Design of a Low Voltage Fast Transfer Switch

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Abstract— Low voltage transfer switch is used to connect an alternate source of ac power to a sensitive load when one source fail .Practical Design of Low Voltage Fast Transfer Switch is presented in this paper which operates within 1msec time duration during transferring of load from one source to another. All results have been taken on CRO during switching.

Index Terms— Protection, Comparison of FTS with mechanical switches, Fast Bus Transfer scheme, ZCD

1 INTRODUCTION

Protection in power system plays an important role because faults on power system cause a lot of power quality problems for sensitive loads. Fast switching technology plays a significant role in protection of these sensitive loads from damage, misoperation and cost .Many techniques are using in the field of protection like current limiters, circuit breakers, on load tap changer mechanical switches etc.[1][2][3][4].

In this research work, a broad concept of high fast switching system and their problems and constraints will be developed. On the bases of these studies and analysis an efficient fast switching of a load to alternate power source system will be designed.

Triac based Static transfer switch consists of two TRIAC connected with each source which allow the fast transfer of power from a main source that is affected by a disturbance e.g. interruption to an alternative healthy source. It consists of two TRIAC (Triode Alternating-Current switch) shown in Fig 1, during normal conditions, TRIAC1 is continuously fired and conducts the load current. When a disturbance occurs like sag swell and interruption, the TRIAC1 is disabled from firing and the TRIAC2 is fired. . The current commutates to the other source or supply in very less time usually less than 1ms after the interruption is detected.

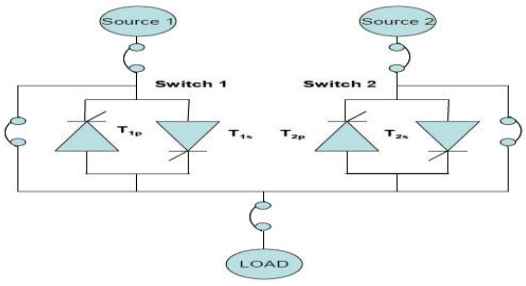

Figure.1 Fast Transfer switch

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2. Comparison of Fast Transfer Switch with Mechanical Transfer Switches

2.1 Mechanical and manual Transfer Switches

Mechanical transfer switches transfer the critical load between two sources when one source fail by using circuit breakers and switches. The transfer switch close the first breaker of one source before the other breaker of the second source opened. It means one source must be connected to the load .This transfer takes more than half a cycle [5].

Human operator is require to operate Manual transfer switch .This type of switching generally require several minutes or more when operator is unavailable.

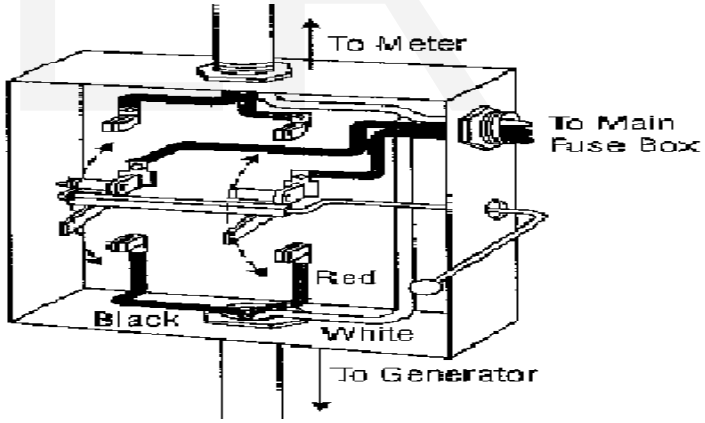

Figure 2. Mechanical transfer switch

2.2 On-Load Tap Changers

A tap changer acts as a switch which is connected to a transformer which perform switching between the tapes of the transformer and changing the turn's ratio of the transformer. Each design have different taps depends on desired range of voltage .Normally a tap changer work on the principle of make before break to maintain the supply load by changing turns ratio.

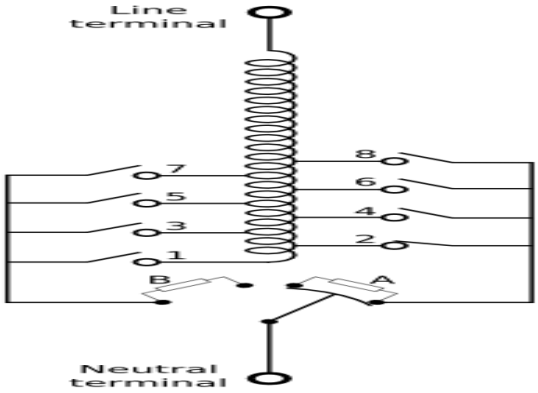

Figure 3. On load tape changer

2.2.1 S11witching time

Normally tap changing require a few minutes, whereas some new tap changers are developed which takes 3 to 10 sec for their operation [6].

