

## Increasing Reliability of a Power System in Presence of Static Transfer Switch

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**Abstract:** Long interruptions cause no compensable problems to the power systems and decrease the reliability of the system significantly. One of new technologies that decrease the fault time is Static Transfer Switch (STS) with alternative power supply. In this study an industrial plant with motor loads has been studied with and without use of STS in front of a voltage fault. The simulations have been done to demonstrate the speed of the motors during the faults. As the interruption duration is an important factor in reliability analyzing, some faults with various durations have been applied to the system to study the reliability of the system with and without STS. The results are given to verify the STS efficiency in increasing the system reliability by restoring the motors' speed drop in least time.

**Key words:** Industrial power system, long interruption, motor load, power system reliability, static transfer switch

### INTRODUCTION

Electric service interruptions can have a profound economic impact on certain customers. Not only can a sustained interruption results in lost production, but momentary interruptions result in ruined processes and lost production costing hundreds of dollars or more. Customers requiring extremely high levels of reliability have historically had to satisfy their own reliability needs through equipment such as Uninterruptible Power Supplies (UPS) and emergency generators (Brown and Ochoa, 2000).

In high-power applications, Electromechanical Transfer Switches (EMTS) have been used to switch critical loads between two medium-voltage feeders (Hornak and Zipse, 1995; Pettigrew, 1993; Mazmdar and Chairmal, 1991). EMTS's are slow in switching operations and can cause power interruptions of several cycles. There has been recent interest in replacing medium-voltage EMTS's with Static Transfer Switches (STS's) to achieve fast load switching between two distribution feeders (Mokhtari *et al.*, 2000).

The STS can be applied to improve reliability and power quality in industrial plants with many induction motors. Induction motors are usually not considered sensitive to voltage sags but high concentration of motor load in an industrial plant can create a voltage collapse problem in the event of voltage sags and/or short interruptions. This interruptions influence on reliability and costs of the system severely (Sannino, 2000).

In this study, a typical industrial plant with motor loads has been simulated and impact of ground fault has been studied on motor loads. A STS system has been used to remedy the effects of faults and restore the motors' speed drops as soon as possible. This study has been organized as follows: in section II the structure of STS system and the voltage fault detection method has been described. Afterwards, the reliability of an industrial power network is explained briefly. Finally, in section IV the simulation and results are shown. Simulation results from Matlab/Simulink, validate the efficiency of STS in increasing the reliability of the expected industrial plant by recovering the motors' drop in least time.

### METHODOLOGY

**Structure of STS:** Schematic diagram of the system with STS is shown in Fig. 1 (Sannino, 2000). The system is composed of two power sources ( $S_1$  and  $S_2$ ) and two switches ( $T_1$  and  $T_2$ ) representing the STS. The motor loads are connected to the system so they can be supplied by either main source ( $S_1$ ) or the alternative source ( $S_2$ ). STS includes two main sections: control circuit and power circuit.

**Control circuit of STS:** The control circuit of the STS detects voltage faults in system. One technique applied in commercial STS systems for detection of the disturbance is based on Park's Transformation (Sannino, 2000). As

