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PERFORMANCE ANALYSIS OF DIGITAL OVER CURRENT RELAYS UNDER DIFFERENT FAULT CONDITIONS IN RADIAL AND PARALLEL FEEDERS

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Abstract

The conventional relays like electromechanical relays, static and microprocessor based digital relays are having their own disadvantages. Digital/ numeric relays are replacing to overcome these drawbacks. Digital protection devices are built with integrated functions and operated using digital binary values. Fast operation, high sensitivity, self-monitoring, low maintenance are the characteristics of the digital/ numeric relays and their cost is also relatively low. Accuracy, flexibility, reliability, multi-functional capability, and working under wide range of temperatures are the advantages of these relays. They have few limitations such as complexity, *short life time due to the new technological developments, and susceptibility to power system transients.*

Digital over Current relays modeling for power system protection has been proposed in this paper. The performance of the proposed relays was tested by applying different types of fault conditions in radial and parallel feeders and results were analyzed. MatLab/Simulink software was used to simulate the proposed protection scheme due to its features like design flexibility and exploration of any physical module.

Keywords

Over-Current Relay (OCR), Digital Over Current Relay (DOCR), Directional Relays (DR)

1. Introduction

Advances in technology enabled new changes in all new substations automation with numerical relays operation with improved dependability as well as better grid-security. Digital relays are immune to parameters variation of components, lowest burden and more flexible because of programmable user friendly and are designing with latest technology.They are preferred due to their quick action and they can be used in Real Time Control of Power Systems compared to Electro Magnetic Relays and Static Relays [1, 2].The dynamic performance of protective relays depends to a large extent on their design principle that addresses things such as selectivity, sensitivity, security, and reliability. Relay characteristics and its performance are the pre requisites for the relay design to meet the industrial requirements.

OCRs can be used to protect any power system elements, i.e. transmission lines, transformers, generators, or motors against the excessive currents caused by short circuits and ground faults etc. These relays performs the operation of detecting abnormal conditions, isolating faulty part of the system, minimizing damage and danger and make system as secure and stable. But due to the limitation of sensing the direction of fault, Directional over current protection is necessary to protect the system against fault currents. The limitation of OCR in sensing the direction of fault is mitigated by adding a directional element along with it in DOCR. They used mostly in power system applications such as protection of ring or loop networks.

Benmouyal G et al. in 1999 has standardized the Inverse-Time Characteristic Equations for Over Current Relays. Logic based detection of negative sequence currents for Six Phase System has been implemented by G.Chandra Sekhar et al in 2011. Jhanwar V and Pradhan, A.K in 2008 has employed accurate Overcurrent Relay Algorithm using fundamental component. M. M. Hussal, et al., in 2011 has studied Digital Directional and Non-Directional over Current Relays: Modelling and Performance Analysis. Sidhu, T.S. et al. in 1991 done work on Design of a Microprocessor-Based Overcurrent Relay. S.S. Venkata et al. in May 1982 have implemented 138kV Six Phase Transmission System-Fault Analysis. Vahidi, B. and Esmaeeli, E. in September 2010, has done research on MATLAB-SIMULINK-Based Simulation for Digital Differential Relay Protection of Power Transformer for Educational Purpose. Yalla V.V.S. Murty, and W.J. Smolinskib, in January 1990has worked on Design and Implementation of a Versatile Digital Directional over Current Relay. Study of a book entitled Fundamentals of Power System Protection authored by YG Paithankar and S R Bhide in 2004.

2. Modelling of Digital over Current Relay

In digital over current relays the overall digital relay output is the logical multiplication (AND) of instantaneous element and inverse characteristic element outputs [3], as shown in block diagram figure 1.

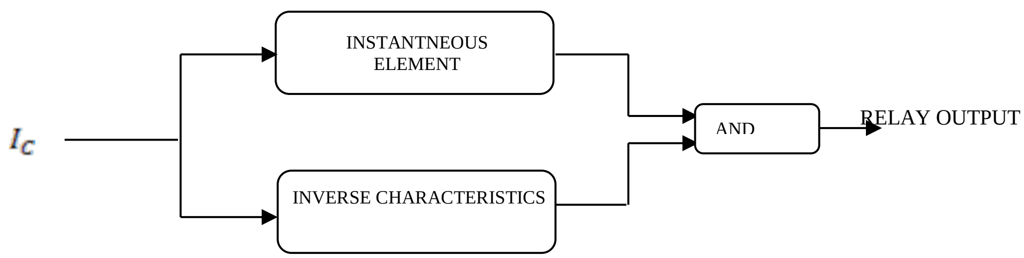

Figure 1: *Block Diagram of Digital Over-Current Relay*

Directional over Current relay can be designed by adding an additional directional element with the OCR relay. As shown in figure 2 the directional element acts as a switch to take decision only to allow current to pass or to power flows in a particular direction to the OC relay.

