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Design and Fabrication of Hybrid Automatic Transfer Switch Using Programmable Logic Controller

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Abstract: Most of the large scale industrial critical loads agonize from voltage intermissions and sags which can source a weighty economic loss. The thyristor-based solid state transfer switch and mechanical based automatic transfer switch used to protect loads against these power quality problems. However, the static transfer switch has a significant amount of losses the reason of forward voltage drop of the thyristor and automatic transfer switch cannot efficiently meets the requirements for the load which are sensitive to voltage and will trip due to delayed transfer time. This research proposes a 3-phase system 400V hybrid Automatic transfer Switch. Hybrid ATS is combination of thyristor switch in parallel with mechanical switch. HATS realizes low power intake in normal operating conditions and transfers efficiently when needed. The HATS has four transfer strategies proposed in this paper which are totally dependent on the type of application. On the basis of different fault locations it takes the decision whether to transfer or not when it realizes the overlapping transfer of neutral wire. Transfer on the source end and not transfer on the load.

Keywords— Power supply reliability, Power quality, transfer switch, Hybrid Transfer Switch

1. INTRODUCTION:

POWER quality problems have been always troubling the large scale industries, for example we can say that iron as well as steel industry. In many cases voltage interruption and sags become the source to show the way to pool quality products and it also make the production line paralysis. Such kind of process can also become reason to cost momentous financial loss for the customers of any industry. The unbroken power supply and changeable voltage restorer are developed to get rid of such kind of issues, but due to high cost they may not be suited to large scale of industries.[1]-[3] Usually, there are two or more power feeds in the enterprise. One's performance as go in far and other is alternative. The thyristor based on solid state transfer switch (STS) and mechanical based on automatic transfer switch (ATS), It can be the most cost effective solution of the power quality issues.

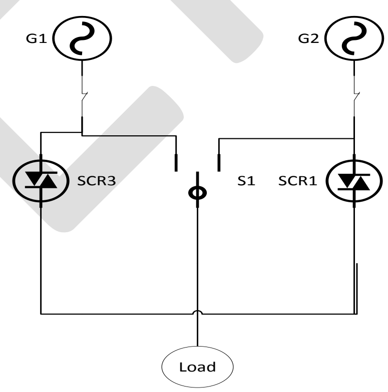

Fig. 1. Main Diagram Structure of HATS

The transfer time of the STS is precise and transfer process has a smaller impact to critical loads. So the power of STS is very patent and plain. When thyristor are undergoing in conduction state. So that, STS requires a huge and cooling system of very high quality. Production or invention of Hybrid ATS is very useful to reduce the loss of consumption. Hybrid switch device contains a pair of antiparallel thyristors and a designed mechanical parallel switch, in this way circuit within 1ms. However structure and motivating circuit are simplified or to become less complex [4]. Structure's perspective four transfer strategies are projected to follow different applications. Projected HATS also realizes the overlapping transfer of the neutral wire and it can easily justify the fault location and decides a correct way to transfer or not first, operation principles contains operation rule transfer strategy. Voltage sag detection method, fault location identification (justification) method. Overlapping transfer of the neutral wire is discussed [5]-[7]. Design details containing hardware and software are presented then laboratory tests are carried out to verify the rules at last, field experiments are carried out, and the results show the prototypes is functional.

2. OPERATION PRINCIPLES:

The structure of the HATS has been mentioned above in Figure 1. TS1 and TS2 are the antiparallel thyristor switches which are connected to the projected (preferred) source and alternative source. Without any hurdle and the moving contact is connected to the load. QS1, QS3, QS5 are solitude switch or isolating switch. QS2 and QS4 are bypass switches. In order to justify maximum flexibility of power supply to load, all the operation rules are necessary for the HATS which are following:

1. In normal state only One Source will be connected the load.
2. When the alternate source voltage is within the normal situation and contains the same phase order with the projected or preferred source it allows transfer operation.
3. The device must be reliably connected the load to the alternate source after cutting off preferred source. If any error happens which was not expected and alternate source cannot be closed any way, then device will be able to reconnect the load the preferred source.
4. To expand the fault range we have to attach or inherit a transfer to HATS when faults happen.
5. Transfer should be stopped during overlapping. For example, during the starting point of motor the load bus voltage may be pulled low. In such kind of case the transfer operation is hindered because the load voltage will difficult to recover even if the HATS transferred to the alternate source.

3. CRITICAL LOAD:

Critical load do not accept any interruption in the power supply. Critical loads such as electronic protection equipment and control. Hence they are always should be online fed from the UPS. The UPS convert the AC voltages which are coming from the main source or preferred source, to DC voltage and store in batteries bank and providing the power supply by converting through DC to AC invertors. But due to high power losses during the converging process and feeding in AC type.

