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Survey of Fault Tolerant Strategies for Shunt Active Power filters

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ABSTRACT: *Shunt Active power filters allied in parallel with non linear load to remove the current harmonics and to compensate reactive power, which improves the stability of the power system. Fault tolerant control is the ability of the system to function in an acceptable behaviour after sustaining a fault to provide adequate reliability. In this paper we discussed various types of faults that may appear in three phase shunt active power filters. Further we also studied various fault tolerant strategies for shunt active power filters .To develop this fault tolerant model, we simulate using Matlab/Simulink to setup a model by injecting faults such as open circuit, short circuit into the system and the system performance is demonstrated in the presence of faults and also in the absence of faults.*

Key words: *Active power filters, Fault tolerant, Fault, Reliability*

I. INTRODUCTION

The Active power filters are used to eradicate current harmonics and control the reactive power at high voltage distribution system. It consists of two elements namely Power circuit and Control circuit. The various components of power circuit are a capacitor, DC/AC converter, Harmonic Filter and System Protection. The function of control circuit includes the generation of reference currents, gate signals, control of capacitor voltage and voltage/current measurement.

The Active Power Filters are basically classified into four different configurations , such as (i) Single Phase - 2 wire (ii) Three phase - 3 wire (iii) Three phase - 3 wire with zig-zag transformers (iv) Three phase - 4 wire. For low power applications, APF with configurations (i) and (ii) are useful. Whereas Medium and High power applications, configuration (iii) and (iv) are applied respectively [1-5].

Fault tolerant control system is the ability to sustain system performance and stability conditions in the occurrence of component failures. Most of the conventional control systems are designed for fault free systems without taking into account the possibility of fault occurrence. To overcome these drawbacks modern controllers are developed with accommodation and tolerant capabilities to provide reliability and performance requirement. Fault tolerant control system is the ability to sustain system performance and stability conditions in the occurrence of component failures. Most of the conventional control systems are designed for fault free systems without taking into account the possibility of fault occurrence. To overcome these drawbacks modern controllers are developed with accommodation and tolerant capabilities to provide reliability and performance requirement. The motivation towards FTC is to enhance reliability and safety of critical applications such as flight control and nuclear power plant operation. [6]

The faults that can occur in the following three possible sub-components of active power filter such as (i) Inverter (ii) Connectors and wires (iii) Control and estimation of current reference. The various faults noticed in the inverter are [15]

- Short circuit of capacitor to ground
- Damage of a switch-open circuit
- Damage of switch-short circuit
- Line to line short circuit on ac side of inverter
- Short circuit of capacitor bank
- Two phases open in the inverter
- Single line to ground faults on ac side of inverter

Fault diagnosis is an effective approach to enhance the reliability of power electronics systems. It consists of two phases, i.e., fault detection and fault identification. Well-timed detection of fault and system protection may avoid fault propagation and cataclysmic results. The methods of fault diagnosis in power electronic systems are classified into two categories namely (i) The methods based on converter terminal parameters i.e., current/ voltage at the terminals [7] (ii) The methods based on voltages / currents of devices. [7]

Fault Diagnosis mechanism based on converter Terminal parameters: The idea is that characteristics of the input/output voltage or current of the converter are different from the one under faulty conditions. The current or voltage of converter are sensed and compared with pre-defined performance metrics to determine where the fault has occurred and identify faulty component and type of fault. The reliability and stability of the system depends on the criteria used may differentiate all possible healthy states from faulty state. This scheme uses input/ output voltages and current data rather than power device states. Thus this scheme belongs to indirect detection method with low cost.

Fault Diagnosis mechanism based on voltage/ current of devices: The principle involved in this method is that the current and voltage of power switches cannot follow gate driver signals from the controller when they are short circuited or open circuited. The controller needs to supervise these current and voltage parameters. The techniques based on voltage and current information of device characteristic will provide accuracy, high speed response and reliability. On the other hand many numbers of sensors are needed because controller needs nearly all voltage and current signals of each device. Hence the associated hardware and additional cost are the main disadvantages even though with developed integrated smart driver technology will alleviate the problem. Conversely, the direct monitoring of voltage and current signals of devices provides reliable solution to error identification with significant requisite.