Conventional tap changers life time is up to 100,000 operations whereas some new tap changing technology have been developed which do 500,000 to 600,000 operations like vacuum switching tap changers[7].

2.3 Motor-generator sets

Motor generator is use in power system for isolating critical loads from sag and interruptions, comes in different variety of size and configuration. The motor is powered by the line drives a generator that give power to the load. Flywheel is installed on the same shaft that provide greater inertia, when a disturbance occur the inertia of machine and flywheel maintains the power supply for several seconds [8].

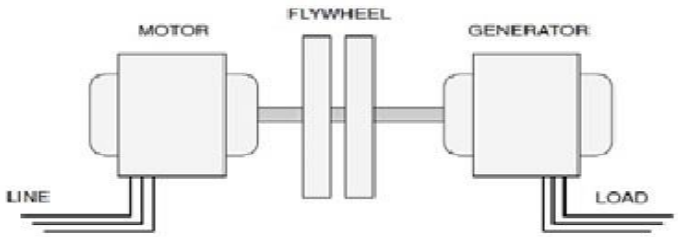

Figure 4.Motor generator with flywheel

2.4 Dynamic Voltage Restorer (DVR)

Dynamic voltage restorer restore the system voltage in efficient and fast way during sag event .It is based on electronics devices which provides three phase voltage which is controllable, whose magnitude adds to the source voltage when sag occur to restore the load voltage [9][10][11][12] .

Dynamic voltage restorer is also called voltage booster or static series compensator, is a device that uses solid states electronics components and are connected in series to distribution system on utility side.

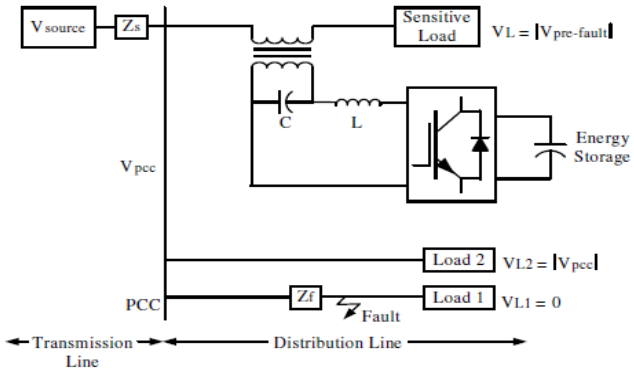

Figure 5. Basic structure of DVR

2.5 Standby UPS

Standby UPS or back up power supply is used nowadays in wide range due to faults on power system to give continuous power to the load and keep the system running .When a disturbance is occurred a switch transfer the load to the battery backed inverter. Mechanical relays are normally used for switching in UPS [13],[14].

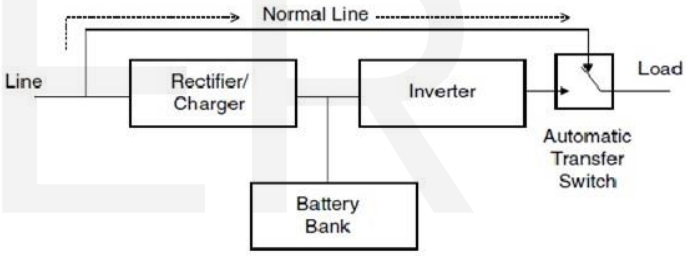

Figure 6.Standby UPS

2.6 Automatic transfer switches

Automatic transfer switches are composed of electromechanical components in which a first connection is first break and then make a new connection by using relays on each source line. This kind of technology break before make is certainly slower than static switches and takes more time.

Lot of verity is available of ATS ranging from breakers to static switches [15][16[.Conventional transfer switches takes time in seconds to switch load from one source to another but fast transfer switches are available that can transfer in about 2 electrical cycles.