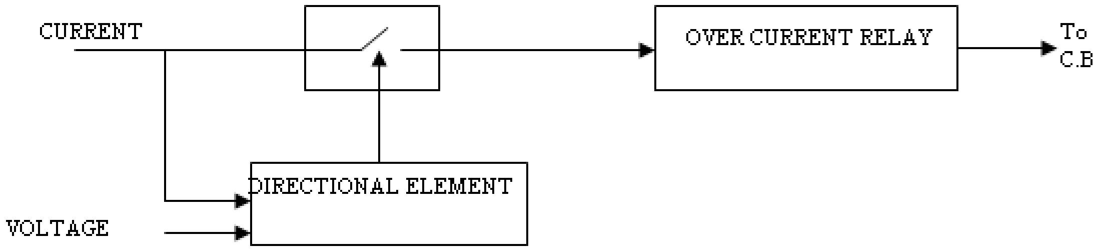

Figure 2: *Execution of Directional Relay*

To determine the direction of the fault directional relays use the phase angle between the fault current and reference quantity [4, 5].

Let 'Ψ' be the angle between current and voltage in a phase then

$-90^{o}<\Psi<90^{o}$ gives the direction of normal load flow and

$90^{o}>\Psi>270^{o}$ gives the direction of reversed power flow

3. Simulink Modeling of Digital Relays

The simulation design of directional element of a relay is based on the difference in the overlapping interval between normal and reversed power flow conditions as shown in figure.3.

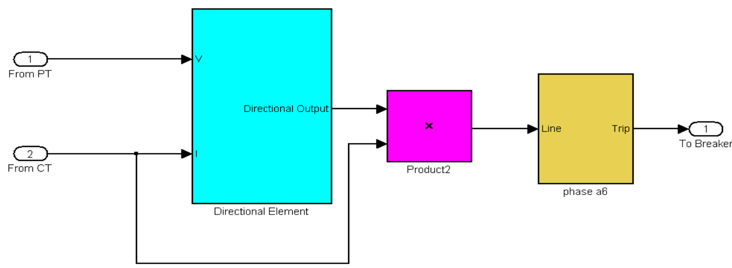

Figure 3: *Directional Relay model using SIMULINK*

As shown in figure 4 the directional element provides an output '1' under abnormal conditions and '0' for all other cases. It acts as a switch and multiplies its output with the samples of current. Its output will be sent to the over current relay and design of Time Delay and Hold Blocks of OCR are as shown in figure 5.

