{d\varphi}{did}\right)$.

Percentage of restraint over subtraction of current input is be seen in fig (11) Second harmonic component of subtraction of current input is be seen in fig (12)

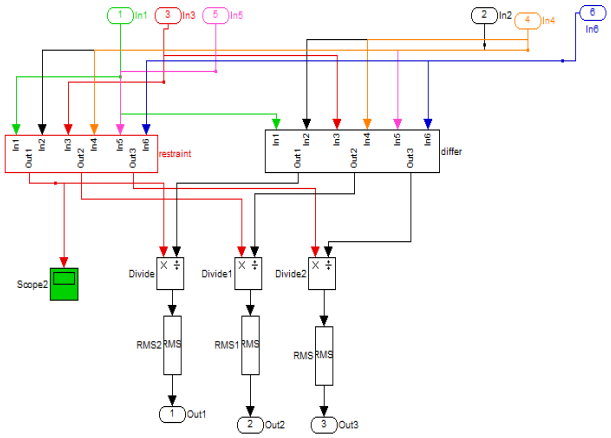

Fig. 11: (IR/ID).

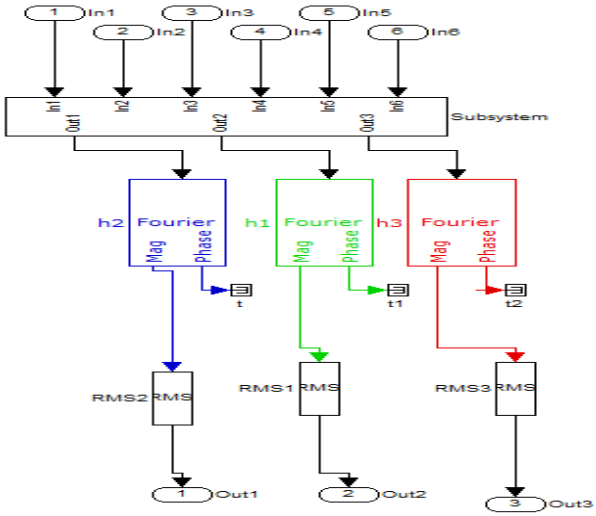

Fig. 12: Second Harmonic.

Fuzzy logic controller is be seen in fig (13)

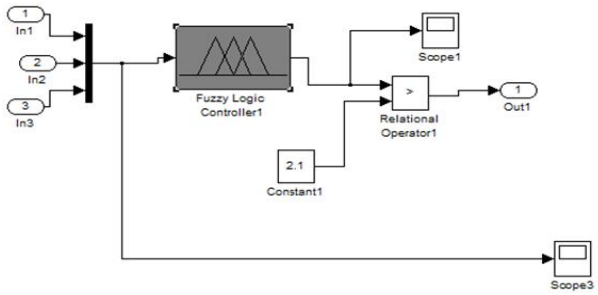

Fig. 13: Fuzzy Logic Controller.

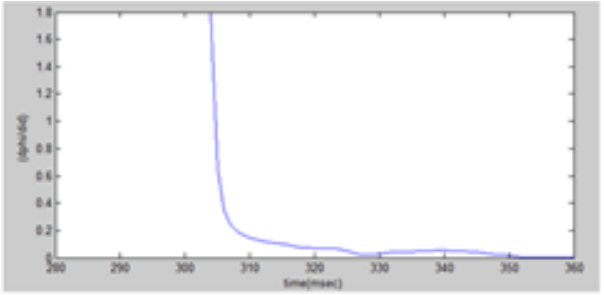

Fig. 14: $\left(\frac{d\varphi}{did}\right)$ wave form.

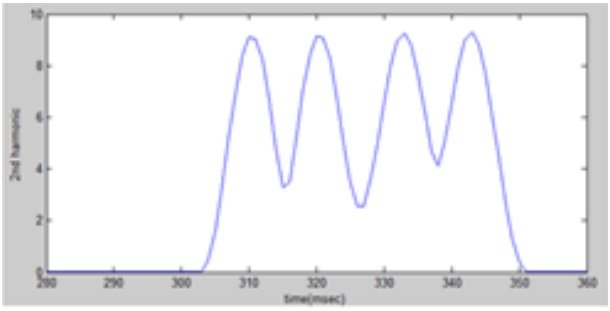

Fig. 15: Second Harmonic Wave Form.

