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Simulation of speed control and protection of DC Shunt Motor

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Abstract: The objective of the paper is to develop a simulation of "speed control and protection of DC Shunt Motor" and analyze the characteristics of the drive system under the influence of fault. The novelty of our paper is in the fact that prior to this simulation works have been done only in the speed regulation of Drives but we decided to incorporate the idea of fault and protection along with it as it is more close to a real time scenario.

As it is known that motion control is required in large number of industrial and domestic application, for this the Drive systems are employed. The reason for selecting DC drive for our paper is because it is widely used in applications requiring good speed regulation and frequent starting, braking and reversing. Even today the variable speed applications are dominated by DC Drives because of lower cost and simple control.

We decided to carry out our work on simulation because it provides with the practical feedback while designing real time systems, allowing the designer to verify the design and be aware of its working and efficiency before the design is actually constructed. In this in many ways if necessary modifications in designs can be made itself in the designing phase rather than in the construction phase. Thus reducing the overall cost. Simulations may also be used to analyze and verify theoretical models which may be too difficult to grasp from a purely conceptual level. Hence proving to be crucial in both industry and academia.

Index: DC Drives, Chopper, Differential Relay, Circuit Breaker, Speed Control

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1. Introduction

Industries are the backbone of the modern era and so it is of utmost importance that they always run with the highest possible efficiency. So it is of prior importance that the machines on which the industries depend upon work optimally and provide good control to the user so that the user can tailor the operation according to the need of time. Interesting fact being DC drives being first developed in the early 19th century is continued to be used until today even after the dawn of era of three phase electric system and AC induction motor. The primary reason being the variable speed characteristics of the DC motor. When the voltage to a DC motor is increased from zero to some base voltage, the motor's speed increases from zero to a corresponding base speed. An induction motor, on the other hand, always runs at full speed. If a speed other than this is desired, it must be achieved via belts and pulleys, hydraulic pumps and motors, or gear boxes and clutches. These devices provide for rotation at a speed something less (or greater) than the design speed, but adds mechanical complexity. For this reason, many industrial application requires DC drives for their

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operation, some by force and some by choice.

For the desired motional operation of the DC motor drives variable speed control mechanism is used and the most common speed control technique being the variable armature voltage control. So in order to vary the speed the armature voltage is to be varied. The conversion of fixed dc voltage to variable dc can be obtained by using semiconductor devices.

Earlier this used to be achieved by AC link chopper but were costly, bulky and less efficient. This is the place where the dc chopper comes into play. Being a single stage conversion device the dc chopper has altogether heralded a new era in rapid transit systems. As most of the traction systems in India still operate via dc motors this paper aims to simulate and analyze a model of dc chopper using power MOSFET and study the speed control characteristics and the advantages and limitations of using a power *MOSFET* along with the setup for the protection of the drive system.

In our work we dealt with two separate domains, one being the speed control part and the other being the protection of the drive system.

Closed loop speed control mechanism is used for the speed control of the drive and the protection against fault is done with the help of differential relay and circuit breakers.

2. Modelling and simulation of DC drive

The original drive system studied in this paper consists of diode – based AC to DC three phase rectifier, power MOSFET chopper and DC shunt motor.

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The simulation is performed in Simulink MATLAB V. 7.7.0.471 (2008), License No. 16051.
The system on which the simulation was performed had the following configuration:

- Processor: Intel® Core ™ i7 – 3610QM CPU@ 2.30GHz
- Memory: 8GB
- Operating System: Microsoft Windows 7 Professional 64-Bit

3. Speed control and protection of DC Motor drive

3.1 Speed control using chopper

A chopper is a particular kind of static device which is adept in converting fixed dc voltage to variable dc voltage. A power semiconductor device is used as a switch in the overall chopper circuitry. This device can be a MOSFET, a GTO or an IGBT. These power electronic devices have a voltage drop of around 0.5-2.5 volts which has been neglected as such in the analysis carried out in this paper.

Chopper is basically a very high speed on/off switching device. Its basic job is to connect and disconnect the load from source at a great speed. In this way the constant dc voltage is chopped and we obtain a variable dc voltage. There are basically two time periods in chopper operation, one is the "on" time denoted as **T**on and other is the "off" time denoted as **T**off. During **T**on we get the constant source voltage Vs across the load and during **T**off we get zero voltage across the load. The chopper plays the role of providing this pattern of providing alternate zero and **V**s. In this way we obtain a chopped dc voltage in the load terminals. It is illustrated in Figure 1.