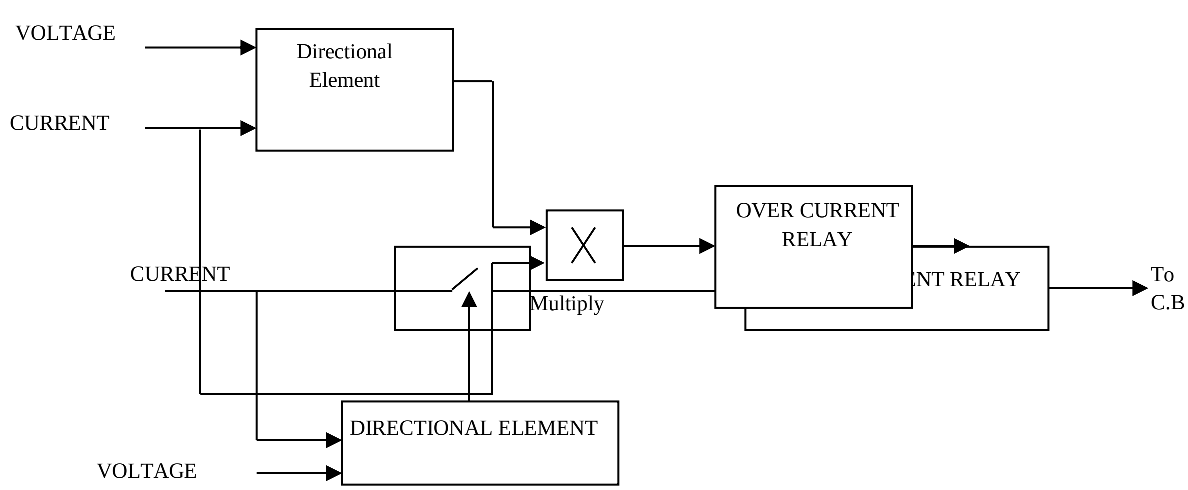

Figure 4: *Directional over Current Relay*

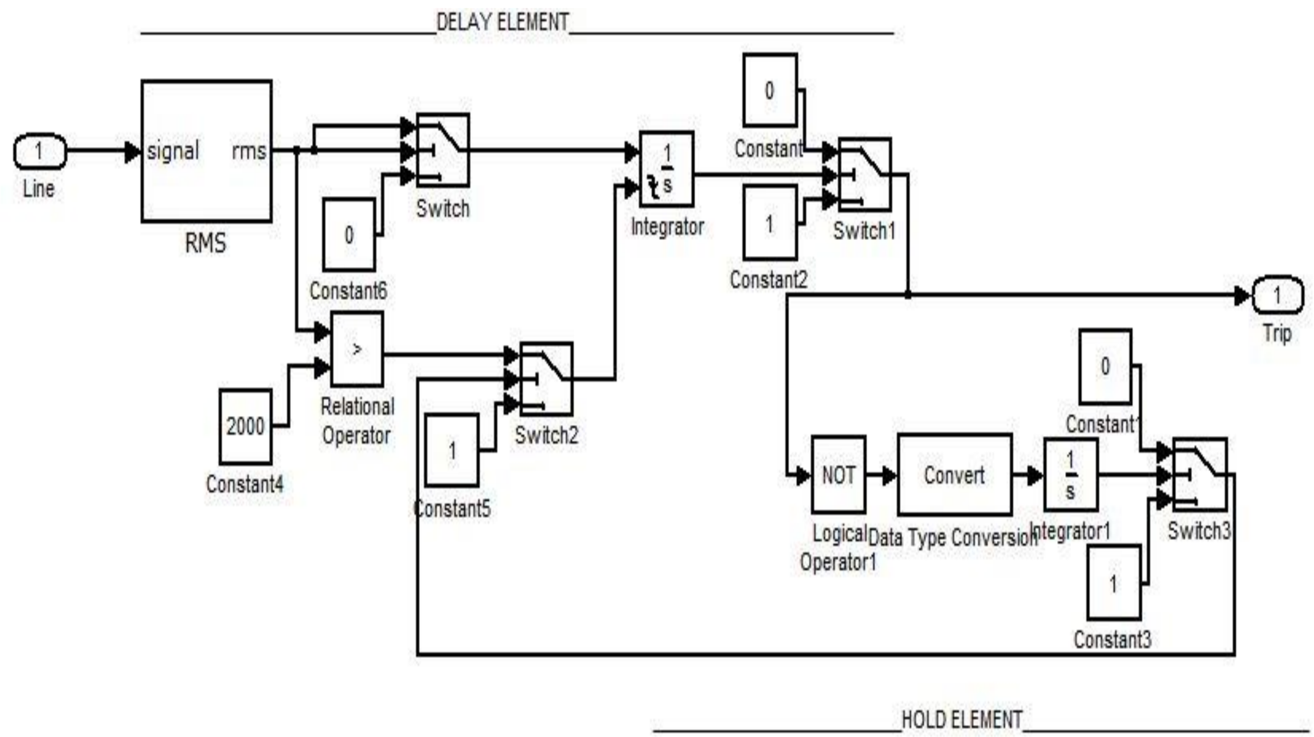

Figure 5: *Time Delay and Hold Blocks Models of OCR using SIMULINK*

3.1 Delay Element

As in figure 5 the delay element performs its operation during temporary fault or transient conditions.

If the integrator received input as “0” it refers as stable condition. To get the output the delay element will be refers to 1and integrator will always be “0” (< value “T”).Under abnormal conditions, the input to the integrator becomes “1” and after “T” seconds, the integral value exceeds T, and causes the delay element to produce “0” output to indicate the fault condition.

3.2 Hold Block

It is placed between the delay and hold elements. The current and voltage signals of the directional element are first converted in to two level square waves, with ‘1’ for positive values and ‘-1’ for negative values of the signals. Then the voltage and current signals are multiplied, to provide an output '1' during the overlapping and '-1' for non-overlapping interval and integrated further.