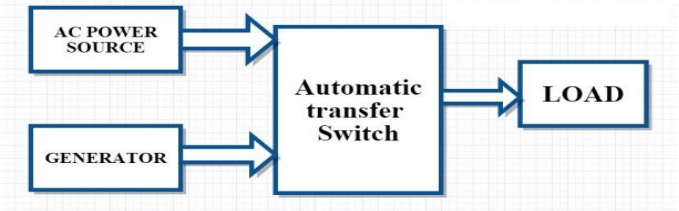

Figure 7. Block diagram of ATS

Compare to other mechanical transfer switches, Fast transfer switch is very fast, more efficient and cost effective as shown in table1. The Fast Transfer Switch, which essentially consists of a pair of thyristor switch devices, enables seamless transfer economically of energy from a primary source to an alternate source in order to avoid service interruption the most critical and sensitive loads. Upon a deficiency in power quality

Table1.A Comparison of Static Transfer Switches and Mechanical Transfer Switches [17]

Parameter	FTS	MTS	UPS	Generator	Flywheel/Gen Set
Operation (ON/OFF)time	1mSec	24mSec-5Sec	<4mSec	10—30Sec	< 4mSec
Cost	Medium	Low	High	High	High
Efficiency	High	High	Medium	Low	Medium
Back-up	Mechanical by-pass	Not normally available	Requires additional equipment	Requires additional equipment	Requires additional equipment
Duration	Unlimited	Unlimited	Duration of batteries	Duration of fuel	Limited w/o Gen backup

3. Sensitive Equipment Vulnerability

Power quality disturbance cause lot of problems for critical loads depending on power quality problem magnitude, duration and equipment sensitivity like equipment's used in Automotive manufacturing, Glass plants, Plastics & Chemicals, Textiles, Semiconductor plants Pharmaceuticals, Data centers etc. These power quality disturbances cause the following problems. [18]

1. Lost production
2. Scrap
3. Cost to restart the whole process
4. Labor costs
5. Equipment damage and repair
6. Data loss

4. Fast Bus Transmission Scheme

45% faults in power system occur on transmission lines, 30% faults occurs on parallel lines and 25% fault generated in own circuit. A typical power system is shown in Fig8. The generator of 11kV delivers. Bus bar 3 is a common point of coupling and a power transformer is used to step up voltage up to 132 kV as shown in Fig 8. The power is delivered to PCC through a double circuit transmission lines.

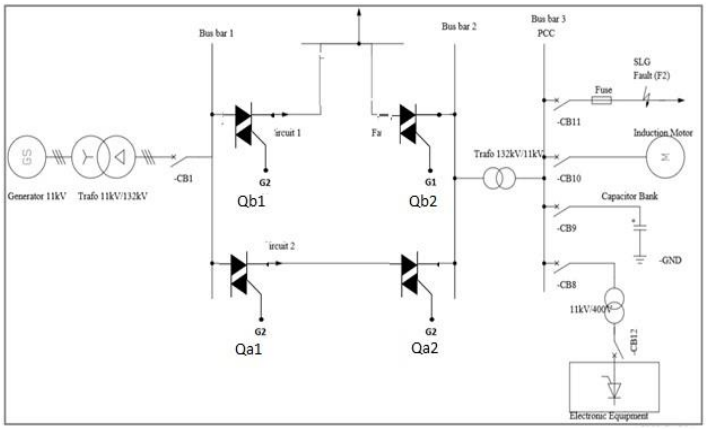

Figure.8.Fast bus transfer scheme

During fault circuit breaker operate and disconnect the faulty circuit; the opening time of a typical circuit breaker is 50-100 milli seconds, because of massive weight and complex system of operating mechanism. Different operating mechanisms for different types of circuit breaker are used. If a single line to ground (SLG) fault occurs in distribution system the fuse is used to protect the healthy system from faulty feeder. Fuse is blown quickly to disconnect circuit than a circuit breaker. The protection relay will give a trip signal for circuit breaker. The protection relay will operate when a fault current and duration match to the relay set values. If the fault current magnitude found very high the relay will operate quickly, if the fault current is found a little high than normal current value the relay will operate slowly.

The transmissions lines are designed to sustain a maximum load capacity and short circuit current capacity. When a fault occurs on one circuit of transmission line the circuit breaker of faulty circuit trips the load of faulty circuit also shift over to healthy circuit. The fault will generate voltage sag for time of the relay operation, breaker tripping of faulty circuit and closing of circuit breaker of healthy circuit. The voltage sag will also generate during transformer energizing, capacitor on-off switching. A large size

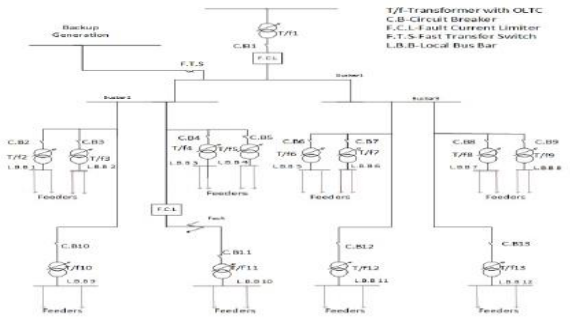

Figure 9. A radial distribution network

Induction motor is connected to bus bar 3and circuit breaker 10. The starting of motor can cause to generate voltage sag at PCC, the sensitive equipment's connected to PCC may cause to trip or miss operate.Fast transfer switch is used instead of circuit breakers to quickly transfer the load to the second bus bar.