It should be noted that all loads are categorized according to the requirement hence determining the equipment size and the overall cost.

4. HARDWARE CONNECTIONS

4.1. Power Circuit:

Connections of power circuit are shown in fig. 2.

Where the three phase load is fed either from Main Source or the Alternative source through the connectors which are parallel with thyristor [8]-[10].

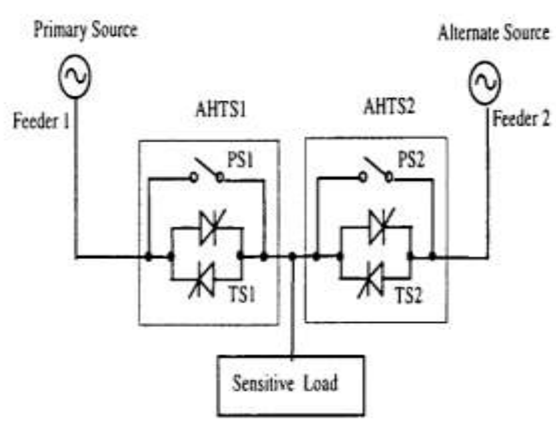

Fig. 2. Power Circuit Diagram

4.2. Control circuit:

The hardware is consist of a DC power supply which'll be use for the control circuit of PLC, sample circuits of alternative source supply and preferred source power supply two SCR driver units [11], ATS1-2 Drivers unit ,etc. A Programmable logic controller PLC is use to control the system to fulfil the requirements of our proposed research. Connections are shown in fig. 3.

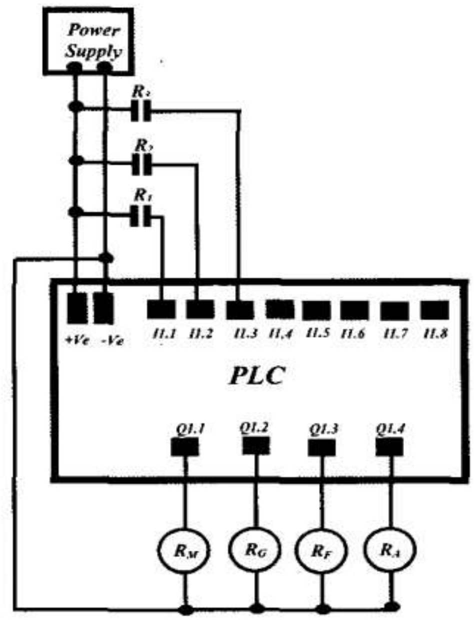

Fig. 3. Connections of Control Circuit of PLC

5. SOFTWARE PROGRAMMING:

The structure of operations for the planned setup can be shortened as

5.1. Fault Condition:

If any phase of main Supply is out of order (R1 or R2 is OFF)

1. Instantaneously disconnect the MAIN Source through its contactor (Rm is OFF)
2. After this Load will be connected through thyristor with minimum (delay Rf is ON)
3. After time delay (T2) ,built up voltage from the alternative Source
4. Check for the alternative Source output voltages (R3 is ON)
5. If not required voltage than disconnect the alternative Source and again connect to Main Source (Rg is ON)

5.2. Normal Condition:

If no one of MAIN source phase is our (R1 & R2 is ON)

1. Load will be disconnected the alternative Source and connect through (RG is OFF) the thyristor with are parallel with Connectors for period (T4)
2. After time delay (T5), Connect the MAIN source through its contactor (Rm is ON)
3. After time Delay (T6), disconnect the thyristors (Rf & Ra are OFF)

6. PROCEDURE DESIGN:

The decision logic module check and deicide to transfer a signal to other source and check the transfer signal is valid or not. If valid then transfer logic module will start the transfer and control the transfer procedure. After the transfer, a verified signal which will be generated on conformation of transfer signal was valid will be sent to the decision logic module and procedure will organize for next transfer signal. [13]

The flowchart of program of decision logic module and the transfer logic module is shown in fig. 4 ATS1 and ATS2 have 3 (Three) position.