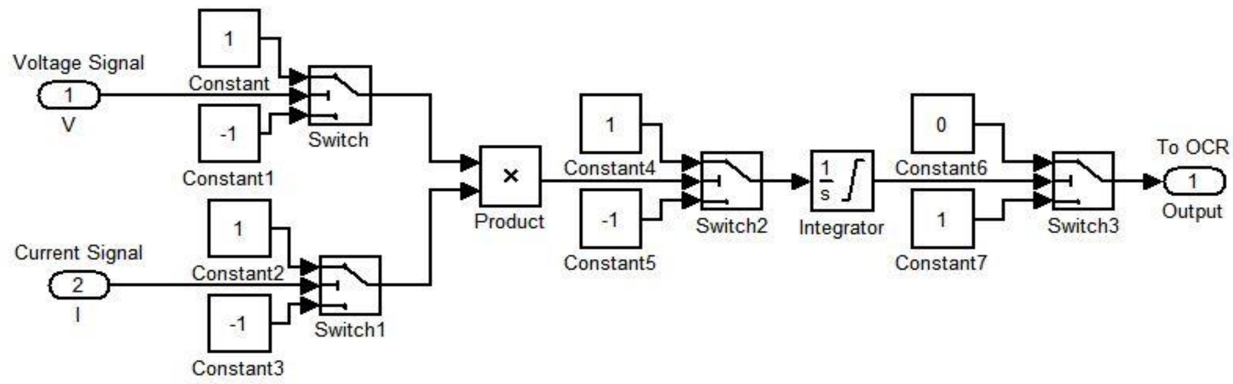

Figure 6: *Modeling of Directional Element using SIMULINK*

4. Performance Analysis of Directional Relays

To demonstrate performance of the Directional OCR relay on MATLAB/SIMULINK, 132kV network as shown in figure 7 was simulated, which shows two parallel 220 kV transmission lines feeding a load(L) such that each carries 900A (peak) under normal conditions.The designed relay has been simulated and tested under different case studies.

- Case 1: For Fault occurrence at point F1
- Case 2: For Fault occurrence at point F2
- Case 3: For Fault occurrence at load point

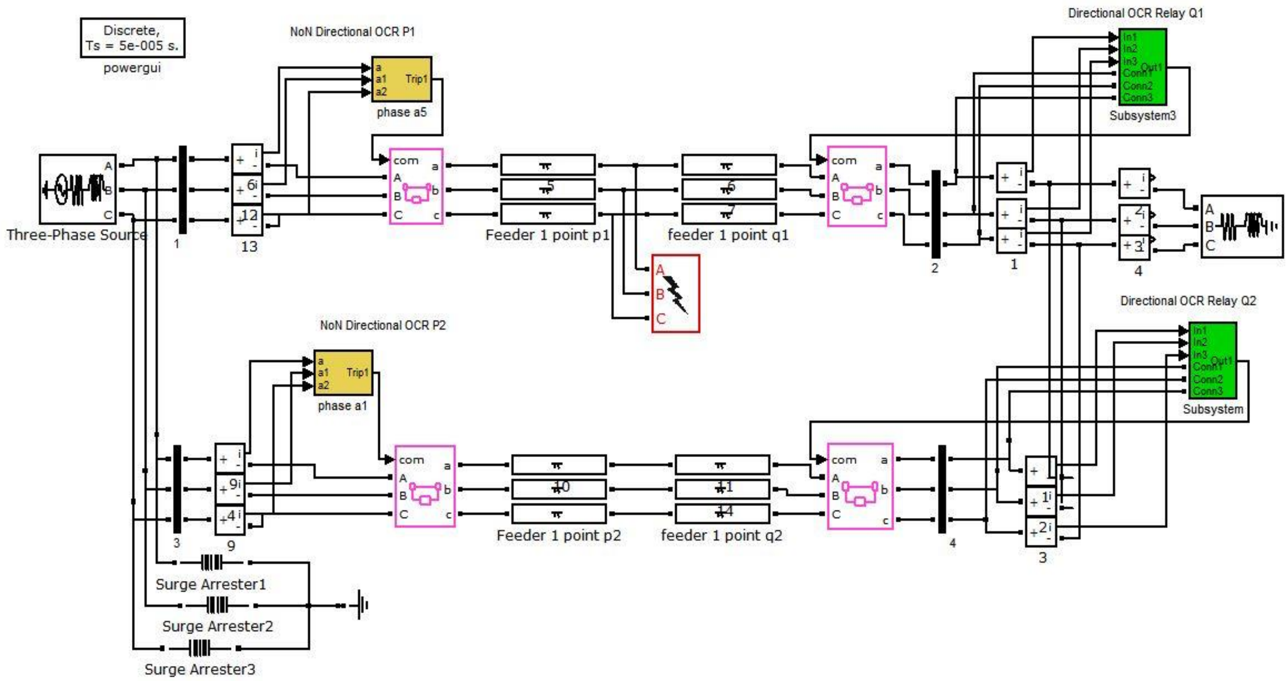

Figure 7: *Simulink model for Four Bus Parallel System*

Case 1: Fault occurrence at point 'R' on Feeder F1

To ensure removal of only line F1 for minimum outage; relays Q1 and Q2 are considered as directional over current relays, with power flows in the direction as shown in Figure 8. Relays P1 and P2 are non-directional OC relays.