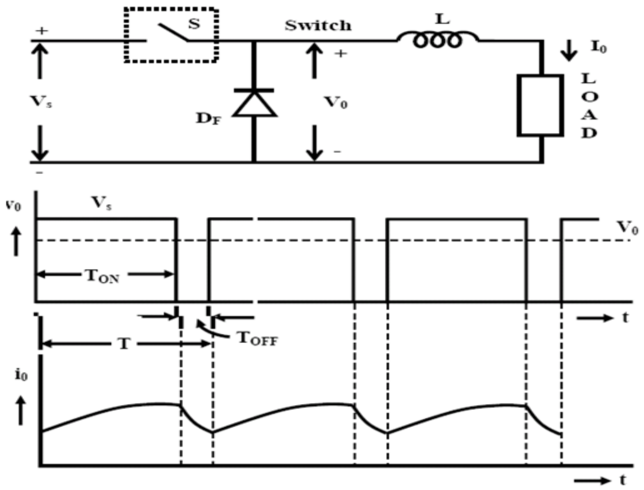

Figure 1: Basic chopper circuit with the output voltage and output current curves

Vo **=** Average output voltage of the circuit**.**

Vs = Source voltage of the circuit.

Vo = **T**on / (**T**on + **T**off) × **V**s (1)

Ton / (**T**on + **T**off) = Duty cycle denoted by α.

The relation of the motor speed with the armature voltage can be given from Equation (2)

$$\omega = \frac{V - i_a R_a}{K\phi} \qquad (2)$$

Where ω is the speed in rad/sec, V is the armature voltage, ia is the armature current, Ra is the armature resistance, K is a constant and ϕ is the flux per pole.

Thus we see that we can control the average output voltage and hence the speed by varying the duty cycle.

A closed loop speed control mechanism is simulated in the MATLAB Simulink shown in Figure 2.

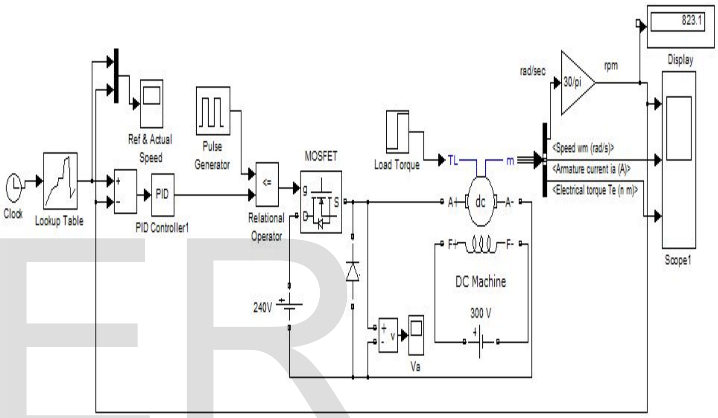

Figure 2: Closed loop speed control of DC shunt motor using chopper

The set of values speed at different time intervals is put as input in the lookup table. The motor speed is fed back to the relational operator through the PID controller which is a closed loop feedback mechanism controller. A PID controller continuously calculates an *error value* as the difference between a desired setpoint (Ref. speed) and a measured process variable (Measured Speed) The controller attempts to minimize the error over time by adjustment of a *control variable*, such as the position of a control valve, a damper, or the power supplied to a heating element, to a new value determined by a weighted sum:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}$$
(3)

Where Kp ,Ki , and Kd , all non-negative, denote the coefficients for the proportional, integral and derivative terms, respectively (sometimes denoted *P*, *I*, and *D*).

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In case when the measured speed is less than the reference speed, triggering pulse is applied to the gate of the MOSFET. For the turn – ON time Ton the MOSFET behaves as a closed switch and the armature is fed with the supply and during the turn – OFF time Toff MOSFET behaves as a closed switch and the armature is cut off from the supply as shown in Figure 1. The duty cycle of the chopper circuit is preset at 0.7 (70%). As a result of this the motor speed begins to increase in order to reach up to the reference speed. If the measured speed is more than the reference speed, then no triggering pulse is sent to the gate of the MOSFET. As a result, the armature is cut off from the supply and the motor speed decreases. This close loop system always ensures that the measured speed is always near to the reference speed in order to achieve proper and optimal speed control.