The rest of the paper is organized as follows. In Section II, we outline the System model and Notation used in this work. Section III, we briefly discuses the architecture of fault tolerant control of Active power filters. Section IV we discuss the fault tolerant strategies of active power filter. Our Simulation results are presented in section V. Finally we conclude in section VI.

II. SYSTEM MODEL AND NOTATION USED

Traditional three leg shunt active power filter configuration is shown in the below Fig. 1. The power grid constitutes three phase source having source resistance R_s per phase and inductance L_s per phase, non-linear load and voltage fed inverter. The non linear load consists of parallel combination of three phase diode rectifier feeding series R,L load. The Voltage fed inverter has filter resistance R_f per phase, filter inductance L_f per phase.

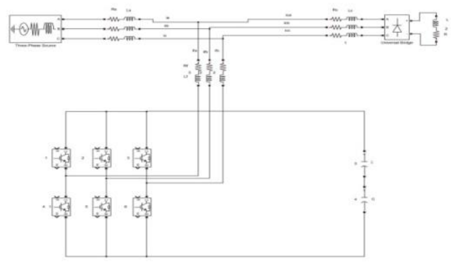

Fig.1 Three phase shunt active power filter configuration

III. ARCHITECTURE OF FAULT TOLERANT ACTIVE POWER FILTERS

Architecture of FTC is shown in Fig. 2. It consists of four components namely, Controller, APF system with fault, Fault detection and isolation component and Reconfiguration component. The APF is subjected to a fault. The FDI identifies the fault and reconfiguration component adjusts the controller to the faulty state.

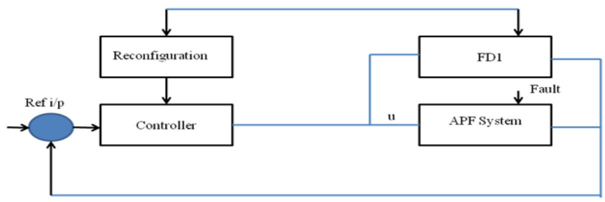

Fig.2. Architecture of fault tolerant Control of APF system

IV. FAULT TOLERANT STRATEGIES OF ACTIVE POWER FILTER

In this paper, we study two fault tolerant strategies of shunt active power filters namely (i) three leg fault tolerant strategy and (ii) Four leg fault tolerant strategy. The three leg fault tolerant strategy consists of fast fuses and three pairs of thyristors. In this strategy when subjected to fault, it leads to two leg configuration with faulty phase is connected to the middle point 'P' of capacitors as shown in Fig 3.

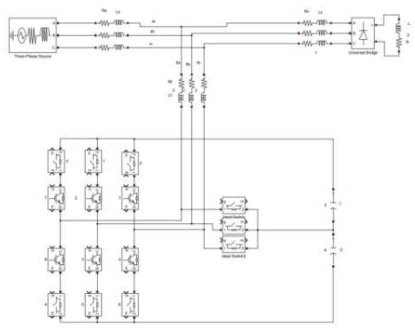

Fig 3. Fault Tolerant Three leg Shunt Active Power Filter configuration

Whereas the four leg fault tolerant strategy of shunt active power filter consists of fast fuses, three pairs of thyristors and redundant leg. When this configuration is subjected to fault, leads to three leg structures with faulty phase connected to fourth leg, which is based on hardware redundancy gives the original structure shown in Fig.3. The above mentioned post fault configuration is Shown in Fig. 4. The reconfigured configuration under post-fault condition is shown in Fig.5

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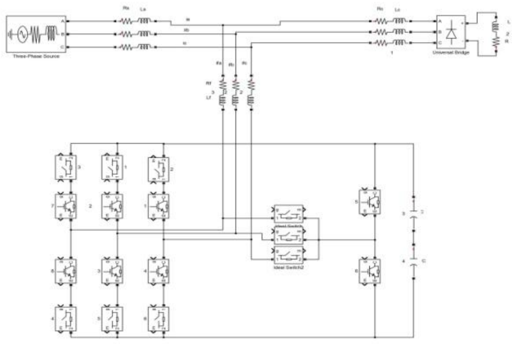

