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An Approach for Overcurrent Protection using PID Controller with Different Fault Condition

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Abstract: ***A power system network generates, distributes and transmits the electricity. The reliable, as well as safe power systems, are very significant for successful operation. However, various losses and faults occur in power system which prevents the power system to work efficiently and also causes various damages. Overcurrent is a very critical fault as it results in extreme production of heat, and the possibility of fire or device damage, if not tripped timely. In order to protect the equipment from overcurrent, the overcurrent relays were designed. In the existing system, the Inverse Definite Minimum Time (IDMT) over-current relay was used for purpose of over-current protection. However, it consists of various drawbacks such as, they take more time to trip which can lead to damage in equipments. Also, the IDMT over-current relay faces the issue of fault severity variation. Thus, in order to overcome the previous issues, the PID based relay is designed in the proposed work which will perform fast tripping and perform well for different faulty conditions. In this paper, the simulation has been performed to ensure the efficiency of the proposed approach over the conventional one.***

Keywords: Power system, Overcurrent protection relay, DSP, PID based relay

I. INTRODUCTION

The electric power can be defined as the product of voltage and current. The current and voltage can change according to time (AC power) or they can remain at a constant level (DC power). It helps in driving the electrical system. The electric power system can be defined as electrical components' network which is implemented for supplying, transferring and using electrical power. A power system network generates, distributes and transmits the electricity.
The overview of the system is depicted in figure 1:

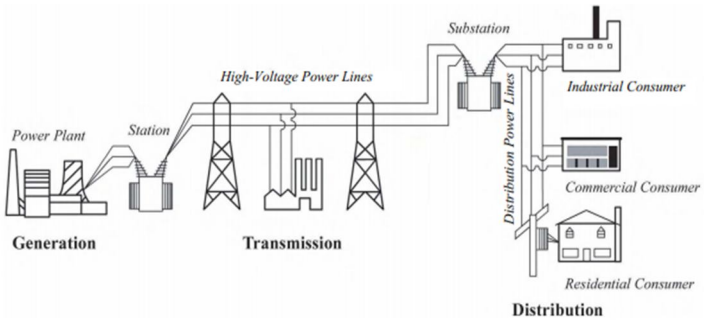

Figure 1: System Overview [1]

Stability is the ability of the power system to attain the equilibrium state for the given initial situations when it is exposed in the physical environment disturbances, providing optimum variables bounded to preserve the system integrity [2].
There are many types of faults that appeared in the electrical system due to external or internal influences; among which overcurrent is the major problem faced in power system devices.
Overcurrent in the electric power system is the situation in which more than anticipated current exists via conductor that results in extreme production of heat and the possibility of fire or device damage [3].
In order to protect the system from the faults, the protective relays are used.
In IEEE, the relays are defined as "a device which identifies the faulty lines or equipment or another anomalous or harmful power system situation and takes the suitable action to control circuit" [4]. With the help of relays, the fault can be limited can losses can be reduced. The protective relay is mainly utilized for isolating faulty parts by causing minimum interruption to service. This interruption can be reduced by controlling the circuit breaker. Relays are intended for the detection of abnormal situations and closing the link between the tripping circuit.
One relay can be used when there is an excess amount of current in the circuit. These relays are known as the overcurrent relay.

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The overcurrent relay protects the device from the overload and the short circuit. Almost every device is equipped with this relay. In order to protect the device in any kind of anomalous current utilization situation, these relays continuously detect the rating current of the device and then isolate the device.

In order to identify the relays' impacts on the parameters of the power system and for controlling the operations of relay, various kinds of techniques are utilized. Among these, DSP is the one which is utilized for controlling the operation of relay [5].

In the power systems, the DSP is utilized in order to control and protect the devices. The relays trip on the sequence. The sequence is intended on the basis of time, equipment damage curve and upper relay tripping time. This sequence is controlled by DSP.

DSP is illustrated in figure 2:

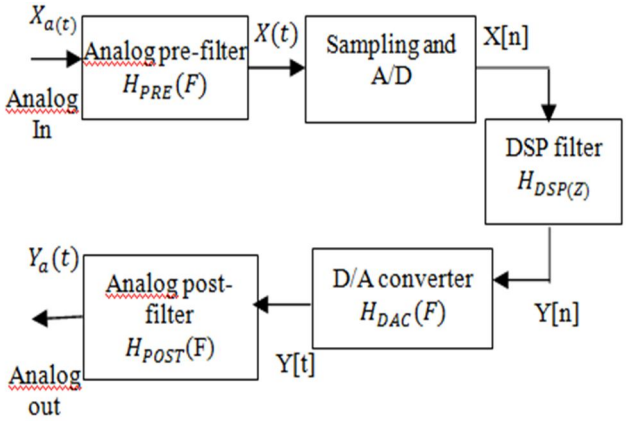

Figure 2: Digital Signal Processing

II. LITERATURE REVIEW

In the past few years, various researchers have proposed approaches for adjusting the overcurrent relay's setting and used various relays for the protection of devices. Some of the conventional techniques among them are discussed in this section:

The paper [6] presented an overcurrent relay and evaluated its performance by considering TMS320F2812 DSP. Operation time, execution time, memory capacity usage, and transient analysis are the parameters taken for the analysis of the proposed system

In paper [7], the author proposed a technique of functional structure to enhance the effectiveness of overcurrent relays. It was shown in this paper that only pick-up current was utilized by the adaptive relay which acts as the fault detector; the time curve of the primary device and pick-up current were used to compute the time operation. Consequently, the adaptive relay imitates the dynamics of the device so that fast back up time operation can be achieved.

The author in [8] proposed a multifunction numerical relay (MNR) to shield the system from over current, over voltage or under-voltage and over frequency or under-frequency. This relay functions as a directional relay.

The paper [9], presented the effect of DGs on power system protection and adaptive overcurrent protection's utilization for addressing such issues.

In paper [10] author had suggested a few novel AI schemes for detecting the faults in systems. The author presented the research work in islanding detection, demerits, merits and control algorithms in this paper. From the author's point of view, there was possibility for further research in the islanding research area in distribution systems.

In [11], the author designed an electrical protection relay by utilizing microprocessors. This model was designed in order to guard electrical equipment while different fault situations. A variety of safety mechanisms such as current unbalance protection, instantaneous earth fault and over-current protection, earth fault and overcurrent protection based on IDMT and thermal overload protection.

In paper [12], a new method was proposed for the concurrent setting of distance relays and DORs.

The paper [13] discussed the overcurrent relay's modeling for the IDMT type utilizing DSP board TMS320F2812.

The paper [4] aimed to design an overcurrent relay in the MATLAB SIMULINK. In this paper, the DSP impact on the operation time of the relay was studied. For protecting the types of equipment from over-current, IDMT over-current relay was utilized in this paper.

However, the IDMT relay used in these conventional works consists of various drawbacks due to which the requirement arises for upgrading these conventional works.

III. PRESENT WORK

The power system is very significant for providing continuous power supply without any interruption. Various losses and faults occur in power system. Various techniques have been developed in the past to overcome these issues in power systems in which researchers studied the effects of digital signal processing on the protection from over-current and the processing time for the power systems.

In the existing system, the IDMT over-current relay is utilized for protecting devices from over-current.

However, this existing approach has some drawbacks such that they take more time to trip which can lead to damage in equipments.

Also, IDMT over-current relay faces the issue of fault severity variation. This implies that for single-phase fault, the relay takes more time for tripping, whereas, for 2-phase or 3-phase fault, it takes less time to trip. However, the single or 2-phase fault can also lead to over-current damage if not tripped timely. Thus, it is required that the relay must trip the current on timely for every fault i.e. whether, single, double or three-phase.

Therefore, the relay is required which will perform fast tripping and perform well for different faulty conditions.

Thus, in the proposed system, the PID controller based relay is designed that can overcome all the existing drawbacks. In the proposed approach, the existing relay is replaced with the PID controller based relay that continuously detects the rating current of the device and will isolate the device, as compared to the existing approach, to protect it in any kind of anomalous current utilization situation. Also, in the proposed approach, the different faulty conditions are considered i.e. the quick tripping will be performed for any of the faulty condition i.e. for single, double or 3-phase fault. It will make the system more secure towards damages caused by the over-current as in this all the fault conditions are analyzed and the fast tripping will be performed.

Thus, the PID controller based relay is suitable to be used as a quick time-delay determination technique of an overcurrent relay in place of the IDMT over-current relay.

IV. RESULTS AND DISCUSSIONS

In the proposed approach, the PID controller based relay is designed and is implemented in the system in order to protect the devices from the over current. The simulation has been performed in this work to ensure the efficiency of the proposed approach and the obtained results are discussed in this section.