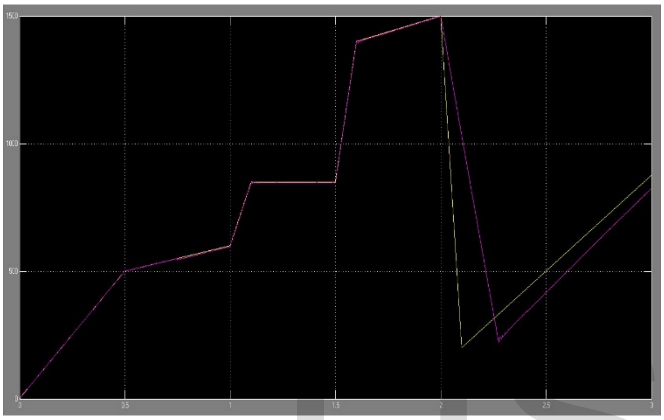

Figure 3: Reference and Measured speed

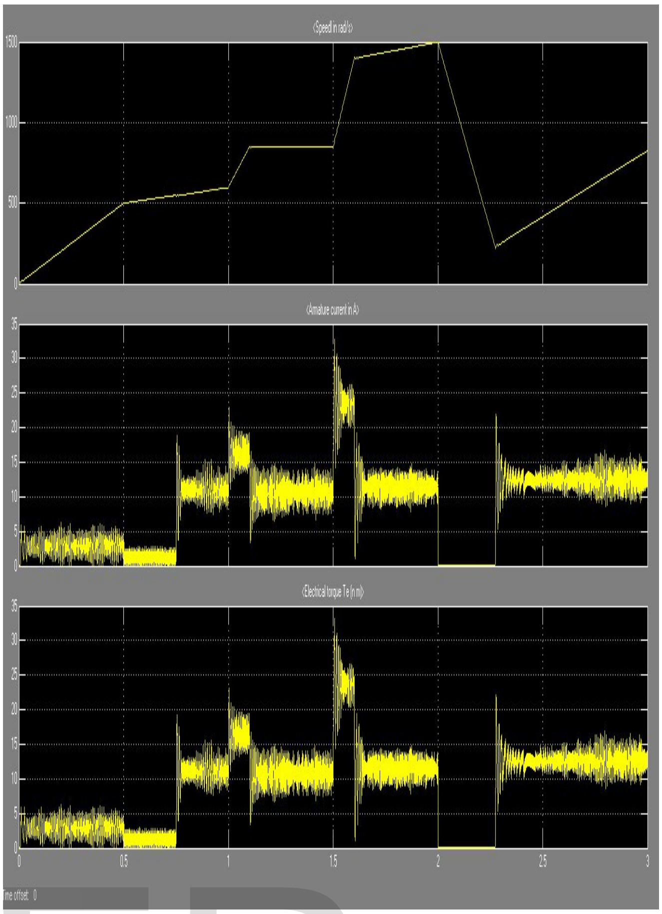

Figure 4: Speed, Armature current and Load Torque

3.2 Protection using Differential Relay

Differential relay is a relay which is used to check the difference between the input and the output current of a system. The difference amongst the currents may be in phase angle or in magnitude or both. For hale and energetic operation, angle and magnitude variations must be zero. In case of fault there would be a difference between the input and the output current which in turn will give rise to a leakage current which is used to actuate the circuit breaker which in turn separates the faulty part from the rest of the system. So basically Differential relay is a sensing device which senses any fault in the system and it the circuit breaker which performs the separation.

