Incorporating Overcurrent and Over Flux Protection for Transformer using Different Time Characteristics

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Abstract— this paper presents the protection for transformer using different time characteristics. To design and develop a protection system for transformer which automatically respond to the over flux based on the definite minimum time(DMT) and inverse definite minimum time(IDMT) characteristics and over current based on the standard inverse(SI), very inverse(VI) and extreme inverse(EI) characteristics. Therefore, over-current relays must de-energize the faulted line as fast and accurate as possible to protect the system from the hazardous effects of the fault. The relay acts based on the program inbuilt to each characteristic. In order to prevent mal-trip of relays resulting from these transients, a longer delay is not initiated for relay trip command. Self checking facility of the occurrence of the fault time is incorporated in the programs which are used in individual relay characteristics.

Key words: Overflux; Overcurrent; Definite Minimum Time (DMT); Inverse Definite Minimum Time (IDMT); Standard Inverse (SI); Very Inverse (VI); Extreme Inverse (EI)

I. Introduction

The main purpose of power systems is to generate, transmit, and distribute electric energy to users without interruptions and in safe manner. Hence, power systems are divided in generation, transformation, transmission and distribution subsystems. All these subsystems are composed of costly components and machines. Power Systems suffer from various faults, many of which result into sudden rise incurrent damaging the subsystem components subsequently. Therefore, overcurrent protection is of vital importance [1][2]. An overcurrent relay can be used which monitors current and operates when current magnitude exceeds apreset value. It is important that a relay should detect all fault conditions and also, it must not trip due to spurious signals generated during power system transients. The Over flux protection is also vital and the relay should all detect fault condition based on over fluxing occurred in the system[4]. The transformer is said to have face over fluxing problem and bad effects towards its operation and life. Specification for electrical power transformer does not stipulate the short time permissible over excitation, though in a roundabout way it does indicate the maximum over fluxing in transformer shall not exceed 110%. Over excitation of transformer in transmission and distribution can cause by over voltages in the network. The magnetic flux density is, therefore, proportional to the quotient of voltage and frequency (V/F). Overfluxing can, therefore occur either due to increase in voltage or decrease in frequency of both. The overfluxing may be also an external fault but it can lead to internal one. The severity of the fault due to overflux and overcurrent in the external can lead to the internal fault. The paperfocuses on implementation of overflux relay Inverse Definite Minimum Time (IDMT) characteristics, Definite Minimum Time(DMT) characteristics and also implementation of overcurrent relay Standard Inverse (SI),Very Inverse (VI), Extreme Inverse (EI) characteristics.

II. Protection with Different Time Characteristics

A. Overcurrent Protection

The overcurrent relay characteristics provide information about the required relay operating time for a particular relay setting and magnitude of actuating quantity which is current for overcurrent relays. The overcurrent relay has a minimum operating current, known as the current setting of the relay. The current setting must be chosen so that the relay does not operate for the maximum load current in the circuit being protected, but does operate for a current equal or greater to the minimum expected fault current[5][8].Although by using a current setting that is only just above the maximum load current in the circuit a certain degree of protection against overloads as well as faults may be provided, the main function of over current protection is to isolate primary system faults and not to provide overload protection. In general, the current setting will be selected to be above the maximum short time rated current of the circuit involved [7]. Since all relay shave hysteresis in their current settings, the setting must be sufficiently high to allow the relay to reset when the rated current of the circuit is being carried. Standard overcurrent relays of Inverse Definite Minimum Time (IDMT) characteristics have trip time inversely proportionally to the fault currents and are defined by the IEC 60255 standard as standard inverse (SI), very inverse (VI) and extremely inverse (EI) are calculated by separate equations

Standard Inverse (SI) $T=TMS*\frac{0.14}{I/IS^{0.02}-1}$ (1)

Very Inverse (VI) $T=TMS*\frac{13.5}{I/IS^{1}-1}$ (2)

Extreme Inverse(EI) $T=TMS*\frac{80}{I/IS^{2}-1}$ (3)

Where,
T = Tripping Time in (S)
I = Fault (Actual)
Is = Set point Current
TMS = Time Multiplier Setting

The selection of overcurrent relay characteristics generally starts with selection of the correct characteristic to be used for each relay, followed by choice of the relay current settings. If current exceeds a threshold value, the trip time for actual current value is calculated and if the current remains above this value for a duration exceeding trip time, trip signal is generated by relay. The current value for each characteristic is to be set so that the tripping signal is generated by the relay depending upon the individual current characteristics. The value for a modern relay is typically 0.95. Thus, a relay minimum current setting of at least 1.05 times the short-time rated current of the circuit is likely to be required In most cases, use of the standard SI curve proves satisfactory, but if satisfactory grading cannot be achieved, use of the VI or EI curves may help to resolve the problem.