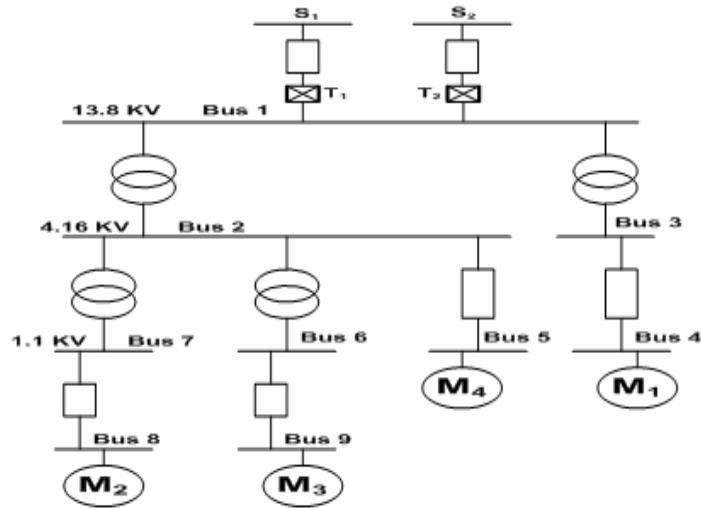


Fig. 1: Schematic diagram of industrial plant

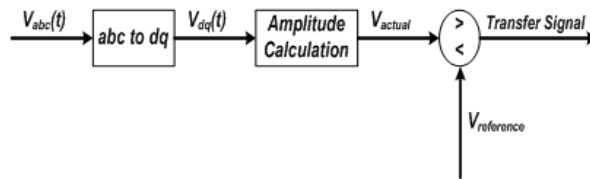


Fig. 2: Detection technique

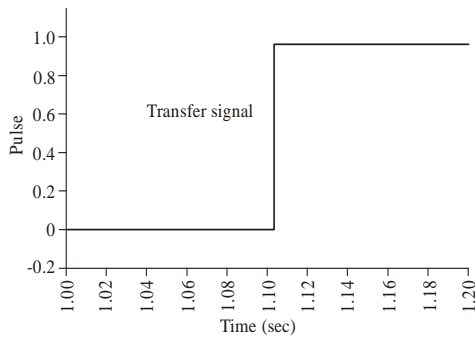


Fig. 3: Transfer signal of detection method

shown in Fig. 2, the instantaneous three phase voltages are transformed into dq reference. The amplitude of this voltage vector is calculated as below:

$$v_{dq}(t) = \sqrt{v_d^2(t) + v_q^2(t)} \quad (1)$$

This value is compared with a reference voltage which is usually between 0.7 and 0.85 p.u. of main voltage. This technique can detect any voltage sag and produces the expected pulses to transfer the power supply.

**Power circuit of STS:** After fault detection, it is the time to change the supply. STS contains of three power switches which can be opened and closed by the transfer signal produced by the detection method. Each switch can connect or disconnect each phase of the transmission line. When the fault has been detected, the pulse signal goes to the preferred switches and these switches disconnect the line between faulty source and the loads. Since the main source is run out, another signal will order the switches of the alternative source to be closed, therefore the  $S_2$  will be connected to the network and the loads will be supplied by this new feeder.

Figure 3 shows a transfer signal which is produced due to a voltage fault for 0.2 s. The fault detection technique could analyze the fault just about 3 ms and then send the required pulses to change the sources. Figure 4 shows the three phase voltage of  $S_1$ . As it can be seen, the  $S_1$  become out of order for about 0.2 s. but when the STS system works properly, the transfer action will be done in about 3 ms and the loads will be supplied with new source. The voltage of phase a which supplies the load after STS action is shown in Fig. 5.

**Power system reliability:** One of important things in reliability study of a power system is interruption and its duration. Interruptions in power networks are inevitable.

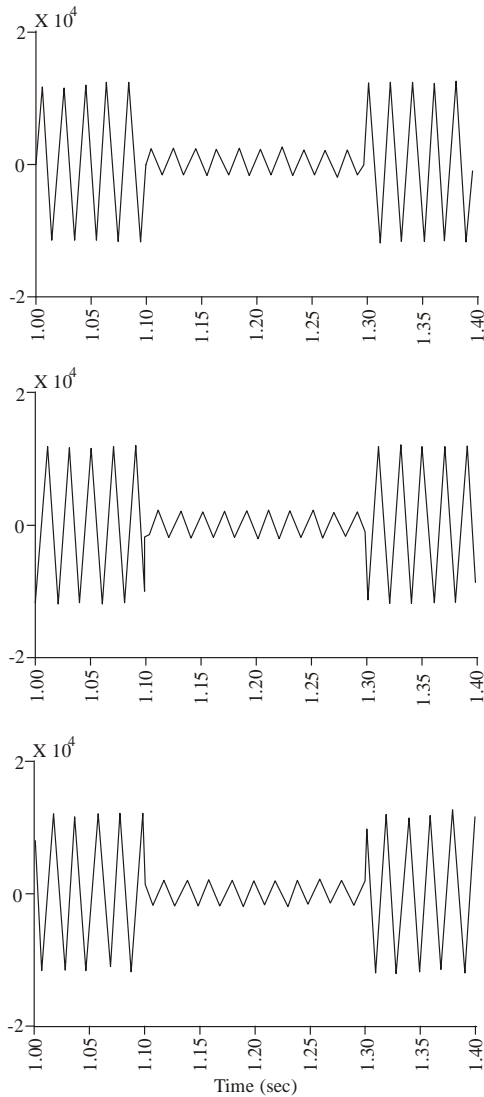


Fig. 4: Three phase voltage due to a fault

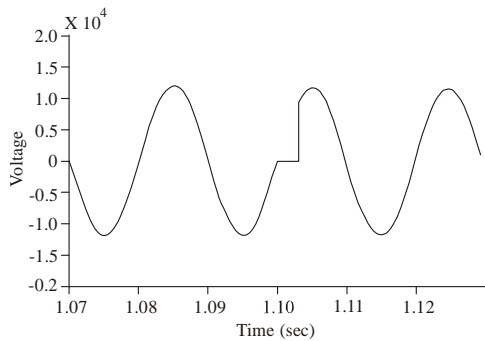


Fig. 5: Voltage of phase a after STS action

If an outage takes a long time, it can lead to an interruption which can harm some parts of systems. Due to low reliability of a system against the interruptions, the

system can be collapsed so the customers cannot be supplied correctly. In an industrial plant, interruptions may lead to break down of a production line, results in low production and lower income, so economical issue is a consequent of system with low reliability.