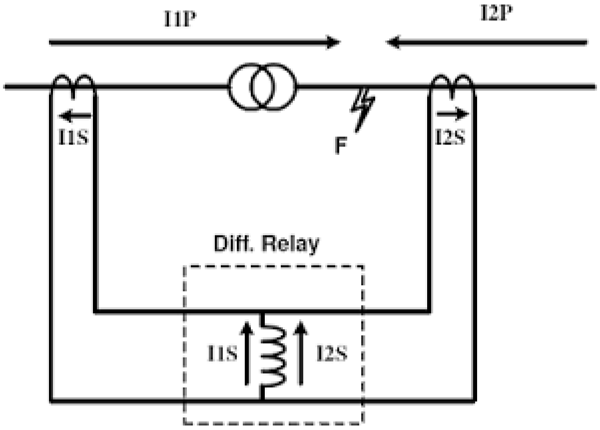

Figure 5: Differential relay in internal fault condition

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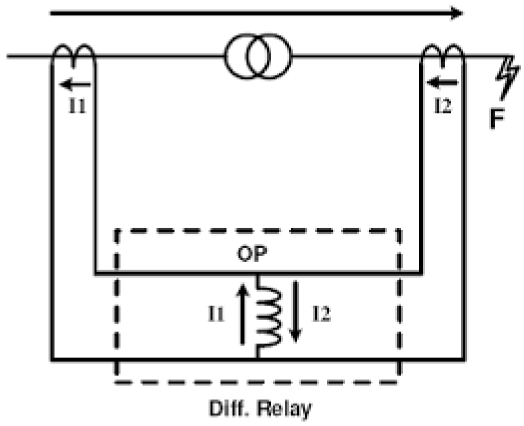

Figure 6: Differential relay in external fault condition

3.3 Simulation of Differential relay protection system

The Differential relay is simulated using the difference between the input and output currents, relational operator and S R Flip – Flops. Illustrated in Figure 7.

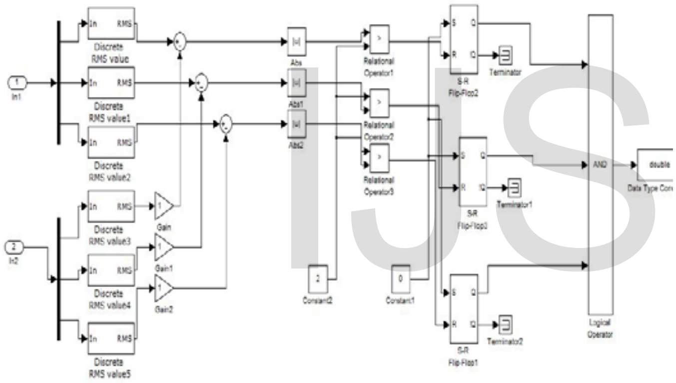

Figure 7: Simulation of Differential relay

The initial state of !Q in the SR Flip – Flops is 1 and the S terminal is fed with binary 0. Now during the normal operation of the difference between the input and the output current will be zero which will be less than the preset constant value set at the other terminal of the relational operator which is 2. As a result, binary 0 is sent to the R terminal of the Flip – Flop. Thus Q remains in logic 1 state and the circuit breaker remains close.

In case of fault the absolute value of the difference between the input and the output current will be greater than the preset constant value of the relational operator which in turn will transmit logical 1 to the R terminal of the Flip – Flop. As a result, Q changes to 0 which causes the circuit breaker to open and isolate the Drive System from the supply. The fault that we have dealt in our simulation is phase to ground fault. The entire protection system can be seen in Figure 8.

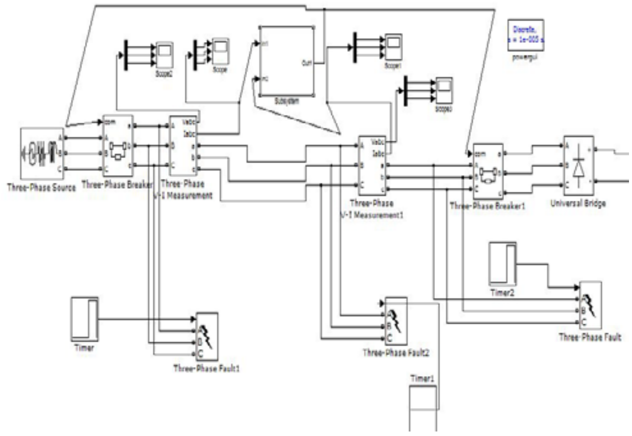

Figure 8: Simulation of protection system

Now the output from the protection system is rectified using an uncontrolled 3 – phase rectifier and fed to the DC Drive System.

3.4 Overall simulation and output curves

The simulation data which was collected from oscilloscope at the end of simulation is given in Table 1.