1. Load is connect to primary source (which is our preferred source)
2. At this Position load is connect to secondary (alternative source)
3. Load is not connect to no source (zero position)

This flowchart fallows the procedure of BBM (Make Before Brake) strategy. During the transfer procedure, if any fault happened in preferred source then logic module will transfer the load to alternative source. After the recovery of preferred source, transfer logic module will return the load to preferred source for the maximum power reliability. During the transfer procedure, neutral wire will not be cut off [1],[11],[12]

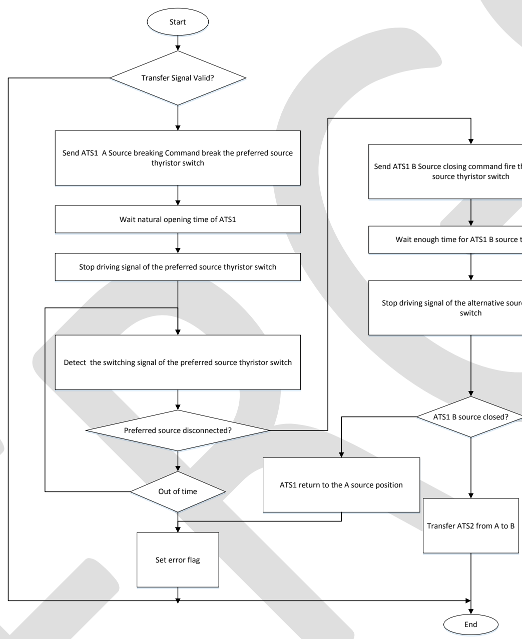

Fig. 4. Transfer logic Flowchart

TABLE 1.

Parameters of Prototype

Rated Voltage	400V
Rated Current	200A /400A
Interrupting Current	450A / 900A
Cooling Method	Natural
Applications	Three phase four wire system
Operation Mode	Auto or manual
Load type	AC-22iA

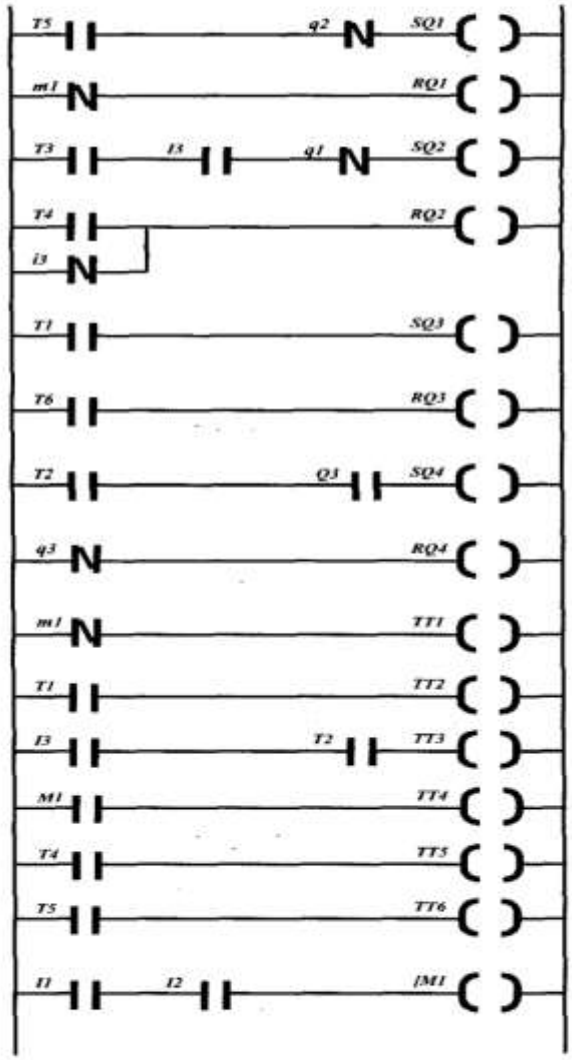

Fig. 5. Ladder Diagram of PLC program

The ladder program, shown in fig. 5. Has been developed using PC software provided with the PLC. Program symbols are listed in Table 1. The program has been simulation than download to the PLC using the PC program which is provided. It should be noted that timer values could be individually set according to system requirements and limitations.

Symbol	**Type**	**Comment**
11	Input	Main voltage Vm
13	Input	Alternative Source voltage
Q1	Output	Main Contactor
Q2	Output	Alternative Source Contactor
Q4	Output	Alternative Source voltage buildup
M1	Marker	Fault/ Normal Condition
T1	Timer	To disconnect the main and connect with Alternative Source
T3	Timer	To Connect with Alternative Source
T4	Timer	To disconnect Alternative Source

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T5	Timer	To connect the Main Source

Table 1 List of Program Symbols

7. INDUSTRIAL PROTOTYPE:

The HATS and control circuit which designed this paper is shown in fig 6.