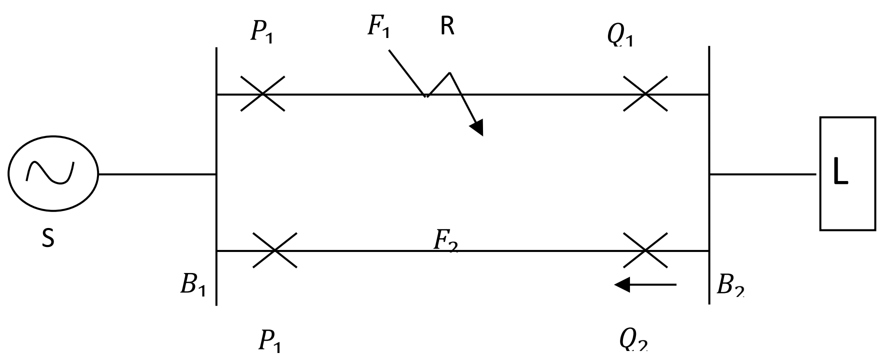

Figure 8: *Proposed Parallel System Circuit*

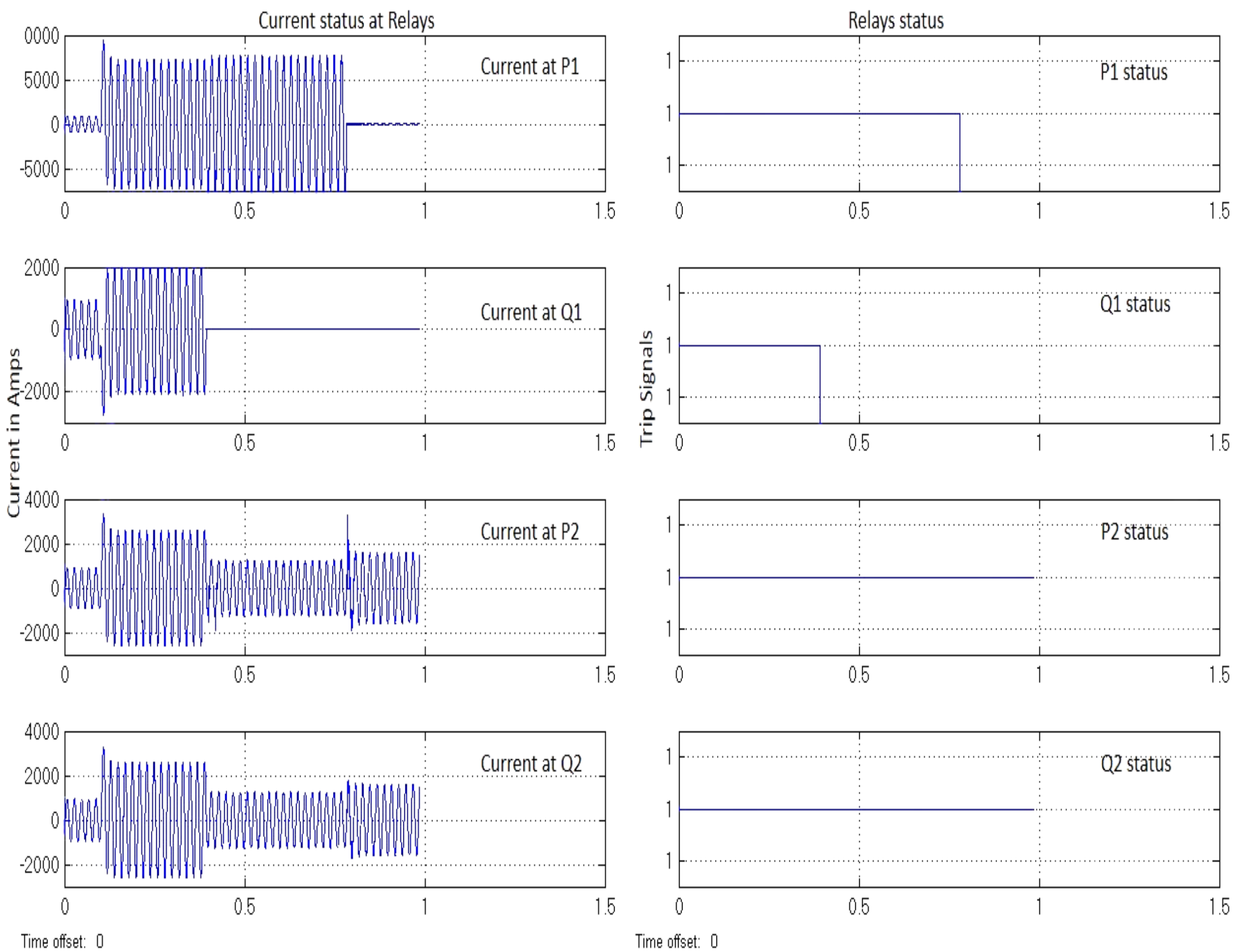

Figure 9: *Fault current and Relay Status in Case 1*

The fault at R which is fed by the supply through paths S-P1-R and S-P2-Q2-Q1-R causes current levels on both feeders to rise. The direction of power flow remains the same as prior to the fault in relay Q2 and reverse in Q1, therefore relay Q2 remains idle no matter how high the current flowing through the respective C.T. is, whereas relay Q1 functions to send a trip command to the its associated C.B. at t=0.4s resulting in the fault current to no longer be fed from path S-P2-Q2-Q1-R. Non directional O.C. relay P1 will trip its associated C.B. at t=0.8sec., thereby ultimately removing the faulty feeder from the network resulting in the entire load current to be fed by healthy feeder F2.

Case 2: Fault occurrence at point 'F2'

Only P2 and Q2 will open for minimum outage, and load will be transferred to the healthy line F1 in this case. Figure 10 shows the status of relays at P1, P2, Q1, Q2 and the currents at the positions of these relays for fault occurring on feeder F2.