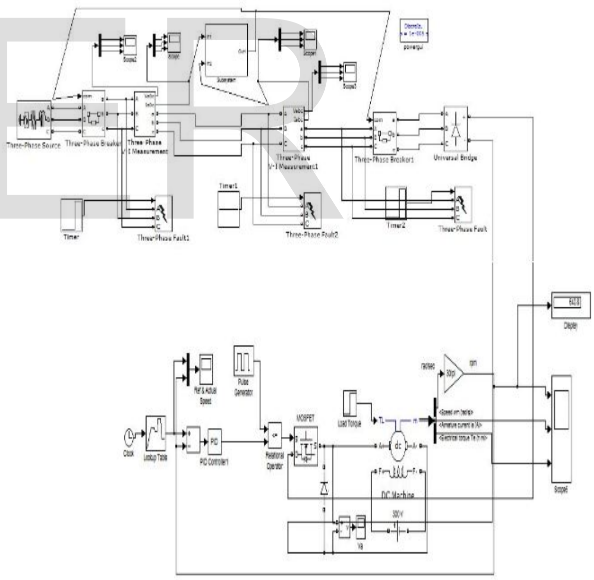

Figure 9: overall Simulation

Time in Seconds	Reference Speed (rad/sec)	Measured Speed (rad/sec)
0	0	0
0.5	1000	1000
1	1000	500
1.1	850	-250
1.5	850	1450
1.6	1500	1800
2	1500	1700
2.1	500	1400
2.5	500	600

Table 1. Reference and actual speed during the fault

The phase to ground fault was introduced in the system for the time duration of 1sec to 1.5sec of the simulation and the output characteristics of the system during fault are illustrated in the following Figures.

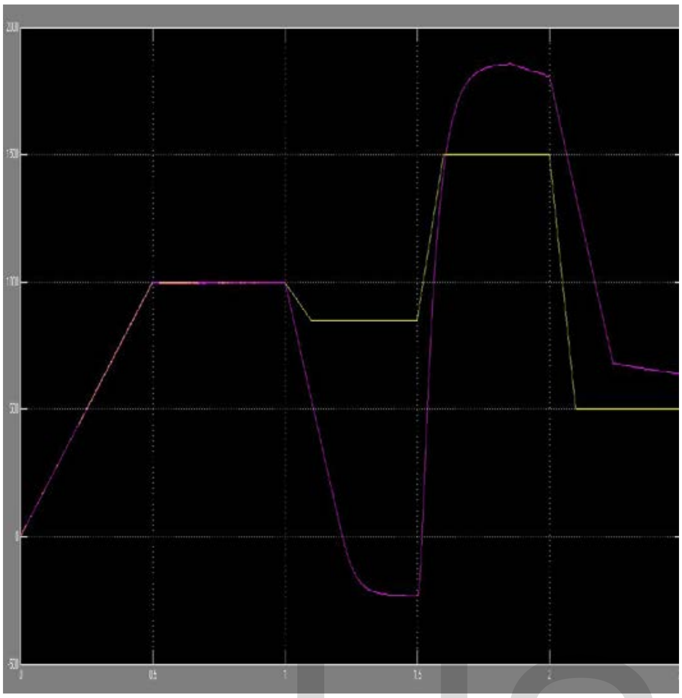

Figure 10: Reference and actual speed during fault

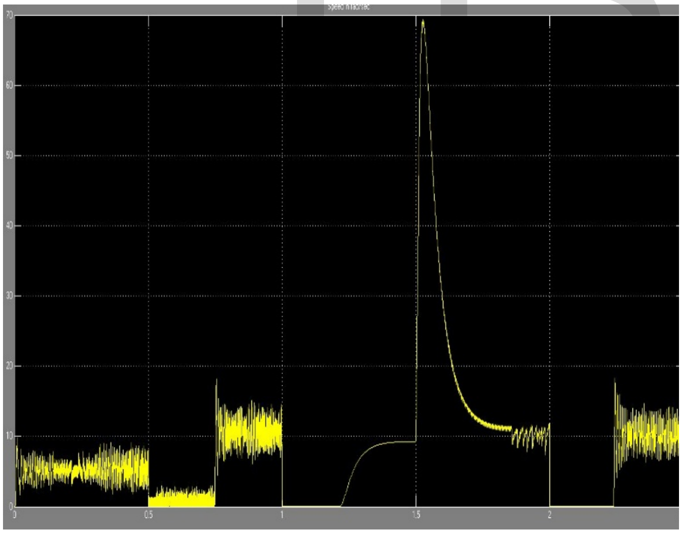

Figure 11: Armature current during fault

As evident from Figure 10 and Figure 11, during the fault the circuit breaker opens and the DC system is cut off from the supply resulting in zero armature current and decrease in speed and hence protecting the drive system.