HATS can work in both mode

1. Automatic Mode 2. Manual Mode

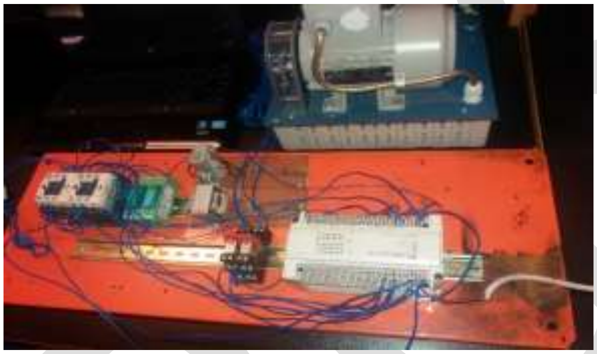

Fig. 6. Control Circuit and Prototype of project

These mode are selected by user through a selector on the front of panel board. In automatic mode, the HATS will work according to the transfer logic module or program which is burn in programmable logic controller. In other mode or manual mode the transfer will take place according to the user requirement.[14] Even when the PLC operate unusually, the HATS can still be worked manually. The characteristics of the HATS are displayed in TABLE 1

8. RESULTS:

The transfer strategy has been implemented on the prototype and tested in lab. The experiments setup is shown in fig 6 and parameters are

I. Source 400V three phase, frequency 50Hz
II. Load Motor R=35ohm and L=4.7mH;
III. Resistance in Series R_f=30 ohm

Rf and a Switch in parallel are used take voltage sag application on primary source. The switch S operate manually. The experiments results of break before make (BBM) transfer strategy are shown in fig 7.

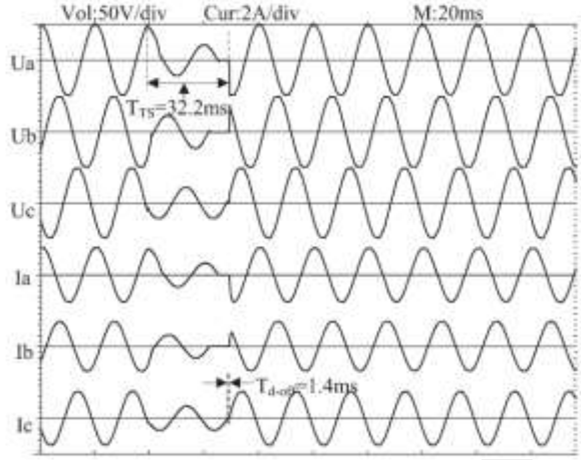

Fig. 7. Load voltages and load currents curves. From top to bottom A,B,C phases of voltages and currents.

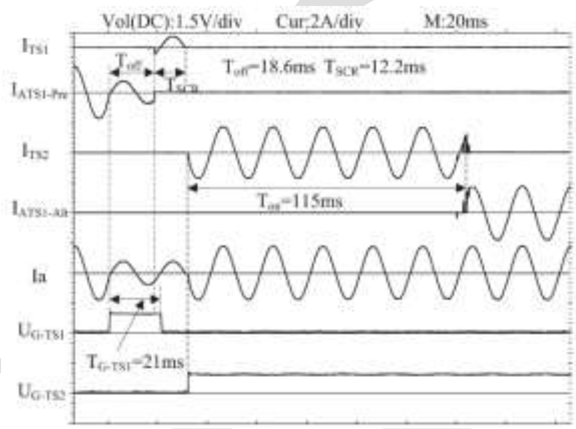

Fig. 8. Commutation Curves of phase A, currents of TS1, ATS1, alternative source for TS2 and ATS1

According to the results, load is not connected to any one of two available sources and their short time is $T_{d-off,}$ 1.4ms at this time, no current is flowing between the sources. The total transfer time T_{TS} is almost equal to 32.2ms. Shown in fig. 8. In figure, a phase commutation graphs during the transfer process.ATS1's characteristic opening time T_{off} is 18.6 ms , and thyristor conducting time is 21 ms to preferred source.

Therefore when ATS1's start to opening, the primary thyristor start conducting instantaneously and thyristor conducting time is almost 12.3 ms as shown in figure mention above.

9. CONCLUSIONS

Automatic transfer switch is most cost operational solution of power quality problems as we seen in industry. As we suggested a Hybrid automatic transfer switch, which will has features and benefits as mentioned below:

- In large scale industries, for power quality enhancement during disturbance.
- In different small scale institute/ industry having their own generation for uninterrupted supply without breakeven not for one second
- For experiments and research work in research organizations

10. ACKNOWLEDGEMENTS

With the blessings of Allah Almighty and prayers of our parents, we have made this humble attempt to achieve the goal that was set for us in the end of 3rd year. Although it was not an easy task, but with the devotion and dedication of our project team and cooperation of our respected teachers, we have at last succeeded in the completion of our project.

We dedicate our research to our parents.

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