As it has described in introduction, increasing use of motor loads in industrial plants may lead to voltage collapse which if the duration of voltage sag is long, the motors cannot be restored and their speed will be dropped and will become out of order, so new technologies like STS would be used to eliminate these faults. Each motor break down cause many problems in an industrial plant with high costs. It should be mentioned that the time to restore each motor is important due to high rate of faults in one year or more.

Decreasing the fault duration improve the reliability of a system, because of the fact that the loads can be restored against a small transient state that occurs due to a small interruptions.

### SIMULATION AND RESULTS

The mentioned system in Fig. 1 has been simulated in Matlab/Simulink to analyze the interruption duration on the motor loads. The system parameters consist of transmission lines and transformers impedances and motors specifications are gathered in Table 1 and 2. A fault with duration of 0.4 s, starts at 1.1 s has been applied to the main source. As it can be seen in Fig. 6, the  $M_3$  has been down due to voltage sag. But the three others motors could restore their speeds and continue their works.

Using STS leads to no break down, so noticing Fig. 7 can prove the efficiency of this technology. The four motors just feel a transient fault and all of them have been recovered to their stable state.

To analyze the reliability of this system, it can be assumed that there are 10 faults with different duration in one year. So the motors would be fallen down due to specific fault. Table 3 shows the simulations results of this assumption.

Now assume that  $\lambda$  is the ratio of faulty situations for each motor. So:

$$\lambda_{M_i} = \frac{N_f}{N_t} \quad (2)$$

where  $N_f$  is the number of outage for each motor and  $N_t$  is the total number of faults that here is 10.  $\Lambda$  for each motor can be calculated as follows:

$$\lambda_{m1} = 0.2, \lambda_{m2} = 0.4, \lambda_{m3} = 0.7, \lambda_{m4} = 0.5$$

If each fault needs 1 h for restoration, do this will be a huge time of no production at that plant which effects mostly on income and makes lots of costs to this system.

Table 1: Parameters of transmission lines and transformers

Line No.	1-3	3-4	1-2	2-7	7-8	2-6	6-9	2-5	1-10
R (p.u.)	0.0304	0.045	0.0042	0.0282	0.108	0.0165	0.0681	0.06	0.0038
X (p.u.)	1.056	0.09	0.017	0.101	0.054	0.0364	0.034	0.12	0.005