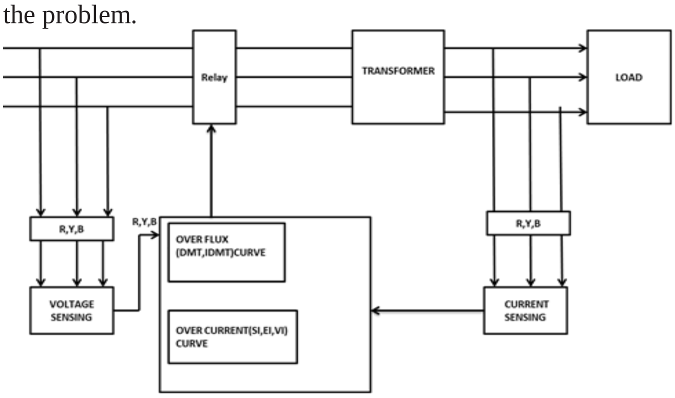

Fig.1: Schematic view of the overall protection

Fig.1 represents the schematic view of the overcurrent and Overflux protection of the system. The voltage can be sensed from source side and the frequency is set to be 50Hz therefore V/F value can be calculated for based on the changes in the source voltage. Similarly, the current can be sensed from the load side and it should not exceed 375A under normal conditions. These sensed voltage and current is given to set the relay program. Therefore, the relay can be tripped out by following the condition of each relay characteristic and the circuit breaker kept open based on the tripping time.

Very inverse overcurrent relays are particularly suitable ifthere is a substantial reduction of fault current as the distance from the power source increases, i.e. there is a substantial increase in fault impedance. The VI operating characteristic is such that the operating time is approximately doubled for reduction in current from 7 to4 times the relay current setting.

The VI curve is much steeper and therefore the operation increases much faster for the same reduction in current compared to the SI curve. This enables the requisite grading margin to be obtained with a lower TMS for the same setting current, and hence the tripping time at source can be minimized.

With the extremely inverse characteristic, the operation time is approximately inversely proportional to the square of the applied current. This makes it suitable for the protection of distribution feeder circuits in which the feeder is subjected to peak currents on switching in, as would be the case on a power circuit supplying refrigerators, pumps, water heaters and so on, which remain connected even after a prolonged interruption of supply. The long time operating characteristic of the extremely inverse relay at normal peak load values of current also makes this relay particularly suitable for grading with fuses.

The relay can be tripped out and the tripping time is based on the individual current characteristics. The normal current is 375A for the load 1MW and the fault current is above 385A.When the current exceeds the value of 385A at the load 1MW, the relay can be tripped.

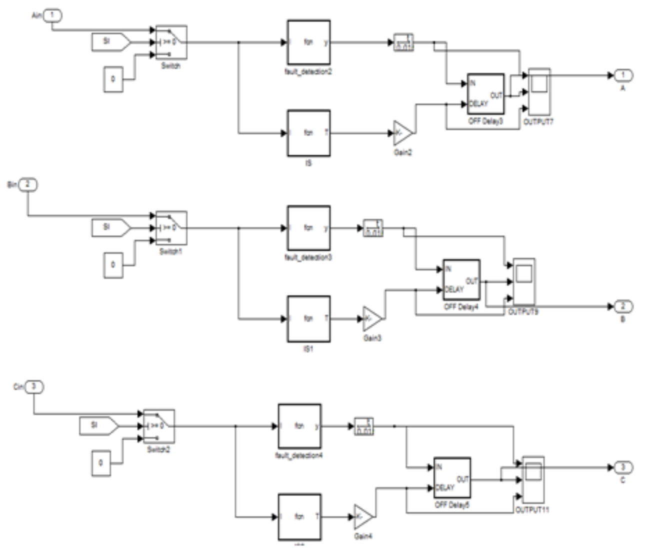

Fig. 2: Simulink model of over current characteristics

B. *Overflux Protection*

Under conditions of excessive overfluxing the heating of the inner portion of the windings may be sufficiently extreme as the exciting current is rich in harmonies. It is obvious that the levels of loss which occur in the winding at high excitation cannot be tolerated for long if the damage is to be avoided. Physical evidences of damage due to overfluxing will be very high with the degree of over excitation, the time applied and the particular design of transformer[8].The Overflux protection can be implanted by using to relay characteristics which are Definite Minimum Time and Inverse Definite Minimum Time.