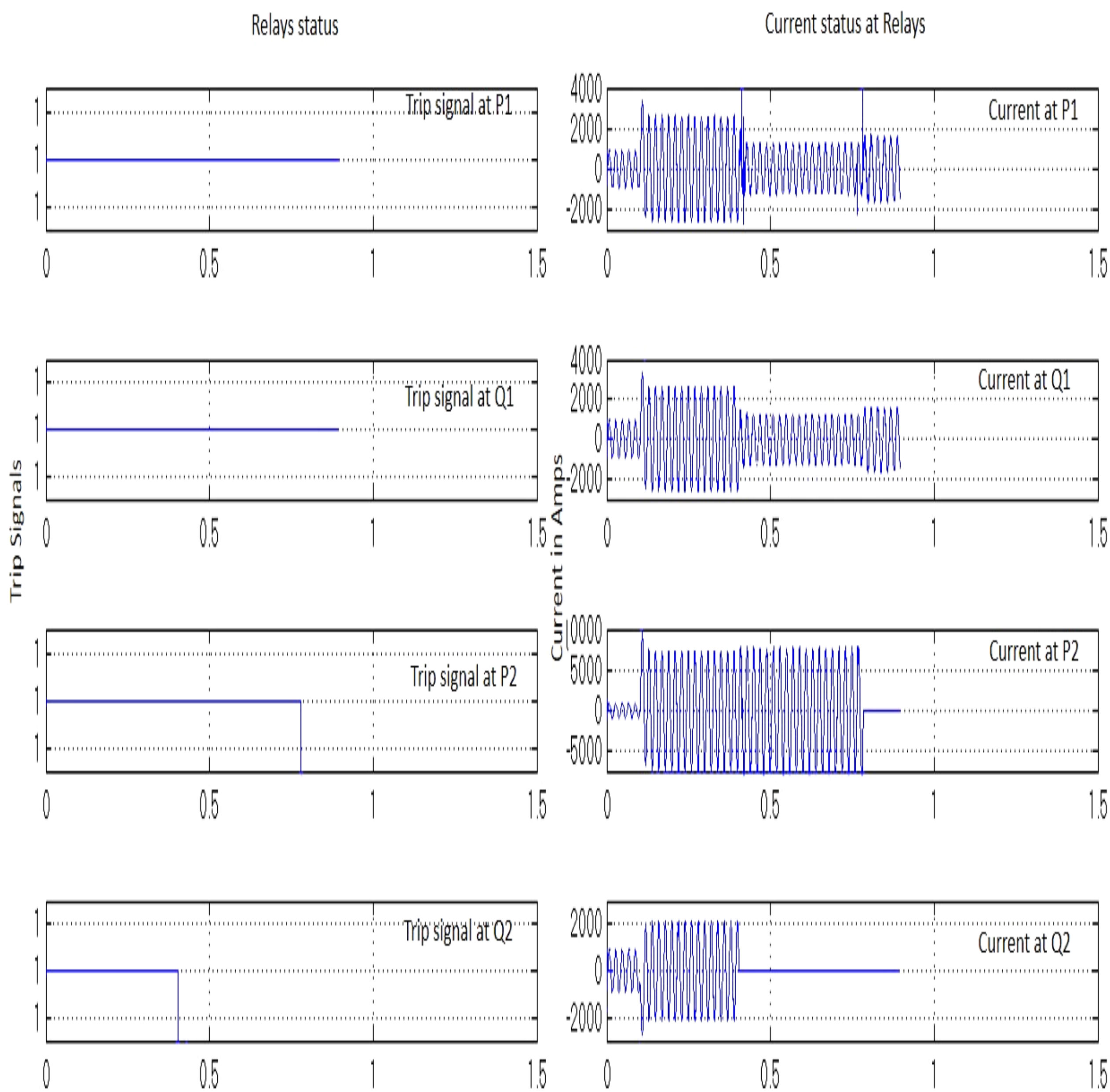

Figure 10: *Fault Current and Relay Status in case 2*

Case 3: Fault occurrence beyond B2

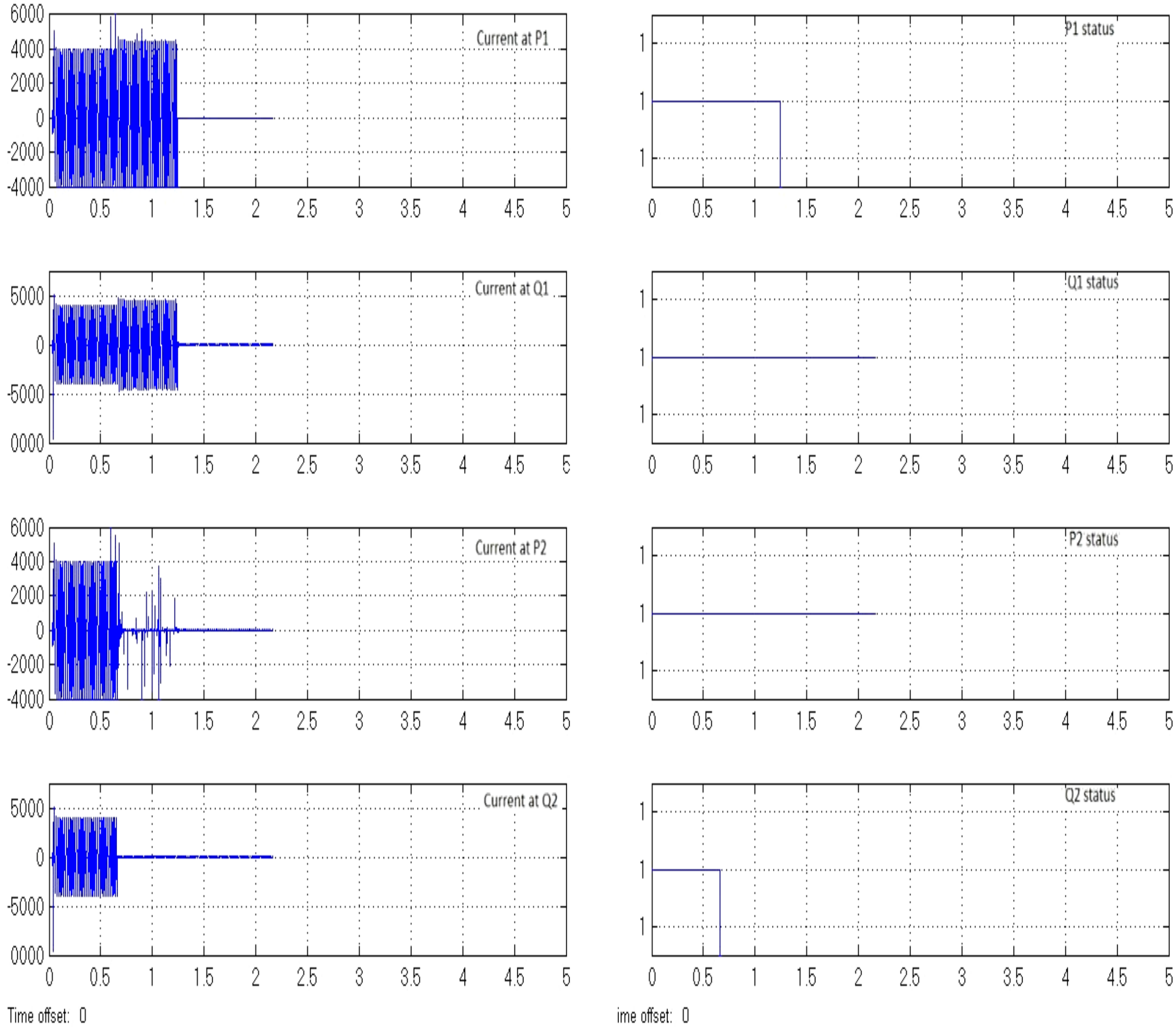

Figure 11: *Fault current and Relay status in case 3*

In this case, only Q2 and P1 will open for minimum outage, figure 11 shows the status of relays at P1, P2, Q1, Q2 and the currents at the positions of these relays for fault occurring on feeder F2.