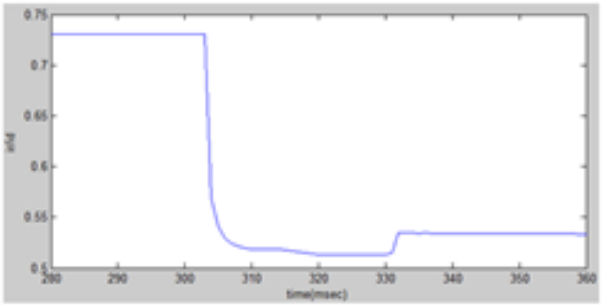

Fig. 16: (Ir/Id) Wave Form.

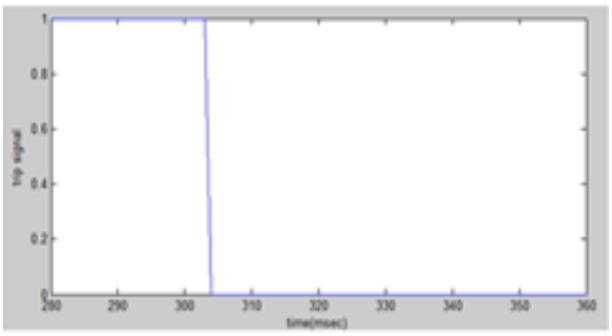

Fig. 17: Trip Signal.

The relay is work at the output of fuzzy controller is 2 or greater than 2 and otherwise is not work.

We take case 1 as mentioned in appendix B as an example is simulated and the input to the fuzzy controller is shown in fig (13-15) and the output of it are be seen in fig (16).

The magnitude and time of trip signal for different cases of the proposed approach and there comparisons with researcher's methods are explained in table (1).

in the proposed approach the output of relay at inrush current and external fault is not trip while for internal fault the output is work with slowness time of 2 ms. approach of Harmonic restraint [1] has no trip result for external fault and work for inrush current and internal fault with slowness time of (2-3)ms.

Flux restraint approach [11] has trip output for internal fault with slowness time of (3-6)ms and not work for inrush and external faults. The output of power differential approach [11] is no trip for external fault and inrush current and when there is internal fault the same is happen. This method has good properties for sensitivity, speed of operation and reliability, where it has (2ms) to operate

Table 1: Comparison Results

		Proposed relay		[1]Harmonic restraint		[11]Flux restraint		[11]Power differential	
No	Status	Output	Time (ms)	Output	Time (ms)	Output	Time (ms)	Output	Time (ms)
1	Inrush without load	No trip	--	Trip	2	No trip	--	No trip	--
2	Internal A-G at LV side	Trip	2	Trip	2	Trip	3	Trip	2
3	Internal AB-G LV side	Trip	2	Trip	2	Trip	3	No trip	--
4	Internal AB LV side	Trip	2	Trip	2	Trip	3	No trip	--
5	Internal ABC-G LV side	Trip	2	Trip	2	Trip	3	No trip	--
6	Internal symmetrical LV side	Trip	2	Trip	2	Trip	3	No trip	--
7	Internal ABC-G HV side	Trip	2	Trip	2	Trip	3	No trip	--
8	Internal A-G HV side	Trip	2	Trip	2	Trip	3	Trip	2
9	Internal AB-G HV side	Trip	2	Trip	2	Trip	2	No trip	--
10	Internal AB HV side	Trip	2	Trip	2	Trip	3	No trip	--
11	Internal symmetrical HV side	Trip	2	Trip	2	Trip	3	No trip	--
12	Inrush with load	No trip	--	trip	2	No trip	--	No trip	--
13	External ABC-G LV side	No trip	--	No trip	--	No trip	--	No trip	--
14	External AB-G LV side	No trip	--	No trip	--	No trip	--	No trip	--
15	External AB LV side	No trip	--	No trip	--	No trip	--	No trip	--
16	External ABC LV side	No trip	--	No trip	--	No trip	--	No trip	--

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