The voltage/time tripping characteristics of IDMT and DMT relays may need to be varied according to the tripping time required and the characteristics of other protection devices used in the network. The Inverse Definite Minimum Time (IDMT) and Definite Minimum Time (DMT) are calculated by separate equations which are

(IDMT) $$T=TMS/\frac{V/Vset^{2}}{1000} \quad (4)$$

(DMT) $$T=TMS/\frac{V/Vset^{0.02}-1}{1000} \quad (5)$$

Where,
T = Tripping Time in (S)
V = Fault (Actual)
Vset = Set point voltage
TMS = Time Multiplier Setting

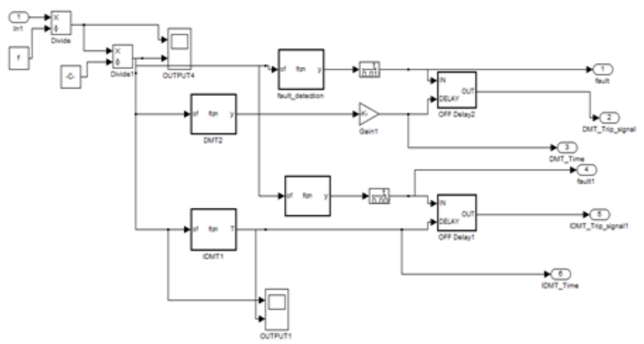

Fig. 3: Simulink model of overflux characteristics

The selection of overflux relay characteristics generally starts with selection of the correct characteristic to be used for each relay, followed by choice of the relay voltage settings. The maximum overfluxing in transformer shall not exceed 110%. The V/F range should be in 100% under normal condition and when it exceeds 110% and below 120% then the inverse definite minimum time(IDMT) relay characteristics is applicable. When the V/F range exceeds 120% then the definite minimum time (DMT) relay can be operated. With the relay characteristic, the time of operationis inversely proportional to the fault current level and theactual characteristic is a function of both 'time' and 'current' or 'voltage' settings.

III. SIMULATION AND TEST RESULTS

This section explains the detailed simulation results of the proposed protection system. The simulated system is shown in Fig.4. MATLAB/SIMULINK tool is used for simulation studies. A different condition in both overflux and overcurrent protection for the entire system is carried out with the help of various relay characteristics.

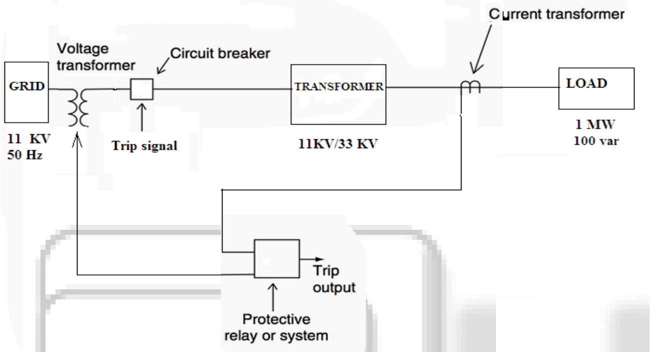

Fig. 4: Schematic view of the simulated system

The overcurrent and overflux protection of the transformer is shown in the graphical representation as follows. There are five relay characteristics which has different tripping time due to the changes in the tripping signal. The standard inverse relay characteristics value for a relay is typically 0.95.Therefore, when the current on the load 1MW exceeds 385A then the standard inverse characteristics is satisfying the condition. In Fig.5 the fault, tripping signal and the tripping time is represented.

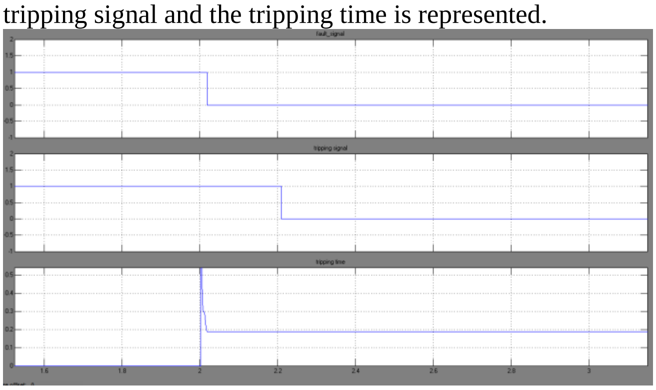

Fig. 5: Graphical representation of standard inverse characteristics

When the current reaches 385A to 500A on the load 1MW, then the very inverse relay characteristics is represented in Fig.6 Similarly, the extreme inverse characteristics is represented when the load current exceeds 500A which is represented in Fig.7 with the tripping time and tripping signal.