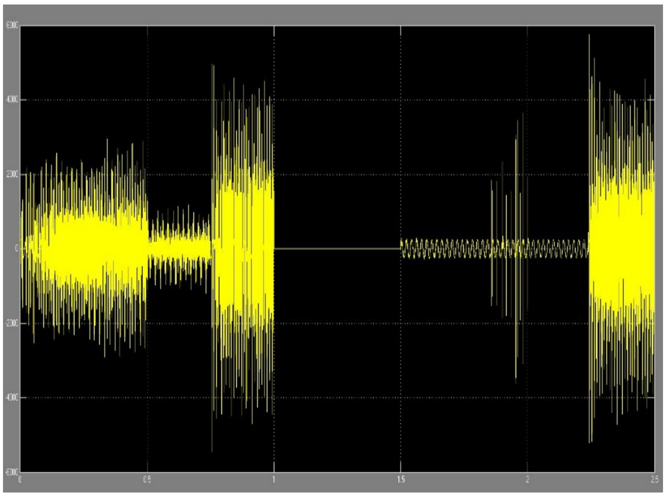

Figure 12: Supply phase voltage during fault

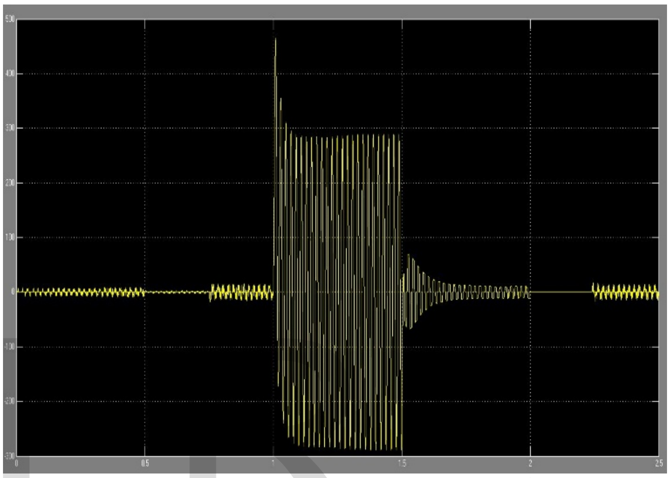

Figure 13: Supply phase current during fault

As shown in Figure 12. and Figure 13. there is a huge rise in the phase current during the duration of fault and since the circuit breaker opens in this period the supply phase voltage becomes zero and the system is protected.

4. Conclusion

The speed control mechanism of the DC Drive system using closed loop control with PID controller was used. The speed control could be further calibrated by changing the pulse width duration being fed to the Gate of the MOSFET which in turn would change the duty cycle and hence would change the armature voltage.

In the protection mechanism following conclusions can be drawn, the supply system contains appreciable amount of inductance and some capacitance. When fault occurs, the energy stored in the system is considerable. Interruption of fault current by a circuit breaker will result in most of the store energy dissipating within the circuit breaker. The remainder being dissipated during oscillatory surges in the system. These oscillatory surges are undesirable and so the circuit breaker should be designed to dissipate much of the stored energy as possible.

As seen from Figure 10. Figure 11. after the fault ends and the circuit breaker closes there is a huge surge in the armature current and the motor speed shoots way above the reference speed as the entire operation of opening and closing of the breaker is being carried out in a very narrow time frame of 0.5 seconds. As a result of it some amount of stored energy is being dissipated into the Drive system when the circuit breaker is closed. This leads to a huge surge in armature current. This can be resolved to some extend if the energy dissipation time response of the circuit breaker is improved.

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REFERENCES

[1] Malviya, P. (2015) "Speed control of DC Motor a Review". *International Journal of Engineering sciences & Research Technology.* 4(8), pp. 298 – 305

[2] Raghuwanshi, S. (2012) "Analysis & Design of Closed – Loop converter – controlled DC Drive". *International Journal of Engineering Trends and Technology.* Volume 3 Issue 3. Pp. 390 – 396.

[3] Gajbhiye, T(2015) "Closed Loop speed control of DC Drive using Atmega 8L Microcontroller". *International Journal of Engineering and Innovative Technology.* Volume 4, Issue 11. pp. 118 - 122

[4] Dubey, G. Fundamentals of Electrical Drives. New Delhi: Narosa Publishing House, 2001.