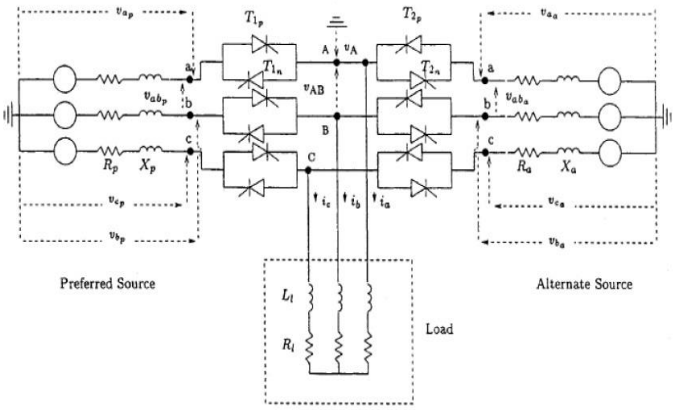

Figure10.Three phase thyristor-based fast transfer switch

5. Zero Cross Detector

To differentiate between an

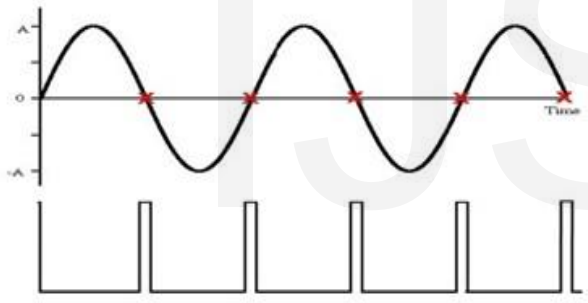

Figure11.Zero crossing pulse at 0,180,360

Interruption and zero that normally occur in AC signal at 0,180 and 360 a zero cross detector is used. At zero degree Controller will generate a pulse to check the voltage and wait for 100µsec if the voltage is still zero then controller consider it an interruption and transfer the load to the other source. Fig8 shows a basic circuit diagram of zero cross detector in which first 220v is step down to 6v and then by passing through bridge rectifier converts into 6v dc .This 6v dc continuously turn ON the photodiode and the 5v go through ground and no signal sends to the controller, but when an interruption occur the photo diode turn off and the 5v signal go to the controller .The controller and wait for 100µsec if the voltage is still zero then controller consider it an interruption and transfer the load to the other source but when an interruption occur the photo diode turn off and the 5v signal go to the controller .The controller then wait for 100µsec and check the voltage level if voltage level is still zero then send a signal to the second TRIAC to turn ON the second source.

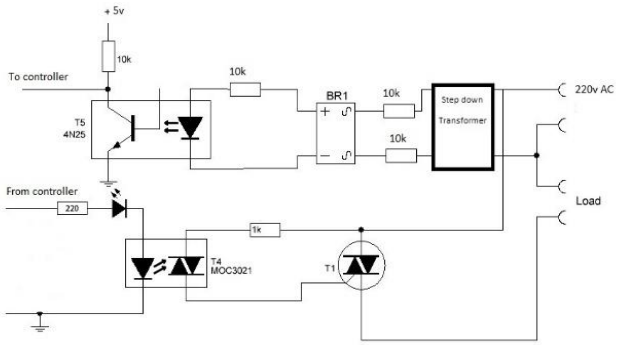

Figure 12 Zero cross detector circuit diagram

6. Working principle of Low Voltage Fast Transfer Switch

A schematic diagram of low voltage fast switch is shown in fig 5.Transformer T1 and T2 are connected with line L1 and L2 of two different sources, which step down the 220v to 6v .Bridge 1 and 2 convert this 6v AC to 6v DC and generates an output voltages v1 and v2 connected to analog input of the controller and controller convert it into digital form .Controller can read an analog value in 100usec in microcontroller there is a default value of 20v .Similarly T3 is connected with bridge 3 which gives v3 as an output voltage to the controller.