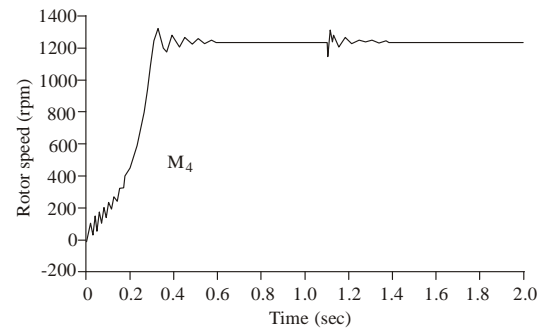
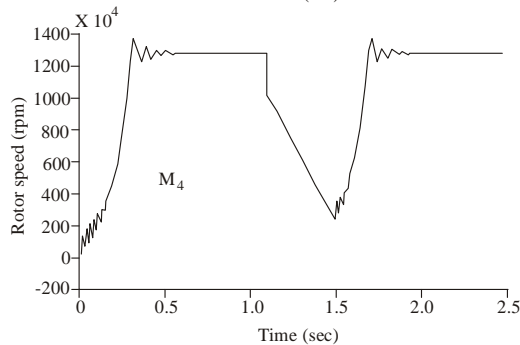
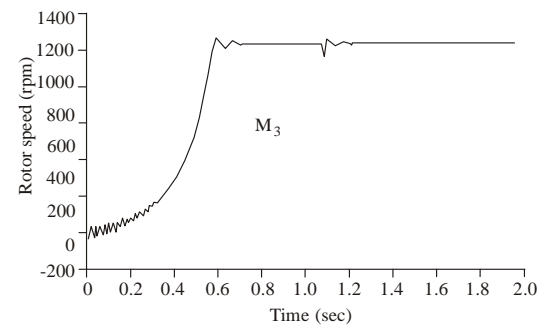
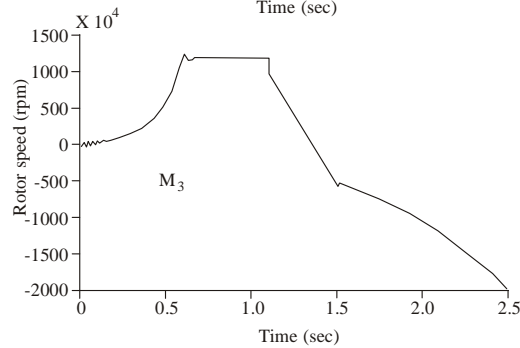
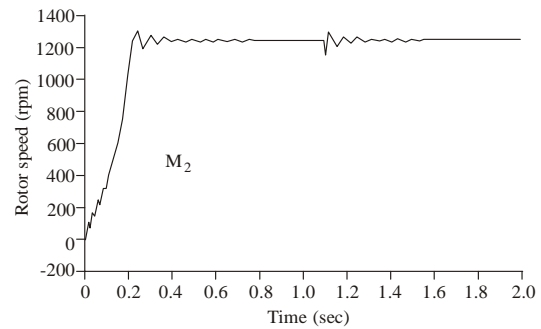
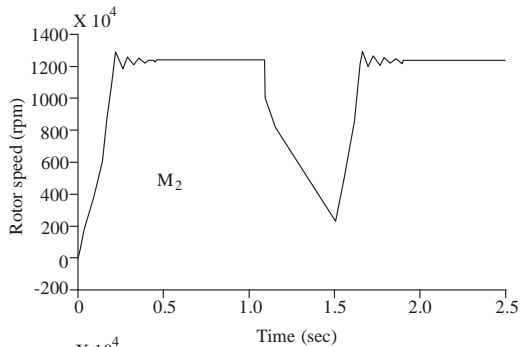
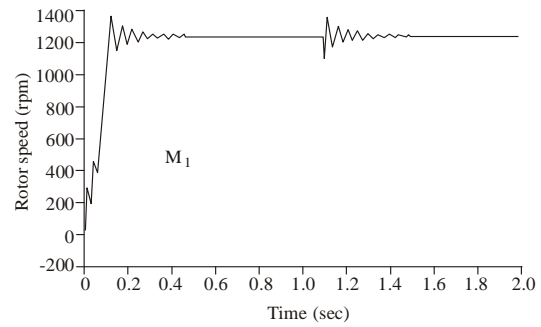
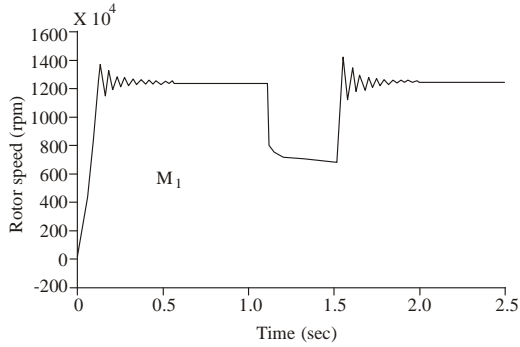


Fig. 6: Rotor speed of motors without STS

Fig. 7: Rotor speed of motors with use of STS

Using STS and alternative sources result in high reliability and proper working of the plant that most of motors would be restored after each fault with its

duration. This high amount of reliability directly influences on production line and level, income and costs of the plant.

Table 2: Parameters of motor loads

Motor	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>
Bus no	0.4	8	9	5
S (KVA)	597	2712	4269	3420
V (KV)	4.16	1.06	1.1	4.16
S (%)	2.209	2.87	3.443	2.147
R <sub>s</sub> (p.u.)	0.016	30.0235	0.0235	0.0022
X <sub>s</sub> (p.u.)	0.0816	0.1353	0.1353	0.0759
X <sub>m</sub> (p.u.)	2.250	2.580	2.580	2.620
R <sub>r</sub> (p.u.)	0.0287	0.044	0.044	0.0288
X <sub>r</sub> (p.u.)	0.0836	0.143	0.143	0.1037

Table 3: Motor loads performance due to various faults' duration  
Motors' states after each fault

Duration of each fault (Sec)	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>
0.1	Restored	Restored	Restored	Restored
0.2	Restored	Restored	Restored	Restored
0.3	Restored	Restored	Restored	Restored
0.4	Restored	Restored	Dropped	Restored
0.5	Restored	Restored	Dropped	Restored
0.6	Restored	Restored	Dropped	Dropped
0.7	Restored	Dropped	Dropped	Dropped
0.8	Restored	Dropped	Dropped	Dropped
0.9	Dropped	Dropped	Dropped	Dropped
1.0	Dropped	Dropped	Dropped	Dropped

### CONCLUSION

In this study the STS structure and its contribution in increasing the system reliability have been studied. A typical industrial system with motor loads which are

sensitive to long interruptions has been simulated and many faults with different durations have been applied to it. The reliability analysis shows high improvement by use of STS and alternative power supply. STS increase the reliability of the system significantly just by reducing the interruption time from seconds to some milliseconds.

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