- Case 4: For DLG Fault occurrence at point F2
- Case 5: For DL Fault occurrence at point F2

Figure 12 shows the status of relays at P1, P2, Q1, Q2 and the currents at the positions of these relays for above two (DLG, LL) non symmetrical faults conditions. For the above cases also it found that the relay also works satisfactorily.

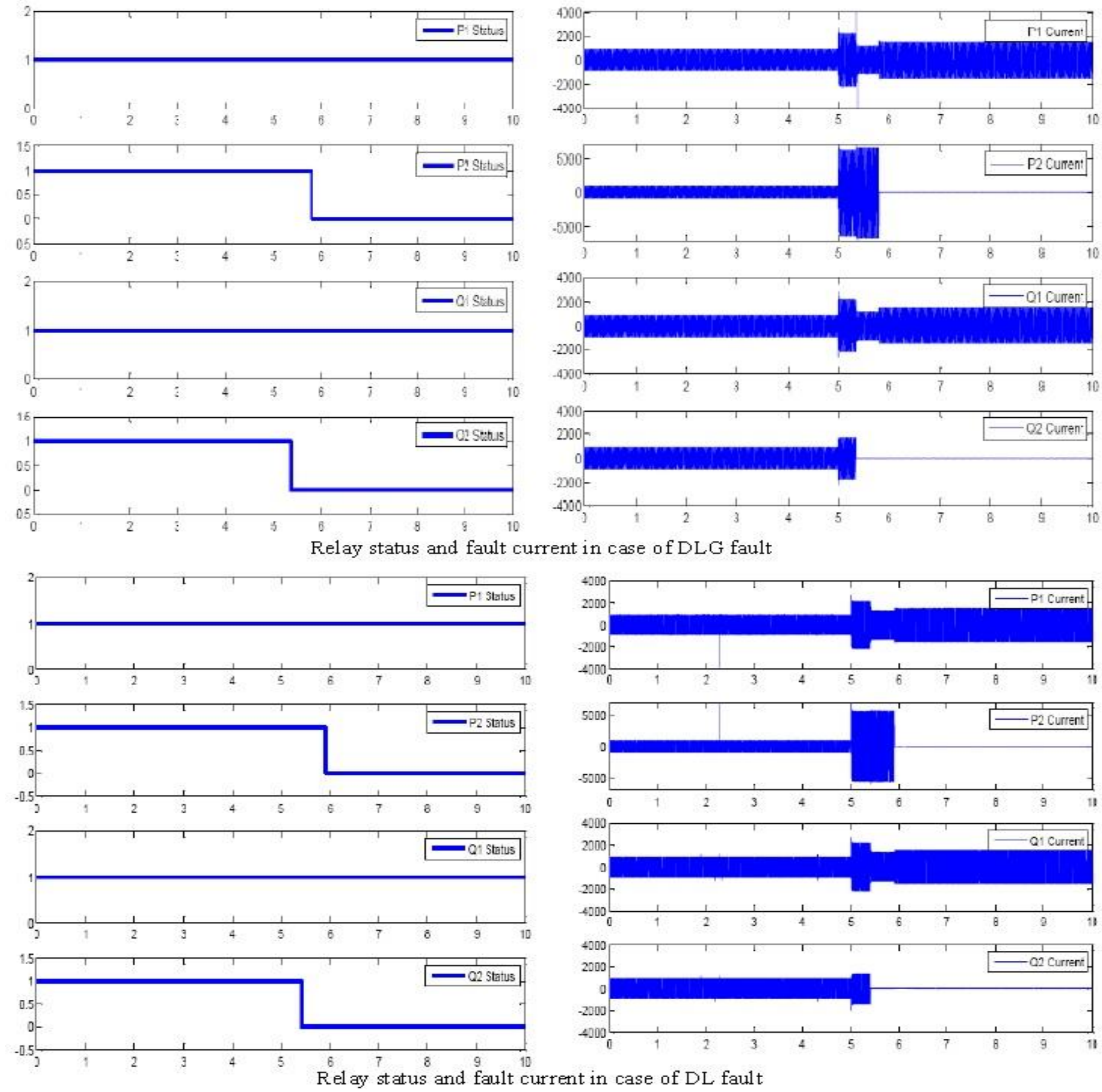

Figure 12: *Fault current and Relay status in case 4 and 5*

5. Conclusion

A methodology for digital over current relay for power system protection using Matlab/Simulink software has been suggested in this paper. The performance of the proposed relay and over current relay has been tested under various case studies. By adding a directional element in directional over current relay the limitation of over current relay can be mitigated and its performance can be improved and they can be employed for protecting ring or loop networks.

It is shown that the proposed model offer effective means for explaining the functionality of over current relay under various fault conditions and it has good advantage in terms of the sensitivity and wide range controlling. The proposed model analyzes the performance of a digital over current relay in radial distribution feeder.

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