The controller receives the voltage levels v1, v2 and the load voltage v3 as an inputs and generates out puts S1 and S2 to drive the TRIAC1 and TRIAC2 by using two optocoup

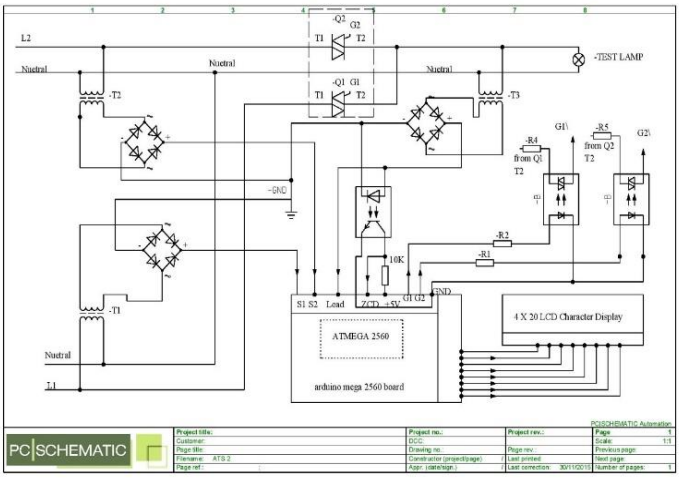

Figure 13. Schematic diagram of low voltage fast switch

plers connected to the controller. Load voltage v3 will be measured in controller if voltage is above or below the nominal voltage .Under normal condition the controller will

biases first transfer switch to connect primary source 1 to the load. When sag, swell or interruption occur on S1, the controller detect the condition and biases second transfer switch and shift the load to source 2. LCD will show voltage status of both sources.

7. Results & Discussion

The following results has been taken by using a contactor which normally tripped during an interruption and load is also connected with this contactor, the horizontal axis show time division that is in msec and vertical axis shows voltage magnitude that is up to 2 volt switching time noted by CRO which is highlighted is 1msec In normal condition when no interruption is occurred the sine wave is smooth, but when an interruption occur on any source the load transfer to the other source at that time a small flicker occur which shows transfer of load to another source.

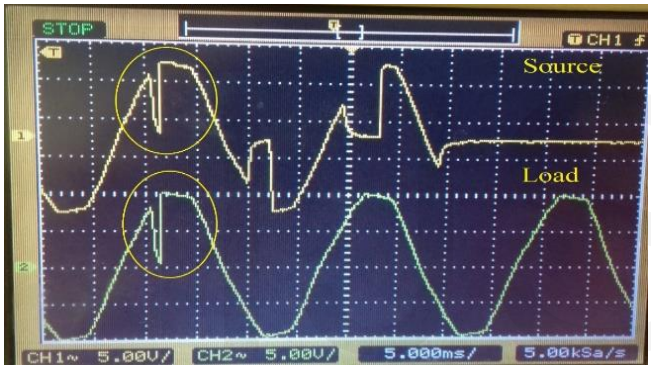

Figure 10.Switching time

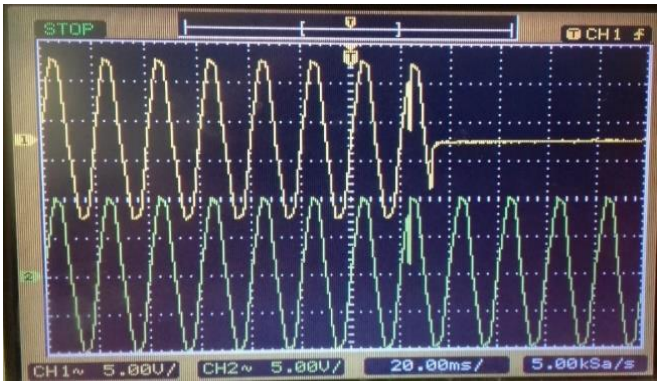

Figure 11. Switching time

8. Conclusion

Circuit breakers and relays operates in time ranges from 5 to 10 msec depending on type of fault and its duration.

This report is an attempt to show that fast switching can have a good value in future technologies.

In this research work a hardware design of fast transfer switch has been presented which overcome the existing technologies for fast switching as discussed in literature .Our proposed solution for fast switching of a load to alternate source is based on TRIAC that perform switching very fast within 1 msec time delay. Controller will perform operation according to default value of voltage as we set in program.

A zero cross detector circuit is used to differentiate between an interruption and zero that occur in sine wave three times in each signal at 0,180 degree and 360 degree. CRO results clearly shows the switching time which ranges from 800µsec to 1msec

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