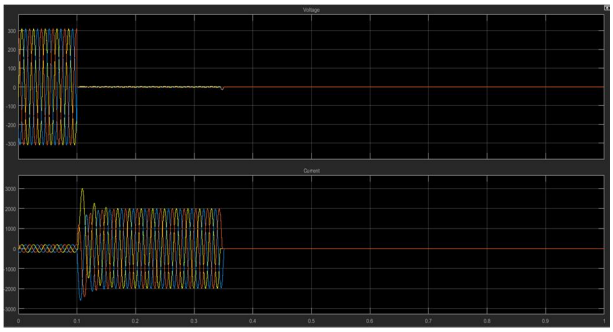

Figure 3: Proposed approach's effect on voltage and current (three-phase)

The voltage and current signals of the system have been analyzed after applying the proposed approach and the above graph is obtained. As the graph indicates, when the three-phase fault occurs in the system then the applied relay isolates the fault in 0.2418 sec. Thus, the proposed approach performs the task (tripping) quickly and consequently protects the types of equipment from the damage that can be caused due to late tripping of over current.

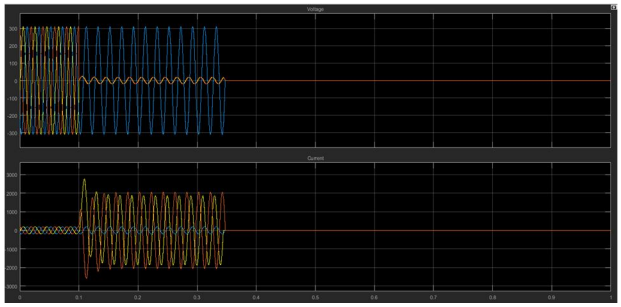

Figure 4: Proposed approach's effect on voltage and current (2-phase)

In the proposed approach, the different faulty conditions are considered i.e. the quick tripping will be performed for any of the faulty condition i.e. for single, double or 3-phase fault. Figure 3 has represented the proposed approach's effect on three-phase fault voltage and current, and the effect of the proposed approach on voltage and current of two-phase fault has been exemplified with the help of figure 4. In a two-phase fault also, the applied relay isolates the fault in 0.2418 sec.

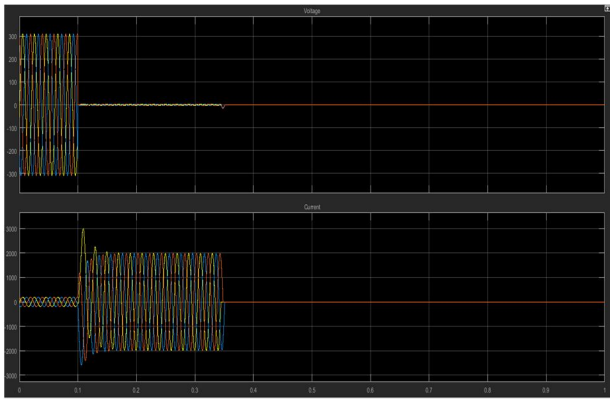

Figure 5: Proposed approach's effect on voltage and current (single-phase)

And finally, the effect of the proposed approach on the single-phase fault has been illustrated in the graph of figure 5. As the above graph delineates, after implementing the proposed PID based relay, the single-phase fault is isolated in 0.2418 sec. It will make the system more secure towards the damages caused by over-current as it performs fast tripping as compared to conventional IDMT overcurrent relay.

The comparative analysis of the proposed approach and conventional approach has been performed to demonstrate the efficiency of the proposed work and the results have been obtained which is represented in the tabular form in table 1, in which the values of operation time of traditional and proposed work are recorded.

TABLE 1
Operation Time of traditional and proposed work

Phase	Traditional Work	Proposed Work
3-Phase	0.3805	0.2418
2-Phase	0.4055	0.2418
1-Phase	0.4517	0.2418

In table 1, the operation time of the conventional and proposed approach is shown for all the faults. In the 1-phase fault, the operation time of the conventional approach is more as compared to the proposed approach, which demonstrates that the proposed one performs quick tripping. Similarly, for two and three-phase fault, the traditional work takes more time for operation in contrast to proposed work. Also, it is comprehensible from the table that the proposed work performs equally for all the three faults and isolates the fault in 0.2418 sec. Whereas the conventional approach does not provide the same results for all the faulty conditions, i.e., for 3-phase, 2-phase, and 1-phase, it's operation time is 0.3805sec, 0.4055sec, and 0.4517sec respectively.

Thus, from all the obtained results, it is demonstrated that the proposed work is more efficient than the conventional one as it is quicker and works equally for all the 3 phases.

V. CONCLUSION AND FUTURE SCOPE

In the proposed approach, the PID controller based relay is designed that continuously detects the rating current of the device and isolates the device quickly, as compared to the existing approach, to protect it in an overcurrent condition.

Also, in the proposed approach, the different faulty conditions are considered i.e. the quick tripping will be performed for any of the faulty condition i.e. for single, double or 3-phase fault.