Fig.4 Fault tolerant four leg shunt active power filter configuration

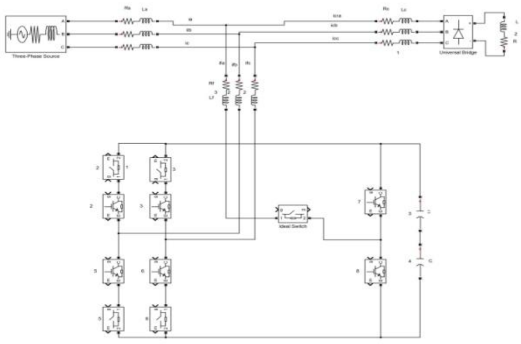

Fig.5 Reconfigured active power filter with fault in first leg

V. SIMULATION SETUP AND RESULTS

Simulation Setups:

In this section we present our simulation results obtained using MATLAB/SIMULINK simulator for the four leg configuration discussed..

Simulation Results:

Fault tolerant Shunt Active Power Filter configuration

Fault tolerant shunt active power filter system uses to remove the harmonics and reactive power compensation. Simulation results are obtained for three phase shunt active power filter configuration in the fault free case and in the presence of fault. Below Figure Fig.6 shows the wave forms of source voltage, source current, filter current, load current for the following three cases (a) shunt active power filter configuration without fault (b) shunt active power filter configuration with fault (c) fault tolerant shunt active power filter configuration. It is observed that the total harmonic distortion is reduced for the Fault Tolerant Shunt active power filter in comparison with shunt active power filter in the presence of fault.

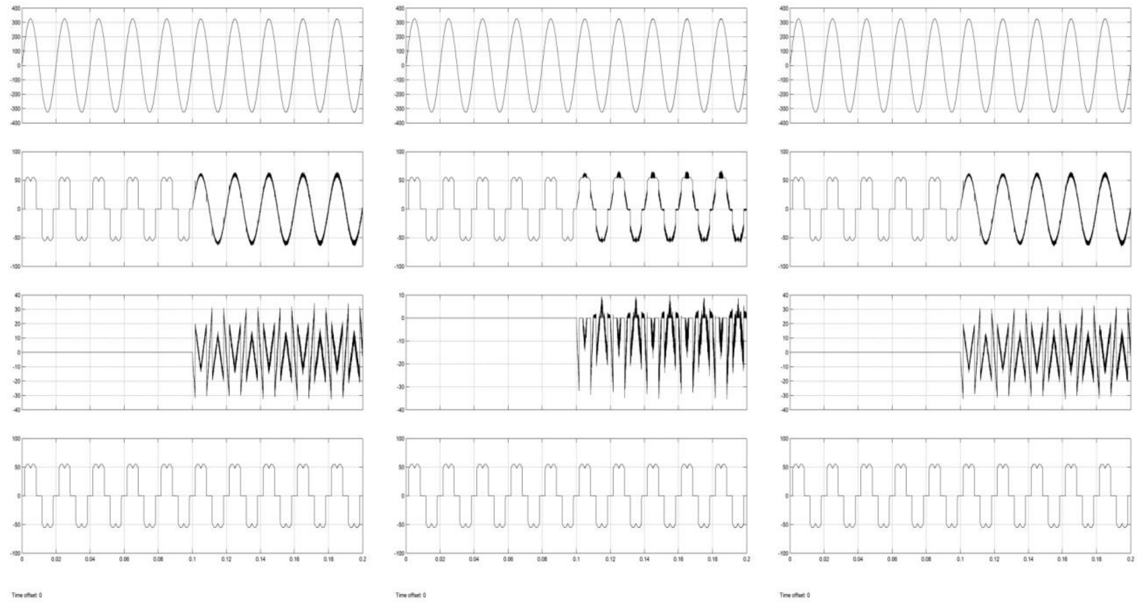

Fig. 6 source voltage, current, filter current and load current waveforms for (a) without fault, (b) with fault (c) fault tolerant of shunt active power filters

VI. CONCLUSIONS

In this paper, we have studied two fault-tolerant operations of active power filters, initially focused on natural redundancy switching state combination i.e. with inverter is to operate with two phase output and next with additional components i.e., four leg topology of inverter to realize fault tolerance for all types of fault (open circuit and short circuit). It is observed that the new topology with redundancy, increase the complexity and cost of systems and even with improved performance. The more effective component level redundant design for power electronic systems should be studied further.

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