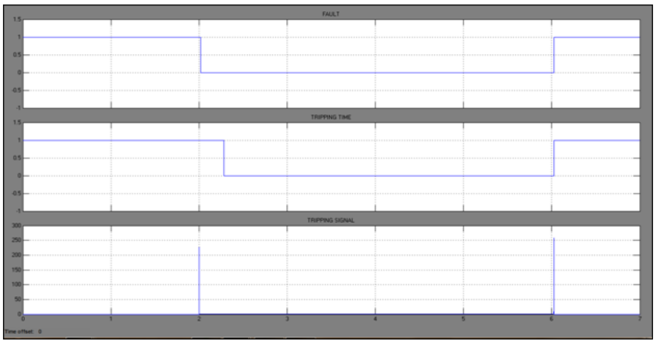

Fig. 6: Graphical representation of very inverse characteristics

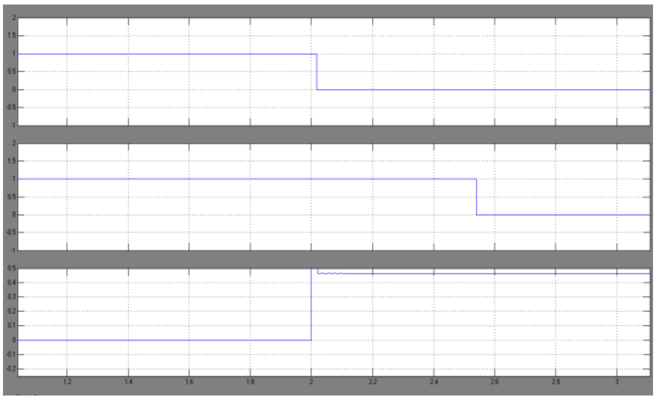

Fig. 7: Graphical representation of extreme inverse characteristics

When the V/F exceeds 110% and then the inverse definite minimum time relay operates due to the change in the source voltage which is calculated approximately 11920V. Therefore the tripping time is calculated with the help of the equation which is mentioned earlier. The graphical representation of the inverse definite minimum time characteristics is obtained in Fig.8.

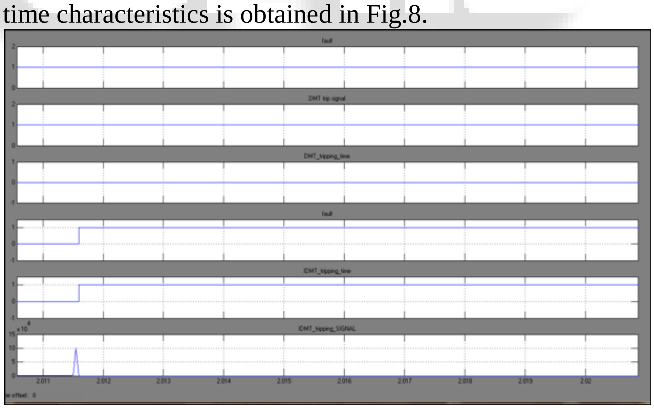

Fig. 8: Graphical representation of inverse definite minimum time characteristics

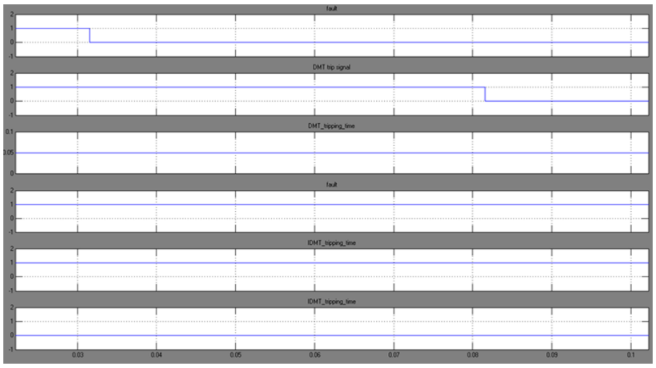

Fig. 9: Graphical representation of definite minimum time characteristics

An embedded system is implemented in the simulation therefore when the IDMT relay operates, the DMT will not be in operation and vice-versa.

When the V/F exceeds 120% and then the definite minimum time relay operates due to the change in the source voltage which is calculated approximately 12920V. Therefore the tripping time is calculated with the help of the equation which is mentioned earlier. The graphical representation of the inverse definite minimum time characteristics is obtained in Fig.9.

IV. Conclusions

In this paper, different time characteristics have been developed to protection the transformer from the external faults such as overcurrent and overflux which can lead to internal one. The Standard Inverse (SI), Very Inverse(VI), Extreme Inverse(EI) relay characteristics for the overcurrent protection. Similarly, Inverse Definite Minimum Time (IDMT) and Definite Minimum Time (DMT) relay characteristics for the overflux protection is implemented.

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