In this work, the proposed PID controller based relay is implemented in the system and the simulation has been performed. From the simulation results, it has been demonstrated that the proposed relay is more efficient and reliable than conventional IDMT relay, as it performs the fast tripping, such that, it isolates the fault in just 0.2418 sec. Also, the operation time of proposed work is equal for all three faults, whereas, conventional relay gives different results for different phase fault conditions, i.e. for 3-phase, 2-phase, and 1-phase; its operation time is 0.3805sec, 0.4055sec, and 0.4517sec respectively.

Therefore, the results ensure the efficiency of the proposed work.

Thus, the proposed work overcome all the previous issues and gives efficient results which makes the power system more reliable and efficient.

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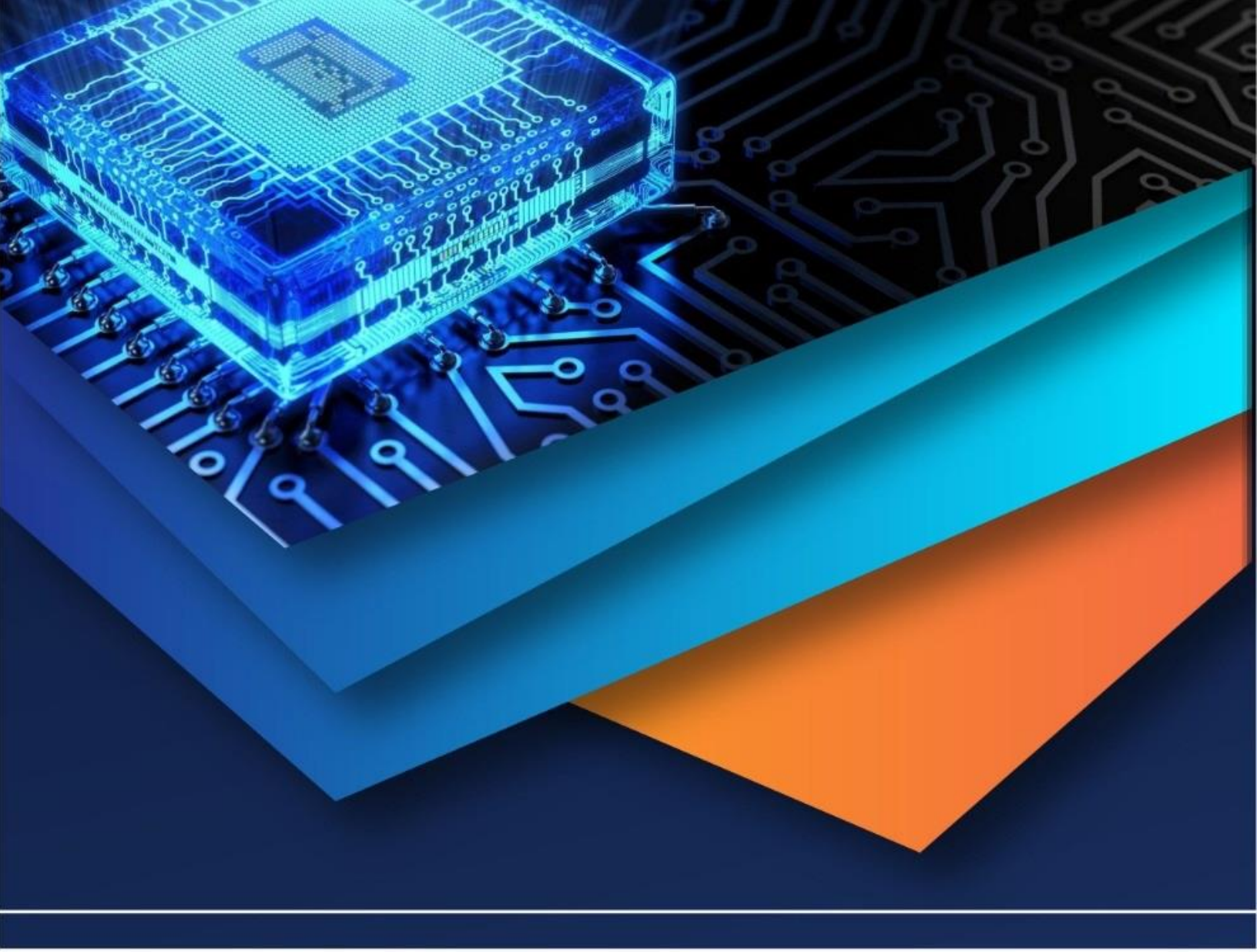

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